UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA STREET, N.W.
ATLANTA, GEORGIA 30323

Report Nos.: 50-259/87-43, 50-260/87-43, and 50-296/87-43

Licensee: Tennessee Valley Authority
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1101 Market Street
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Docket Nos.: 50-259, 50-260 and 50-296 License Nos.: DPR-33, DPR-52, and DPR-68

Facility Name: Browns Ferry 1, 2, and 3

Inspection at Browns Ferry Site near Decatur, Alabama

Inspection Conducted: November 6-20, 1987

Team Inspectors:

G. L. Paulk, Senior Resident Inspector
W. H. Miller, Resident Inspector
R. G. Wescott, Plant Systems Engineer

Contributing Inspectors:

C. A. Patterson, Resident Inspector
C. R. Brooks, Resident Inspector
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Approved by: _____ 12/21/87
G. L. Paulk, Team Leader Date Signed
TVA Projects Division
Office of Special Projects

SUMMARY

Scope: This special announced inspection was conducted for the Browns Ferry Unit 2 drywell fire of November 2, 1987. This inspection was not intended to focus on regulatory enforcement issues. The inspection team was charged with investigation of the fire in order to identify and document all relevant and specific facts associated with the fire. Specifically the inspection team addressed: the sequence of events which portrayed the chronological activities prior to and during the fire, an assessment and evaluation of the fire impact on plant operations, the proximate root cause of the fire and licensee actions to cope with the fire. The licensee conducted concurrently a Serious Accident Investigation Team inspection to evaluate the root causes, program deficiencies, and lessons learned from the event. During the TVA inspection effort, it was noted that one of the potential root causes, consistent with test results, would

lead to the fire being of a suspicious origin. At this point, TVA and NRC informed the Bureau of Alcohol, Tobacco, and Firearms (ATF) and the Federal Bureau of Investigation (FBI) who conducted a joint investigation independent of the TVA investigation. Preliminary results of the ATF inspection of the fire scene are included in this report. The FBI and ATF investigations are ongoing and will be concluded separately. The final TVA report will be issued after ATF and FBI complete their investigations.

Results: Based on test results and an investigation of the fire scene by a Bureau of Alcohol, Tobacco and Firearms (ATF) representative, a preliminary evaluation indicates the fire to be of suspicious origin. Additional investigations by TVA, ATF and FBI are on going at the time of this report to resolve the suspicious nature of the fire and to complete a tracing of the cables involved to attempt to establish that they had been properly terminated. Should the suspicious nature of the fire be resolved, the next most probable cause is considered to be improper electrical connections within some temporary connections. Also, eighteen technical concerns were identified during the NRC investigation as delineated in Appendix A. Followup inspections will be conducted by Office of Special Projects (OSP) as further details become available.

REPORT DETAILS

1. Licensee Employees Contacted:

   a. TVA Serious Accident Investigation Team Members:

Name	Job Title
*B. F. Painter, Team Leader	Deputy Construction Manager, Watts Bar Nuclear Plant
Ronald E. Cox	Design Electrical Engineer, Division of Nuclear Engineering
Vic D. Humm	Fire Protection Specialist, Division of Nuclear Services
Keith Fogleman	Assistant to the Modifications Manager, Modifications, BFN
*Jerry D. Martin	Assistant to the Plant Manager, BFN
Jerry S. Olson	Plant Superintendent, Units 1 and 3, BFN
Charles R. Petty	Health and Safety Auditor, Division of Occupational Health and Safety
Albert J. Salatka	Fire Protection Specialist, Division of Nuclear Services
Ricky L. Tye	Chief, Fire Protection and Safety Branch, Division of Nuclear Services
*Terry C. Valenzano	Modifications Advisor, BFN

   b. Other licensee employees contacted:

H. P. Pomrehn	Site Director
*John Walker	Plant Manager
Billy Gamble	Electrician, Modifications
William Leath	Electrician, Modifications
Donald Heathcock	Electrician, Modifications
Daniel J. Shope	Q. C. Inspector
J. S. Patel	Electrical Engineer - Modifications
*Patrick Carier	Manager, REG Licensing
Bill Stadden	Electrical Engineer - Modifications
Russell Johnson	Reactor Operator

Robert Brown	Electrician, Maintenance
Jerry Tate	Electrician, Maintenance
Timothy Fulmer	Electrician, Maintenance
George Benton	Q. C. Inspector
R. Berryman	Electrician, Modifications
Eugene L. Tomlinson	Shift Engineer
Michael W. Miller	Shift Engineer
Charles Yell	Electrician, Modifications
Dennis Segres	Q. C. Inspector
Donald L. McGrady	Public Safety
Gary Faust	Electrician, Modifications
Kenneth C. Samples	Q. C. Inspector
Ed Gambrell	Electrical Foreman, Modifications
Clay L. Chandler	Electrical Foreman, Modifications
Raymond S. Journey	Electrical Supervisor, Modifications
J. L. Murphy	Electrical Foreman, Modifications
S. Tidwell	Electrician, Modifications
Tony Kirk	Electrician, Modifications
Henry Hatcher	S/W Q.C. Inspector
James Martin	Assistant Shift Engineer
James E. Gorham	Electrical Supervisor, Modifications
Joe Mantooth	Restart Test Coordinator
Ernie Ball	Drywell Coordinator
Jimmy Little	Firewatch
Johnny Dollar	Fire Brigade Leader
Ron Stowe	Auxiliary Unit Operator
*Tom Davis	Fire Protection Staff
Jim Kern	Fire Protection Supervisor
*Ron Lemke	Fire Protection Engineer
R. H. Windmiller	Fire Protection Staff
Joe Savage	Compliance
Clark Madden	Compliance
Vick Humm	Fire Protection Staff
S. Patterson	Modifications
J. Poag	Modifications
L. Hyde	Modifications
B. Horn	Electrical Modifications
H. Rutledge	Electrical Modifications
W. J. Percle	Design Modifications
Rick Tye	Fire Protection Staff
Al Salatka	Fire Protection Staff
Billie Miller	Training Staff (Records)
Joe Patterson	Division of Nuclear Constructions, Modifications - Pipefitter
Joe Darmer	Division of Nuclear Construction, Modifications - Pipefitter
Jimmy Landtroop	Division of Nuclear Construction, Modifications
James J. Clemmons	Firewatch
Jimmy Myhan	Shop Steward

Barth Loney	Assistant to Lead Mechanical Engineer
Robert Wimbrow	Senior Fire Protection Specialist
Jim Ballard	Principal Electrical Engineer
Steve Drzycimski	Division of Nuclear Engineering, Mechanical Engineering Branch
David Horn	Engineering Associate - Environmental Qualification
Ed Connell	Mechanical Engineer
Wayne Reid	Radcon Technician
*Dwight Mims	Manager of Technical Support Services
*A. Sorrell	Health Physics Manager
H. Crowson	Health Physics Staff Manager
R. McKeon	Unit 2 Superintendent

*Attended exit interview

2. Exit Interview (30703)

The inspection scope and findings were summarized on November 24, 1987 with the Serious Accident Investigation Team Members, Plant Manager, Superintendents and other members of the TVA staff. Licensee response for this event related to plant security will be addressed in Inspection Report Numbers 50-259/87-44, 50-260/87-44, 50-296/87-44.

The licensee acknowledged the findings and took no exceptions. The licensee did not identify as proprietary any of the materials provided to or reviewed by the inspectors during this inspection. Materials reviewed during the inspection are identified in Appendix C.

3. Methodology

The inspection began as initial information was being collected and continued in an iterative fashion throughout the investigation. The team convened to analyze the relevant factual information and pursue the probable causes for the fire. Established, analytical methods, were used to guide the fact-finding process and ensure a thorough investigatory analysis of the facts. Some of the analytical methods used include:

a. Management Oversight and Risk Tree (MORT) analysis
b. Causal factors analysis
c. Change analysis
d. Engineering judgment

Worksheets developed from these techniques are attached to this report in Appendix D.

4. Summary of Browns Ferry Unit 2 Fire - November 2, 1987

On November 2, 1987, a fire occurred at the Browns Ferry Nuclear Plant, located near Decatur, Alabama. The Browns Ferry Plant is a three-unit electric generating station owned by the Tennessee Valley Authority. At the time of the fire, Units 1, 2, and 3 were defueled and undergoing an outage. The fire, which originated in the Unit 2 drywell burned for thirty minutes and damaged several hundred cables of Division I and Division II safety-related and non-safety-related equipment. A sketch of the fire area scene is enclosed as Appendix E.

Tennessee Valley Authority representatives notified the U. S. Nuclear Regulatory Commission (NRC) at 11:42 a.m. (EST) on November 2, 1987, as required by the Code of Federal Regulations. NRC representatives from the Office of Special Projects (OSP) and Region II initiated an immediate investigation of the fire by the establishment of a Special Inspection Team. On November 2 members of the initial TVA site investigation team inspected the fire area to assess damage and evaluate potential hazards in the drywell. Members of the TVA Fire Protection and Safety Branch were members of the initial site team and inspected the scene on November 3 to conduct an initial evaluation and collect fire residue samples. These samples were sent to the TVA laboratory in Muscle Shoals for analysis. The laboratory report was returned on November 6 with evidence of long-chain hydrocarbons. The Muscle Shoals laboratory does not have the equipment to identify particular types of hydrocarbons. TVA established a multi-disciplinary fire investigation team (Serious Accident Investigation Team) on November 4, 1987, to determine the cause of the fire and to assess the extent of fire damage on plant systems. On November 4 the SAIT leader outlined the actions to be taken during the investigation which included field investigations, interviews, additional photographs, and pertinent document review. Actions outlined included the use of the Kepner-Tregge Problem Analysis as a mechanism to analyze the information obtained in document reviews, inspections, and interviews. On November 3 and 4, the NRC inspectors requested, and TVA agreed, to quarantine various electrical and mechanical equipment associated with the fire to allow a more thorough systematic approach to root cause analysis. The NRC and TVA teams coordinated activities through daily meetings and joint approval for release of quarantined equipment. On November 12 residue samples were sent to the Alabama Department of Forensic Science (DFS) in Huntsville, Alabama. The laboratory notified the SAIT that gasoline was detected in three samples. This was later verified through independent office analysis by the DFS in Birmingham, Alabama. With the results from the DFS, the investigation became redirected. TVA and NRC concurrently reported the lab results to the Bureau of Alcohol, Tobacco, and Firearms (ATF) and the Federal Bureau of Investigation (FBI). On November 12, the SAIT met with AFT agents. The AFT reviewed photographs of the fire scene and the report from the DFS. At that time, the agents felt the evidence was inconclusive and the SAIT should wait until additional laboratory reports could confirm or deny the presence of gasoline.

Laboratory results received on November 14 from the previous day's samples revealed that one of the samples contained gasoline. This was verified by both DFS laboratories which used different analytical techniques. A member of the Huntsville DFS also came to the site on November 14 and took samples for additional tests. These tests proved to be inconclusive. This would be expected due to the extensive length of time since the fire. On November 19, 1987, a representative of the Bureau of Alcohol, Tobacco and Firearms (ATF) concluded through field investigation that the fire was of a suspicious nature.

The SAIT established programs/activities listed below to be conducted for additional evidence/information and to assess the fire damage and impact on the plant.

Damage Assessment
Recovery Program
Assessment of Fire
Evaluation of Operational Events
Radiological and Chemical Cleanup
Release of Quarantined Areas/Components
Residue and Material Sampling
Area Cleanup

A SAIT member was assigned the responsibility for maintaining supporting documentation, i.e., transcripts, tapes, procedures, accident report, etc., during the SAIT investigation.

A program has been established for release of the drywell and the fire scene for normal work activities. This program is underway at this time. The overall program is being concurrently reviewed and approved by the NRC.

The present report provides the results of the OSP, TVA, and ATF investigation through the period November 6-20, 1987. This report is of limited scope involving only the events leading up to the fire, the subsequent steps taken by TVA to fight the fire and the determination of proximate root cause. An ongoing investigation by the ATF and FBI is in progress.

5. Probable Cause

a. Fire of Suspicious Origin

A special agent from the ATF along with an NRC fire protection specialist and a TVA fire investigation team member conducted a joint investigation and evaluation of the fire scene on November 19, 1987. Based on the experience and judgment of the special agent from ATF the following indicators were observed which tended to substantiate that the fire was of suspicious origin.

(1) The fire burn pattern observed on the plywood scaffolding adjacent to the fire scene indicated the presence of flammable liquid.

(2) The horizontal burn rate along the cables indicated an unnatural progression of the fire which could be explained by the presence of an accelerant.

(3) Physical damage to the insulation of cables inside two pull boxes also indicated an unnatural fire progression.

(4) The detection of gasoline in laboratory samples taken from inside an electrical pull box and debris found on the plywood scaffolding and under the cable trays indicates a widespread presence of gasoline. A total of 4 lab samples out of 16 taken were positive for gasoline. Confirmatory samples by an independent laboratory backed up the findings.

(5) The fire load in the area was judged to be insufficient without the presence of the accelerent to produce the temperature profile developed by TVA.

b. Fire Due To Modification Work Activities

Should an explanation be determined to discount the suspicious nature of the fire, the next probable cause would be the failure to have proper modification controls to assure temporary power connections are adequately terminated and controlled. An electrical short due to bare, unterminated, or damaged conductors could have acted as an ignition source to ignite the temporary linen tags in the area thus fueling the fire. This item is fully discussed in paragraph 8.

6. Sequence of Events

A fire occurred in the Unit 2 drywell (primary containment) on November 2, 1987, at approximately 9:40 a.m. (CST). The fire was located at the 580' elevation, azimuth 225 degrees, near electrical penetrations EE and EF. Two contract quality control employees performing a walkdown inspection of a mechanical piping system within the Unit 2 drywell noted what appeared to be an arc from the vicinity of penetration EE which was followed by a small fire about 6 feet from their location. Upon further investigation they noted that the fire was in the middle of a bundle of electrical cables which had a large number (100) of linen identification tags attached. The apparent arcing between the electrical cables appeared to ignite the tags and the fire rapidly spread. The two employees evacuated the area and reported the fire to the security officer posted at the equipment hatch to control entrance into the Unit 2 drywell. The security officer reported the fire to the control room by telephone. The fire alarm sounded and the control room operator dispatched the fire brigade at 9:47 a.m. (CST).

The fire brigade responded and began moving fire fighting equipment to the drywell equipment hatch at the 565'elevation of the reactor building. At 10:00 the fire brigade team leader arrived at the equipment hatch and found smoke being discharged into the reactor building from the equipment hatch opening to the drywell. He stopped the drywell fan blowers to help reduce the smoke concentration near the fire area. At this time, two brigade members who were dressed out in anti-contamination clothing and equipped with self-contained breathing apparatus (SCBA) were sent into the drywell to locate the fire. The two brigade members attempted to extinguish the fire using a portable CO2 fire extinguisher but this was not effective.

Meanwhile, other brigade members began pulling two 1 1/2-inch fire hose lines to the drywell equipment hatch and checked the containment wall inside the reactor building to assure that there was no fire spread through the electrical containment penetrations and into the reactor building. One hose line, supplied from hose station 2-26-878, located at column line R13-U, was advanced to the fire area at approximately 10:10 by the two brigade members who had originally entered the drywell. Water was sprayed on the fire intermittently in a spray pattern until extinguished. This took approximately two minutes. Two other brigade members checked areas adjacent to the fire and verified that it had not spread into other portions of the drywell.

At 10:15 the fire was under control and the first two brigade members were relieved due to low air supply in their SCBA cylinders. These members changed their SCBA bottles and then pulled the other hose line, supplied from hose station 2-26-866 to the platform beneath the fire at elevation 563' and charged this line. However, no fire was observed in this area and this hose was not used. The fire was fully extinguished by 10:20. Four fire brigade members remained in the fire area until 11:30. A firewatch was maintained in the area following the fire and remained assigned to the area during this inspection.

A total of 20 fire brigade members responded to the fire of which six entered the drywell and the remainder assisted in support activities in the reactor building. Due to the heavy concentration of smoke in the reactor building all fire brigade members and other support personnel wore SCBA during the early stages of the fire. The ventilation system for this portion of the reactor building was out of service prior to the fire due to an inoperative motor generator set. Necessary repairs/modifications were made during the fire and the ventilation system was restored to service at approximately 10:30. This rapidly exhausted the smoke from the building. Three portable smoke ejectors(fans) were used during the fire to help diminish the smoke generated by the fire. Response by the fire brigade was timely and the operations staff was effective in extinguishing the fire and limiting fire damage to a small area in the drywell.

A more detailed timeline sequence of events is included as Appendix B.

During the fire, several safety systems either spuriously actuated or failed to operate on demand. The following paragraphs describe these occurrences and where possible, an explanation is offered. These explanations are preliminary but based upon the best judgement at the time. The licensee's Plant Operations Review Staff (PORS) has been assigned the task of assessing the operational events in detail.

The first indication in the control room occurred about five minutes after the fire was discovered. A trip signal was generated almost simultaneously from the Intermediate Range Monitoring (IRM) System and the Average Power Range Monitoring (APRM) System in trip Channel B of the Reactor Protection System (RPS). IRM Channel D became inoperable presumably due to a loss of the power supply. APRM Channels D and F gave high-high fixed (15% power) trips due to the multiple failures of about 18 of their Local Power Range Monitor (LPRM) inputs (LPRMs fail upscale on loss of power). Twenty-five minutes later at about the same time water was being applied to the fire, a full scram signal was generated when RPS Channel A tripped. This occurred due to an upscale trip of APRM Channel A. No rod motion occurred as a result of this scram signal since all rods were previously inserted. Some confusion was initially generated regarding a"quarter-scram" following receipt of the initial trip of the B RPS channel and the licensee included a discussion about this in the 4-hour report to the NRC Operations Center pursuant to 10 CFR 50.72 at 2:40 p.m. This situation occurred because one-fourth of the scram solenoid valves were previously deenergized for corrective maintenance of the subchannel scram relays of RPS Channel A. Thus with one-fourth of the A RPS channel scram solenoids previously deenergized and all of the B RPS channel scram solenoids deenergized after the fire, a full scram signal was generated to one-fourth of the rods. This unusual situation is not pertinent to the system response caused by the fire and is only presented here to clear up any confusion resulting from the 4-hour report.

At about 11:30 a.m., the Shift Engineer ordered the breakers opened for the following list of equipment; Drywell blowers 2B-1, 2B-3, 2B-4, 2B-5 and Reactor Recirculation Pump A suction and discharge valves (FCV-68-1 and FCV-68-3). Prior to the fire, recirculation pump A discharge valve was closed for maintenance and its suction valve was open. Position indication was lost after the associated breaker was opened, however; at 7:00 p.m., operators noted the Recirculation Pump A seal pressure was abnormally high at 1450 psig. During normal operation, the pressure drop across each of the two pump seals is about 500 psig. Operators speculated that the recirculation pump suction valve had gone closed and thus the control rod drive pump (CRD), which normally supplies the pump seal purge flow, was applying full pump discharge pressure to the pump seals, pump casing, and piping between the suction and discharge valve. The CRD system was removed from service and when the recirculation pump suction valve was throttled slightly open by the manual handwheel, pump seal pressure was vented off, thus confirming the assumption that the suction valve had somehow gone closed. The licensee proposed one possible explanation for the change in position of this Limitorque motor-operated

valve. Two 120 volt AC control power cables which pass through the drywell near the fire at penetration EE and which were part of the temporary splicing activity in support of IHSI could have shorted together generating a "hot short". This "hot short" would have bypassed the normal control switch contacts, the limit switch interlock, and the torque switch directly energizing the valve control closing coil. 480 Volt AC power would then be applied to close the valve until interrupted by the thermal overloads or the circuit breaker.

At 2:30 p.m., electricians and fire watch personnel near the fire damaged area noted some electrical arcing. This prompted additional inspections outside the drywell and a renewed urgency on the part of the operators to determine power sources that might still be energizing the fire damaged cables. At 3:00 p.m., operators found the 480 volt AC circuit breakers for both drywell floor drain sump pumps and one of the two equipment drain sump pumps tripped. The remaining equipment drain sump pump breaker was opened to deenergize the fire affected area. Operators continued to research drawings and issue Clearance Hold Orders until about 10:30 p.m., that night.

7. Description of Fire Area and Damage

The fire appears to have originated at elevation 580 in the Unit 2 drywell near penetrations EE and EF. The fire area is about 15 feet above the drywell platform at elevation 563 and 13 feet above the reactor floor at elevation 565. The fire area is about 45 feet north of the southern most equipment hatch. After ignition the fire propagated approximately 10 feet to the left and 2 feet to the right of the cable splice box for penetration EF. Total horizontal propagation amounted to approximately 12-15 feet. The propagation of the fire was along the top two trays of a tier of 3 horizontal cable trays (GV,RY,HX). Power supplied to cables in the area of the fire was 480 V.A.C., 120 V.A.C. and 250 V.D.C.

Combustible materials in the fire area consisted of linen tags used to identify splices, cable insulation, a flame retardant blanket used to protect cable trays from welding activities, and fire resistant plywood. The plywood was placed over gaps in the aluminum scaffolding which was setup in the drywell and extended to the cable trays.

The fire resulted in destruction of the cables in the affected section of the cable trays, the melting of two aluminum conduits above a penetration splice box, and the discoloration of the galvanized steel junction boxes, cable trays and conduits in the area. A section of the splice box was discolored white, from the heat of the fire inside the box. No melting or structural failure of steel components was noted. Charred remnants of the flame retardant blanket were found on top of the cable trays. The flame resistant plywood underneath and directly beneath the fire origin was charred.

The following is a list of the equipment impacted or potentially impacted by the fire induced cable damage. It should be noted that no equipment was damaged directly by the fire. Only power and control circuitry to this equipment was damaged by the fire.

a. Drywell Atmosphere Control and Monitoring

(1) Drywell blowers 2B-1 through 2B-5 (power and control).
(2) Drywell ventilation dampers (pilot solenoid valves).
(3) Reactor Building Closed Cooling Water (RBCCW) supply valves to drywell cooling coils.
(4) Drywell airspace temperature elements.
(5) Drywell cooler inlet and outlet temperature elements for Bank B.

b. Drywell Leak Detection

(1) Drywell equipment drains sump pump 2A and 2B (power).
(2) Drywell floor drain sump pump 2A and 2B (power).

c. Main Steam System

(1) Main steam relief valve soleniods (PSV-1-34,42).
(2) Main steam line drain valves (FCV-1-14,26,37,51).
(3) Main steam relief valve acoustic monitors and tailpiece temperature elements.
(4) Main steam relief valve backup air accumulator pressure switch.
(5) Main steam isolation valve (MSIV) position switches.

d. or Recirculation System

culation pump B temperature elements (windings, bearings d seals).
(2) Recirculation pump A and B motor heaters.
(3) Recirculation pump B speed indicator.
(4) Recirculation pump B suction valve power and control (FCV-68-77).
(5) Recirculation pump A suction and discharge valve power and control (FCV-68-1,3).
(6) Recirculation loop equalizer valve power and control (FCV-68-35).

e. Neutron Monitoring

(1) Source Range Monitor (SRM) drive motors for channels C and D.
(2) SRM Signals for channels C and D.
(3) Intermediate Range Monitor (IRM) drive motors for channels E, F, G, and H.
(4) IRM signals for channels C,D,G and H.
(5) Local Power Range Monitors (LPRM) for the following Average Power Range (APRM) channels, A (21 detectors), C (21 detectors), D (22 detectors), F (22 detectors).

f. Miscellaneous Equipment

(1) Feedwater nozzle and sparger temperature indicators.
(2) Reactor vessel temperature elements.
(3) Manual valve position indicators for Core Spray (CS), Standby Liquid Control (SLC), Residual Heat Removal (RHR), and Feedwater Systems.
(4) Traversing Incore Probe (TIP) calibration and indexing mechanisms.
(5) Control rod position indicators (80 rods).
(6) Refueling bellows seal high leakage flow switch.
(7) Service outlets on the rod drive handling platform.
(8) Core spray system testable check valve control.
(9) Reactor Core Isolation Cooling (RCIC) inboard steam supply isolation valve (control and power).

The types of cable material involved in the fire are summarized below:

(a) Cross-linked polyethylene insulated wires of various sizes (10-16 AWG) bundled in single conductor to 9-conductor cables with primarily polyvinyl chloride (PVC) outer jacket. Some had chlorosulfonated polyethylene outer jackets. All cables are rated at 600 V, 90 degrees C. According to the licensee these cables are "obsolete" and are not to be used in new designs.

(b) Plain polyethylene insulated wires applied as above.

(c) Thermocouple wire with cross-linked polyethylene insulation and a neoprene jacket.

(d) Flame retardant cross-linked polyethylene or flame retardant ethylene propylene rubber with either a chlorosufonated or chlorinated polyethylene jacket.

No equipment was damaged other than the cables and there were no personnel injuries. Minor smoke inhalation and heat exhaustion was experienced by one fire brigade member and one fire watch. The fire watch overcome by smoke was sent back in the drywell as a reflash watch later the same day. Accountability control should be evaluated to ensure full healthy personnel are used as reflash watches.

8. Activities Prior to the Fire

Both the TVA and NRC teams began the search for a probable root cause to the fire by evaluation of the changes in plant operations and equipment immediately prior to the fire. Although, the ATF investigator considers the fire to be of suspicious origin, it was apparent from an inspection in the area of modification work that a probable cause could have been an

electrical short between temporary power cable connections. Deficiencies detected in this area are summarized in the following paragraphs for followup inspection activity and potential enforcement concerns.

a. Modifications Prior to the Fire

One of the probable causes of the fire pursued by the inspectors during the investigation involved the use of temporary electrical power connections routed through drywell electrical penetration EE. The fire was initially observed in this area by a contract quality control inspector performing walkdowns inside the drywell. The temporary power connections and modification work in the area were evaluated as a possible cause of the fire. The sequence of events for these work activities is detailed below:

July 25, 1986	Engineering Change Notice (ECN) P 3180 was approved to replace primary containment electrical penetration EB, EC, and EE with environmentally qualified Conax penetration.
May 13, 1987	Maintenance Request (MR) A-775468 was initiated to provide some temporary power connections through the unconnected penetrations. The power was necessary to support operation of the recirculation system for the Induction Heat Stress Improvement (HSI) Program.
May 21, 1987	Temporary connection of the cables was completed.
October 6, 1987	MR A-793993 was initiated to provide temporary power connections through penetrations EC and EE. This was done to support the restart test involving the drywell blowers which were required to load shed during the diesel generator load acceptance test.
October 21, 1987	Temporary connection of the cables was completed. Identification labeling problems were encountered inside the drywell.
October 24, 1987	MR A-762856 - 762860 were worked to correct problems with the indicator lights associated with the drywell blower dampers. When circuit breaker 314 was closed, no lights were illuminated.
October 30, 1987	MR A-822017 was worked to temporarily determinate the temporary power connections to verify conductors to resolve the indicator light problem. Cable identification problems were encountered outside the drywell. The work was completed at 7:00 p.m.

November 2, 1987 Power to the drywell blower dampers was restored at 0830 by closing circuit breakers 314 and 213 supplied from the 120 VAC I&C bus. At 9:47 the fire alarm sounded. Operations, maintenance, and modification each considered the temporary connections as a possible cause for the fire and personnel from each of these groups reported to breakers 314 and 213. Breaker 314 was found tripped immediately after the fire alarm was sounded. Breaker 213 was opened by operations personnel as a precaution.

The temporary nature of the connections and the problems encountered with the identification labeling presents the possibility of a connection problem or error. A detailed description of the electrical connections and modification activities follows.

(1) Penetration Modification

Primary containment electrical penetrations EB, EC, and EE were being replaced with environmentally qualified Conax penetrations to satisfy the requirements of 10 CFR 50.49. The old type penetration had plug type connections; and the new type has ports containing short cables that (pigtails) are connected inside and outside the drywell using amp butt splices covered with Raychem shrink tubing. The cable connections to the old penetration were disconnected and each conductor tagged with a temporary white identification tag. This was accomplished under work plan 2100-86 and contained first (craft) and second party (Q.C.) signatures for the attachment of the temporary tags. The new penetration containing 24 ports was installed and the temporary power cables were connected to four of the ports to support IHSI and restart testing.

(2) Temporary Power Connection for IHSI Program

In May 1987, under MR A-775468 power connections were made in port 17 of penetration EE to support the IHSI program. No identification or connection problems were noted with these connections. Although these cables remained connected until the event, the cables were not energized.

(3) Temporary Power Connections to Support the Restart Test Program

(a) Missing temporary tags inside the drywell

In October 1987, under MR A-793993, connections were made in ports 2, 3, and 19 of penetration EE to support restart testing. As part of a diesel generator load acceptance test the drywell blowers are required to load shed.

Connections were necessary to the drywell blower control limit switches and dampers for the planned testing. All of the splices were made outside the drywell first and no problems were noted. Work proceeded inside the drywell but missing identification tags were found. First, in port 19 on 12 conductor cable 2V1890, 2 temporary identification tags could not be located. Ten of the twelve conductors with temporary tags were connected and in the process of identifying the other two a discrepancy was noted in the wire colors. An attempt to identify the wires from a junction box a few feet away where a permanent tag was on the cable failed because the wire colors did not agree. Further evaluation revealed that some of the previous splices likewise did not agree. This connection error was corrected inside the drywell but no continuity check was performed from inside to outside of the drywell. This information was learned based on interviews with the craft personnel performing the work. The work performed under the MR only referenced connecting the single cable and did not document all problems encountered.

(b) Missing vendor tags inside the drywell

Also, based on interviews it was learned that inside the drywell three of the vendor installed identification labels for conductors coming from penetration EE were missing. The labels are black sleeves one inch long with white letters that slide over the end of the wire. These conductors were "talked-out" using a telephone connected to ground and the conductor both inside and outside the drywell. The inspector questioned the craft personnel on how "cross-talk" between the conductors was checked. For example, while testing splices located inside the drywell, if the conductors were connected to a common point outside the drywell, continunity checks may be meaningless unless the conductors outside were disconnected. The craft stated no disconnecting was done outside the drywell. A probe was inserted into the Raychem splice outside the drywell and electrical tape applied over the probe hole when complete. The inspector identified three Raychem splices outside the drywell from port 2 with tape attached. These were to conductor locations 2-12, 2-16, and 2-18. Likewise, none of these problems were documented anywhere.

(c) Incorrect terminations outside drywell

After the test of the indicating lights on October 24, 1987 in which no lights were illuminated, MR A-822017 was issued to verify conductor identifications on cables 2V1888 (outside) and 2V1890 (inside). Cable 2V1888 connects to

the backup control panel 25-32. It was identified that the cable tagging and color codes on 2V1888 did not match panel 25-32. Conductors were lifted at panel 25-32 and the conductors "talked-out". Incorrect termination was noted on 8 of 12 conductors associated with cable 2V1888. No work or check was performed on cable 2V1890 at this time. The electrical engineer recommended that both inside and outside be checked and wrote the MR to this effect. However, the engineer was overruled by his management and the check inside the drywell was not done. The cable was reterminated at 7:00 p.m., on 10/30/87. No additional work activity verifications were done between October 30, 1987 and November 2, 1987.

b. Maintenance Activities On The Day of Fire - November 2, 1987

0830 a.m. - Unit Operator closed breaker 314 and 213 per request of Maintenance Electricians who were troubleshooting valve position indicating light problems. Damper lights were observed on associated dampers as follows.

HS-70-16	-	Red light control room panel and panel 25-32.
HS-70-18	-	Red light control room panel and panel 25-32.
HS-70-20	-	No lights in control room panel or panel 25-32.
HS-70-64	-	Both lights (red and green) in control room panel.
HS-70-66	-	Both lights in control room panel.

After recording light indications at the Backup Control Panel and Control Room the electricians proceeded to their shop office to review drawings and discuss findings with their foreman. The electricians left the control room at 0930 with breakers 314 and 213 still energized.

0945 a.m. - Operation was in process of loading the 2B RPS M-G set. The 2B RPS M-G Set was loaded approximately four minutes after fire alarm was sounded.

0947 a.m. - Control Room received fire alarm unit 2 drywell.

The missing vendor labels and temporary identification tags represent a possible connection error. Since the work proceeded over several days and only the cable termination and not individual conductor terminations are documented, the possibility for a conductor being unterminated when energized existed. These facts coupled with the initial eye witness of the fire location made the temporary power connections a possible source of the fire.

The licensee plans to perform continuity checks on all the conductors as part of the fire inspection troubleshooting phase.

9. Licensee Fire Prevention Program Areas

a. Fire Brigade Training

The plant fire brigade training program is described in the Browns Ferry Fire Protection Program Plan (BF-PPP). To meet the TVA fire brigade requirements each brigade member is required to attend a 32 hour comprehensive fire protection training course prior to being assigned to the brigade and once every four years thereafter. Each member must also pass a fire brigade medical evaluation, attend quarterly classroom fire brigade training, participate in at least two fire brigade drills per year and attend an annual eight hour refresher fire training session which includes an actual practical fire fighting exercise. The fire brigade leaders are required to successfully complete a 32 hour fire incident command course conducted prior to being assigned a fire brigade leader and once every four years thereafter. These training requirements meet the NRC requirements and guidelines.

The inspectors reviewed the training records for the brigade members. The Training Department records indicate that 53% or 67 of the 126 brigade members assigned to the five operating crews are ineligible for fire brigade duty due to overdue medical examinations, or failure to attend the minimum number of drills or training sessions. Three of the six fire brigade members who entered the drywell for fire fighting operations were not eligible for fire brigade duty.

b. Fire Watch Training

The fire watch training program is described in the BF-FPP. To meet TVA requirements each employee designated as a fire watch is required to receive a four hour fire watch training program prior to assuming these duties and annually thereafter. This program consists of video tape and general class discussion which cover fire watch duties and responsibilities, fire protection/prevention criteria and practical exercise utilizing portable fire extinguishers. These requirements meet the NRC guidelines.

The inspectors reviewed training records and interviewed several fire watch personnel. Interviews during the investigation indicated that a firewatch, assigned duty in the drywell for a welding activity left his post before the required 30 minutes stay time expired after "hot work" was completed. This may indicate a specific training program weakness. Overall, fire watch training and response to questions during interviews appeared adequate.

c. Fire Emergency Procedures and Prefire Plans

The procedures for reporting a fire, fire brigade response and subsequent actions following a fire are addressed by the Browns Ferry Fire Protection Program Plan - Attachment P, Fire Emergency Procedures and Prefire Plans. These procedures conform to the NRC guidelines and requirements, however; there are no prefire plans for the primary containment. It appears that prefire plans should be developed for these areas due to the number of maintenance and modifications conducted in these areas during an outage.

The Fire Emergency Procedure designates the fire brigade leader as the responsible authority to select the appropriate fire protection measures and fire brigade protective clothing and breathing apparatus in the event of a fire in any plant area including radiation areas and in areas involving potential toxic hazards. The industrial safety group is available from 7:00 a.m. until 12:00 p.m. (midnight) to assist in taking air samples and aid in determining the appropriate personnel protective equipment required. However, no one is normally available to perform this function from 12:01 until 7:00 a.m. It appears that this function should be assigned to a group who is adequately trained and available at all times.

d. Containment Fire Protection Modifications Following the 1975 Fire

The inspectors reviewed TVA document entitled "Plan for Evaluation, Repair, and Return to Service of Browns Ferry Units 1 and 2 (March 22, 1975 fire)." Based on the primary containments at Browns Ferry being maintained inerted during normal operations it appears that no fire protection modifications were required for the primary containments following the 1975 fire. Therefore, most of the cable within the primary containments do not meet the current IEEE 383 fire retardant criteria, are not coated with a fire retardant coating (flamastic), are not provided with horizontal or vertical fire stops, nor are they provided with fixed fire suppression systems as are provided for other areas at Browns Ferry. The NRC Safety Evaluation Report issued March 1976 found the lack of these features to be satisfactory. Furthermore, 10 CFR 50, Appendix R, Section III.G exempts inerted containments from having to meet the separation and fire protection features normally required inside non-inerted containments. It appears that the primary containments at Browns Ferry meet the NRC fire protection and safe shutdown requirements.

e. Housekeeping

The inspector reviewed the Site Directors Standard Practice (SDSP) 14.6 "Building and Facilities Housekeeping and Cleanliness", as well as the Monthly Housekeeping Inspection Report and the accompanying Forms and Daily Housekeeping Logs for the Unit 2 drywell. The review of the monthly report and daily logs covered the months of September

and October 1987. This review indicated that portions of the Unit 2 drywell area were inspected by various foremen during this time. Generally, no significant housekeeping deficiencies were noted during the inspections. More thorough inspections may be appropriate to assure excess materials are not left in drywell. The drywell was noted, however; to be relatively clean considering outage activities were in progress.

10. Licensee Followup Activites

The licensee has turned the investigation over to a team of ATF and FBI agents and intends to disband the special TVA Serious Accident Investigation Team. Cleanup and corrective modifications will be handled by the licensee's recovery team. The recovery team charter will be to determine corrective action, damage assessment and resolve non-fire associated findings.

a. Recovery of Damaged Electrical Equipment

The electrical equipment identification program will be similar to that developed for the March 22, 1975 fire which consisted of three basic elements. The program identified equipment exposed to high temperatures, equipment contaminated by smoke and soot, and equipment exposed to abnormal electrical power conditions.

A high temperature zone was established from the temperature profile study. All electrical equipment within this zone will be identified and checked for degradation. A visual inspection will be made for signs of distress or overheating damage sustained by insulation components. Where necessary components will be disassembled to verify observations. Non-destructive electrical tests and pre-operational test may be specified to verify the correct functional performance of the equipment, controls, or circuits involved.

A larger zone than the high temperature zone will be established for the purpose of removing soot and smoke residues from electrical equipment. Physical inspection of equipment in this zone will be performed during cleanup. A verification program of non-destructive electrical tests and pre-operational testing may also specified for this equipment.

If overcurrent is determined to have been a possible outcome of the November 2, 1987 fire, procedures will be developed to evaluate affected components. After the 1975 fire, diagnostic tests were performed on all electrical equipment that may have been exposed to abnormal electrical power components.

b. Evaluation of Other Equipment

The licensee developed criteria to evaluate the effects of the fire on non-electrical components subjected to environmental conditions resulting from the fire. Similar criteria are expected to be developed for evaluation of plant components after the November 2, 1987 fire. Effects identified as requiring detailed evaluation after the 1975 fire were:

(1) Stress corrosion due to chloride contamination from combustion products.
(2) Embrittlement from liquefaction of low melting point metals.
(3) Elevated temperature exposure effects on materials.

Chloride contamination was evaluated by identifying components likely to be affected (stainless steel and high strength ferretic steels), establishing temperature areas (800 degrees to 1200 degrees F) where susceptibility to stress corrosion would be enhanced, and determining the actual concentration of chlorides deposited on the component. Based on these criteria, contaminated components were either cleaned or replaced.

Minimum temperature criteria will be established to evaluate the environmental effects of elevated temperature on components:

(1) Safety-related heating, ventilating and air conditioning ducts were evaluated on the basis of exposure to temperature of 500 degrees F or greater and visible distortion of the ducts.
(2) Replacement of structural steel was specified for steel in temperature zones of 1000 degrees F or greater.
(3) Replacement of aluminum piping or components was specified for aluminum piping or components within a temperature zone of 340 degrees F or greater.

A temperature criteria was not established for cable trays, however; in general all cable trays in direct and near contact with cables actually consumed by the fire were replaced without further evaluation following the 1975 fire.

A significant item not assessed after the 1975 fire was the drywell carbon steel liner. The licensee is developing criteria to evaluate the liner.

The licensee developed a fire temperature profile of the November 2, 1987, fire area to assist in root cause determination. The determination of the fire temperature profile follows the criteria prepared for "Determination of Temperature Zones for the March 22, 1975, Fire at the Browns Ferry Nuclear Plant" Design Criteria No. BFN-50-0702, May 8, 1975, as modified by W. E. Pennel's memorandum of November 10, 1987. These documents established uniform criteria to be followed in

identifying and estimating the intensity of the temperature zones in the regions affected by the March 22, 1975 fire at BFN. The data resulting from the application of those criteria was used as the basis for evaluation of the structures and all mechanical and electrical equipment in the areas affected by the November 2, 1987 fire.

Temperature indicators were selected based on results from the 1975 fire study. The indicators selected are materials which had undergone visible or suspected change after being subjected to the temperature experienced in the fire.

The identification of sufficient specimens of temperature indicating material was used to establish 80 temperature data points within the burn region. Each specimen is identified by a material data point number and 3-dimensional coordinate point, catalogued, and photographed.

The reduced data was plotted to an appropriate scale from which temperature zones were constructed. The final determination of these zones included the actual data points where possible. Interviews with fire brigade personnel, initial observers, and some measure of judgement on the part of the analyst were used to fill in regions where little or no physical data is available. Any information not traceable to actual physical data was so indicated.

11. Electrical Testing of Circuit Breakers

As of November 16, 1987 a total of 10 electrical circuit breakers were tested with 4 breakers identified as having trip setpoints out of tolerance. It was noted that no procedure existed for checking the overload trips on the starters associated with the applicable breakers. This could constitute a deficiency in that periodic testing of electrical circuit breakers and starters is necessary to prevent failures in electrical equipment. The inspector will continue to monitor the ongoing testing activities.

APPENDIX A

FINDINGS AND CONCERNS

1. Prefire plans are not provided for primary containment areas of the reactor building.

2. Trained personnel are not always available to aid the fire brigade team leader in determining the appropriate personnel protective equipment needed in plant areas containing toxic hazards. Toxic gas sampling of the air following the fire was not well controlled. No method was available at the time of the fire for detection of phosgene gas which would be expected as a result of burning polyvinyl chloride (PVC). The majority of the sampling effort was directed toward carbon monoxide although no contemporaneous logs were kept on the test results.

3. A fire watch left the 580 drywell area immediately after welding ceased. He should have maintained his watch for an additional 30 minutes after welding as required by plant procedures.

4. No post-maintenance testing was performed following the termination of temporary electrical connections through penetration EE.

5. The temporary electrical connections through penetration EE were not controlled as a temporary alteration and control room drawings were not updated.

6. When wires were found reversed and unlabeled, no condition adverse to quality report (CAQR) was initiated to document the problem and control resolution of the deficiency.

7. A significant number (53%) of the fire brigade members are not eligible for fire brigade duty due to training or medical deficiencies.

8. Temporary electrical connections were made for the purpose of restart testing. This practice was probably unnecessary and should be discouraged.

9. Welding leads are routinely energized and left unattended in the drywell.

10. Fire Brigade members wasted valuable time while dressing out in radioactive contamination protective clothing instead of rapidly donning Fire Protection "turn-out" gear. The turn-out gear in all probability provides equal or better protection from radioactive contamination.

11. Maintenance records were inaccurate for documenting the cable splicing of the temporary drywell equipment power connections. Not all of the splicing that occurred was recorded; and the completion dates were not always the dates that the work was actually performed.

12. Vendor identification tags are not securely attached to penetration pigtails. Temporary line tags used for conductor identification should be evaluated for acceptability due to fire load.

13. An engineer's decision to check cable continuity both inside and outside the drywell was overruled by management. (MR A-822017) This event potentially led to incorrectly terminated cable conductors.

14. Electricians training may not be adequate for checking "cross-talk" between conductors, while performing continuity checks.

15. Numerous craft worked on the same job (temporary power connections) through penetration EE over a two week period without proper turnover or communication awareness.

16. The practice of using an ice pick probe to insert into Raychem splices to check for continuity should be evaluated for acceptability by the licensee.

17. Electrical testing of circuit breakers did not include all breaker components to verify operability status. This is a generic concern.

18. The plant operators have no quick reference drawing to determine power distribution through drywell penetrations. Days after the fire, questions still existed as to whether all power in the area was secured.

APPENDIX B

BROWNS FERRY NUCLEAR PLANT UNIT 2
NOVEMBER 2, 1987
SEQUENCE OF MAJOR EVENTS

10/24/87 12:40 - Closed BKR 314 - no indications - opened BRKS
14:03 - Closed BKR 314 - no indications - opened BKR - terminations at EE do not match panel 25-32

10/30/87 - Wiring corrections made in cables 2V1888/2V1890
- cable to FCV 70-66 fed by BKR 314

11/01/87 - 11:17 - 2B reactor protection system (RPS) MG set smoked
- RPS Trp functions occurred
15:00 - Status 2B RPS MG set inop. (alt power source out) - 1/2 scam - group 6 isolation - standby gas treatment (SGBT) in service

11/02/87 - 04:55 - Picked up hold order 2-87-817 - RPS MG set bumped for rotation
07:16 - 09:12 - Day shift work activities resume in Unit 2 drywell. During this period 48 persons including 12 visitors entered the drywell. Work activities in process included: welding, cleanup, health pnysics work, system walkdowns, engineering work, and fire watches.
08:00 - Drywell leak rate, .006 GPM = (9gpd)
08:05 - Panel 9-9, Breakers 314 and 213 released from hold orders, left deenergized
08:30 - Unit operator closed breakers 314 and 213 on panel 9-9
08:40 - Running 2B RPS M/G set 1 hr.
09:45 - Contract QC inspector discovers fire, exit drywell
09:45 - ASE Loaded 2B RPS M/G set - called UO to reset 1/2 scram
09:47 - FIRE ALARM (PER FIRE CALL 2299)
- Fire reported in Unit 2 Containment at 583' elevation
09:50 - 1/2 Scram D & F APRM
- Approx 17-18 LPRM Hi
- D IRM inoperable
10:00 - Placed RX bldg vent in service
- Notified U1 and U3 to place RX vent sys in service
- U2 PCIS reset
10:00 - Unit operator discovers panel 9-9 BKR 314 tripped, BKR 213 closed, operator opened BKR 213
- Fire Brigade responded to Equipment Hatch of Unit 2 containment at 565' elevation
- Two fire brigade members entered area in anti-c's and SCBA to verify fire condition and then return to get fire equipment

- Fire brigade leader stopped drywell fans
- Fire extinguisher CO2 type used but not effective
- Two fire brigade members checked adjacent areas for fire spread
- Other brigade members checked penetration outside containment for fire spread
- Other brigade members advance two hose lines into containment

10:08 - NOTIFICATION OF UNUSUAL EVENT
10:10 - CO levels 500 ppm C-zone boundry of drywell
10:15 - 1/2 Scram U2 A APRM HI HI or inop for full scram
- A APRM scram bypassed, 1/2 scram reset
- A fire hose was pulled into containment by two fire brigade members and water spray was applied intermittently for approximately two minutes to fire area.
- First two fire brigade members in SCBA relieved by two other fire brigade members
- First two fire brigade members changed their SCBA bottles and pulled a second hose into containment to the area below the fire at 560' elevation - hose charged but not used
- Fire under control
- Portable fans used for ventilation at 565' of reactor building

10:20 - FB REPORTS TO B.O.P. S.E. "NO FLAME VISIBLE"
- Fire out/alarm secured
- Two fire brigade members remained until 11:30, then fire watch and electrician remained in the area

10:30 - Reactor building ventilation system placed in service to remove smoke
10:40 - NRC NOTIFIED OF UNUSUAL EVENT
10:50 - CO levels 10 ppm C-zone boundries of DW
10:59 - FD leader declared "All clear"
11:07 - Medical emergency Rx Bldg between U2 & U3
- One fire brigade member suffered from heat exhaustion and medical emergency declared

11:30 - DW entry by investigation team
- CO levels less than 5 ppm C-zone boundary of DW
- Removed or checked removed power from U2 DW EE

11:35 - UNUSUAL EVENT CANCELLED
12:15 - U2 ASE surveys damage in DW
12:34 - SBGT placed on standby
14:30 - (Approx time) - Operator attempted to start sump pump
14:30 - Arcing discovered in area of fire
14:57 - BKRS to drywell sump pumps found tripped
15:00 - U2 operator panel walkdown (250 volt ground noted)

16:30 - Jumper found off RPS B channel group 3
17:20 - Deenergizing fire damaged cables in drywell
17:30 - Deenergized power range monitors A & B channel
19:00 - CRD sys O/S due to high pressure RX Recirc Pump A #1 seal
19:45 - Electrical Bd insp - no additional BKRs found tripped
22:00 - 23:00 - Hold orders place on additional drywell equipment

11/03/87 - 01:30 - Drywell sump level 3" below top
04:00 - 04:30 - Hold orders on drywell blowers and recirc pump motor heaters
14:39 - 250 volt ground cleared (Partial)
20:30 - Cleared 250 volt ground (Full clear)

APPENDIX C

ITEMS REVIEWED BY NRC TEAM

1) The Actual Fire Scene and Pictures of the Fire Scene
2) Temperature Monitoring Logs of Drywell
3) Related Maintenance Requests
4) Associated Work Plans Related to Fire Area
5) Temperature Monitor Log
6) Lab Reports
7) Drywell Access List
8) Clearance Sheet for Hold Orders
9) DNE Approach for Fire Investigation
10) Shift Engineer Notes/Logs
11) Interview Sheets from SAIT
12) Dwg. 45A852 (Whole Series) - Electrical Penetrations 45N2620 45N2750-17
13) Recirc Pump Flow
14) Fire Protection Plans
15) Fire Permits
16) Computer Alarm Printout
17) AUO Logs
18) ASE Logs
19) RPS MG Sets Test
20) Temporary Power Leads (welding/fans)
21) Security Access Logs
22) Breaker Trip Trouble-Shooting MRs
23) Drywell coordinator Log Book
24) MR History on Drywell Blowers
25) 32 hr Fire Brigade Member Training Course outline
26) DNE Fire Chemistry Chart
27) List of Fire Watches
28) Summary description of Fire Affected Area (#of cable trays, major safety-related equipment)
29) Fire Temp Profile Description/Procedure
30) Fire Sequence of Events
31) List of Mark # vs. Cable Type Crossreference
32) Drywell Layout Dwg Picture of Mockup
33) Fire Investigation Preliminary Report
34) Quarantine List
35) Requested Additional Pictures
    - Outside Penetration
    - Walk Thru from Drywell Entry (Series)
    - Top View of Fire Area
36) Hold Orders - applicable to time of fire
37) Record for Cable and Flammastic Inspection (3 yr record)
38) NFPA Fire Investigation Procedure
39) Radiation Work Permits
40) Fire Watch Training Records - Current
41) Fire Watch Training Syllabus

42) Drywell Housekeeping Logs
43) Drywell Tool Accountability Logs
44) Reports for Drywell Fires within Last Year
45) Welding Permits
46) TACF/Jumper Logs from 4/87 to present
47) 1975 BFN Fire Recovery Plan
48) Cable Division Separation Criteria Drywell Cables BFN-50-758
49) List and Description of Flammable Liquids Inside the Drywell
50) Copy of Physical Field Fire Investigation Plan
51) Circuit Breaker Analysis Procedure
52) Chemical Analysis for Chlorides and Fluorides
53) Serious Accident Investigation Plan

APPENDIX D

ANALYTICAL WORKSHEETS

EXHIBIT 1: FAULT TREE ANALYSIS

EXHIBIT 2: CHANGE ANAYLSIS WORKSHEFT

APPENDIX E

SKETCH OF FIRE SCENE

EXHIBIT 1: FAULT TREE

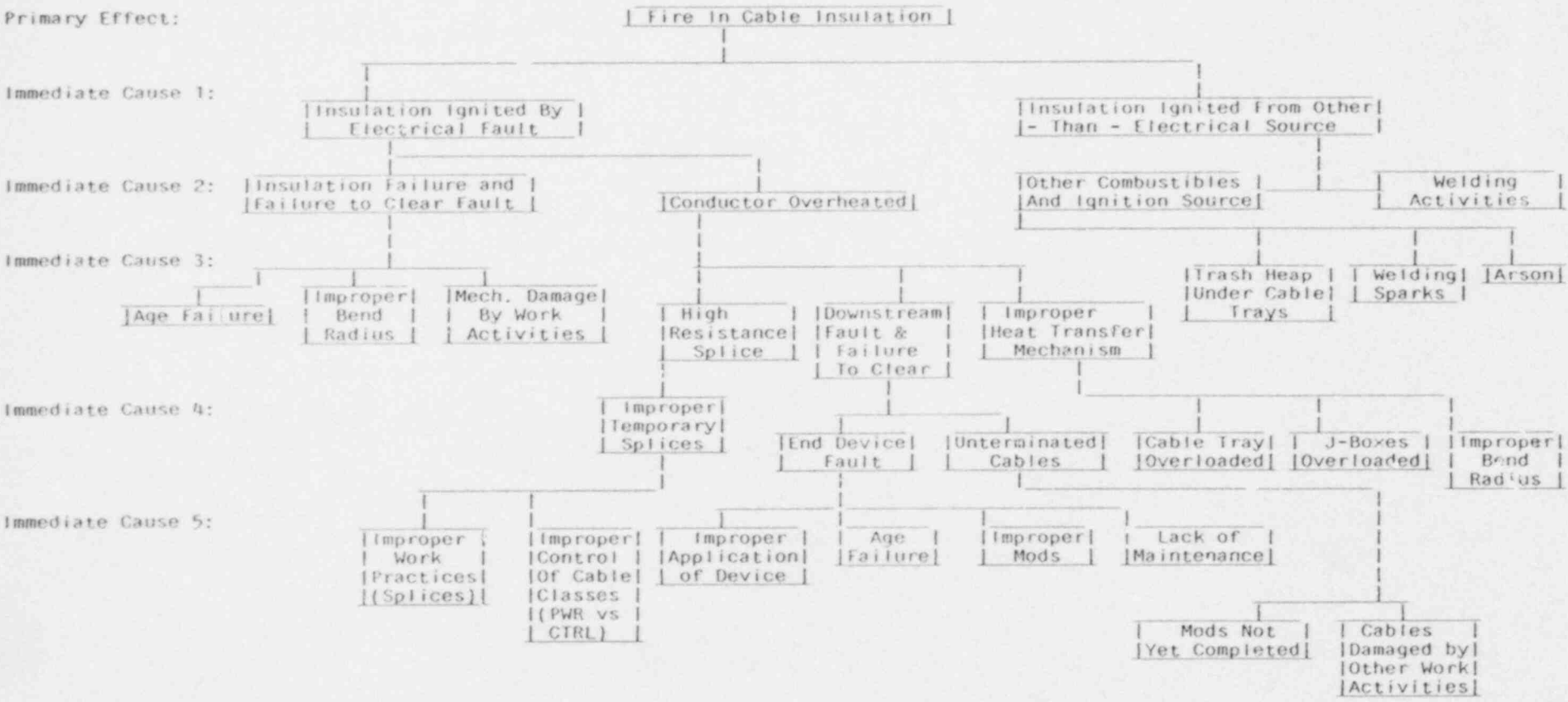


EXHIBIT 2: CHANGE ANALYSIS WORKSHEET

CHANGE ANALYSIS WORKSHEET

(For Closing Breaker on Unfinished Work Scenario)

		Identifying Aspects	Exclusion or Omission	Distinctive Characteristics	Change
WHO	Maintnance	Splices	No Post Maintenance Test	Temporary Power Patch	No Post Maintenance Test (PMT)
	Operations	Unaware of Temporary Splices	Clearance Released	Being Driven By Restart Test Sched.	Perfunctory Check or PMT Completion
WHAT	People	None	Bypassed Admin. Controls	Lax Attitude Due To Temporary Nature	Released Clearance
	Equipment	Penetration Splices Drywell Blowers and Dampers	DNE Involvement in Modification	Temporary Hook-Ups	Restored Power
WHERE	In Drywell	Many Cables	Routing and/or Splice	Protected From Welding Activities	Welding in Area
	Outside Drywell	Panel 9-9 BKR 314	None	Tripped Free, Hard To Open	Breakers Closed
WHEN	In Process	Permanent Mods Not Completed	Wires Rolled	1 Week Prior to Event	Wires Possible Rolled 1 Week Before Closed Breaker Soon After Shift Turnover
	In Time	Morning Shift Change	Hasty Check of Work Status	Unitized Maintenance Crews	
HOW MUCH	Coordination	Activities Occurred Over Many Shifts	Lost Track of Micro Status	Temporary Splices Not Shown On Drawings	No Temp. Alteration Control Form (TACF)
	Direct Knowledge	Word of Mouth	No Physical Inspection of Job Site	Job Site in Drywell	Job Site not Inspected
PER-NONAL FAC-TORS	Miscommunication	Telephone OK to Release Clearance	Check of Job Status	Schedule Was Artificial	OPS Artifically Pressured For Maintenance Job
	Scheduling Pressures	Pressure on Operations	Responsibility was Maintenance		
JOB FAC-TORS	Task Responsibility	Maintenance	No Engineering Input	Maintenance Was Actually Modification	Doing Modification on Maintenance Request
	Task Coordination	Operations	No Engineering Input	Driven By Restart Schedule	Restart Test Should Have Coordinated
WHY		TO BE DETERMINED AS	INVESTIGATION	CONTINUES	

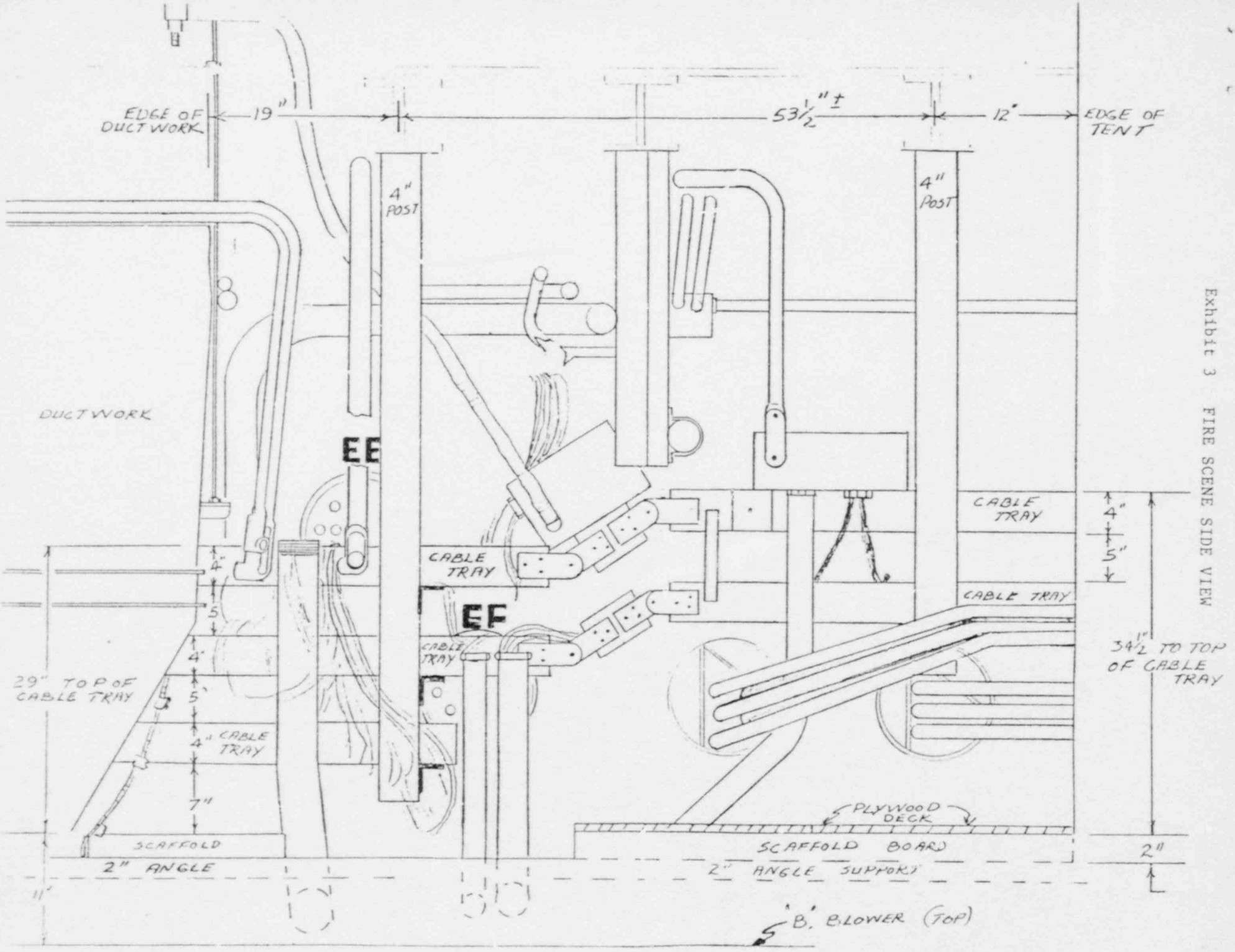
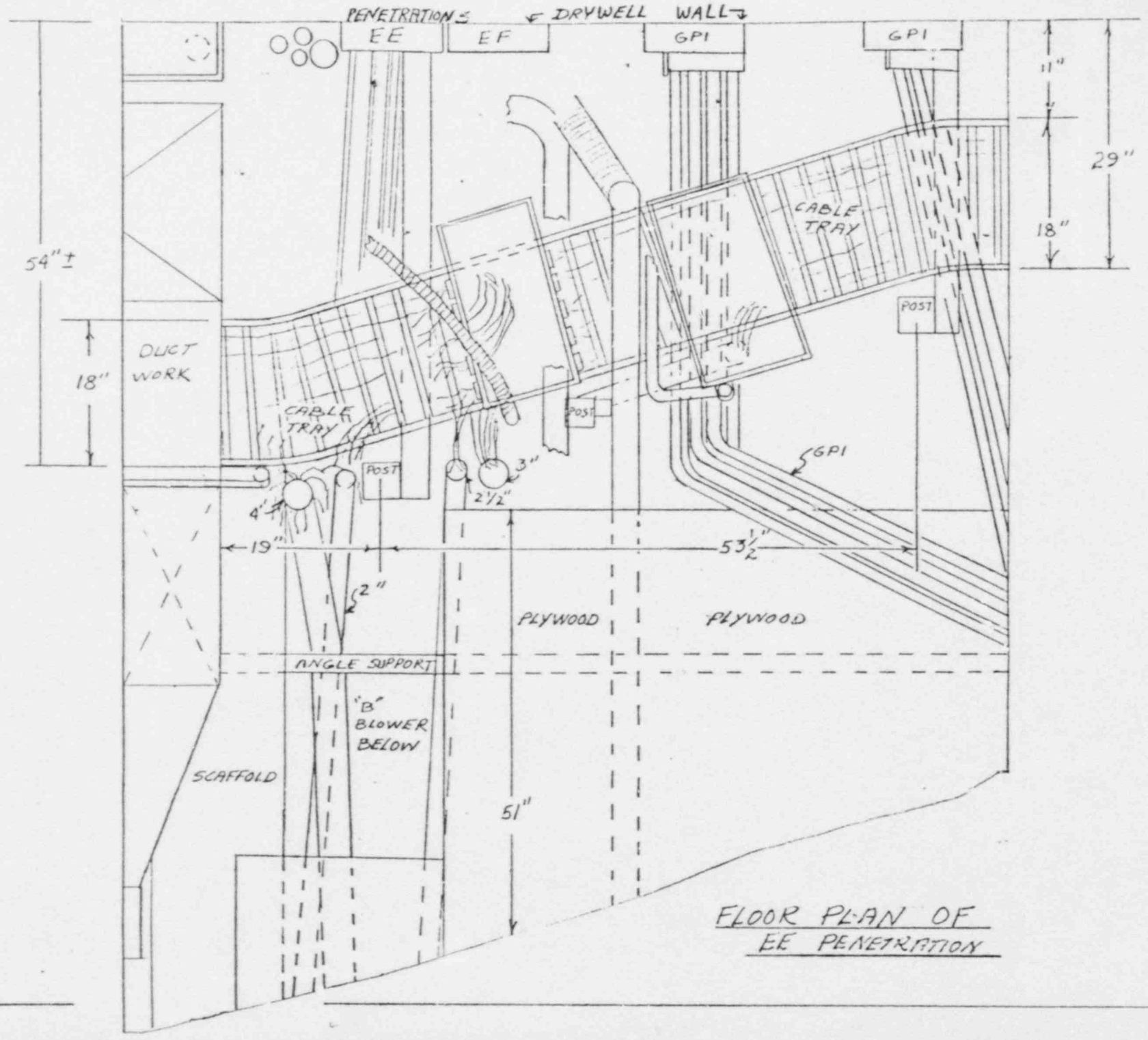


Exhibit 3 FIRE SCENE SIDE VIEW

EXHIBIT 4 FIRE SCENE TOP VIEW



FLOOR PLAN OF EE PENETRATION