DOE/ORO-2155

U. S. Department of Energy
Oak Ridge Operations Office

Type B Accident Investigation of the April 8, 2003 Electrical Arc Blast at the Foster Wheeler Environmental Corporation TRU Waste Processing Facility Oak Ridge, Tennessee

May 2003

CRCC887

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Oak Ridge Operations Office
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INDEPENDENT REPORT

This report is an independent product of the Type B Accident Investigation Board (Board) appointed by Gerald Boyd, Manager, Oak Ridge Operations Office, U.S. Department of Energy (DOE). The Board was appointed to perform a Type B investigation of the accident and prepare an investigation report in accordance with DOE Order 225.1A, *Accident Investigations*.

The discussion of the facts, as determined by the Board, and the views expressed in this report are not necessarily those of DOE and do not assume and are not intended to establish the existence of any legal causation, liability, or duty at law on the part of the U.S. Government, its employees or agents or contractors, their employees or agents or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.

RELEASE AUTHORIZATION

On April 10, 2003, I appointed a Type B Accident Investigation Board to investigate the April 8, 2003, electrical arc blast incident at the Foster Wheeler Environmental Corporation Transuranic Waste Processing Facility. The responsibilities of the Accident Investigation Board have been satisfied with respect to this investigation. The analysis and the identification of contributing and root causes and Judgments of Need resulting from this investigation were performed in accordance with Department of Energy Order 225.1A, *Accident Investigations*.

I accept the report of the Accident Investigation Board and authorize release of this report for general distribution.

Gerald Boyd

Gerald G. Boyd
Manager
Oak Ridge Operations Office

Date Accepted: 5/22/03

PROLOGUE

This Type B Accident Investigation is an important reminder that the activities we carry out every day have important safety and health implications.

Many of the activities performed for the Oak Ridge Operations Office (ORO) involve the routine use of potentially dangerous industrial equipment to accomplish the work. This equipment has the potential to cause serious personal injury and property damage unless appropriate safety measures are implemented. Therefore, it is imperative that the guiding principles and core functions of Integrated Safety Management are carried out from the highest level of the organization down to the work being performed.

This Type B Accident Investigation report is important in improving safety at Oak Ridge. The lessons learned contained in this report are applicable to all types of work activities. The report provides lessons on many aspects of conducting work safely and represents ORO's continued commitment to support the U.S. Department of Energy's *Safety Management System Policy*.

I trust that all Federal employees and contractors supporting ORO will take the time to read this report, think about its applicability to their work, and recognize that every piece of equipment represents a unique challenge to identify and negate its hazards. I encourage all Federal and contractor employees to vigorously continue their efforts to fully implement Integrated Safety Management.

Gerald G. Boyd
Manager
Oak Ridge Operations Office

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ACRONYMS

AHJ	Authority Having Jurisdiction
ASME	American Society of Mechanical Engineers
AWG	American Wire Gauge
CFR	Code of Federal Regulations
DCN	Design Change Notice
DOE	U. S. Department of Energy
e-mail	electronic mail
ESH&Q	Environmental, Safety, Health, and Quality
FWENC	Foster Wheeler Environmental Corporation
ISM	Integrated Safety Management
JON	Judgments of Need
kA	Kiloamperes
MCC	Motor Control Center
MVSTs	Melton Valley Storage Tanks
NCR	Nonconformance Report
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations Office
OSHA	Occupational Safety and Health Administration
QA	Quality Assurance
QC	Quality Control
TRU	Transuranic
UL	Underwriters Laboratories
V	Volt
VAC	Volts Alternating Current
VDC	Volts Direct Current

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EXECUTIVE SUMMARY

THE EVENT

At approximately 0330 hours on April 8, 2003, a phase-to-phase arc blast occurred in the boiler electrical control panel at the Foster Wheeler Environmental Corporation (FWENC) Transuranic (TRU) Waste Processing Facility. The boiler was providing steam for the evaporator and was reportedly operating at about 10% of its capacity.

The FWENC Operations staff (located in the adjacent control room building) heard a loud noise and proceeded to investigate. When the boiler building door was opened, blue smoke exhausted. The operators left the area and called the appropriate management. The operators checked the boiler main switchgear breaker in the electrical equipment building and found it in the tripped position.

FWENC experienced a similar incident on March 3, 2003, in the same electrical panel in the boiler room. No injuries occurred during either incident, although two employees were present at the time of the first incident. FWENC performed an internal investigation into the initial event (Investigation Report: *TRU/ALPHA Project – Boiler Electrical Short Circuit*; attachment to Corporate ESQ Report 0049).

After evaluating the conditions associated with the events of March 3, 2003, and April 8, 2003, the Oak Ridge Operations Office (ORO) requested that a Type B Accident Investigation be conducted in accordance with Department of Energy (DOE) Order 225.1A, *Accident Investigations*. The Accident Investigation Board (Board) convened on April 10, 2003, and began investigating the circumstances involving the electrical arc blast.

BACKGROUND

The TRU Waste Processing Facility, which is under construction in Oak Ridge, Tennessee, will process waste generated from past isotope production and research and development activities at the Oak Ridge National Laboratory. Construction began in 2000, and the facility is scheduled to become operational in 2003. ORO entered into a fixed-price contract in 1998 with FWENC to construct, operate, decontaminate, and decommission the TRU Waste Processing Facility.

RESULTS AND ANALYSIS

The Board reviewed the equipment procurement process, physical evidence related to the incident, modifications, and the first incident report and associated corrective actions. In the course of the investigation, Board members visited the boiler manufacturer's facility and conducted numerous interviews with representatives of FWENC; Tetra Tech NUS, Inc.; Tennessee Associated Electric; Precision Boilers, Inc.; Lockwood Greene; Bechtel Jacobs Company LLC; and DOE. Applicable Code of Federal Regulations, other relevant codes, and consensus standards were consulted. In addition, an independent experimental analysis of the panel material was reviewed.

The Judgments of Need were developed that considered the actions necessary to prevent recurrence of this event. The Board focused on the management of the procurement, procedures, change process, and Quality Assurance (QA).

It is the opinion of the Board that the procurement process inadequately identified and defined the functions and requirements for the boiler package. After installation and initial startup, FWENC management ineffectively administered the change control process, thus compromising the operational integrity of the boiler electrical panel and ultimately resulting in the event. The actions identified by the FWENC investigation and FWENC engineers following the event of March 3, 2003, were either inadequate or, in some cases, not implemented. The QA processes failed to identify the deficiencies throughout the procurement and change processes that might have averted the failure.

CONCLUSIONS

The Board concludes that this event and the event of March 3, 2003, were preventable. The event highlighted weaknesses in key aspects of procurement, change control, procedures, and QA. The root cause is FWENC management ineffectively administered the change control process. Although the direct cause was the improper modification of the electrical panel, the contributing causes were instrumental in the event.

The electrical panel operated successfully for approximately four months without incident. Although excessive wear of the components was noted, failure did not occur until the panel was modified without sufficient evaluation and coordination with the manufacturer.

The Board determined that ORO's oversight function was adequate for the contracting mechanism used in the construction phase of the project.

Table ES-1. Judgments of Need

No.	Judgment of Need	Related Causal Factors
JON 1	FWENC management needs to evaluate the change process and implement appropriate procedures to ensure the effective management of change and configuration control.	RC CC - 1, 2, 3, 5, 7, 8
JON 2	FWENC management needs to evaluate the current QA program and integrate a comprehensive QA/quality control component into all project aspects.	CC - 1, 2, 4, 5, 6, 7

Table ES-1. Judgments of Need (continued)

No.	Judgment of Need	Related Causal Factors
JON 3	Vendor manuals, vendor recommendations, codes, and standards need to be included or addressed in procedures, designs, and modifications.	RC CC - 2, 4, 5, 6, 7, 8
JON 4	FWENC management must ensure that procedures are reviewed, updated, or amended to reflect the current state of the equipment operation, personnel, or process.	RC CC – 2, 3, 4, 5, 6, 7
JON 5	FWENC must ensure that equipment is operated within design parameters.	CC - 6, 7
JON 6	FWENC management must ensure that corrective actions and recommendations from accidents/ incidents are addressed, implemented, and disseminated through a lessons learned program.	CC- 4, 5, 6, 7

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1.0 INTRODUCTION

1.1 Background

On March 3, 2003, a phase-to-phase electrical fault occurred in the boiler control panel at the Foster Wheeler Environmental Corporation (FWENC) Transuranic (TRU) Waste Processing Facility. At approximately 0330 hours on April 8, 2003, a second phase-to-phase electrical fault occurred in the panel after being repaired from the first event. No injuries were sustained in either event. FWENC performed an internal investigation into the initial event (Investigation Report: *TRU/ALPHS Project – Boiler Electrical Short Circuit*, attachment to Corporate ESQ Report 0049).

The U.S. Department of Energy (DOE) Oak Ridge Operations Office (ORO) Environmental Management requested an independent review of the adequacy of the FWENC investigation. The reviewer determined that "The interim Foster Wheeler occurrence report investigation concluded that metal filings (from drilling in the top of the metal panel) fell onto the electrical contacts inside the panel, thus causing the phase-to-phase fault. This reviewer does not believe that adequate evidence was presented for this being the cause. From review of the installation, and various possible occurrence causes, this reviewer was unable to pin point a definite cause."

On April 10, 2003, ORO management categorized the event of April 8, 2003, as a Type B. The ORO Manager formally appointed a Type B Accident Investigation Board (Board) to investigate the event in accordance with DOE Order 225.1A, *Accident Investigations*. This report documents the facts of the event and the conclusions of the Board.

1.2 Facility Description

The TRU Waste Processing Facility, which is under construction in Oak Ridge, Tennessee, will process waste generated from past isotope production and research and development activities at the Oak Ridge National Laboratory (ORNL). In 1998, DOE entered into a fixed-price privatization contract with FWENC to construct, operate, decontaminate, and decommission the facility.

DOE issued a Comprehensive Environmental Response, Compensation, and Liability Act Record of Decision on the processing of TRU and alpha low-level waste at ORNL in August 2000. DOE also prepared a National Environmental Policy Act environmental impact statement for the TRU Waste Processing Facility, which was issued in June 2000. FWENC is responsible for achieving compliance with all applicable environmental safety and health laws and regulations. Construction began in 2000, and the facility will become operational in 2003.

Waste types to be processed at the facility include TRU waste, alpha low-level waste, mixed waste, and low-level waste. ORNL currently manages the largest inventory of remote-handled TRU/alpha low-level waste in the DOE complex, and it also manages a smaller portion of contact-handled TRU/alpha low-level waste. DOE expects to process approximately 5,300 cubic meters of TRU/alpha low-level waste and low-level waste in the facility.

Much of the waste to be processed is currently being stored or consolidated in the Melton Valley Storage Tanks (MVSTs). The liquid waste stored in the MVSTs originated from the old Hydrofracture tanks, Gunite tanks, and Bethel Valley Storage tanks. In addition, solid waste is being stored in bunkers, subsurface trenches, and metal storage buildings. Waste generated from ongoing operations at ORNL during the operation of the TRU Waste Processing Facility will also be processed in the facility. The processed TRU waste will be disposed of at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. Low-level waste will be disposed of at the DOE Nevada Test Site.

The TRU Waste Processing Facility is being constructed on about 20 acres of land adjoining the MVSTs. Supernate and mixed waste sludge will be transferred via above-ground pipelines from the MVSTs to the facility, where they will be concentrated before undergoing a low-temperature drying process. The arc blast event occurred in the electrical panel of the boiler used to supply heat in the drying process.

1.3 Scope, Purpose, and Methodology

The Board began its activities on April 10, 2003, and completed its investigation on May 19, 2003. The scope of the Board's investigation was to identify all relevant facts; analyze the facts to determine the direct, contributing, and root causes of the event; develop conclusions; and determine Judgments of Need that, when implemented, should prevent recurrence of the incident. The investigation was performed in accordance with DOE Order 225.1A, *Accident Investigations*, using the following methodology:

- Facts relevant to the event were gathered through interviews and reviews of documents and evidence.

- The event scene was inspected, and photographs were taken of the scene.

- Facts were analyzed to identify the causal factors using event and causal factors analysis, barrier analysis, root cause analysis, and change analysis.

- Judgments of Need for corrective actions to prevent recurrence were developed to address the causal factors of the event.

Accident Investigation Terminology

A **causal factor** is an event or condition in the accident sequence that contributes to the unwanted result. There are three types of causal factors: **direct**, which is the immediate event(s) or condition(s) that caused the accident; **root cause(s)**, which is (are) the causal factor(s) that, if corrected, would prevent recurrence of the accident; and **contributing causal factors**, which are causal factors that collectively with the other causes increase the likelihood of an accident but which did not cause the accident.

Event and causal factors analysis includes charting, which depicts the logical sequence of events and conditions (causal factors that allowed the event to occur), and the use of deductive reasoning to determine the events or conditions that contributed to the accident.

Barrier analysis reviews the hazards, the targets (people or objects) of the hazards, and the controls or barriers that management systems put in place to separate the hazards from the targets. Barriers may be physical or administrative.

Change analysis is a systematic approach that examines planned or unplanned changes in a system that caused the undesirable results related to the accident.

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2.0 FACTS

2.1 Event Description

At approximately 0330 hours on the morning of April 8, 2003, the FWENC TRU Waste Processing Facility lost power to the steam boiler. The FWENC Operations staff (located in the adjacent control room building) heard a loud noise that came from the steam boiler room. The control room operators in the adjacent control room went to investigate. When they opened the boiler building door, blue smoke exhausted. The operators left the area and called the appropriate management. The operators checked the boiler main switchgear breaker in the electrical equipment building and found it in the tripped position.

The operators then checked the 120-Volt (V) power source supply located in the electrical equipment building. The breakers were still in the on position and supplying power to the boiler control circuits. At this time, the operators opened the two breakers (#28 and #30) for the 120V power in the Motor Control Center (MCC) power distribution panel to totally de-energize the separate control power source to the boiler. Next, the operators entered the boiler building and noticed that the boiler control panel doors were open and one 480V insulating panel (identified as "micarta" by electricians) was lying on the floor. (See Exhibit 1.) The remaining insulating panels of the boiler electrical panel were still in place but dislodged from their normally installed location. (See Exhibit 2.)

FWENC experienced a similar incident on March 3, 2003, in the same electrical panel in the boiler room. No injuries occurred during either incident, although two employees were present at the time of the first incident. FWENC performed an internal investigation into the initial event. During the course of this investigation, it was necessary to review the FWENC report to evaluate its relevancy to the second event.

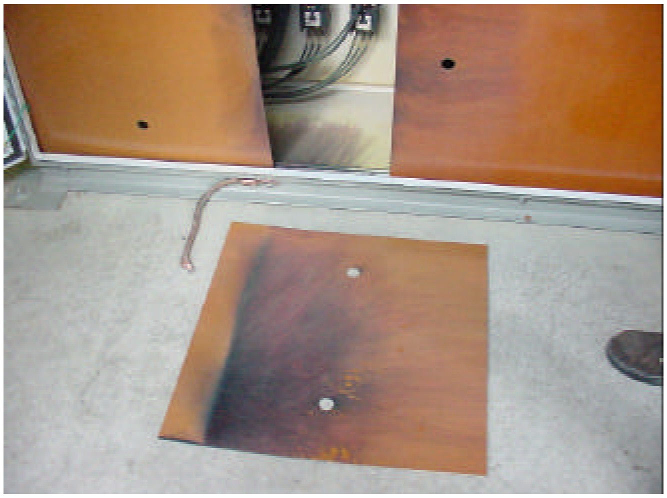


Exhibit 1. Micarta Insulating Panel

Exhibit 2. Dislodged Micarta Insulating Panel

2.2 Chronology

Table 2-1 provides the events leading up to and immediately following the April 8, 2003, incident.

Table 2-1. Event Chronology

Date	Event
1998	DOE entered a fixed-priced contract with FWENC
10/01/01	"Requisition Form – Equipment Solicitation" for the following items: • Electric boiler and control system • Boiler feed/condensate return tank with complete duplex feed pumps • Deionization vessels complete with resin • Blowdown tank complete with pump • Chemical feed package complete with tank, mixer, and pump
11/26/01	Precision Boilers, Inc., was approved to begin testing equipment at the vendor site by FWENC
12/05/01	Purchase Order 038780 for the electric boiler and control system was issued
01/03/02	Precision Boilers, Inc.'s authorized representative signed the Purchase Order
02/27/02	Purchase Order/Change Order 038780 was amended by strikethrough that • Changed the delivery date • Changed the 200-amp, non-fused disconnect to 2000-amp, non-fused
03/02/02	Original delivery date for the boiler system per Purchase Order 038780

Table 2-1. Event Chronology (continued)

Date	Event
04/01/02	Revised delivery date for the boiler system per Purchase Order 038780
04/24/02	The vendor submitted its electrical test plan and report to FWENC
04/26/02	Boiler was shipped from vendor
04/30/02	Boiler was received on the FWENC site
08/26/02	Boiler cables and electrical panel were installed
10/28/02	Boiler was operational
11/20/02	FWENC Quality Assurance (QA) inspection for acceptance of boiler package completed
02/03/03 (Work Request date)	Modification 1 (TRU-DCN-EE-060) • External control power source provided • Factory-installed transformers removed to provide 120V power supply to the control panel • Installation of on/off switch
02/10/03	Last boiler operation prior to the first event: the boiler was shut down to install insulating panels (1400 hours)
02/13/03	A visual inspection was performed after the modifications. However, the electrical panel was not meggered (a device that puts direct current voltage across the device to be measured and records the resistance) as part of the inspections per the *Boltswitch Installation, Operation, and Maintenance Manual* from Boltswitch, Inc.
02/17/03 (Work Request date)	Modification 2a (TRU-DCN-EE-061) (Work Request SN-OPS-03-127) • Installation of barrier material support channels (Unistrut®) • Specifies installation of eight fixed panels • The vent access for the exhaust vents was blocked • "Repair boiler local electrical panel, replace any damaged components, wire, or insulating panels. Complete any additional action req'd to close the NCR." • Electrical connections on the fuse blocks torqued to 40 pounds per inch, and all power connections on the contactors to 45 pounds per inch. Wire connections to the busbars tightened.
02/17/03 (Work Request date)	Modification 2b (TRU-DCN-EE-061, Revision 1) (Work Request SN-OPS-03-127) The Design Change Notice (DCN) was modified to reflect "as constructed" modifications to the electrical panel
03/03/03	Initial boiler incident
03/03/03	Nonconformance Report (NCR) – 77 opened
03/03/03	Work Suspension issued by the Operations Manager
03/03/03	FWENC Construction inspection of electrical panel
03/04/03	DOE required FWENC to issue an Occurrence Report
03/04/03	FWENC Operations inspection of electrical panel
03/04/03	FWENC Engineering inspection of electrical panel
03/04/03	Vendor Inspection completed by Precision Boilers, Inc.

Table 2-1. Event Chronology (continued)

Date	Event
03/06/03	ORO Environmental Management requested an independent review of the first boiler incident
03/07/03	FWENC Forensic Specialist consultant inspection of electrical panel
03/11/03	A Change Proposal was submitted to increase the contactor ratings from 50 to 60 amp
03/11/03	NCR–78 was opened to repair other electrical damage and discrepancies
03/17/03	A preoperational checklist was performed on the boiler for startup (Precision Boilers, Inc. – "2nd Boiler Startup after customer rebuild.")
03/24/03	FWENC Operations accepted the first incident repairs • Work was performed under previous Work Request SN-OPS-03-127 • DCN number TRU-DCN-EE-074, Revision 1
03/31/03	Work Suspension and NCR-77 and NCR-78 corrective actions completed for boiler restart
03/31/03	FWENC notified Precision Boilers, Inc., that the contactors had been changed
04/04/03	ORO's independent review of the first boiler incident was completed
04/05/03 – 04/08/03	The boiler was operational. A no-load test was performed prior to the boiler being operational.
04/08/03	(0330 hours) Second Boiler Incident

2.2.1 Procurement

FWENC issued Requisition BAR 120301-A to Precision Boilers, Inc., on October 1, 2001. This was used as a solicitation bid for this job.

The original Purchase Order 038780 was issued by FWENC to Precision Boilers, Inc., on December 5, 2001. The order requested (1) a 1600 Kilowatt electric boiler and control system, (2) a boiler feed/condensate return tank and a duplex feed pump, (3) deionization vessels with ion-exchange resin, (4) a blowdown tank complete with pump, and (5) a chemical feed package with a tank, mixer, and pump. The Purchase Order specified that "The items to be procured have been graded by FWENC to be Category C quality level items, implying that an intermediate level (between standard commercial and safety class) of quality control and degree of assurance shall be applied during the accomplishment of the work under this contract."

Change Order 1 to the original Purchase Order 03870 was issued by FWENC to Precision Boilers, Inc., on February 27, 2002, included the addition of a 2000-amp, non-fused disconnect switch. The "General Statement of Work" in the procurement package references a specification for fabrication, testing, and delivery of the boiler and a specification for operation and maintenance of the boiler. Specification and requirements from the procurement package are as follows:

(a) Equipment Specification T-CM-FW-S-ME-006 for fabrication, testing, and QA of the boiler was issued on September 6, 2001, and revised on November 30, 2001. This document requires compliance with the American Society of Mechanical Engineers *Boiler and Pressure Vessel Code* and certain standards issued by National Fire Protection Association (NFPA), National Electrical Code (NEC), National Electrical Manufacturers Association (NEMA), American Society of Nondestructive Testing, American Welding Society, Instrument Society of America, and Manufacturers Standardization Society. In Paragraph 3.7, "Electrical," FWENC requires a single-point power source for all 120V and 480V power in the panel and a fused 120V transformer for control circuits and branch circuits. This system was installed by the vendor.

Section 3.8 requires the electrical panel to be grounded to the major skid beams, and it states that the skid beams were connected to the facility ground by FWENC Construction personnel.

Section 3.10 requires the vendor to design for an ambient outdoor temperature of 92°F. This is consistent with average summer temperatures for the Knoxville area.

Attachment 3, "Data Sheet," of this specification requires the boiler to be Underwriters Laboratory (UL) listed and to bear the UL label. The boiler is, in fact, UL listed, as was verified by the Board's contacts with UL.

(b) Specification T-CM-FW-S-00-009, "Operation and Maintenance Data," gives requirements for vendor submission of data on the boiler system, such as operations and maintenance manuals, training requirements, drawings submittals, etc.

(c) FWENC document T-CM-FW-A-QP-001/R2, *Quality Assurance Program Description*, describes the FWENC QA Program. It also includes requirements for review of the procurement package and technical specifications by the QA; Environment, Safety, and Health; and Purchasing organizations, for design reviews and review of subcontractor-submitted documents by FWENC staff, and for inspection and acceptance testing by the QA staff.

(d) Exhibit A-14 of the contract requires the vendor to comply with all Federal, state, and local laws and regulations (see Appendix D), including Occupational Safety and Health Administration (OSHA) and the FWENC *Project Rules Handbook* of safety and health work practice rules and guidelines.

(e) A procurement submittal required of the vendor was its operation and maintenance manual. The *Precision Boilers Operation and Maintenance Manual* requires in Section 2.D that "If the boiler is to be placed in a room with little or no ventilation, a supply of ducted filtered air may have to be brought to the lower portion of the control cabinet to limit the control cabinet interior temperature to 50°C (122°F) maximum." No ducted, filtered air was supplied to the panel to ensure adequate cooling. The temperature inside the panel could not be verified, since no temperature monitoring sensors were installed inside the electrical panel.

The fuse blocks were manufactured by the Bussman Company. (See Exhibit 3.) The Bussman Company recommended the use of #6 American Wire Gauge (AWG) or, with a safety factor, #4 AWG for connections, based on design specifications, application, and panel components, as stated in the *Bussman Electrical Handbook* and as taken from the 2002 NEC Table 310.16. (See the following web address: http://www.bussman.com/library/docs/spd02/SPBSection04.pdf.)

The original factory design shows #6 AWG on the drawings, but FWENC and Precision Boilers, Inc., representatives maintained that this was a mistake in the drawings and that the intent was to use #8 AWG. The fact that #8 AWG had been installed instead of #6 AWG was noted in March 2003 during a detailed inspection of the electrical panel following the first incident. The corrective action for this finding was to change the drawings to show #8 AWG as being “as constructed.” The FWENC *Receipt Inspection Report*, ultimately completed on November 20, 2002, documents that the boiler meets “PO, drawing, specification requirements.” An inspection by the FWENC Electrical Supervisor, documented on November 20, 2002, also does not identify an issue with #8 AWG being installed instead of #6 AWG. (See Appendix C to this report for copies of the FWENC records documenting this issue.)

FWENC NCR 2003-TRU-078, dated March 12, 2003, states that “Power wiring from bus bars to fuse blocks is #8 AWG. Vendor drawing WD-B011003 (Part of T-UT-52-A-EE-001) shows that wire as #6 AWG.”

On March 18, 2003, FWENC DCN TRU-DCN-EE-074, Revision 1, was issued with a note to “Notify boiler supplier of contactor and wiring problem. Have him correct and resubmit WO-B011003 (Part of T-UT-52-A-EE-001). Note 3 from #6 AWG to #8 AWG, as delivered.”

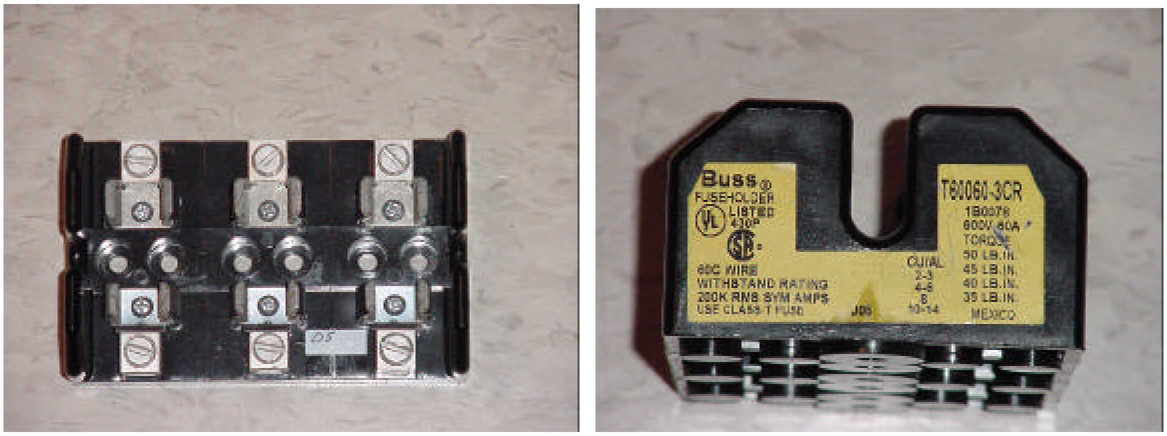


Exhibit 3. Fuse Block

2.2.2 Modifications

The electrical panel associated with the boiler contains a 120V control panel and a 480V power feed for the boiler heater elements. Operations personnel requiring access to the control panel to adjust boiler timing sequences are exposed to the hazards associated with the 480V components of the panel as originally designed. This appears to be the basis for providing an external 120V power source to the control panel. The micarta insulating panels were installed to establish separation of the different voltage systems. An internal FWENC electronic mail (e-mail) message (see Exhibit 15) dated November 8, 2002, from the Environment, Safety, Health, and Quality (ESH&Q) Manager states "that a number of pieces of equipment at the Waste Processing Facility may not have the ability to be worked on in a de-energized condition. In addition, due to the type of maintenance/repair required, appropriate electrical PPE may not be able to be worn while performing work." Electrical workers interviewed stated that the requirements of the e-mail pertained to work on panels with voltages exceeding 24V.

FWENC made the following modifications to the electrical panel on the boiler purchased from Precision Boilers, Inc. However, Precision Boilers, Inc., was not consulted about the potential impacts on performance and/or the suitability of the proposed changes to the electrical panel.

Modification 1 (2/03/03) – DCN TRU-DCN-EE-060 (Work Request SN-CON-03-003)

- Added a 120V external power source to the control panel inside the boiler electrical panel.
- Removed the 480V to 120V transformers installed by the manufacturer in the electrical panel to provide 120V power to the control panel. (See Exhibits 4 and 5.)
- Installed a Square D Class 9001 on/off selector switch with legend. The switch was mounted on the side of the control cabinet above the emergency stop switch. The purpose of the switch is to provide control of the 120V power source to the control panel at the boiler electrical panel.

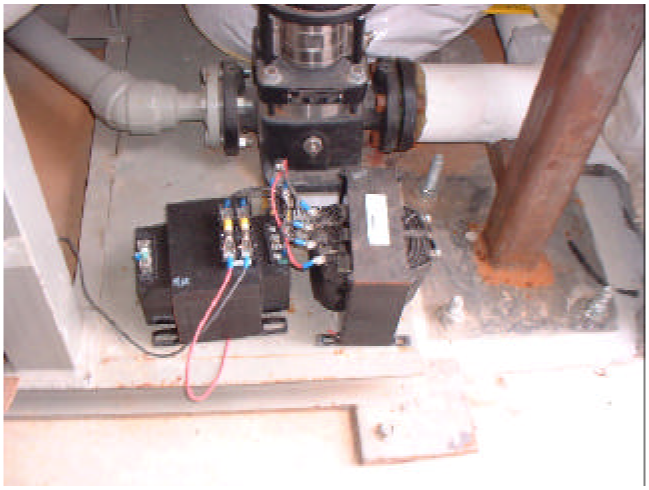


Exhibit 4. Two of the Removed 120V Control Transformers

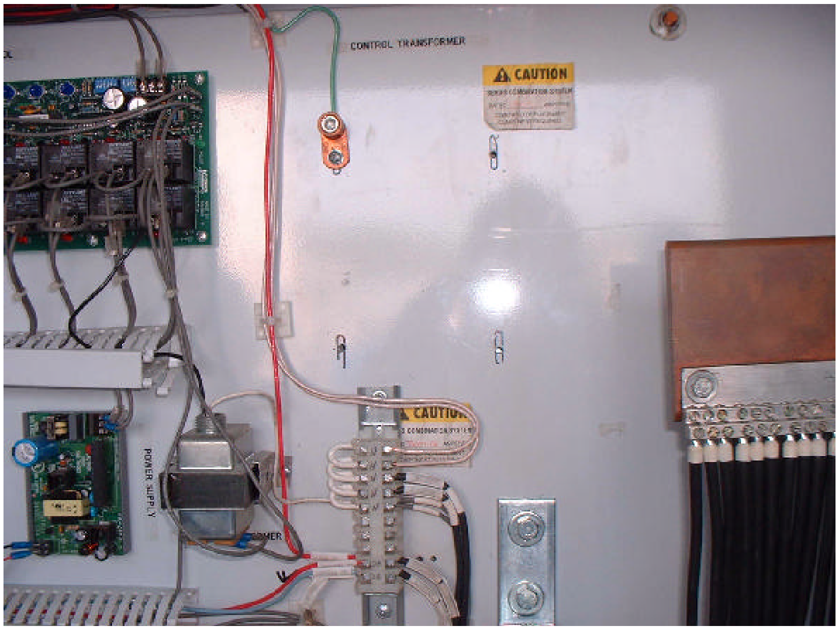


Exhibit 5. Original Location of One 120V Control Transformer in Panel

Modification 2a (2/17/03) – DCN TRU-DCN-EE-061 (Work Request SN-CON-03-004)

- Installed support channels (Unistrut®) necessary to support the insulating barrier material. (See Exhibit 6.)

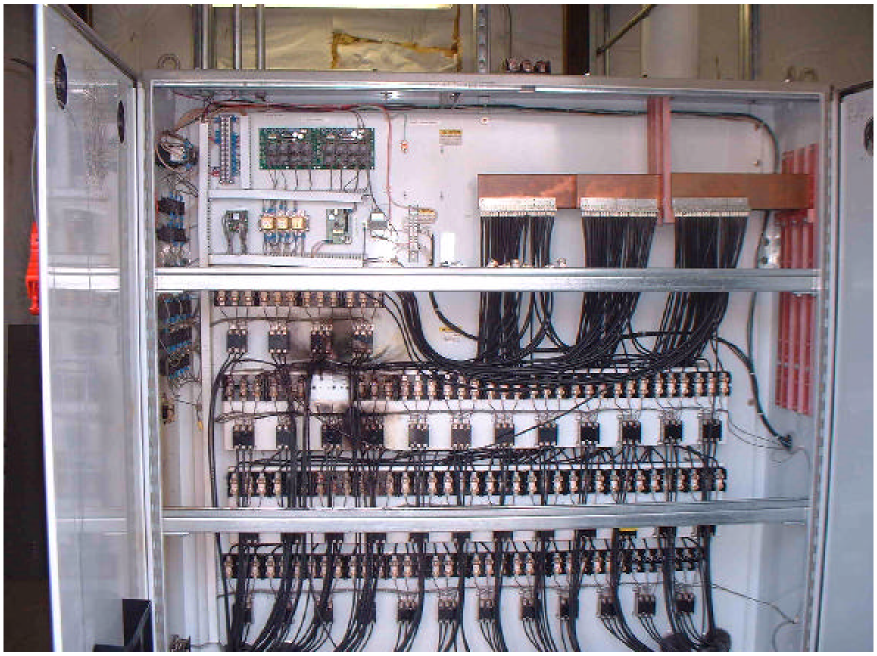


Exhibit 6. Installed Unistrut®

- This DCN defines the installation of eight fixed insulating panels to segregate the worker from the 480V power source. The specification for the barrier material to be installed is 600V, 1/8-inch insulating boards.
- The insulating material plate dimensions specified in the DCN do not provide vent access for the cabinet fans (bottom) or the exhaust vents (top). (See Exhibit 7.)

Exhibit 7. Sliding Panels, Vent, and Fan

Modification 2b (2/17/03) – DCN TRU-DCN-EE-061, Revision 1 (Work Request SN-CON-03-004)

- The DCN was modified to reflect the "as constructed" modification to the electrical panel.
- The revision provides for installation of insulating barrier material in the sliding panels and the horizontal Unistrut® support.
- The specification for the actual barrier material to be installed is 600V, 1/8-inch insulating boards.

FWENC's restart of the boiler system was in accordance with T-UT-FW-P-OP-504, *Boiler, Steam, and Condensate Systems*, Revision 0, which did not incorporate the revisions to the boiler electrical panel.

2.2.3 Initial Boiler Incident of March 3, 2003

In the course of the investigation, it was necessary to review the investigative report (Corporate ESQ Report 0049) prepared by FWENC on the boiler electrical short circuit of March 3, 2003. It is not the charter or intent of the Board to dispute the findings discussed in the report but rather to evaluate the event of April 8, 2003, including all relevant facts.

Prior to the failure, the boiler had been operated until February 10, 2003. At that time, the boiler had been shut down, a lockout/tagout had been installed so that nonconductive guard panels could be installed as a safety enhancement (per the company requirements), and work had been performed on some flow control valves in the system. This work was completed on February 13, 2003, and the lockout/tagout was removed. The FWENC Operations personnel completed a walkdown of the system to verify that all lockout/tagouts were clear on March 3, 2003.

On March 3, 2003, the boiler panel experienced the first phase-to-phase fault, tripping the circuit breaker. The report noted the sequence of events as "A wet waste operator (WWO) then proceeded to start-up the system in accordance with T-UT-FW-P-OP-504, Rev. 0. The WWO opened the main steam isolation valve and verified that all the individual heater elements were off. The WWO then proceeded to close the main 480-volt disconnect switch that would energize the 480-volt power sources in the boiler control panel." . . . "Following the closure of the switch (at approximately 2:00 p.m.) a phase-phase electrical short circuit occurred immediately."

In response to this event, FWENC performed an investigation and issued corporate ESQ Report 0049 on March 14, 2003. FWENC's root cause for the short circuit event concludes that "there may have been environmental factors that individually or in combination affected the phase-to-phase continuity across the fuse block (moisture, metal shavings, broken wires, or others) and physically initiated the short-circuit event. However the ultimate root cause was found to be the lack of procedural controls for testing and verifying the integrity of a high-amperage electrical panel following modification of the panel and/or following shutdown of the panel for an extended period."

ORO Environmental Management requested an independent review of the adequacy of the FWENC investigation. The review determined that "The interim Foster Wheeler occurrence report investigation concluded that metal filings (from drilling in the top of the metal panel) fell onto the electrical contacts inside the panel, thus causing the phase to phase fault. This reviewer does not believe that adequate evidence was presented for this being the cause. From review of the installation, and various possible occurrence causes, this reviewer was unable to pinpoint a definite cause."

2.2.4 Repairs After the First Incident

Incident Repair/Modification 3 (3/24/03) – DCN TRU-DCN-EE-074, Revision 1 (Work Request SN-OPS-03-127)

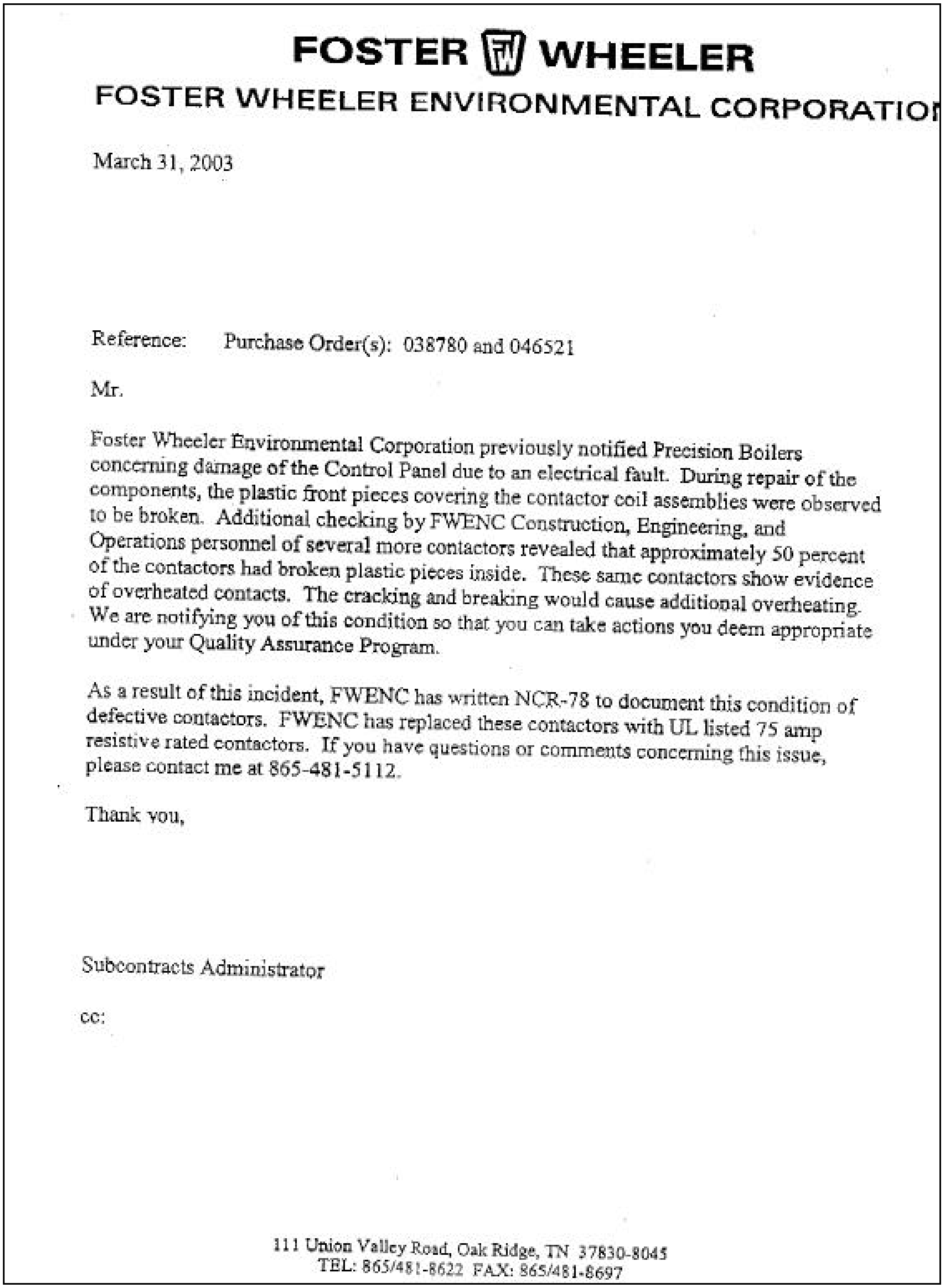
- Repaired the boiler electrical panel and replaced any damaged components, wires, or insulating panels and completed any additional actions required to close the NCR.
- Removed/replaced damaged fuse blocks
  - A1 through A4
  - B1 through B6
  - C1 through C6
  - D1 through D6
  - C10
- Replaced damaged 125°C conductors from busbars to fuse blocks with #8 AWG 150°C conductors (no crimping sleeves used).
- Replaced all bare conductors from the fuse blocks to the contactors with #8 AWG 150°C conductors.
- Replaced all contactors with Cutler Hammer components with a 60-amp rating for inductive loads and a 75-amp rating for resistive loads.

The boiler resumed operation after repairs. FWENC's restart of the boiler system was in accordance with T-UT-FW-P-OP-504, *Boiler, Steam, and Condensate Systems*, Revision 2. Precision Boilers, Inc., was formally notified about the repairs in a letter dated March 31, 2003. (See Exhibit 8.)

2.2.5 Second Boiler Incident of April 8, 2003

FWENC purchased the boiler for the TRU Waste Processing Facility from Precision Boilers, Inc., of Morristown, Tennessee, and it was delivered in April 2002. The unit is rated at 1,600 kilowatts and has 40 individual three-phase circuits to power its heaters at 480V. The boiler control panel was provided in a NEMA 12 enclosure (intended for indoor use) and was UL listed.

The main power source for the TRU Waste Processing Facility is supplied at 13.8 kilovolots (kV). This system feeds a Delta (13.8kV) to WYE (480/277V) transformer, although the manufacturer specifically warns against using the WYE or Star configuration for the boiler (Chapter 3.B.3, page 7, *Precision Boilers Operation and Maintenance Manual*). The 480V electrical power is provided to the panel from a 480V switchgear breaker. The breaker has a 3,200-ampere frame and 2,500-ampere trip rating. According to FWENC's engineering calculations, the available fault current from the switchgear is approximately 43,000 amperes. Exhibit 9 shows the switchgear breaker supplying the 480V to the boiler.



FOSTER WHEELER

FOSTER WHEELER ENVIRONMENTAL CORPORATIO

March 31, 2003

Reference: Purchase Order(s): 038780 and 046521

Mr.

Foster Wheeler Environmental Corporation previously notified Precision Boilers concerning damage of the Control Panel due to an electrical fault. During repair of the components, the plastic front pieces covering the contactor coil assemblies were observed to be broken. Additional checking by FWENC Construction, Engineering, and Operations personnel of several more contactors revealed that approximately 50 percent of the contactors had broken plastic pieces inside. These same contactors show evidence of overheated contacts. The cracking and breaking would cause additional overheating. We are notifying you of this condition so that you can take actions you deem appropriate under your Quality Assurance Program.

As a result of this incident, FWENC has written NCR-78 to document this condition of defective contactors. FWENC has replaced these contactors with UL listed 75 amp resistive rated contactors. If you have questions or comments concerning this issue, please contact me at 865-481-5112.

Thank you,

Subcontracts Administrator

cc:

111 Union Valley Road, Oak Ridge, TN 37830-8045
TEL: 865/481-8622 FAX: 865/481-8697

Exhibit 8. FWENC’s Letter to Precision Boilers, Inc.

Exhibit 9. Switchgear Breaker

On the morning of the April 8, 2003, incident, the outside temperature was approximately 58°F, and the relative humidity was approximately 94%. The estimated temperature in the boiler building at the time of the event ranged between 90°F to 95°F.

A power bss was experienced at 0330 hours in the boiler room. When the operators investigated, they noticed the condition explained in Section 2.1, "Event Description." The investigation of the event revealed that a phase-to-phase fault had occurred inside the boiler panel. This developed into a three-phase fault due to the ionized gases and the 480V clearances. This phase-to-phase short resulted in the copper vaporization and spray inside the panel. (See Exhibit 10.)

Exhibit 10. Panels After Arc Blast

This condition was evident after both events. These copper vapors are easily sprayed and can result in additional short circuits, such as those seen on the other fuse blocks in the electrical control panel. (See Exhibit 11.)

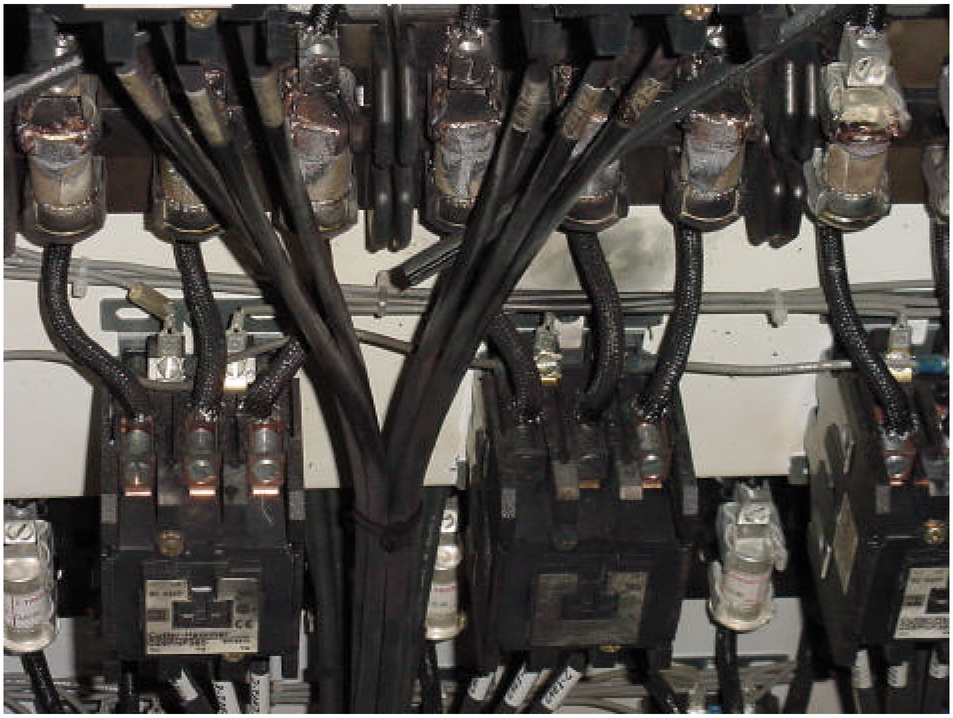


Exhibit 11. Damaged Fuse Blocks

The available fault current at the boiler is approximately 43.2 kiloamperes (kA) (based on calculations by General Electrical as a part of the original purchase of the electrical equipment) ". . . which would mean that the short circuit magnitude could have potentially been in the range of 16.4kA to 38.4kA. Since the trip indication on the breaker indicated that the short circuit was at 22.4kA or above, the actual short circuit was in the approximate range of 22.4kA to 38.4kA." An electrical fault of this magnitude can initiate all of the following:

- Temperatures in the range of 35,000ºF
- Pressure waves in excess of 2,000 pounds per square foot traveling at speeds in excess of 740 miles per hour
- Decibel sound waves in excess of 165 decibels
- Molten metal and shrapnel
- Copper vapors in excess of 1,000ºC traveling at speeds of approximately 740 miles per hour
- Intense light and radiation waves in excess of 50 cal/cm^2 traveling in excess of 670,000,000 mph

2.2.6 Independent Analysis of the Rubber Tubing

An analysis was performed (see Appendix D) on the rubber tubing or gasket material that fits over the metal flange located within the electrical panel which supplies power to the boiler. "The entire piece of rubber tubing is about three feet long, quarter inch in diameter and is split down its length on one side so that it can be tightly attached to a horizontal sharp metal flange above the fuse holders." The purpose of this material is to keep nearby wires from chafing on the edge of the sheet metal flange. "It was observed that most of the tubing was still attached to the flange but that several inches of the tubing had come off and fallen down in a diagonal fashion and to be almost touching the fuse holder metal clips." The resistance of the rubber tubing inside the electrical panel was checked using a Megger Instrument (BM11D). This device puts 1,000 Volts Direct Current (VDC) across the rubber tubing to measure and record the current resistance. The current flow is converted to a resistance via Ohm's law. The following resistances were measured along the length of this section of rubber tubing:

Length (inches)	1	3	10	36
Resistance (k-ohm)	10	20	20	20

According to the analysis performed by this independent reviewer, the measured resistance of the rubber tubing was sufficiently low to state that the rubber tubing is more of a conductor than an insulator. According to the independent reviewer, further investigation was warranted, which resulted in the primary experiment.

The primary experiment involved four "virgin pieces of rubber tubing of the same type as used in the fuse panel were obtained from Precision." The experiment consisted of applying a 500VDC power supply feeding a milliamp meter connected in series with the four inches of rubber tubing. When the power supply was turned on, 35 milliamps of current initially flowed through the rubber tube. As the current flowed, the tubing heated, then smoked, and after 90 seconds caught on fire and resulted in the power supply circuit breaker being tripped. This experiment was repeated three more times on other virgin pieces of tubing, four inches in length, and the results were almost identical. Five hundred VDC at 35 milliamps equals 17.5 watts. The experiment concluded that four inches of this rubber cannot absorb 17.5 watts without burning up.

The power supply voltage was then reduced to 350VDC, and the experiment was repeated. This time, 15 milliamps flowed through the rubber tubing, causing the rubber to absorb 350 x 0.015A = 5.2 watts of power. In this case, the rubber tubing became very hot, almost melting, but it did not burn or catch on fire. As a result of the experiments, the independent agency concluded "that this rubber tubing is a relatively good conductor and that it can easily conduct from a 480 VAC (678V peak)/2000 amp power source."

However, it is important to note that the rubber tubing was installed by the manufacturer as a chafing guard. The chafing guard is a mechanical means of protecting the insulation on the wires from damage by the sharp edges of the electrical panel and is not intended to be used as an insulator.

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3.0 ANALYSIS

The Board used several analytical techniques to determine the causal factors of the incident. Events and causal factors were charted using the Integrated Safety Management (ISM) core functions. The Board used change and barrier analysis techniques to analyze the facts and identify the causes of the incident. The causal factors related to weaknesses in implementation of the ISM core functions collectively contributed to the incident. The causal factors contributed to the incident. The Judgments of Need are presented in Table 4-1.

3.1 Board Analysis of Independent Review of the Rubber Tubing

A review of the independent analysis of the rubber tubing was performed. The investigator indicated that it is entirely possible that the rubber tubing was the foreign material that could have initiated the arcing in the 480 Volts Alternating Current (VAC)/2000 amp power panel.

The experiment involved only one small piece of virgin rubber tubing that was obtained from Precision Boilers, Inc., and the other pieces of rubber tubing tested came from inside the electrical panel that had experienced two electrical arc blasts. Therefore, it is the Board's opinion that sufficient data was not available to substantiate this conclusion.

3.2 Barrier Analysis

Barrier analysis is based on the premise that hazards are associated with all accidents/ events. Barriers are developed into a system or work process to protect personnel and equipment from hazards. For an accident/event to occur, there must be a hazard that comes into contact with a target because the barriers or controls were not in place, not used, modified, or failed. A hazard is the potential for unwanted energy flow to result in an incident or other adverse consequence. A target is a person or object that a hazard may damage, injure, or fatally harm. A barrier is any means used to control, prevent, or impede the hazard from reaching the target, thereby reducing the severity of the resultant accident or adverse consequence. The results of the barrier analysis are used to support the development of the causal factors. Table 3-1 contains the barrier analysis.

Table 3-1. Barrier Analysis

Barrier	Purpose	Why Did the Barrier Fail?	Analysis/Effect on Accident
1. Adequate Definition of Equipment Function and Requirements	To ensure that equipment obtained is suitable for the intended purpose	1. The intended application for the equipment was not clearly defined. 2. Off-the-shelf equipment was not properly evaluated for the specific application. 3. Additional system requirements were identified after installation, prompting equipment modifications. 4. Components added during modification were not properly evaluated for application.	A failure to sufficiently define all parameters pertaining to the intended use of the boiler prompted modifications that ultimately resulted in a system failure.
2. Operating/Maintenance Procedures	To make certain that vendor requirements are defined pertaining to proper equipment operation and personnel safety	1. The vendor's operation and maintenance manual was not followed or integrated into FWENC's procedures. 2. The procedures were not revised to address equipment modifications.	Certain aspects of the vendor's manual were not followed, resulting in improper maintenance and operation of the equipment.

Table 3-1. Barrier Analysis (continued)

Barrier	Purpose	Why Did the Barrier Fail?	Analysis/Effect on Accident
3. Evaluation of Modifications	To evaluate changes to operating parameters of equipment being modified in order to assess potential operational and safety impacts	1. Modifications were performed without evaluation of their impact on equipment performance. 2. Components were selected for the cabinet size, not necessarily for functionality. 3. Modifications were not communicated to the manufacturer for evaluation of their impact on the equipment design parameters.	Modifications (components, wire, insulating panels, power supply, and contactors) were not evaluated for their potential impacts on the electrical panel's performance. The result was elevated temperatures inside the electrical panel.
4. Configuration Management	To provide for a systematic evaluation of proposed modifications while maintaining control of system components	Key components of the change process were not evident.	The FWENC change process should include the following: 1. TRU Project Change Proposal 2. DCN 3. Work Request 4. Performance of the work 5. QA (verification) Analysis of a matrix reveals that work was completed without timely completion of certain program aspects.

Table 3-1. Barrier Analysis (continued)

Barrier	Purpose	Why Did the Barrier Fail?	Analysis/Effect on Accident
5. Regulations and OSHA Compliance	Establishes parameters for qualified/unqualified workers that ultimately provide for worker safety	Installation of the insulating panel could circumvent certain requirements, allowing unqualified workers inside the energized electrical panel.	The installation of the insulating panels resulted in elevated temperatures inside the electrical panel, which ultimately resulted in a failure of the electrical panel.
6. NEC Regulations	To provide for personnel safety and equipment protection	Modifications to the UL-listed equipment resulted in the equipment functioning outside the parameters of that listing.	Modifications voided the UL listing of the electrical panel, resulting in the equipment failure.
7. QA/Quality Control (QC)	To ensure and validate quality	The FWENC QA Program failed to identify the deficiencies in procurement, the change process, and procedures.	1. The equipment was not configured as specified in the procurement. 2. The installation was not in accordance with the vendor's operating and maintenance manual. 3. The current procedure does not reflect the existing configuration of the equipment. 4. "As designed" drawings were modified to reflect the "as constructed" installation of #8 AWG wire instead of #6 AWG wire six months after acceptance, installation, and operation. 5. FWENC failed to adhere to its change control procedure.

3.2.1 Barrier Analysis Narrative

During the procurement process, the functions and requirements for the boiler were not adequately defined. FWENC's Engineering, Operations, QA, and Health and Safety organizations were not adequately involved in the process to clearly identify the intended location and application of the equipment. This resulted in a decision to use a generic-designed boiler that subsequently required modification.

A procurement submittal required the vendor to provide an operation and maintenance manual. The *Precision Boilers Operation and Maintenance Manual* was supplied, but key elements were not followed or appropriately integrated into FWENC's procedures. For example, the *Precision Boilers Operation and Maintenance Manual* states:

> **!Caution!**
>
> "If the boiler is to be placed in a room with little or no ventilation, a supply of ducted filtered air may have to be brought to the lower portion of the control cabinet to limit the control cabinet interior temperature to 50°C (122°F) maximum."

No ducted, filtered air was supplied to the panel to ensure adequate cooling. The temperature inside the panel could not be verified, since temperature monitoring sensors were not installed inside the electrical panel.

The *Precision Boilers Operation and Maintenance Manual*, Chapter 4, paragraph C.3, advises the user that:

> "All branch circuit connections should be tightened to 35-40 inch lbs torque to avoid component damage from heat build-up."

The Electrical Supervisor's notes regarding the changes/repairs performed as prescribed in Work Request WR-SN-OPS-127 state that "I torque all electrical connections on the fuse blocks to 40 lb-in, and all power connections on the contactors to 45 lb-in." There are no records of torquing other than the Electrical Supervisor's notes regarding "lb-in" (pounds per inch) use to secure the connections to the busbar.

Modifications to the boiler electrical panel were necessary for the equipment to meet the facility's operational requirements. The modifications (components, wire, insulating panels, power supply, and contactors) were not evaluated for their potential impacts on the electrical panel's performance. The modifications were not communicated to the manufacturer for evaluation of their impact on the equipment design parameters. This resulted in voiding the UL listing and manufacturer's warranty of the electrical panel.

Certain aspects of the FWENC change process were not evident through the course of the modifications to key components of the electrical panel. The normal FWENC change process should include the following:

- TRU Project Change Proposal
- DCN
- Work Request
- Performance of the modification/maintenance
- QA (verification)

A review of the documents related to the modifications performed on the electrical panel shows that the work was completed without proper, complete, and traceable documentation. In fact, modification to the electrical panel to install the insulating panel could circumvent certain requirements, allowing unqualified workers inside the energized electrical panel.

OSHA states that a Qualified Person is "one who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved." OSHA further states that additional requirements for qualified persons shall, at a minimum, be trained in and be familiar with the following:

(1) The skills techniques necessary to distinguish exposed live parts from other parts of electric equipment

(2) The skills and techniques necessary to determine the nominal voltage of exposed live parts

(3) The clearance distances specified in Title 29 Code of Federal Regulations (CFR) Part 1910.333(c) and the corresponding voltages to which the qualified person will be exposed.

The modifications to the electrical panel were made without contacting or obtaining approval of the manufacturer. If the approval of the manufacturer is not obtained, approval of the modification should be obtained from the Authority Having Jurisdiction (AHJ). This process should follow the guidance in the *DOE Electrical Safety Handbook*, which addresses modifications and who should approve these modifications. The handbook states that when modifications are made to equipment, an individual designated as the electrical AHJ should approve the modifications. The AHJ should possess such executive ability as is required for performance of the position and should have thorough knowledge of standard materials and work practices used in the installation, operation, construction, and maintenance of electrical equipment. The AHJ should, through experience or education, be knowledgeable of the requirements contained in the OSHA standards, the NEC, the National Electrical Safety Code, DOE requirements, and other appropriate local, state, and national standards. The AHJ should be responsible to interpret codes, regulations and standards and to approve equipment, assemblies, or materials.

In addition to the *DOE Electrical Safety Handbook*, NEC 80.19 and 90.4-2002 state that "By special permission, the AHJ may waive specific requirements in this Code or permit alternative methods where it is assured that equivalent objectives can be achieved by establishing and maintaining effective safety."

NEC also states in 90.7-2002 that "It is the intent of this Code that factory-installed internal wiring or the construction of equipment need not be inspected at the time of installation of the equipment, except to detect alterations or damage, if the equipment has been listed by a qualified electrical testing laboratory that is recognized as having the facilities described in the preceding paragraph and that requires suitability for installation in accordance with this Code." However, the modifications to the equipment at the FWENC TRU Waste Processing Facility were made without approval of the manufacturer or the AHJ and resulted in the UL listing and manufacturer's warranty being voided.

Subsequent to the procurement of the equipment, a FWENC QA receipt inspection and verification of all equipment components did not identify discrepancies between the "as constructed" configuration and the "as received" configuration of the electrical panel. Specifically, the drawings were modified to reflect an "as constructed" installation of #8 AWG instead of #6 AWG without an appropriate revision date identified on the drawing. Additional programmatic deficiencies of the FWENC QA Program include the following:

- Equipment was not configured as specified in procurement.
- Installation was not in accordance with the vendor's operating and maintenance manual.
- The current procedure does not reflect the existing configuration of the equipment.
- FWENC failed to adequately adhere to all facets of its change control procedure.

3.3 Change Analysis

Change is anything that disturbs the "balance" of a system which is operating as planned. Change is often the source of deviations in system operations. Change analysis examines planned or unplanned changes that caused undesired results or outcomes related to the incident. This process analyzes the difference between what is normal (or "ideal") and what actually occurred. The results of the change analysis are used to support the development of the causal factors. Table 3-2 contains the change analysis.

Table 3-2. Change Analysis

Normal or Ideal Condition	Actual Condition	Analysis
1. A defined set of functions and requirements is developed.	FWENC selected an off-the-shelf system that was marginal for the planned use.	1. Ambient conditions exceeded design parameters, resulting in accelerated degradation of components. 2. The vendor's recommendations for external ventilation and torquing of connections were not followed. 3. Operational requirements identified after installation of the boiler resulted in the need to modify the electrical panel.
2. The panel is operated as originally configured.	1. The panel was modified to an external 120V controller power source. 2. Installation of the insulating panels could circumvent certain requirements, allowing unqualified workers inside the electrical panel.	1. Impacts to equipment from modifications were not evaluated by the vendor or the AHJ. 2. The equipment modifications voided the UL listing. 3. The electrical panel modifications resulted in failure.
3. The Configuration Management Program maintains control of system components.	Key configuration management components were not adequately implemented for equipment modifications.	Changes to the panel were made without adequate controls and management approval. This resulted in a failure to adequately include all procedural aspects of change control.

Table 3-2. Change Analysis (continued)

Normal or Ideal Condition	Actual Condition	Analysis
4. Ensure that equipment modifications do not degrade equipment performance or compromise safety.	Modifications were made without vendor input and sufficient engineering analysis.	1. When a separate 120V power source was provided and the 480V circuit was energized, all of the contactors could simultaneously activate. 2. The addition of micarta insulating panels restricted ventilation and resulted in temperatures above those recommended for safe operation. 3. Crimping end caps were not used for the replaced conductors at the busbar. 4. The 50-amp contactors were replaced with 60-amp contactors. 5. The solid unshielded wire between the fuses and contactors was replaced with flexible shielded wire. 6. Some wires were changed from #8 AWG 125°C to #8 AWG 150°C.
5. Adequately qualified/trained electrical workers are available to perform adjustments to the electrical/control panel.	The modifications may allow nonqualified electrical workers to access panel area.	Current electrical work is performed by FWENC Construction personnel for the Operations organization. • Construction utilizes qualified electrical subcontractors • FWENC electricians are qualified to access electrical control panel • The wet waste operators are not qualified to access 480V electrical components

Table 3-2. Change Analysis (continued)

Normal or Ideal Condition	Actual Condition	Analysis
6. The vendor's operations and maintenance manual equipment configuration are reflected/captured in FWENC's operating procedures.	FWENC's operations and maintenance procedure do not reflect the current equipment configuration.	1. The original equipment configuration is not in the *Precision Boilers Operation and Maintenance Manual*. 2. FWENC's modifications to the equipment were not included in its procedures.
7. An engineering analysis of electrical component is performed prior to modification.	No evaluation of the electrical components was performed prior to installation.	1. For the contactor replacement, "bigger may not be better." 2. Crimping sleeves were not used. 3. Binding conductors into bundles increased the heat/transfer of heat between the clusters of conductors. 4. FWENC changed the uninsulated conductors from fuse blocks to contactors.
8. Follow the manufacturer's recommendation for power supply configuration.	A separate power source was supplied for equipment outside the manufacturer's design.	A WYE-configured power system supplied electrical energy to the boiler. The manufacturer specifically warns against using the WYE or Star configuration (Chapter 3.B.3, page 7 of the *Precision Boilers Operation and Maintenance Manual*).

3.3.1 Change Analysis Narrative

The development of the functions and requirements identified in the procurement process did not adequately capture the operational parameters. The result was a need to modify the electrical panel to meet revised facility operation requirements. As a result, the ambient conditions exceeded the design parameters, which caused accelerated degradation of components.

The boiler and the associated electrical panel were UL listed as designed by the manufacturer. FWENC's modifications to provide an external, 120V-controller power source and installation of insulating panels were not evaluated by the manufacturer or AHJ.

FWENC removed, without vendor approval, the 120V power supply for the boiler controller and provided service to an external power supply. The modification to add a separate power source of 120V was not adequately evaluated to determine the potential hazards that could be introduced. According to Precision Boilers, Inc., this configuration is an option that can be provided. However, when it is supplied by the vendor, provisions are made to regulate the engagement of contactors. Special notes in the startup instructions specifically address boilers with "shunt trip disconnects" and remote 120V power.

Significant components of the FWENC Configuration Management Program were not adequately implemented for modifications to the electrical panel. Changes to the panel were completed without adequate controls and requisite management approval. This resulted in failure to implement all aspects of the appropriate procedures.

The original assembly by the manufacturer used crimping sleeves (see Exhibit 12) on the wire connected to the busbar. The purpose of the crimping sleeve is to provide protection to the individual strands of copper in the connector. In addition, the crimping sleeves maintain the cohesiveness of the individual strands within the conductor so that the electrical load can effectively be transmitted via all strands in the conductor.

Modifications to the type of wire (see Exhibit 12), connectors, and contactors, (the 50-amp contactors that were built to International Electrotechnical Commission standards were changed to 60-amp contactors), etc., were changed after the first event without approval of the manufacturer of the equipment. (See Exhibit 13.) A second power switch was also installed in the control panel on the 120V power supply that was not shown in Revisions 1, 2, or 3 of the boiler operation procedure.

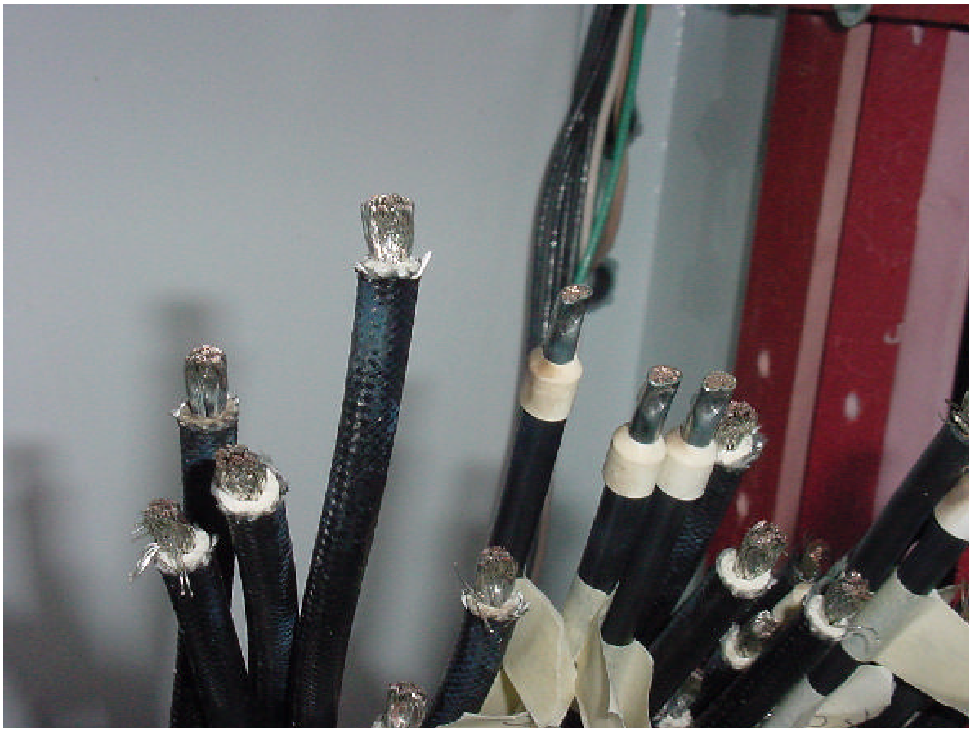

Exhibit 12. Wire With Crimping Sleeves and Without

Exhibit 13. Contactors Used by Precision Boilers, Inc.

Further, the installation of the micarta insulating panel (see Exhibit 14) resulted in the reduction of the manufacturer's ventilation system and increased the amount of heat inside the panel. With the temperature in the boiler room being estimated between 90°F and 95°F, the temperature inside the panel can be assumed to be notably higher.

Exhibit 14. Micarta Insulating Panel

The *Precision Boilers Operation and Maintenance Manual* states the following:

> **<u>!Caution!</u>**
>
> "If the boiler is to be placed in a room with little or no ventilation, a supply of ducted filtered air may have to be brought to the lower portion of the control cabinet to limit the control cabinet interior temperature to 50°C (122°F) maximum."

The modifications were the result of an interpretation of OSHA and NFPA 70-E requirements for qualified and unqualified electrical workers that was improperly implemented by FWENC. (See Exhibit 15.) This exhibit is a quote of the text of an electrical policy e-mail sent out on November 8, 2002, by the FWENC ESH&Q Manager to the Electrical Engineer, Senior Supervisor Engineer, Health and Safety Officer, Operations Manger, Construction Manager, Electrical Supervisor, Deputy Project Manager, Design Manager, and Tetra Tech Foster Wheeler Project Oversight representative.

"11/08/2002 10:44 AM

Subject: Electrical Equipment

It was identified in a meeting yesterday afternoon that a number of pieces of equipment at the Waste Processing Facility may not have the ability to be worked on in a de-energized condition. In addition, due to the type of maintenance/repair required, appropriate PPE may not be able to be worn while performing the work. The equipment identified where this may be an issue is as follows:

Boiler
Air Handling Units
JAYGO Panel
Duct Heaters
Buffalo Technologies Panel
H-202 Controller
LLW Bogie
Crane Controls

We discussed the possibility of retrofits and/or barriers to this equipment. Please provide feedback as to the hazard associated with the above mentioned equipment and advise on the possibility of retrofits/barriers or other means to allow working on the equipment in a safe OSHA compliant manner. I'm at . . . if you wish to discuss this further. Thanks."

Exhibit 15. FWENC Policy E-Mail

OSHA states that a Qualified Person is "one who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved." OSHA further states that additional requirements for qualified persons shall, at a minimum, be trained in and be familiar with the following: (1) the skills techniques necessary to distinguish exposed live parts from other parts of electric equipment, (2) the skills and techniques necessary to determine the nominal voltage of exposed live parts, and (3) the clearance distances specified in 29 CFR 1910.333(c) and the corresponding voltages to which the qualified person will be exposed.

The following notes are excerpts from 29 CFR 1910 explaining qualified and unqualified persons.

"Note 1: Whether an employee is considered to be a 'qualified person' will depend upon particular circumstances in the workplace. It is not uncommon for an individual to be considered 'qualified' to work on certain equipment in the facility, but 'unqualified' regarding other duties and/or equipment in the same facility. See 29 CFR 1910.332(b) (3) for electrical training requirements that specifically apply to qualified persons."

"Note 2: An employee who is in an on-the-job training status and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person is considered to be a qualified person for the performance of those duties."

OSHA states in 29 CFR 1910.333(a) "General. Safety-related work practices shall be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts, when work is performed near or on equipment or circuits which are or may be energized. The specific safety-related work practices shall be consistent with the nature and extent of the associated electrical hazards."

OSHA also states in 29 CFR 1910.333(c)(2) that "Work on energized equipment. Only qualified persons may work on electric circuit parts or equipment that has not been deenergized under the procedures of paragraph (b) of this section. Such persons shall be capable of working safely on energized circuits and shall be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools."

In addition, OSHA states in 29 CFR 1910.335(a)(1)(i) that "Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed."

In addition, NFPA 70-E states that "a qualified person is an employee whose duties require working on or in the vicinity of energized equipment or lines and who shall perform only those tasks for which they are trained, equipped, authorized, and so directed."

FWENC's operations and maintenance procedure does not reflect the current equipment configuration such as the following:

- Checking/verifying the torque of connections daily for the initial 10 days of operation.

- Procedures used for restart of the boiler do not address the modifications made to the equipment. Restart of the boiler after providing an external 120V to the control panel was done using a procedure that did not address the modification.

An adequate evaluation of the electrical components was not performed prior to installation. Examples of electrical components not properly evaluated were the replacement of the contactors, the lack of crimping sleeve use, and bundling of conductors together.

The electrical power supplying the boiler was a WYE configuration. The manufacturer specifically warns against using WYE or Star configuration (Chapter 3.B.3, page 7 of the *Precision Boilers Operation and Maintenance Manual*).

3.4 Events and Causal Factors

The direct cause is the immediate events or conditions that caused the accident/incident. The contributing causes are the events or conditions that, collectively with the other causes, increased the likelihood of the incident but which did not cause this incident. Root causes are the events or conditions that, if corrected, would prevent recurrence of this and similar incidents. The direct cause of the incident was the improper modification of the electrical panel.

Table 3-3. Causal Factors

Direct Cause: Improper modification of the electrical panel.	
Root Causes	**Discussion**
FWENC management has ineffectively administered the change control process.	Management systems did not provide assurance that all items procured met the requirements for their intended use or that the modifications were appropriate. Engineering evaluations were not reliably performed during the procurement or modification processes.
Contributing Causes	**Discussion**
CC-1. The system requirements were not clearly defined.	The details of the boiler operation were not adequately conveyed to the vendor prior to fabrication. The omission of basic requirements during procurement was fundamental to a subsequent need to modify the electrical panel.
CC-2. The FWENC QA Program is ineffective.	1. Receipt inspection of the equipment was documented six months after actual receipt. 2. The original acceptance criteria for the equipment and postmodification inspections lacked sufficient rigor. 3. "As designed" drawings were modified to reflect the "as constructed" configuration subsequent to delivery and acceptance. 4. Modifications and repairs to the electrical panel voided the UL listing for the equipment.

Table 3-3. Causal Factors (continued)

Contributing Causes	Discussion
CC-3. There is inadequate documentation for the change process.	Inconsistent application of the change process by FWNC, which should encompass the following aspects: 1. TRU Project Change Proposal 2. DCN 3. Work Request 4. Performance of the work 5. QA (verification)
CC-4. FWENC's procedures do not reflect the vendor's operation and maintenance manual and other vendor recommendations.	1. The electrical cabinet was installed in a building that has a potential to exceed the manufacturer's recommendations for operating temperature inside the panel without installing an external, filtered air supply. 2. The electrical configuration of the system supplying the electrical panel did not meet the manufacturer's recommendation. 3. The vendor's recommendation for force and frequency for torque of connections was not met.
CC-5. FWENC failed to follow procedures that reflect the current equipment configuration.	1. Startup of the boiler subsequent to the modification used a previous procedure revision that did not address the changes. 2. The current FWENC procedure does not reflect the current electrical panel configuration.
CC-6. FWENC operated the equipment outside the design parameters.	1. The electrical configuration of the system supplying the electrical panel did not meet the manufacturer's recommendation. 2. The electrical cabinet was installed in a building that has a potential to exceed the manufacturer's recommendations for operating temperature inside the panel without installing an external, filtered air supply.

Table 3-3. Causal Factors (continued)

Contributing Causes	Discussion
CC-7. FWENC did not evaluate the impact of the changes on equipment/system performance.	1. The shunt trip disconnects (which would have been included by manufacturer) were not included in the modification that provided an external 120V power source to the control panel. 2. Modification of the electrical panel without the vendor's approval voided manufacturer's warranty and the UL listing for the equipment. 3. Installation of the micarta insulating panels blocked ventilation, which could potentially elevate the temperature inside the electrical panel above the manufacturer's recommendations for the components.
CC-8. FWENC misapplied the OSHA and NEC requirements.	Installation of the insulating panel could circumvent the requirements, allowing unqualified workers into the electrical panel.

3.5 Integrated Safety Management

In April 2001, ORO conducted an ISM system focused Phase I and Phase II verification on construction for FWENC. The verification team made the following recommendations:

"1. The DOE ORO Manager should approve Revision 2 of the FWENC ISMS description contingent on FWENC's resolving minor inconsistencies in accordance with Opportunity for Improvement OP-OBJ-OFI.1.

2. The DOE ORO Manager should concur with FWENC's implementation of its ISMS in the construction phase of the project."

It should be noted that the identified weaknesses in implementation of the ISM core functions have resulted since the verification was concluded, including the original procurement of the boiler in October 2001. FWENC is transitioning from a construction to an operational phase of the project.

Table 3-4. Weaknesses in Implementation of ISM Core Functions

There are significant weaknesses in FWENC's implementation of the five core functions of ISM that contributed to this event. These weaknesses include the following:

Core Function 1 – Define the Work

- Equipment functions and requirements identified in the procurement process did not adequately capture the operational parameters for the facility.
- FWENC's Engineering, Operations, QA, and Health and Safety organizations were not adequately involved in the process to clearly identify the intended location and application of the equipment.
- FWENC modified the electrical panel to meet revised facility operation requirements.
- Postmodification ambient conditions exceeded the design parameters, producing an accelerated degradation of contactors.

CC-1. The system requirements were not clearly defined.

Table 3-4. Weaknesses in Implementation of ISM Core Functions (continued)

There are significant weaknesses in FWENC's implementation of the five core functions of ISM that contributed to this event. These weaknesses include the following:

<u>Core Function 2</u> – Analyze Hazards

- The manufacturer used crimping sleeves on the wire ends connected to the busbar. The sleeves provide protection to and maintain the cohesiveness of the individual copper strands within the connector so that the electrical load is effectively transmitted via the entire conductor.
- FWENC made modifications of the type of wire, conductors, and contactors after the first event without involving the manufacturer of the equipment.
- FWENC made the modifications to the electrical panel without contacting or obtaining approval from the manufacturer or the AHJ.
- The modifications to the equipment resulted in the UL listing and warranty being voided.
- A second electrical switch was installed in the control panel and was not included in Revisions 1, 2, or 3 of the boiler operation procedure.
- FWENC installed insulating panels that blocked the exhaust vents.

CC-7. FWENC did not evaluate the impact of the changes on equipment/system performance.
CC-8. FWENC misapplied the OSHA and NEC requirements.

<u>Core Function 3</u> – Develop and Implement Controls

- Certain aspects of the change process were not evident through the modifications to the electrical panel.
- The *Precision Boilers Operation and Maintenance Manual* was supplied, but key elements were not followed or appropriately integrated into procedures.
- Inadequate ventilation and/or elevated room temperature may require a supply of ducted, filtered air to be supplied to the control cabinet as recommended by the boiler manufacturer.
- Connections were torqued in excess of the required 35-40 inch lbs.

CC-3. There is inadequate documentation for the change process.
CC-4. FWENC's procedures do not reflect the vendor's operation and maintenance manual and other vendor recommendations.

Table 3.4. Weaknesses in Implementation of ISM Core Functions (continued)

There are significant weaknesses in FWENC's implementation of the five core functions of ISM that contributed to this event. These weaknesses include the following:

<u>Core Function 4</u> – Perform Work Safely

- FWENC's procedures do not incorporate revisions to the boiler electrical panel.
- The electrical power supplying the boiler was a WYE configuration, which was contrary to the *Precision Boilers Operation and Maintenance Manual*.
- Although electrical workers are qualified and trained to perform their respective tasks, systems were modified to allow wet waste operators to access the control panel inside the electrical panel.

CC-5. FWENC failed to follow procedures that reflect the current equipment configuration.
CC-6. FWENC operated the equipment was outside the design parameters.

<u>Core Function 5</u>– Feedback and Improvement

- QA receipt inspection and verification of all equipment components failed to identify discrepancies between the "as constructed" configuration and the "as received" configuration of the electrical panel.
- QA receipt inspection was not completed until approximately six months after receipt of the equipment.
- FWENC failed to adequately adhere to all facets of its change control procedure.
- FWENC's restart of the boiler system was in accordance with T-UT-FW-P-OP-504, *Boiler, Steam, and Condensate Systems*, Revision 0, which did not reflect significant modifications to the electrical panel.

CC-2. The FWENC QA Program is ineffective

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4.0 CONCLUSIONS AND JUDGMENTS OF NEED

Judgments of Need (see Table 4-1) are the managerial controls and safety measures determined by the Board to be necessary to prevent and/or minimize the probability or severity of a recurrence. The Judgments of Need flow from the causal factors, which are derived from the facts and analyses. Judgments of Need are directed as providing guidance for managers during the development of corrective actions.

The Board reviewed the equipment procurement process, physical evidence related to the incident, the modifications, and the first incident report and associated corrective actions. In the course of the investigation, Board members visited the boiler manufacturer's facility and conducted numerous interviews with representatives of FWENC, Tetra Tech NUS, Inc.; Tennessee Associated Electric; Precision Boilers, Inc.; Lockwood Greene; Bechtel Jacobs Company LLC; and DOE. Applicable codes, CFRs, and consensus standards were consulted, and an independent experimental analysis of panel material was reviewed.

Judgments of Need were developed that considered the actions necessary to prevent recurrence of this event. The Board focused on the management of the procurement change process and QA.

It is the opinion of the Board that the procurement process inadequately identified and defined the functions and requirements for the boiler package. After installation and initial startup, FWENC management ineffectively administered the change control process meant to correct problems, thus compromising the operational integrity of the boiler panel and ultimately resulting in the event. QA failed to identify the deficiencies throughout the process that might have averted the failure.

Table 4-1. Judgments of Need

No.	Judgment of Need	Related Causal Factors
JON 1	FWENC management needs to evaluate the change control process and implement appropriate procedures to ensure the effective management of change and configuration control.	RC: FWENC management has ineffectively administered the change control process. CC-1: System requirements were not clearly defined. CC-2: FWENC's QA Program is ineffective. CC-3: There is inadequate documentation for the change process. CC-5: FWENC failed to follow procedures that reflect the current equipment configuration. CC-7: FWENC did not evaluate the impact of changes on equipment/system performance. CC-8: FWENC misapplied the OSHA and NEC requirements.
JON 2	FWENC management needs to evaluate the current QA program and integrate a comprehensive QA/QC component into all project aspects.	CC-1: System requirements were not clearly defined. CC-2: FWENC's QA Program is ineffective. CC-4: Procedures do not reflect the vendor's operations and maintenance manual and other vendor recommendations. CC-5: FWENC failed to follow procedures that reflect the current equipment configuration. CC-6: FWENC operated the equipment outside the design parameters. CC-7: FWENC did not evaluate the impact of changes on equipment/system performance.

Table 4-1. Judgments of Need (continued)

No.	Judgment of Need	Related Causal Factors
JON 3	Vendor manuals, vendor recommendations, codes, and standards need to be included or addressed in procedures, designs, and modifications.	RC: FWENC management has ineffectively administered the change control process. CC-2: FWENC's QA Program is ineffective. CC-4: Procedures do not reflect the vendor's operations and maintenance manual and other vendor recommendations. CC-5: FWENC failed to follow procedures that reflect the current equipment configuration. CC-6: FWENC operated the equipment outside the design parameters. CC-7: FWENC did not evaluate the impact of changes on equipment/system performance. CC-8: FWENC misapplied the OSHA and NEC requirements.
JON 4	FWENC management must ensure that procedures are reviewed, updated, or amended to reflect the current state of the equipment operation, personnel, or process.	RC: FWENC management has ineffectively administered the change control process. CC-2: FWENC's QA Program is ineffective. CC-3: There is inadequate documentation for the change process. CC-4: Procedures do not reflect the vendor's operations and maintenance manual and other vendor recommendations. CC-5: FWENC failed to follow procedures that reflect the current equipment configuration. CC-6: FWENC operated the equipment outside the design parameters. CC-7: FWENC did not evaluate the impact of changes on equipment/system performance.

Table 4-1. Judgments of Need (continued)

No.	Judgment of Need	Related Causal Factors
JON 5	FWENC must ensure that equipment is operated within design parameters	CC-6: FWENC operated the equipment outside the design parameters. CC-7: FWENC did not evaluate the impact of changes on equipment/system performance.
JON 6	FWENC management must ensure that corrective actions and recommendations from accidents/ incidents are addressed, implemented, and disseminated through a lessons learned program.	CC-4: Procedures do not reflect the vendor's operations and maintenance manual and other vendor recommendations. CC-5: FWENC failed to follow procedures that reflect the current equipment configuration. CC-6: FWENC operated the equipment outside the design parameters. CC-7: FWENC did not evaluate the impact of changes on equipment/system performance.

5.0 BOARD SIGNATURES

David L Buhaly

David L. Buhaly, Chairperson
Laboratory Support Team
Oak Ridge Operations Office

Date: 16 MAY 2003

Jacqueline Noble-Dial

Jacqueline Noble-Dial
DOE Accident Investigation Trained Board Member
Melton Valley Closure Project
Oak Ridge Operations Office

Date: 16 May 2003

Charles F. Wright

Charles F. Wright
DOE Accident Investigation Board Member
EM Facility Representative Group
Oak Ridge Operations Office

Date: 16 May 2003

John D. Pearson

John D. Pearson
DOE Accident Investigation Board Member
Laboratory Support Team
Oak Ridge Operations Office

Date: 16 May 2003

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6.0 BOARD MEMBERS, ADVISORS, AND STAFF

Chairperson	David L. Buhaly, ORO
Trained Accident Investigation Member	Jacqueline Noble-Dial, ORO
Member	Charles F. Wright, ORO
Member	John D. Pearson, ORO
Subject Matter Expert, Consultant	Larry Perkins, Operations Management International, Inc.
DOE Office of Chief Counsel	Nancy Carnes, ORO
Technical Coordinator	Diane Miller Visionary Solutions, LLC
Technical Coordinator	Barbara Kneece-Hogle Parallax, Inc.
Technical Editor	Karen Brown Informatics Corporation
Technical Assistance	Melisa Hart Critique, Inc.

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Appendix A – Type B Investigation Board Appointment Memorandum

DOE F 1325.8
(3/96)

United States Government

Department of Energy
Oak Ridge Operations Office

memorandum

DATE: April 10, 2003

REPLY TO
ATTN OF: SE-32:Mullins

SUBJECT: **TYPE B INVESTIGATION – APRIL 8, 2003, ELECTRICAL ARC BLAST, TRU WASTE PROCESSING FACILITY, FOSTER WHEELER ENVIRONMENTAL CORPORATION – OAK RIDGE, TENNESSEE**

TO: David L. Buhaly, Laboratory Programs Support Team, Operations Division, SE-31

You are hereby appointed Chairperson of the Investigation Board to investigate the subject incident that occurred at the Foster Wheeler Environmental Corporation TRU Waste Processing Facility on April 8, 2003. You are to perform a Type B investigation of this incident and to prepare an investigation report. The report shall conform to requirements detailed in the Department of Energy (DOE) Order 225.1A, *Accident Investigation,* and DOE G 225.1A-1, *Implementation Guide for Use with DOE 225.1A, Accident Investigations*. The Board will be comprised of the following members:

Jacqueline Noble-Dial, Environmental Technology Group, Accident Investigator
Charles Wright, EM Facility Representative, Team Member
John Pearson, Laboratory Support Team, Team Member
Larry Perkins, Subject Matter Expert, Operations Management International, Consultant
Nancy Carnes, Legal Advisor

The scope of the Board's investigation is to include, but is not limited to, identifying all relevant facts; analyzing the facts to determine the direct, contributing, and root causes of the incident; developing conclusions; and determining judgments of need that, when implemented, should prevent the recurrence of the incident. The Board will focus on and specifically address the role of DOE and contractor organizations and Integrated Safety Management Systems. The scope will also include an analysis of the application of lessons learned from similar accidents within the Department.

If additional resources are required to assist you in completing this task, please let me know and it will be provided. You and members of the Board are relieved of your other duties until this assignment is completed.

The Board will provide my office with weekly reports on the status of the investigation but will not include any findings or arrive at any premature conclusions until an analysis of all the causal factors have been completed. Draft copies of the factual portion of the investigation report will be submitted to my office and the contractor for factual accuracy review prior to the report finalization.

The final investigation report should be provided to me by May 12, 2003. Any delay to this date shall be justified and forwarded to this office. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report. A copy of the Oak Ridge Accident Investigation Guidelines is attached for your use. If you have any questions, please contact me or Robert Poe at 576-0891.

Gerald Boyd

Gerald G. Boyd
Manager

Attachment:
ORO AI Guidelines

cc w/attachment:
Jacqueline Noble-Dial, EM-93, ORO
Charles Wright, EM-94, ORO
Nancy Carnes, CC-10, ORO

cc w/o attachment:
B. A. Cook, EH-1, HQ/FORS
J. H. Roberson, EM-1, HQ/FORS
R. P. Berube, EH-4, HQ/FORS
M. D. Johnson, SC-3, HQ/FORS
R. H. (Chip) Lagdon, EH-21, HQ/270/GTN
D. L. Vernon, EH-24, HQ/270/GTN
G. J. Malosh, M-2, ORO
R. J. Brown, M- , ORO
S. L. Wyatt, M-4, ORO
R. W. Poe, SE-30, ORO
R. C. Smyth, EM-90, ORO
D. Boggs, EM-90, ORO
T. Noe, EM-94, ORO
M. Ferrer, EM-93, ORO
H. Monroe, SE-31, ORO
M. Robinson, SE-31, ORO

Appendix B – Event and Causal Factors Chart

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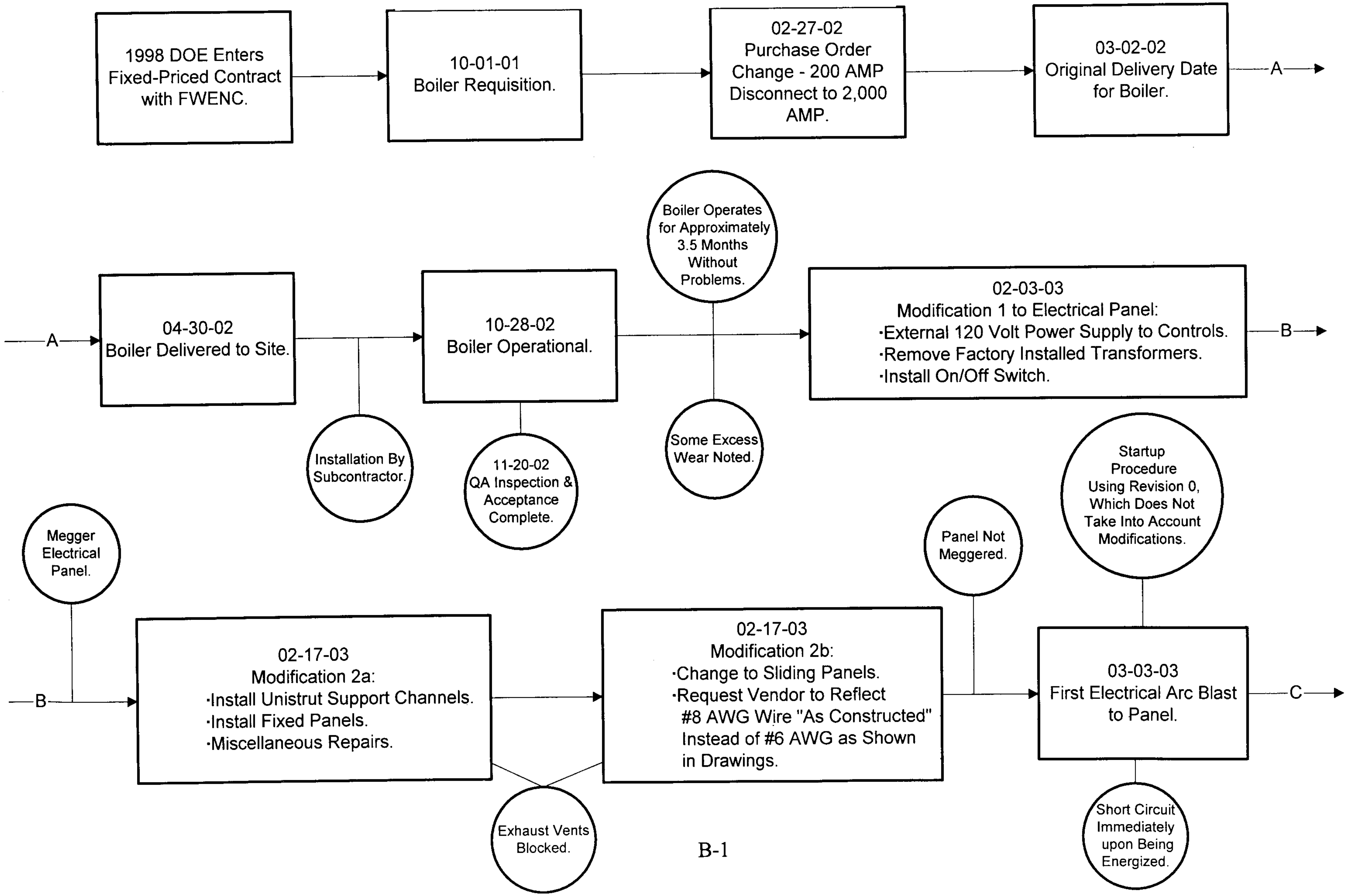
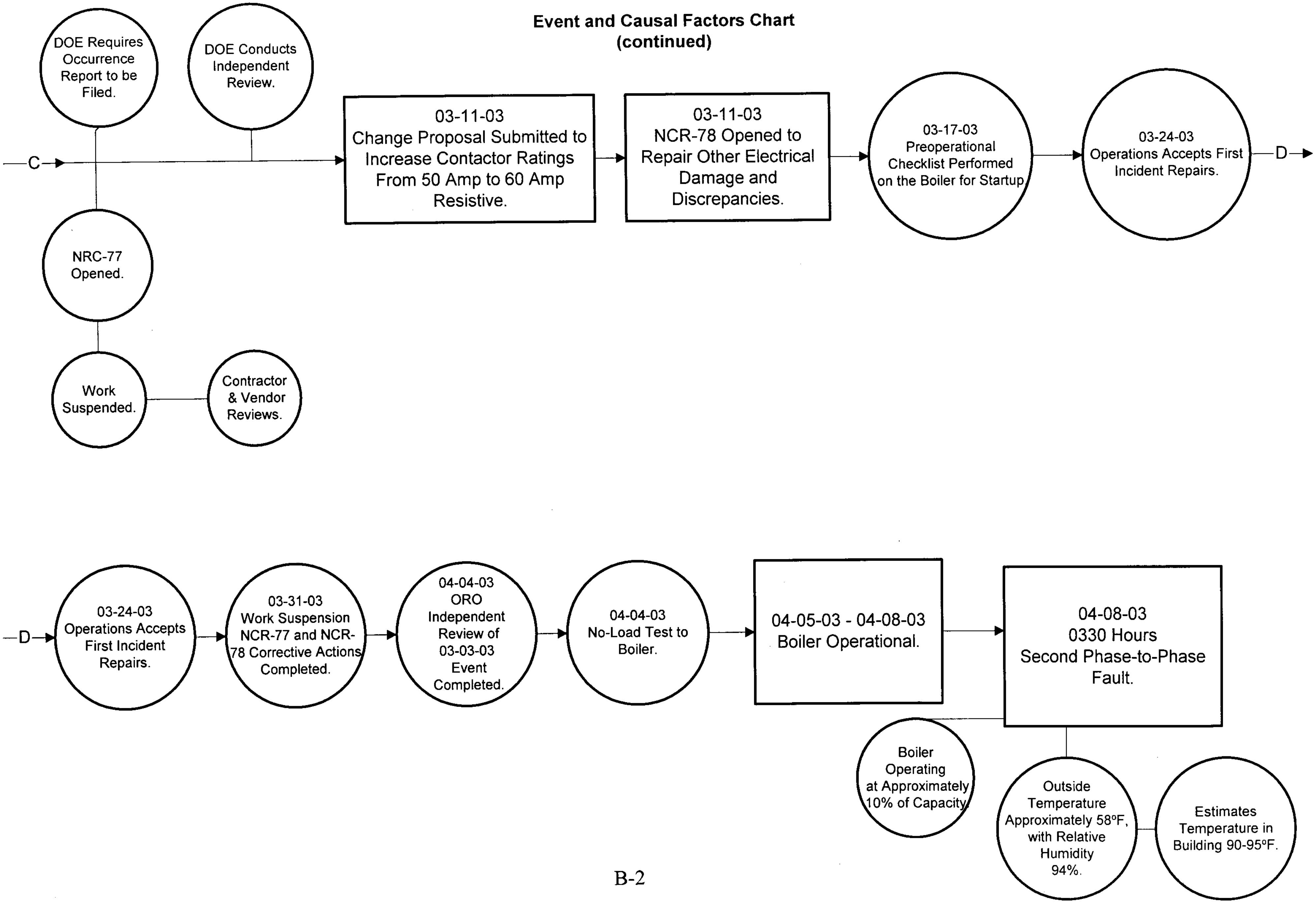
Event and Causal Factors Chart



Event and Causal Factors Chart (continued)



Appendix C – Receipt Inspection Report

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Attachment F: Receipt Inspection Report (Example)

RIR No: 2002-TRU-102
Quality Category: C
Page 1 of 8

FWENC PO No: 038780
BL No:

Supplier: PRECISION BOILERS, INC. c/o WADE & ASSOCIATES
Shipment: Partial/[✓ Complete]

Dwg/Rev No: SEE ATTACHED QC VERIFICATION PLANNING

Spec/Rev No: T-CM-FW-S-ME-006, R1

Description/Quantity: ONE (1) BOILER SYSTEM CONSISTING OF BOILER, BOILER FEED SYSTEM, BLOWDOWN TANK, AND CHEMICAL FEED SYSTEM.

Applicable Initial/Date	Receipt Inspection Criteria	A/R	Initial/ Date	Notes
A mwa 4/30/02	1. Item(s) identification/description meets PO, drawing, specification requirements.	A	mwa 11/20/02	
A mwa 4/30/02	2. Item(s) is clean and free from handling or shipping damage.	A.	mwa 11/20/02	SEE NOTE 1
A mwa 4/30/02	3. Item quantity received matches quantity ordered (if not, document difference).	A	mwa 11/20/02	
A mwa 4/30/02	4. Item(s) dimensions meet drawings/specifications requirements.	A	mwa 11/20/02	
N/A mwa 4/30/02	5. Item(s) inspected to verify fabrication, testing or inspection as required by PO, drawing, specification, applicable codes.	N/A	mwa 11/20/02	
A mwa 4/30/02	6. Item(s) inspected to confirm no "visible" suspect counterfeit parts.	A	mwa 11/20/02	
A mwa 4/30/02	7. RECORD ON RIR INDIVIDUAL SYSTEM COMPONENTS AND ANY LOOSE/SPARE PARTS	A	mwa 11/20/02	NONE
A mwa 4/30/02	8. ELECTRICAL INSPECTION TO VERIFY NO LOOSE CONNECTIONS, PANEL CLEANLINESS, ETC.	A	mwa 11/20/02	SEE NOTE 2

Notes: 1. SKID BASE DAMAGED DURING FACTORY HANDLING. DISPOSITIONED BY VENDOR LETTER DATED MAY 11, 2002 (ATTACHED).

Revew/Completion By: ______________ Printed Name ______________ Signature ______ Date

A/R = Accept/Reject

2. SEE ATTACHED ELECTRICAL INSPECTION.

3. MAJOR PORTION OF INSPECTION CONDUCTED AT RECEIVING 4/02. THE RIR COMPLETED AND ISSUE RESOLUTION COMPLETED 11/20/02

Packaged Boiler Electrical Inspection

CONDUCTED BY JOE CAPEZZA

1) Chemical Feed Skid:

   a) The three position switches and the indicating lights on the control panel do not have any tags, labels or escutcheons. TAGGING BY OPS. MWA 11/20/02

   b) Need "As Built" for drawing T-UT-52-D-EE-001, rev. 1. Vendor has provided a red indicating light; green indicating light marked up by FWENC is not installed. SUBMITTED AND APPROVED IN T-UT-52-M-ME-001, R1. MWA 11/20/02

2) Duplex Feed System:

   a) Need "As-Built" for T-UT-52-D-EE-002. Vendor has supplied two position On-Off switches instead of three position Hand-Off-Auto switches. Vendor wiring is shown color coded from the terminal strip to the control transformer and motors, actual color is gray. SUBMITTED AND APPROVED BY T-UT-52-M-ME-004, R1. MWA 11/20/02

3) Boiler Skid:

   a) Need "As-Built" for DD-B-011003. Locations of control components do not agree with the front view, see attached mark-up; control power pilot light is green, drawing shows amber. SUBMITTED AND APPROVED IN T-UT-52-M-ME-001, R1. MWA 11/20/02

   b) There are no escutcheons or labels on the combination switch/pilot lights for steps on. TAGGING BY OPS. MWA 11/20/02

   c) Need "As-Built" for T-UT-52-D-EE-003. Vendor revision 2 dated 2/2/02 is glued to the inside of the door. SUBMITTED AND APPROVED IN T-UT-52-M-ME-001, R1 MWA 11/20/02

2002-TRU-102-R1R
Pg 2 of 8

Appendix D – Independent Analysis of the Rubber Tubing

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Analysis of Rubber Tubing for Foster Wheeler TRU/Alpha Low Level Waste Treatment Project

By

Paul B. Crilly, Ph.D.
Associate Professor of Electrical and Computer Engineering
University of Tennessee, Knoxville, TN 37996
Telephone (865) 974-5470 (V), (865) 974-5483, Email: Crilly@utk.edu
May 6, 2003

Executive Summary

It is possible that the rubber tubing or gasket material that fits over a bended metal flange located above the fuse bank could have caused the April 8, 2003, 480 VAC phase-to-phase arcing and subsequent melting of the fuses to their holder. This is based on three pieces of evidence. First, in a previous arcing incident on March 3, 2003, with this electrical panel, the findings indicated that arcing was caused by a foreign material coming between the fuse contact and ground. Secondly, after the April 8 incident occurred and the fuse panel was opened up, rubber gasket material was found loosely draped across the melted fuses. Thirdly, it was determined by a separate experiment that unused (i.e. virgin) rubber material is conductive to 500 VDC. In fact, if several inches of this material is connected to a 500 VDC source, a current of 35 MA will flow and within approximately 90 seconds, the rubber material catches fire and shortly burns up. Therefore, if this rubber material did happen to dislodge itself from the metal flange and fall across the fuse block, the material could cause current to flow across the phase contacts and thereby eventually cause a phase-phase arcing. This report will describe the activity that leads me to this conclusion.

Preliminary activity and evaluation of possible causes

Situation

On April 11, 2003, I was asked to assist in the investigation of the cause of a 480 VAC phase-to-phase arc between several sets of fuse contacts in a 480 VAC/2000 amp power panel. The incident occurred on April 8, 2003. Note that 480 VAC is a root-mean-squared (RMS) value and thus has a peak value of 678 volts. I was able to physically inspect the damage inside the panel and observed that several fuses were melted to their holders and a section of rubber tubing was draped across or at least in the immediate vicinity of the nearby melted fuses. The entire piece of rubber tubing is about three feet long, quarter inch in diameter and is split down its length on one side so that it can be tightly attached to a horizontal sharp metal flange above the fuse holders. Its purpose was to keep nearby wires from chaffing the edge on the sheet metal flange. It was observed that most of the tubing was still attached to the flange but that several inches of the tubing had come off and had fallen down in a diagonal fashion and to be almost touching the fuse holder metal clips.

I did not observe any metal filings or other foreign particles inside the cabinet. The wiring and components appeared to be installed in a workmanlike manner.

I did observe that most of the melting was centralized to one or two sets of fuses, with lesser melting occurring on adjacent fuse holder contacts. This indicates that probably an arc started at one set of fuse contacts with the air heated such that arcing spread the adjacent contacts.

Possible causes

There are several possible causes for the arcing to occur. Most of these involve some type of foreign material that would go across the fuse contacts that in turn would initiate the arc. Again, once an arc is initiated, it can spread to other contacts. It is possible that a power line surge or other power line quality problem could have initiated an arc. However, I am not aware of any power line quality problems at the time the incident occurred. Therefore, it is my opinion that there is strong evidence that the arcing was caused by foreign material in contact with the fuse clips and specifically I feel this material was the rubber tubing that had become detached from the metal flange right above the fuse blocks.

Experimental

Preliminary

Several lengths of rubber tubing had their resistance measured by a *Megger* Instrument (BM11D). This device puts a 1000 VDC across the device to be measured (i.e. the rubber tube) and records the current flow. The current flow is converted to a resistance via ohms law. The following resistances were measured:

Length (inches)	1	3	10	36
Resistance (k-ohm)	10	20	20	20

The measured resistance of the rubber tubing was sufficiently low to state that the rubber tubing is more of a conductor than an insulator. Further investigation was warranted.

Primary experiment

Several virgin pieces of rubber tubing of the same type as used in the fuse panel were obtained from *Precision*. The virgin material was selected in order to best duplicate what happened on April 8. Note that the damaged rubber tubing had an excess buildup of carbon and its composition was somewhat changed. Therefore, it did not make sense to use this material in our experiment. A circuit consisting of a 500 VDC power supply feeding a milliamp meter in series with the four inches of rubber tubing was constructed. Note that 500 VDC is below the 480 RMS VAC (768 volts peak) that caused the arc in the first place. When the power supply was turned on, 35 milliamps (mA) of current initially flowed through the rubber tube. As the current flowed, the tubing heated, then smoked, and after 90 seconds caught on fire and popped the power supply circuit breaker. This experiment was repeated three more times on other virgin pieces of rubber tubing, four inches in length, and the results were always identical. The rubber warmed up, smoked, caught on fire and the power supply's circuit breaker popped. Five hundred volts DC at @35 mA is 17.5 watts. This means four inches of this rubber cannot absorb 17.5 watts without burning up.

The power supply voltage was then reduced to 350 VDC and the experiment was repeated. This time, 15 mA flowed through the rubber tube causing the rubber to absorb 350 x 0.015A = 5.2 watts of power. In this case, the rubber tubing became very hot, almost melting, but did not burn or catch on fire. It appears that the 350 VDC did not supply enough power to the rubber to cause it catch on fire.

Again it should be noted, in this experiment, the only path for the power supply current to travel was the rubber tubing and therefore, *we can say that this rubber tubing is a relatively good conductor and that it can easily conduct from a 480 VAC (678 volt peak)/2000 amp power source.*

Analysis

In a previous incident (March 3) with this fuse panel, arcing was attributed to metal shavings that came between the electrical conductors. The metal shavings were the foreign material that caused the arcing to occur. The above experiment demonstrates that rubber tubing, like metal shavings, is also conductive and is thus capable of initiating an arc when there is an excess of 480 VAC.

It is not clear how or when the rubber tubing dislodged itself from the metal flange and went to the vicinity of the fuse holder. Two possibilities exist. The first is that the rubber tubing was removed during maintenance and was left dangling near the fuse holders. The rubber has a black color and at first glance is easily indistinguishable from the black wires going to the fuse holders. I have no pictures indicating what the inside of the panel looked like after it was "buttoned up" between March 3 and April 8 and so we cannot say for sure whether or not the rubber was properly installed. A second possibility is that the heating inside the panel could soften the rubber and with vibration, heat, etc. cause a section of the rubber tubing to become dislodged from the metal flange and drift down to the fuse holders. In any case, we do know that after the April 8 incident occurred, when the panel was opened up and a section of rubber was draped near the fuse holders.

Recommendations

The data indicates that it is entirely possible that the rubber tubing was the foreign material that could have initiated the arcing in the 480 VAC/2000 amp power panel. Therefore, at least some other type of nonconductive material should be used in future designs. *A better alternative is that the wiring should be re-routed so that it cannot chafe against the edge of the metal flange.*

In order to provide better failure analysis in the future it is suggested that some type of power line monitoring be incorporated. Specifically the current and voltage to each panel, and the panel's internal temperature would be continuously sampled and recorded. This could be done via a computer system with the data stored for at least 24 or 48 hours before the storage media is re-used (similar to security videos). If an incident occurred, this data could provide a great deal of useful information on the state of the system before and during the incident. Furthermore, we could have an accurate determination if in fact power line quality problems were the cause of the problem.

Appendix E – Exhibit of Special Provisions in Contract

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EHS 1-4 ATTACHMENT A

FOSTER WHEELER ENVIRONMENTAL CORPORATION

SPECIAL PROVISIONS – ENVIRONMENTAL HEALTH AND SAFETY PROGRAMS

____________________________ Subcontractor

____________________________ Subcontract No.

Subcontractor hereby agrees to:

1. Comply with all federal, state, and local laws and regulations as well as all site rules and plans adopted by Foster Wheeler Environmental Corporation (FWENC) and its clients, pertaining to safety and health, pollution control, water supply, fire protection, sanitation facilities, waste disposal, emergency response notification and other related items.

2. Require their Site Manager to be available for all health and safety (HS) meetings.

3. Provide training and certification of training for all of their employees to perform site work safely and in accordance with OSHA and other applicable regulations and site procedures. Training for employees working on hazardous waste sites will meet the requirements of 29 CFR 1910.120, including initial, on-the-job, refresher, and supervisor training, as necessary. Training for employees who perform hazardous materials functions related to transportation must meet the requirements of 49 CFR 172, Subpart G, and employees who manage or otherwise handle hazardous waste will meet 40 CFR 264.16 or 265.16 training requirements. The PESM will determine the adequacy of subcontractor training programs, if required.

4. Provide or arrange for adequate first-aid facilities, persons qualified in first aid, and emergency transportation services. The SM shall be determine the adequacy of these arrangements and facilities.

5. Ensure that employees working on hazardous waste sites and other regulated areas are medically qualified and certified by a physician as capable of wearing personal protective equipment.

6. Report all site incidents that result in, or could have resulted in employee injury or illness, fire, explosion, spill, environmental release, permit exceedence or property damage immediately to the FWENC site representative. Such incidents will be investigated by the subcontractor to determine the causes and corrective actions. Copies of the investigation reports will be provided to FWENC and maintained on site.

7. Comply with the requirements of the FWENC Environmental Health and Safety (EHS) Plan(s) for the site work or develop and implement a Site EHS Plan in accordance with FWENC requirements.

8. Practice good housekeeping at all times. Waste, debris, and garbage shall be removed daily or placed in appropriate waste containers. All materials, tools, and equipment shall be stored in a safe, orderly and environmentally compliant fashion.

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Appendix F – *Boltswitch Installation, Operation and Maintenance Manual*

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BULLETIN 85

boltswitch®
bolted pressure contact switches

INSTALLATION, OPERATION AND MAINTENANCE MANUAL

boltswitch, inc.
6208 COMMERCIAL ROAD
CRYSTAL LAKE, ILLINOIS 60014

RECEIVING, HANDLING and STORAGE

Before installing, or operating this product, read these instructions carefully.

Upon receipt, examine the package for any damage sustained in shipment. Report any damage sustained in transit immediately.

Unpack carefully to avoid damage to the device. Be sure that no loose parts are missing or left in the packaging material. Remove any debris or loose packing material on or in the device. Most switches can be operated while standing on a bench. This makes it easy to test the switch for proper operation before installation.

The switch should be stored in a clean, dry location. Do not cover the switch with any packing or other material which absorbs moisture that may cause corrosion of parts. Cover the device with kraft, or other non-absorbent paper to keep it clean.

Manual switches are shipped in the closed position. Switches equipped with shunt trip operators are shipped in the open position.

INSTALLATION

Location

Better performance and longer life may be expected if the area is clean, dry, dust-free, and well ventilated. The switch should be easily accessible, and there should be sufficient space allowed for maintenance.

Mounting

These switches are designed to be mounted in a vertical position. Gravity does affect the operating characteristics.

Stationary Mounted Switches

Open switches are designed for mounting in a switchboard or enclosing case of the customer's design and construction. Adequate space must be provided to maintain electrical clearances. If installed in a switchboard enclosure, adequate ventilation may have to be provided. An additional opening is required for the switch operating means. Outline drawings provide the required dimensions for mounting the switch and these openings.. The fuse door of the switchboard or enclosing case should be hinged on the right side.

Mounting the switch consists of bolting the switch base to the supporting structure within the switchboard or enclosure and connecting the power buses or cables.

The surface to which the switch mounts must be true, flat, and capable of supporting the weight of the switch. After mounting the device in a switchboard or enclosure, it should be checked for squareness. If out of true, it may be necessary to loosen the mounting bolts, square up the switch as required, and then retighten the mounting bolts.

With the switch securely bolted to the supporting structure, mount the power buses or cable to the upper and lower terminals. Be sure that all terminal connections are of good conductivity and that the cables or bus are properly aligned and supported. Mating surfaces must be clean, parallel, have a smooth surface and be firmly bolted together. The bus or cable must have adequate current-carrying capacity to prevent excessive heating.

Check to see that the enclosure does not interfere with any of the moving parts of the switch.

ENERGIZING SWITCH

⚠ WARNING

BEFORE ENERGIZING THE SWITCH, THE CIRCUIT IT IS FEEDING SHOULD BE RUNG OUT TO MAKE SURE THAT IT IS FREE FROM SHORT CIRCUITS AND GROUND FAULTS.

Closing

The switch is closed by rotating the handle counter clockwise.

Opening

Manually operated switches are opened by rotating the handle clockwise.

Switches equipped with shunt trip operators are opened by use of the "trip lever" or by electrical tripping means. DO NOT USE THE HANDLE TO INITIATE OPENING.

Position Indicator Feature

If the switch is equipped with a position indicator, the actual position of the switch blades can be determined by the color showing in the indicator window. The position indicator window is located above and to the right of the operator shaft.

The color code is as follows:

Green -	The switch is open
Red -	The switch is closed
Yellow -	WARNING, THE SWITCH IS PARTIALLY CLOSED

IF ANY YELLOW APPEARS IN THE WINDOW, IMMEDIATE ACTION IS REQUIRED. This indicates that the switch blades are not fully closed. If the switch is left in this position, overheating and severe damage may occur. A thorough examination of the entire switch, with particular attention to the switch contacts, should be made as soon as possible.

Open the switch as indicated above (on shunt trip operators, USE THE MANUAL TRIP LEVER). If yellow still appears in the indicator window, the handle can be used to assist in breaking welds by rotating it in a clockwise direction.

Class I Ground Fault Systems

Switches equipped with optional Class I ground fault components provide protection to equipment only, not personnel. DO NOT WORK ON EQUIPMENT HOT.

MAINTENANCE

⚠ WARNING

MAKE SURE POWER IS DISCONNECTED TO THE LINE TERMINALS BEFORE REMOVING THE BARRIERS OR TOUCHING ANY CURRENT CARRYING PARTS.

Inspection

Periodic inspection of the switch is recommended at least once a year. More frequent inspections are recommended if operated under severe conditions, such as frequent operation, severe loads, high ambient temperature, dusty environment, moisture or other unfavorable conditions exist. A complete inspection of the device should always be made after the switch has interrupted a fault.

At regular inspection periods the switch should be operated. Observe the contact alignment and make sure all mechanism parts move freely without binding or excessive friction.

If overheating is observed, a complete inspection of the switch should be made including connections and contacts.

The insulating surfaces of the switch should be kept free of pencil lines, paint, oil or other foreign materials as they may cause low resistance between points of different potential and result in electrical breakdown.

Maintenance After Interrupting a Fault

⚠ WARNING

IF A GROUND FAULT RELAY CAUSES A SWITCH TO OPEN, THE FAULT SHOULD BE LOCATED AND REMOVED BEFORE RECLOSING THE SWITCH. A thorough inspection of the device should be made before putting the switch back in service. Particular attention should be given to the arcing contacts (both stationary and moving), blades, jaw terminals, and arc quenchers. Removal of the barriers may be necessary for inspection or repairs.

Any weld marks, pitting or burrs on the blades or jaw terminals should be filed smooth and relubricated. Excessive overflash on the barriers may warrant their replacement. Arcing contacts and arc quenchers should be examined as previously explained.

By disconnecting one end of the connecting rod (remove cotter pin and clevis pin), the crossbar of the switch can be operated slowly by hand. This provides an easy means of checking blade alignment, arcing contact adjustment and ease of blade closing. The arcing contacts should make brushing contact, should all touch simultaneously, and should make contact prior to the blades making contact. Be sure to reinstall the cotter pin when reassembling the connecting rod.

The switch should be operated several times without power connected. Check to see that the blades close fully. Observe the crossbar to see that it travels completely. It should rotate approximately 90 degrees and be near or touching the blades when closed. On opening, the blades should rotate approximately 45 degrees and should be clearly separated from the jaw contacts.

BEFORE ATTEMPTING TO PUT THE SWITCH BACK IN SERVICE, BE CERTAIN THE GROUND FAULT SENSING EQUIPMENT HAS BEEN RESET.

Lubrication

In general, the switch is adequately lubricated before shipment to withstand normal service requirements. However, when severe operating conditions are encountered, the following lubrication procedure is recommended:

A - Hardened grease and dirt should be removed from bearing surfaces by using kerosene.

B - A thin film of nonconductive lubricant should be applied to all contact sliding surfaces. Petroleum jelly (Vaseline) works very well, and is readily available.

C - Linkages and operator joints may be lubricated with light machine oil.

⚠ WARNING

DO NOT USE ELECTRICALLY CONDUCTIVE GREASE. THE USE OF A CONDUCTIVE GREASE, SUCH AS GRAPHITE GREASE OR CONDUCTOR TERMINATION COMPOUND, COULD CAUSE SEVER DAMAGE.

High temperature greases are not recommended for general use because they tend to solidify at lower temperatures.

Arc Quencher Replacement

The arc quenchers should be inspected for cracks in the molded sides and excessive erosion of the steel plates. Damaged parts should be replaced.

Arcing Contact Replacement

The stationary arcing contacts and the movable arcing contacts should be inspected for excessive erosion. Excessively worn parts should be replaced.

⚠ CAUTION

READJUSTING THE BOLTED PRESSURE CONTACT MECHANISMS TO OTHER THAN FACTORY SPECIFICATIONS COULD CAUSE SWITCH FAILURE.

The bolted pressure contact mechanisms are factory set and should not need to be readjusted under most circumstances. If adjustment is needed, consult the factory.

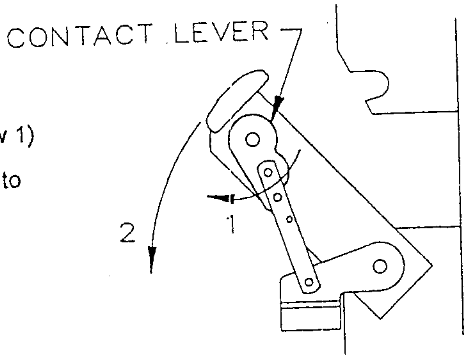
MAINTENANCE TIP

For easy maintenance, the blades may be "dropped down".

To drop the blades:

1. Rotate the contact lever as shown (arrow 1)
2. As it rotates, the blades will rotate down to allow improved access (arrow 2).

BE SURE TO RETURN THE BLADES TO THEIR ORIGINAL POSITION BEFORE OPERATING SWITCH. To do this, push the blades up until they click into position.



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Appendix G – *Precision Boilers Operation and Maintenance Manual*

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PRECISION Boilers

Electric Hot Water and Steam Boilers

OPERATION AND MAINTENANCE MANUAL

→ WARNING ←

A complete understanding of this manual is required before attempting to operate or maintain the equipment. Improper installation, adjustment, alteration, service or maintenance can cause injury or property damage.

The equipment should be operated and maintained only by personnel who have read this manual and who have a working knowledge and understanding of the equipment.

NOTE

These instructions are intended as a guide for the Installing Contractor and as a reference for the Operator, Owner and Serviceman.

RETAIN THESE INSTRUCTIONS NEAR THE EQUIPMENT FOR READY REFERENCE

The instructions contained in this manual are intended as a guide only and do not supplant any National, State or Local Codes.

This unit must be installed in accordance with those installation regulations in force in the local area where the installation is to be made. These shall be carefully followed in all cases. Authorities having jurisdiction shall be consulted before installation is made.

PRECISION has a commitment to product improvement and continually strives for the highest standards of product performance. In pursuing this policy of continuous development of products, the manufacturer reserves the right to vary any details in this manual without notice.

TABLE OF CONTENTS

Chapter 1
INTRODUCTION

1.A. GENERAL INFORMATION

This PRECISION Electric Hot Water and Steam Boiler Operation and Maintenance Manual presents information that will help to properly operate and care for the equipment. Study the contents carefully. The unit will provide good service and continued operation if proper operating and maintenance instructions are followed. The standard Limited Warranty does not apply to boilers not installed or operated in accordance with these procedures.

PRECISION boilers are designed and engineered to provide excellent service and to give long life on the job. Although the unit and its components afford a high degree of protection and safety, operation of the equipment is not to be considered free from hazards inherent in the handling of electricity and pressurized hot water or steam.

Pay close attention to WARNINGS and CAUTIONS as these present situations of potential hazard, and remember no amount of written instruction can replace intelligent thinking and reasoning.

1.B. LOCAL REGULATIONS

Consult local building and safety codes before proceeding with work. The operation of this equipment by the owner and his operating personnel must comply with all requirements or regulations of the authorities having jurisdiction.

In the absence of such authorities, the installation must conform to the safety codes set forth by the American Society of Mechanical Engineers (ASME).

1.C. RECOMMENDATIONS

1.C.1. Preventive Maintenance

A Preventive Maintenance Schedule is provided as a recommendation for periodic boiler inspections. Recording of daily, weekly, monthly and yearly maintenance activities, as well as the recording of any unusual operation, will serve as a valuable guide to any necessary investigation.

The standard Limited Warranty does not cover any damage caused by lack of required maintenance.

1.C.2. WATER TREATMENT

Feedwater and Boiler Water Properties should be maintained in accordance with the table provided in this manual. It is customary to engage the services of a qualified water treatment consultant to recommend the proper water treatment program.

Damage from scaling, corrosion or erosion attributed to improper treatment of boiler water is not covered by the standard Limited Warranty.

Chapter 2
STORAGE & HANDLING

2.A. RECEIVING

Each PRECISION boiler is completely inspected at the factory and carefully packaged for shipment. Upon receipt of the shipment, immediately inspect the packing for signs of exterior damage. Verify receipt of all packages listed on the packing slip. Advise the carrier of any shortage or damage. Any such claims should be filed with the carrier. The carrier, not the shipper, is responsible for shortages and damage to the shipment.

2.B. STORAGE

Electrical equipment can be damaged if exposed to adverse weather. *The boiler should be stored inside.* The electrical panel and controls should be covered with plastic throughout all construction to avoid accumulation of dust and moisture on the controls and load components. The contactors can be damaged by dust/dirt in the mechanism.

2.C. UNCRATING

2.C.1. Care must be taken not to damage controls or deform the boiler sheet metal during removal of the crate.

2.C.2. If using pry bars or fork lifts, be certain to support the boiler weight by the skids or channel base.

2.D. PLACEMENT

! CAUTION !

If the boiler is to be placed in a room with little or no ventilation, a supply of ducted filtered air may have to be brought to the lower portion of the control cabinet to limit the control cabinet interior temperature to 50°C (122°F) maximum.

2.D.1. Provide a *firm, level* foundation for the boiler.

NOTE: Standard electric boilers are not suitable for placement on combustible flooring.

2.D.2. Leave a permanent space for element removal opposite element access panels as shown on the Dimensional Drawing (DD), and 36 inches opposite electrical panels.

NOTE: 42" is required opposite electrical panels if the opposing surface is conductive.

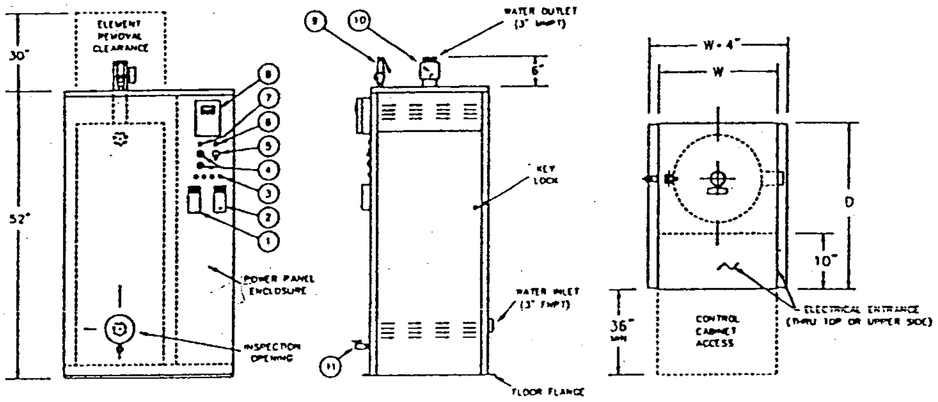
2.D.3. Be sure to keep electrical panels and controls covered at all times while work is in progress.

! CAUTION !

Do not use the boiler housing top for scaffolding.

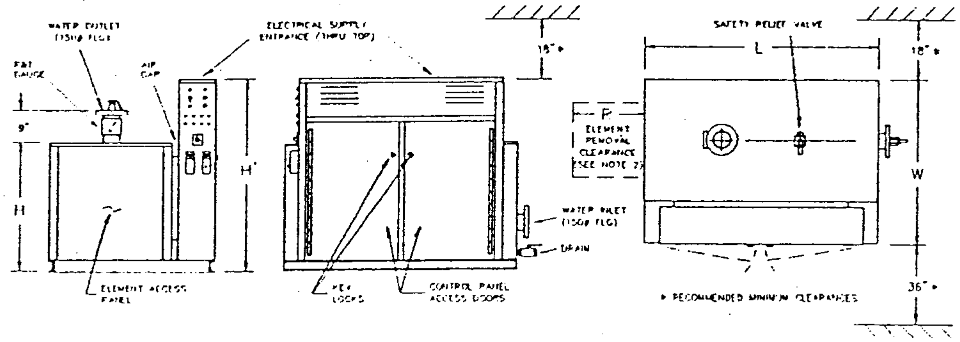
Minimum Clearance Recommendations and General Dimensional Data for Boiler Placement

PRECISION Compac (PCW)



SIDE FRONT TOP

PRECISION Electric Hot Water (HW)



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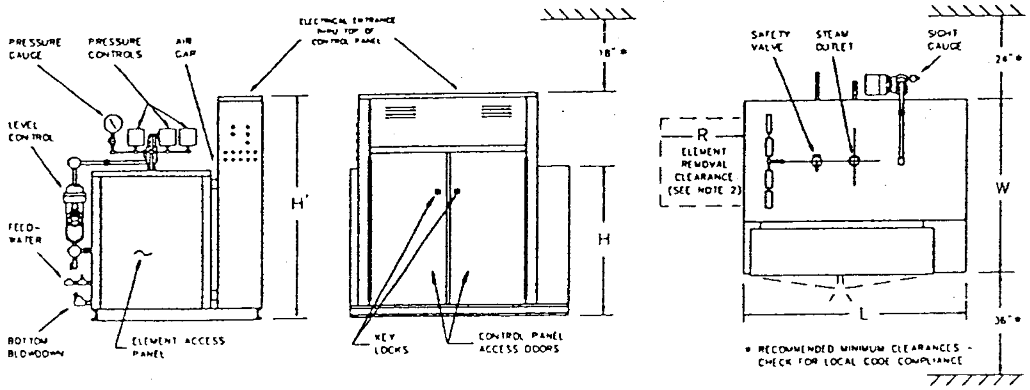
PRECISION Electric Steam Boiler (ST)



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NOTE: Consult local codes for specific requirements and refer to the Dimensional Drawing (DD) and Wiring Diagram (WD) provided with the unit.

Chapter 3
INSTALLATION

3.A. PIPING CONNECTIONS

NOTE: Some of the following piping may have been completed at the Factory.

3.A.1. Boiler piping connections and valves MUST comply with state and local codes, in addition to compliance with ANSI piping requirements.

! CAUTION !

The pipe extensions outside the boiler are usually the extensions of pipes which are permanently welded into the boiler vessel. Normally the only removable (threaded) connection is the boiler drain pipe. *DO NOT ATTEMPT TO REMOVE ANY OTHER PIPING.*

3.A.2. Install the safety relief valve(s) on the pipes provided. Plumb the relief valve outlet connections full size to the floor drain. Check local codes for proper safety valve discharge for steam boilers above 15 psi which normally are required to be piped to overhead discharge outside safely away from personnel.

3.A.3. Hot water boilers may be equipped with an air vent pipe on the top of the boiler. Plumb this connection to the expansion tank or install an automatic air vent on this pipe.

3.A.4. The direction of flow through hot water boilers must be from the inlet to the outlet (ie, bottom to top). *Do not reverse these connections.*

NOTE: Do not oversize feedwater piping and valves on steam boilers, as this may result in severe pressure fluctuations during feedwater cycles if the fill rate is too rapid.

3.B. ELECTRICAL CONNECTIONS

3.B.1. Power Feed Wiring

The recommended wire size is listed on both the boiler Bill of Materials (BOM) and the Wiring Diagram (WD). Also, the full load amperage and maximum voltage are listed on both the Bill of Materials and the nameplate. Feed wires must be rated for the voltage and 125% of the full load amperage, according to Article 424-3 of the NEC. The wiring must be insulation-rated 75°C or greater. Copper wiring is recommended for all power connections.

! CAUTION !

Do not exceed the maximum voltage as listed on the nameplate.

3.B.2. Equipment Grounding Conductors

The boiler is equipped with grounding lug(s) inside the power panel(s). The grounding conductors must be installed and sized in accordance with NEC Article 424-14. The recommended size is noted in the Notes on the wiring diagram.

3.B.3. Control Wiring

Alteration of, or additions to, control wiring may void the Underwriters Laboratories Listing and the Manufacturer's Warranty. Field-installed controls, control connections, and modifications must be approved in writing by PRECISION.

NOTE: All power connections to PRECISION boiler(s) are 3-Phase, 3-Wire. (Exception: If boiler is single phase.) There is no provision for a neutral connection; ie, the boiler should not be wired "wye" or "star".

3.C. FILLING THE SYSTEM

3.C.1. The system and the boiler must be thoroughly flushed before the final fill. Steam boilers should be "boiled out" before operation.

3.C.2. Water Treatment

Consult a local water treatment firm for recommendations on proper water treatment and boilout procedure to prevent damage to the boiler vessel, components and heating elements.

The internal materials of the boiler are Steel, Incoloy and Cast Iron, which all are compatible with standard boilout compounds. In lieu of a commercial boilout compound, the following mix of chemicals can be used for every 1,000 gallons of water:

30 lbs tri-sodium phosphate (Na_3PO_4)
5 lbs caustic soda (NaOH)
2 lbs ordinary detergent

These chemicals should be dissolved in warm water prior to their addition to the boiler. The boiler should be heated for at least 3 hours, then drained and flushed.

NOTE: Standard hot water boilers are suitable for ethylene glycol mixtures up to a 50/50 mix.

Chapter 4

PRE-STARTUP INSPECTION

4.A. MINIMUM EQUIPMENT REQUIRED FOR STARTUP AND TROUBLESHOOTING

1. Volt-Ohm Meter
2. Clamp-On Ammeter
3. Megohm Meter
4. Torque Wrench - inch lbs
5. Torque Wrench - foot lbs

4.B. MECHANICAL SYSTEM CHECKS

4.B.1. Plumbing Connections Completed

- ☐ Inlet/ Makeup water?
- ☐ Discharge/Outlet?
- ☐ Drain/ Blowdown?
- ☐ Relief/ Safety Valve discharge?

4.B.2. Feedpumps/ Circulating Pumps

- ☐ Pumps wired, connected and checked for proper rotation?
- ☐ Is the boiler filled to the proper level with water?

4.B.3. System Flush

- ☐ Has the System been flushed?
- ☐ Has the unit been cleaned of all construction debris?

4.B.4. Valves

- ☐ Are all valves in the proper open or closed positions?

4.C. ELECTRICAL SYSTEM CHECKS

With boiler main power switch(es) OFF and locked out:

☐ **4.C.1.** Inspect all components, external and internal, to assure that there has been no damage during shipment or installation.

☐ **4.C.2.** Remove one of the boiler control circuit transformer primary fuses. Then check the resistance phase-to-phase for all three phases. Make sure that there are no short circuits phase-to-phase or phase-to-ground.

With a megger (500VDC minimum) check contactor load side terminals to ground. If a reading of <1 megohm is obtained, consult the PRECISION Agent or Factory.

Replace the control transformer fuse which was previously removed.

☐ **4.C.3.** Remove element access panel(s) and open the doors to the electrical control panel(s). Run an inspection of the tightness of all electrical connections; (ie, at fuse lugs, power entrance lugs, contactors, heating elements).

All branch circuit connections should be tightened to 35-40 inch lbs torque to avoid component damage from heat build-up.

This tightness inspection is vital, because the vibration during shipment can often loosen electrical connections. If this is not done, damage may occur to component parts when power is switched on, and those damaged parts will not be covered under the manufacturer's warranty.

☐4.C.4. With an ohmmeter, check the resistance between the phases on the load side of the contactors. Each should read the same and approximately what is shown on the wiring diagram.

☐4.C.5. Check the electrical panels for loose material, dust and/ or moisture. Thoroughly vacuum the panels if dust or foreign materials have accumulated there.

If there has been severe exposure to dust, the contactors should be disassembled and cleaned. Dust in the contactors will cause contactor chattering and eventual destruction of the contacts.

All components should be clean and free of dust, moisture, and foreign matter!

☐4.C.6. Verify that field-installed control and load connections have been properly installed.

4.D. HEATING ELEMENTS

! CAUTION !

Moisture in the elements may result in damage to the elements.

NOTE: There is a possibility that, during shipment or storage prior to operation, the elements may accumulate moisture. The moisture will turn to steam when the elements are turned on and may rupture the element casing.

4.D.1. How to check Elements for Moisture

Take a reading with a megger between the contactor terminals (load side) to ground for each contactor. Moisture is present if the reading is less than 1 megohm for standard 3-phase connection.

4.D.2. Removal of Moisture in Element *Method #1*

Remove the fuses going to that contactor. The fuses should be removed so that, during the first day of operation, the affected element will not be energized allowing the hot boiler to drive the moisture out at a controlled rate.

4.D.3. Removal of Moisture in Element *Method #2*

An alternate heating method is to direct a heat lamp at the suspect element, or remove the element, bake it in a 200°F oven for 8 hours, then reinstall and rewire.

4.D.4. After completion of either of the above Methods for moisture removal, recheck the Element with a megger. When the reading indicates an acceptable level, the element may be put in operation by replacing the fuses.

4.D.5. Replace of Element Access Panel(s) and close electrical/ control panel doors.

4.E. INSPECTION POWER/ VOLTAGE

4.E.1. Verify the boiler ON/OFF control switch is in the "OFF" position. Close the boiler main power switch, switch the control switch to "ON" and then:

4.E.1.a. Check the phase-to-phase voltage at the main terminals in the boiler electrical panel. The phase-to-phase voltage between any two of the phases **must not exceed** the boiler nameplate voltage.

4.E.1.b. Check the voltage at the boiler control circuit fuse. It should be between 105 volts and 125 volts.

4.E.1.c. Open the boiler main power switch.

4.E.2. If all of the above prove satisfactory, proceed with "Startup Instructions". Replace all covers and close all doors.

Chapter 5
STARTUP INSTRUCTIONS

5.A. CONTROL SETTINGS

5.A.1. Controller

(See Parts List for Part No. and Type)

5.A.1.a. The controller is the pressure or temperature sensing device which controls the operation of the step control.

5.A.1.b. Set the Controller for the desired Outlet Water Temperature (or Steam Pressure).

NOTE: Outdoor reset (dual-bulb) controllers are set at the temperature at which the boiler should operate when the outdoor temperature is 70°F (this outdoor reference temperature is adjustable on most solid state controls; fixed on Honeywell T991B controllers). The reset ratio (fixed on Honeywell T991B type; adjustable on Honeywell T775J) is the number of degrees the boiler control temperature will increase for a 1 degree decrease in outdoor temperature.

5.A.1.c. Throttling Range - The throttling range is the number of degrees (or psi) the outlet water temperature (or steam pressure) must change to drive the step controller from full-off to full-on.

For instance, if the controller is set at 160°F, and the throttling range is set for 10°F, the step controller will be full-on at 155°F (1/2 of throttling range below setpoint) and full-off at 165°F (1/2 of throttling range above setpoint). The more stable the load on the boiler (from system demands), the smaller the throttling range may be set.

5.A.2. High Limit

(Temperature or Pressure)

Set the automatic reset high limit 10°F (or 5 psi), or twice the throttling range, whichever is greater, above the setting of the controller.

Manual reset limits should be set slightly higher than the automatic reset limits. For steam boilers, the manual reset high limit should be set at least 10% below the safety valve set pressure.

5.A.3. Low Water Cutoffs

These cutoffs are always factory-set. If additional cutoffs are field-installed, the cut-off levels should be at least three inches above the highest heating element. Manual reset cutoffs should be set below automatic reset cutoffs.

5.A.4. Low Limit Sensors

(Temperature or Pressure)

Low limits should be set below the controller setting by at least the same margin as specified for high limits to be above the controller setting.

5B. OPERATING INSTRUCTIONS

5.B.1. With the boiler main power ON/OFF or ON/OFF/PREHEAT switch "OFF", close the boiler main power switch. Close the boiler disconnect switch, if provided.

NOTE: Boilers with shunt trip disconnects and remote 120-volt control power may require turning the boiler control power switch "ON" and activating the 120-volt power before closing the boiler main power switch(es).

5.B.2. Electric Door Interlocks

For boilers equipped with electric door interlocks, do not attempt to open electrical panel doors after the main switch is closed. The lock tabs are mechanically restrained by the electric interlocks.

5.B.3. 120-Volt Power Source

If a separate 120-volt power source is provided, close its disconnect switch.

5.B.4. Turn the boiler main power ON/OFF or ON/OFF/PREHEAT switch to "ON".

5.B.5. Alarm and Reset Circuits

5.B.5.a. If the alarm sounds when the control switch is turned "ON", depress the alarm silence button. Check the boiler to make certain that no limit conditions exist by noting if the alarm pilot light is illuminated. The alarm will sound momentarily on some boilers when power is initially applied.

5.B.5.b. Boilers with Manual Reset Button(s) may require resetting of the manual reset switch upon initial application of power, and after the interruption of power or the trip-out of a limit control.

5.B.6. Sequencing of Element Circuits

5.B.6.a. On boilers with step controls, the boiler will always start with no steps energized.

5.B.6.b. As the steps begin cycling on, the pilot lights will light up one at a time, indicating that power has been applied to the associated contactor coils.

5.B.6.c. For electric boilers with ON/OFF/PREHEAT switches, when the switch is down in the "PREHEAT" position, only part (approximately 25%) of the steps may be activated.

5.B.6.d. When the boiler outlet water temperature (or steam pressure) is at or near setpoint, turn the boiler ON/OFF/PREHEAT switch "OFF", then to "ON" again. The controls will recycle to the no-load condition. The steps should then begin to cycle on as needed, and all of the steps may come on if necessary.

Chapter 6
SEQUENCE OF OPERATION

6.A. ACTIVATION OF HEATING ELEMENT CIRCUITS

6.A.1. Contactors

The heating elements are energized by pilot operation. That is, the power to an element circuit is supplied through the contacts of a contactor. The contactor is activated (on a call for heat) by the closure of a temperature (or pressure) switch or by a contact in the step control circuit.

6.A.2. Fuses

All power leads to the elements are fused. The fusing is on the line side of the contactors.

6.B. SEQUENCING CONTROLS

6.B.1. Staged Control Circuit

6.B.1.a. In this type of circuit, the contactor coils are energized directly by the contacts of immersion thermostats (or pressuretrols). There is usually one thermostat (or pressuretrol) for each stage; or a multi-stage thermostat (or pressuretrol) may be provided in some cases.

6.B.1.b. The safety limit devices (high temperature, low water, etc) interrupt the power to the contactor coil circuits.

6.B.2. Proportional Step Controls

6.B.2.a. Step Control Sequence

The controller senses the boiler water temperature (either via 135-ohm device or thermistor) or the boiler steam pressure (either via 135-ohm device or 4-20ma transducer). The output signal of the controller causes the step control to sequence the steps on, or off, depending on whether the boiler output is below or above setpoint.

When one of the switches closes on the step control, a contactor coil (or coils) is energized in a step-wise fashion. This type of step control will mid-position (bring on half of the steps) when the boiler water temperature (or steam pressure) is at setpoint.

For example: an 8 step steam boiler with the pressure controller set at 12 PSIG, will have 4 steps on when the boiler steam pressure is at 12 PSIG.

6.B.2.b. Progressive Sequence Step Controls

These controls are provided as standard and include Selectronix SLC series, Solitech M72 series, and Honeywell W7100J series. They provide first-on, first-off staging of the element circuits.

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As the boiler temperature (or pressure) drops below setpoint, the control brings on more steps. As the temperature (or pressure) increases and approaches setpoint, the step control drops out stages. The first step to drop off is the one that has been on the longest. This provides even usage of the system's components.

6.B.2.c. Linear Sequence Step Controls

This type of step control is limited to the Solitech M72. In this sequence progression, the control applies power by progressing from Step 1 to the maximum number required to satisfy the load, and then decreases power by retracing this sequence down toward the first step.

NOTE: Refer to the applicable vendor literature provided on the step control installed in your boiler.

6.B.3. Recycle Feature

All step controls now incorporate the recycle feature which returns the step control to the no-load condition upon loss of control power.

6.B.4. Preheat Switch

The preheat switch is a manual limit switch. In order to preheat the boiler, the ON/OFF/PREHEAT switch must be in the down position. When the ON/OFF/PREHEAT switch is in its down or PREHEAT position, the boiler output is limited to approximately 25% of full load power. This allows the operator to limit the boiler output during startup cycles (particularly if the boiler is shut off at night and turned on again in the morning), which could lessen electrical demand charges.

When the boiler has been brought up to the setpoint temperature (or pressure), the ON/OFF/PREHEAT switch is moved slowly from its down or PREHEAT position to its up or ON position passing through the OFF position to cause the control to recycle to the NO-LOAD position. Thereafter, the boiler can operate up to full load if necessary.

NOTE: The PREHEAT switch is included as standard equipment on boilers of 9 or more steps. It is intended to be used to prevent setting demand peaks on "cold starts". It does not have to be used if so desired.

Chapter 7
OPERATIONAL TESTING

7.A. STANDARD CONTROLS

7.A.1. 135-ohm Controllers
(T991, T915, L91, etc)

With the boiler water temperature (or steam pressure) at setpoint, the step controller should bring on nominally one half of the steps. An adjustable proportional band is provided on the controller (sensor) to enable tuning the boiler to system demand.

7.A.2. Solid State Controls

With the boiler water temperature (or pressure) at setpoint, the step control should bring on nominally one half of the steps. Adjustable time delays between steps and adjustable proportional bands are normally provided on the step control to enable tuning the boiler to system demand. Most solid state controls also include band width adjustment at the control itself, and normally include PID control action.

7.B. OUTDOOR RESET CONTROLS

7.B.1. 135-ohm Type Outdoor Reset Controller
(Honeywell T991B type)

These controllers have a fixed reset ratio: either 1-to-1, 1-to-1.5 or 1.5-to-1.

The outdoor reference temperature is 70 °F; ie, the boiler outlet water control point temperature is equal to the setting on the controller when the outdoor temperature (at the outdoor bulb) is 70°F. In order to test the operation of this controller:

7.B.1.a. Check the outdoor temperature at the outdoor air sensing bulb; then determine the number of degrees this temperature is above, or below, 70°F.

7.B.1.b. Check the boiler outlet water temperature; if the outdoor temperature is below 70°F, multiply the difference between 70°F and the actual outdoor temperature by the reset ratio (1, 0.67 or 1.5); and subtract this from the temperature of the boiler outlet water.

7.B.1.c. Then set the controller at this resultant temperature; the step controller should maintain nominally half of the steps on.

NOTE: If the outdoor bulb is at 70°F, or can be maintained at 70°F, simply set the controller at a temperature equal to the actual outlet water temperature to perform this test.

EXAMPLE: SETTING THE TEMPERATURE CONTROLLER

Reset Ratio: 1:1-1/2 (ie, 2/3:1)
Outdoor Temperature: 40°F
Boiler Water Temperature: 130°F

STEP "A"	Difference between outdoor temp and 70°F	70 - 40 = 30°F
STEP "B"	Multiply 30°F times the Reset Ratio 2/3	30 x 2/3 = 20°F
	Subtract 20°F from the Boiler Water Temp 130°F	130 - 20 = 110°F
STEP "C"	Set the Controller at 110°F	

NOTE: If the Outdoor Temperature is above 70°F, add the difference in STEP "A", multiplied by the Reset Ratio, to the Boiler Water Temperature.

7.B.2. Solid State Dual Input Reset Controls

(Honeywell T775J controls and Honeywell W7100J Sequencers)

These are dual sensor reset controllers with adjustable reset ratio and outdoor reference temperature. The "reset ratio" is the ratio of the change in the temperature at the secondary sensor to the opposing change in the control point. If the reset ratio is 2:1, then every 2°F change at the outdoor sensor will cause an automatic inverse change of 1°F at the control point.

Example:

Assume a reset ratio of 2:1, a primary set point of 100°F, and a secondary setpoint at 70°F. The first number of the reset ratio indicates change in outdoor temperature; the second, the change in the control point. If the outdoor temperature drops from 70°F to 20°F, a change of 50 °F; the control point will increase from 100°F to 125°F, a change of 25°F.

NOTE: Refer to the applicable vendor literature provided on both the setpoint controls and step controls installed in your boiler.

Chapter 8
PREVENTIVE MAINTENANCE

8.A. GENERAL

Electric immersion heating element boilers are automatic, quiet and safe. Consequently, they are all too often neglected. Like any piece of electrical mechanical equipment, they require care and maintenance to keep them in top working condition.

If electrical connections are allowed to become loose or dirty, there is danger of an electrical fault. If the elements are not inspected periodically for leaks, the water from leaking elements can leak onto adjacent elements, causing external element damage and resulting in the blowing of load fuses in the boiler electrical panels. If the boiler water is not properly treated, element failure could occur due to the formation of scale.

Treat the boiler with respect.

! CAUTION !

Always work on the boiler with all electrical power sources disconnected.

8.B. WATER TREATMENT

Boiler water should be periodically checked through a sampling procedure. Properties should be maintained in accord with *TABLE 8.1* at the end of this chapter. For consultation relative to water treatment, please contact a reputable water treatment firm.

8.C. BOILER ELECTRICAL SYSTEM MAINTENANCE

8.C.1. Clean the boiler periodically (as often as needed) to keep both the interior and the exterior free of dust, moisture and foreign matter The interior cleaning of the electrical panels must be done with the POWER OFF!!

NOTE: For units supplied with control cabinet cooling fans, the condition of the fan filter must be periodically checked and the filters cleaned or replaced as necessary.

8.C.2. With the POWER OFF, periodically check the tightness of electrical connections; particularly at power entrance lugs, fuses (line side) and contactors (load side).

8.C.3. Inspect the condition of the contactors. Look for burned or corroded contacts or overheated coils and wires. If the contactors chatter or hum during operation, they should be disassembled and cleaned to remove dust or other foreign material in the works or replaced if needed.

8.C.4. Inspect the heating elements. Make sure that the terminal contacts are tight, clean, and corrosion-free.

8.C.5. Check all the wiring throughout the boiler for frayed or brittle insulation. Replace any wiring having exposed metal parts.

8.D. BOILER MECHANICAL SYSTEM MAINTENANCE

8.D.1. With the POWER OFF, remove the element access covers. Inspect all internal plumbing connections, particularly at the heating elements. Spot check torque on element flange bolts. The acceptable torque range is 10-15 ft lbs.

! CAUTION !

DO NOT OVERTIGHTEN ELEMENTS

8.D.2. Remove and replace any leaking elements or element gaskets. Inspect handhole and manhole gaskets. If these gaskets are brittle they should be replaced.

! WARNING !

Over-torqueing of the element nuts will damage the element gasket.

8.D.3. Repair any leak at any place on the boiler or adjacent piping.

8.D.4. The interior of the pressure vessel must be inspected at least once a year. If there is any presence of scale, refer to Preventive Maintenance Water Treatment above and consult a local water treatment firm immediately. Scale formation on the elements will cause heating element failures. Scale formation elsewhere in the boiler can cause erratic control operation, particularly on water level controls.

8.D.5. When the boiler is inspected, rod out the pipes to the water column(s). Inspect the operation of the floats in the level controller(s).

8.D.6. Remove and clean the low water cutoff probe.

8.D.7. Steam Boiler Special Maintenance

8.D.7.a. All PRECISION steam boilers are supplied with a surface blow-off connection. If surface blow-off valves are not Factory-installed, they should be installed in the field. The surface blow-off should be used as often as necessary to remove organics which accumulate at the water surface, and to limit TDS. (Boiler water TDS should not exceed 3500 PPM).

8.D.7.b. Both the boiler and water column should be blown down periodically to remove bottom sludge.

8.D.7.c. The water column should be blown down daily to assure proper operation of the level control/LWCO assembly.

8.D.7.d. Water Treatment

Water treatment is required for satisfactory operation of steam boilers to prevent both deposition of scale and corrosion from acids, oxygen and other harmful elements that may be in the water supply. A qualified water treatment specialist should be consulted to establish a proper water treatment program.

8.E. ELEMENT REPLACEMENT PROCEDURE

(4-Bolt Style Element)

! CAUTION !

Before element replacement, make certain main power to boiler is turned off, that there is no pressure in the boiler, and that boiler is drained below element opening.

NOTE: To prevent hazardous conditions of leaking water/ steam at the element terminal ends, defective elements or element gaskets should be replaced immediately upon leak detection.

8.E.1. Adequately tag wires and then remove wires from defective elements.

8.E.2. Remove element by removing the 4 (four) attachment nuts.

8.E.3. Install replacement element with new gasket and torque nuts to 10 - 15 ft lbs.

! WARNING !

Do not exceed 15 ft lbs.

8.E.4. Connect phase wires to new element.

8.E.5. When boiler is filled and pressurized, check for leaks.

TABLE 8.1

Recommended Feedwater and Boiler Water Properties

FEEDWATER

Type of Boiler	Hardness (ppm)	pH	Oxygen (cc/ l)	Total Dissolved Solids TDS (ppm)
Hot Water	0-10	7.5 - 9.5	4.0	0-500
Steam	0-5	7.5 - 9	.03	0-350

BOILER WATER

Type of Boiler	Hardness (ppm)	pH	Oxygen (cc/ l)	Total Dissolved Solids TDS (ppm)
Hot Water	0-10	7.5 - 9.5#	0	0-5000
Steam	0	7.5 - 9.5#	0	0-3500

The limit of 9.5 pertains to copper elements; a pH of 10.5 is allowable for Incoloy elements

INSTALLATION MANUAL

ELECTRIC STEAM BOILER AND AUXILIARY EQUIPMENT

TRU-ALPHA WASTE TREATMENT PROJECT, LENOIR CITY, TN

Chapter 9
WARRANTY & RETURNS

9.A. ASSISTANCE

Furnish Complete Information

Before calling the PRECISION Agent or the Factory with questions concerning boiler operation, needed parts, or warranty, please be sure to have the information readily available that is stamped on your Boiler's Data Plate (see Data Plate details below *FIGURE 9.1*).

All files are maintained by Serial Number, so please have this number available when corresponding about your boiler. All order(s) should state the Manufacturer's part number, if known, and the name and description of the part required. Also, state the quantity desired and specify the method of shipment.

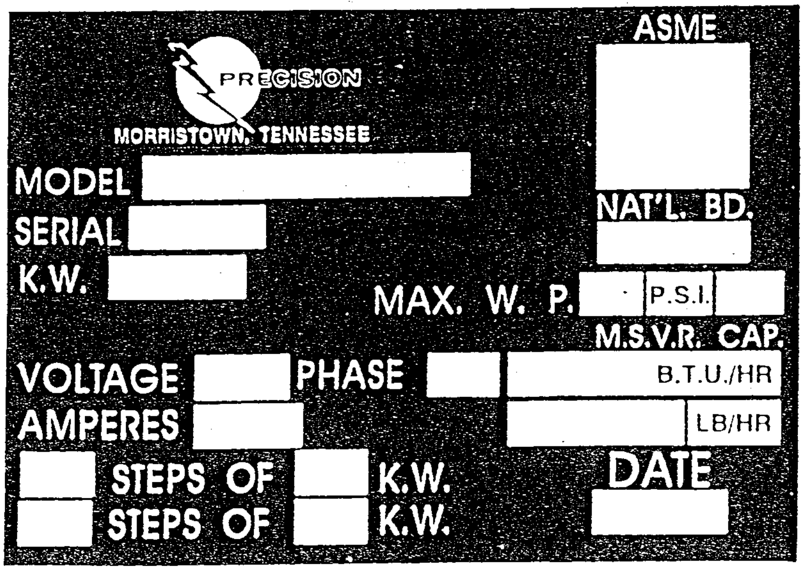
9.B. PART ORDERS

Repair or replacement parts for PRECISION boilers may be ordered through the PRECISION Agent in your area. You may also contact the Factory directly at the address or phone number listed on the back of this manual. Refer all inquires directly to the Parts Department.

9.C. REPAIR PROCEDURES

Parts to be repaired should be returned freight prepaid to the address indicated on the back of this Manual. Please indicate the urgency of the repair.

FIGURE 9.1



9.C. WARRANTY RETURN PROCEDURES

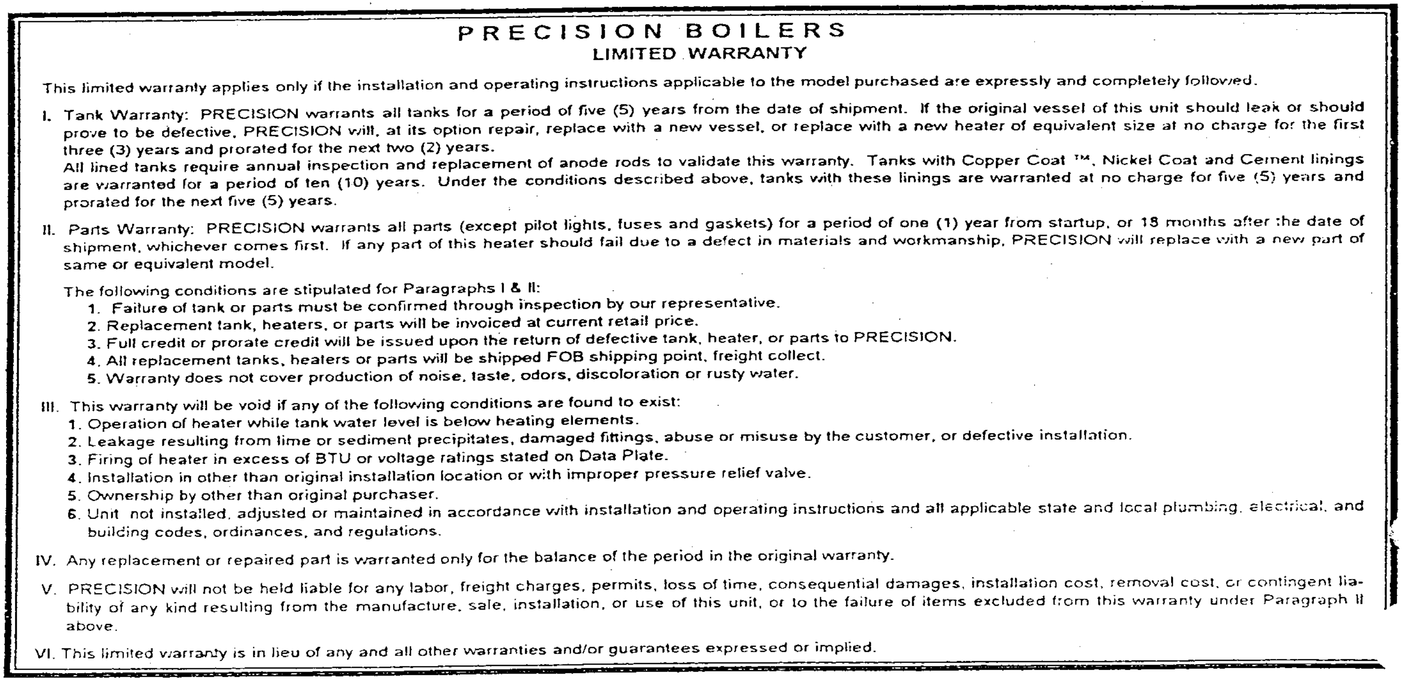
A purchase/ service order, or a letter authorizing repairs, showing Model Number and Serial Number of the Boiler, and giving complete details, should be mailed to the address listed on the back of this manual. Please include inside the package a packing slip identifying the parts with your company's name. Return shipment must be freight prepaid. Freight collect shipments will not be accepted.

9.D. PRECISION LIMITED WARRANTY

The Limited Warranty was shipped with the Boiler and thoroughly identifies the period, items covered, and terms of the Limited Warranty, see *FIGURE 9.2*. Parts being returned for replacement or repair covered under the warranty as defective must be identified and accompanied by a Return Goods Authorization (RGA). RGA's are available from the Factory Service Department.

When defective goods are returned with the appropriate information, either a replacement or repair part will be provided under the conditions of the Limited Warranty. If a replacement part has been purchased from the Factory, these goods will be invoiced and shipped under standard sales terms. Once the defective goods are returned within the authorized 30 day time period, and the Factory verifies that the material and/ or workmanship is defective, then appropriate credit will be issued for the part or a repair will be made. Return shipments must be freight prepaid. Freight collect shipments will not be accepted.

FIGURE 9.2



PRECISION BOILERS
LIMITED WARRANTY

This limited warranty applies only if the installation and operating instructions applicable to the model purchased are expressly and completely followed.

I. Tank Warranty: PRECISION warrants all tanks for a period of five (5) years from the date of shipment. If the original vessel of this unit should leak or should prove to be defective, PRECISION will, at its option repair, replace with a new vessel, or replace with a new heater of equivalent size at no charge for the first three (3) years and prorated for the next two (2) years.
All lined tanks require annual inspection and replacement of anode rods to validate this warranty. Tanks with Copper Coat ™, Nickel Coat and Cement linings are warranted for a period of ten (10) years. Under the conditions described above, tanks with these linings are warranted at no charge for five (5) years and prorated for the next five (5) years.

II. Parts Warranty: PRECISION warrants all parts (except pilot lights, fuses and gaskets) for a period of one (1) year from startup, or 18 months after the date of shipment, whichever comes first. If any part of this heater should fail due to a defect in materials and workmanship, PRECISION will replace with a new part of same or equivalent model.

The following conditions are stipulated for Paragraphs I & II:
1. Failure of tank or parts must be confirmed through inspection by our representative.
2. Replacement tank, heaters, or parts will be invoiced at current retail price.
3. Full credit or prorate credit will be issued upon the return of defective tank, heater, or parts to PRECISION.
4. All replacement tanks, heaters or parts will be shipped FOB shipping point, freight collect.
5. Warranty does not cover production of noise, taste, odors, discoloration or rusty water.

III. This warranty will be void if any of the following conditions are found to exist:
1. Operation of heater while tank water level is below heating elements.
2. Leakage resulting from lime or sediment precipitates, damaged fittings, abuse or misuse by the customer, or defective installation.
3. Firing of heater in excess of BTU or voltage ratings stated on Data Plate.
4. Installation in other than original installation location or with improper pressure relief valve.
5. Ownership by other than original purchaser.
6. Unit not installed, adjusted or maintained in accordance with installation and operating instructions and all applicable state and local plumbing, electrical, and building codes, ordinances, and regulations.

IV. Any replacement or repaired part is warranted only for the balance of the period in the original warranty.

V. PRECISION will not be held liable for any labor, freight charges, permits, loss of time, consequential damages, installation cost, removal cost, or contingent liability of any kind resulting from the manufacture, sale, installation, or use of this unit, or to the failure of items excluded from this warranty under Paragraph II above.

VI. This limited warranty is in lieu of any and all other warranties and/or guarantees expressed or implied.

Chapter 10
ADDITIONAL INFORMATION

10.A. BOILER PARTS LIST AND SCHEMATICS

Refer to supplemental pages attached.

10.B. VENDOR LITERATURE

Refer to supplemental pages attached.

10.C. TROUBLESHOOTING

Refer to the Troubleshooting Guide located in the O & M packet.

10.D. FACTORY STARTUP CHECKLIST

Refer to supplemental pages attached.

10.E. RECOMMENDED SPARE PARTS

A "care package" of basic spare parts has been included with your boiler (normally shipped in the control cabinet). It is strongly suggested, however, that additional spare parts be purchased. These should include at least (2) elements and (6) power fuses.

PRECISION Boilers
5727 Superior Drive, Morristown, TN 37814
Phone: (423) 587-9390 / Fax: (423) 581-7749

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