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Powerhouse Fire Detection/Protection Case Study of Corps Powerhouse Fires and Their Impact to Hydropower

Presented by
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to the
The Southwestern Regional Hydropower Conference
June 11, 2008, Ft. Worth, TX

AIRLINE MECHANIC SOLUTIONS:

- P: Left inside main tire almost needs replacement.
- S: Almost replaced left inside main tire.

- P: Something loose in cockpit
- S: Something tightened in cockpit

- P: Dead bugs on windshield.
- S: Live bugs on back-order.

AIRLINE MECHANIC SOLUTIONS:

- P: Evidence of leak on right main landing gear.
- S: Evidence removed.

- P: Friction locks cause throttle levers to stick.
- S: That's what friction locks are for.

- P: Number 3 engine missing.
- S: Engine found on right wing after brief search

AIRLINE MECHANIC SOLUTIONS:

- P: Aircraft handles funny.
- S: Aircraft warned to: straighten up, fly right, and be serious.

- P: Radar hums.
- S: Reprogrammed target radar with lyrics.

- P: Noise coming from under instrument panel. Sounds like a midget pounding on something with a hammer.
- S: Took hammer away from midget

HDC, the Corps' Hydropower Design Center, Portland, Oregon

OVERVIEW

- Summary of Significant Corps of Engineers (CoE) and North American Power Plant Fires
- Summary of Fire Impacts to Hydropower
- Corps of Engineers and Industry Hydropower Fire Design Standards
- Standard Practice: Fire System Recommendations
- A Case History and Illustrative Example from the Detroit Fire

POWER PLANT FIRES

"Recent" Corps Experience

- Detroit Lake
- Garrison
- John Day
- Bonneville
- Chief Joseph

TVA Experience

- Watts Bar

Significant North American Hydro Power Plant Fires – Maybe Not As Rare As You Might Think

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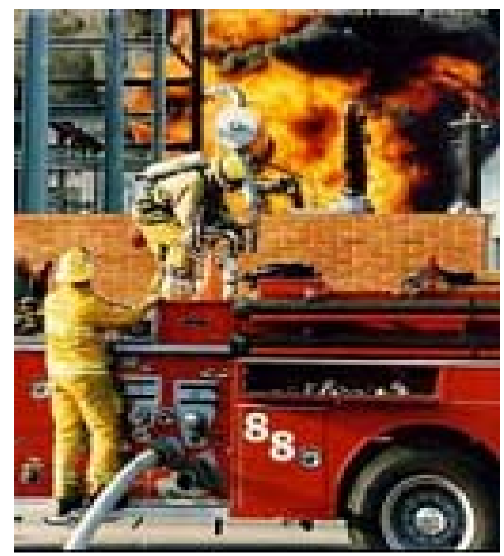
- **Bonneville (CoE) Non-segregated Bus 1978**
- **John Day (CoE) Switchgear 1990**
- **Grand Coulee (BoR) Generator Third PH 1977**
- **Grand Coulee (BoR) Station Service Switchgear 2000**
- **Grand Coulee Third PH 500kv Oil-filled Power Cable Fire 1981**
- **Pilot Butte (BoR) 1966 Generator**
- **John Hart (BCH) 1981 Generator**
- **Chandler (BoR) 1981 Generator**
- **Flatiron (BoR) 1995 Generator**
- **West Point (CoE) Generator - 2003**
- **GM Shrum (BCH) Generator - 2005**
- **Detroit (CoE) Switchgear - 2007**
- **Watts Bar (TVA) Cable - 2002**
- **Garrison (CoE) Switchyard Xfrm 2001**
- **Whitehorse Falls (YEC) 1997**
- **Ear Falls (OPG) Computer Room RTU 1997**
- **Chats Falls (OPG) Oil Filled Disconnect Inside Powerhouse – 1953**
- **Revelstoke (BCH) Control Room Panel And Cable Fire – 1993**
- **Chief Joseph Dam (CoE) 500 kV GSU T1 - 1991**
- **Webers Falls MUB and Generator – 1977**
- **Bull Shoals Oil Filled Feeder Cable - 2006**



Increasing Frequency of Hydro Power Plant Fires

- The number of fires appears to be increasing. Higher frequencies may be due to:
  - Run-to-failure strategies or practice
  - Aging equipment
  - More frequent load cycling
  - Equipment pushed to or past operating limits
  - Reduction in operating, testing and maintenance budgets

Fire Impacts to Hydropower: Personnel Safety

Fire Impacts to Hydropower: Cost of Equipment Replacement

Fire Impacts to Hydropower: Lost Revenue

Fire Impacts to Hydropower: Cost of Environmental Cleanup

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Fire Impacts to Hydropower: Cost of Temporary Equipment

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Fire Impacts to Hydropower: Cost of Lots of Extra People

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Fire Impacts to Hydropower: Water Temperatures & Dissolved Gas Levels

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Fire Impacts to Hydropower: Reputation as Good Stewards

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Salem-News.com - June 2, 2008 - 5:34 pm

Jun-19-2007 15:54

Fire at Detroit Dam Powerhouse Halts Electricity Generation

Salem-News.com

Extent of damage unknown but no risks posed to people or environment.

(SALEM, Ore.) - An electrical fire in the Detroit Dam powerhouse on the North Santiam River last night caused the shutdown of power generation equipment at the facility.

The incident poses no health risk to residents in the area or environmental risks to the lake or the river, announced the U.S. Army Corps of Engineers.

Shortly after midnight, a fire broke out on the lower level of the Detroit Powerhouse.

Staff was evacuated and emergency procedures put in place to extinguish the fire and secure the facility.

The outage does not affect the Corps' ability to produce and distribute power from any of its other Willamette Valley facilities.

"Our primary objective today is to keep people safe, get the smoke cleared, check air quality and put auxiliary power in place for pumps to keep the powerhouse from flooding," stated Dwane Watsek, chief of operations for the Corps' Portland District.

Following clearance from local emergency authorities and using air-purifying respirators, a Corps team will mobilize today to assess the damage to the powerhouse, investigate the cause of the fire and develop a detailed recovery plan.

The Corps halted power generation indefinitely and water typically released through the powerhouse is now being released over the spillway to maintain river flow and provide for fish listed as threatened or endangered under the federal Endangered Species Act.

Detroit Dam is one of 13 multi-purpose dams operated by the Corps of Engineers in the Willamette Valley.

The dam stores water from the North Santiam River, providing flood damage reduction, irrigation, power generation, recreation, navigation, and downstream water quality improvement.

The powerhouse contains two generator units with the capacity to produce a total of 100,000 kilowatts.

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Impacts to Hydropower: Increased Safety Risks from Temporary Repairs

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Impacts to Hydropower: Additional Safety Risks from Temporary Processes

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Approaches to Fire Protection: Fire Risk Philosophies

- Regulatory compliance
  - Do it because we have to
- Accept the risk
  - Ignore the risk – it will never happen
  - Accept the risk – we will accept the losses
- Mitigate the risk
  - personnel safety
  - Fire prevention: reduce the hazard
  - Fire mitigation:
    - early notification
    - control/suppress fires

COE & INDUSTRY DESIGN STANDARDS

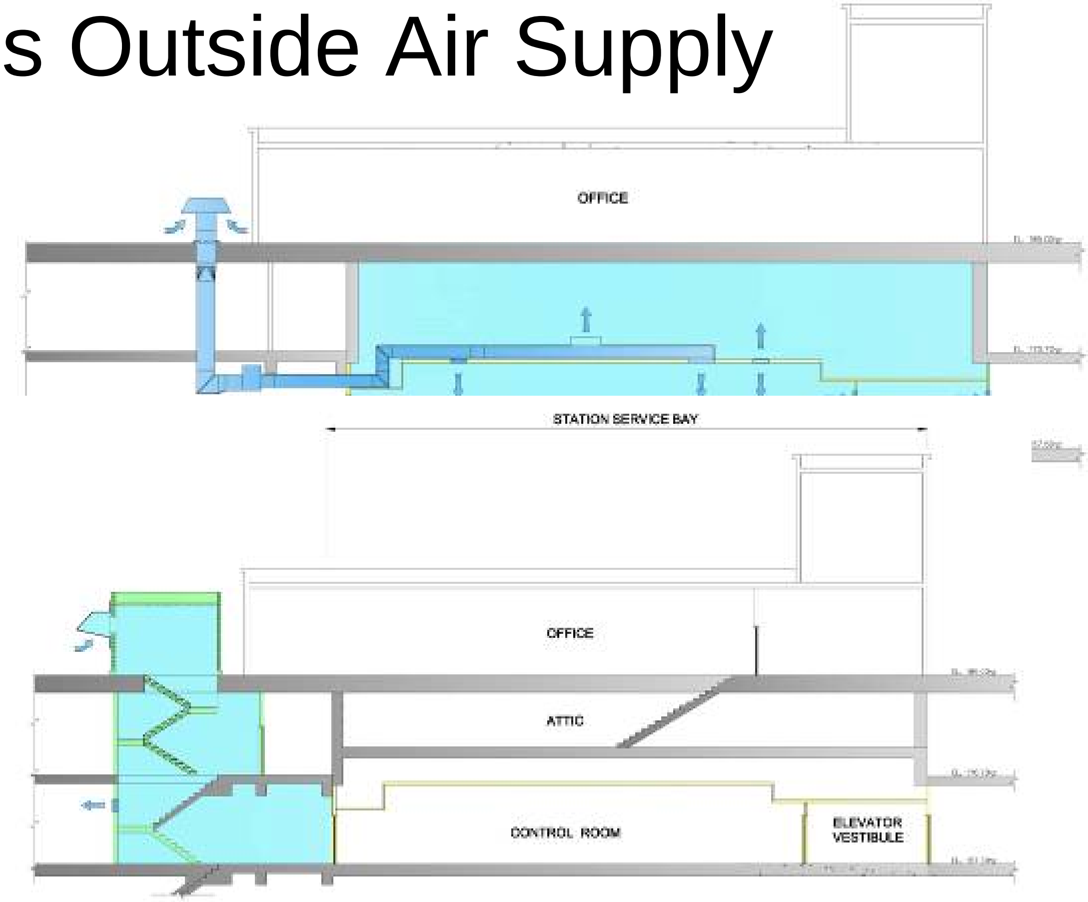
- **NFPA 851** - Recommended Practice for Fire Protection for Hydroelectric Generating Plants
- **NFPA 12** - Standard on Carbon Dioxide Extinguishing Systems
- **NFPA 750 -** Standard on Water Mist Fire Protection Systems
- **NFPA 92A** - Standard for Smoke-Control Systems Utilizing Barriers and Pressure Differences
- **IEEE 979** – Guidelines For Substation Fire Protection

COE & INDUSTRY DESIGN STANDARDS

- **Corps EM 1110-2-4205** - Hydroelectric Power Plants Mechanical Design
- **Corps ETL 110-2-245 –** Fire Protection in Hydroelectric Power Plants
- **BuRec Fist Vol 5-2** - Firefighting and Fire Preventions
- **BuRec Fist Vol 5-12** - CO2 System Operation and Maintenance

HDC FIRE SYSTEM RECOMMENDATIONS

Personnel Safety: Control Room & Egress Outside Air Supply



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HDC FIRE SYSTEM RECOMMENDATIONS

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Suppression Systems for:

- Generators
- Transformers
- Flammable liquid storage areas
- Survey may identify other hazards

HDC FIRE SYSTEM RECOMMENDATIONS

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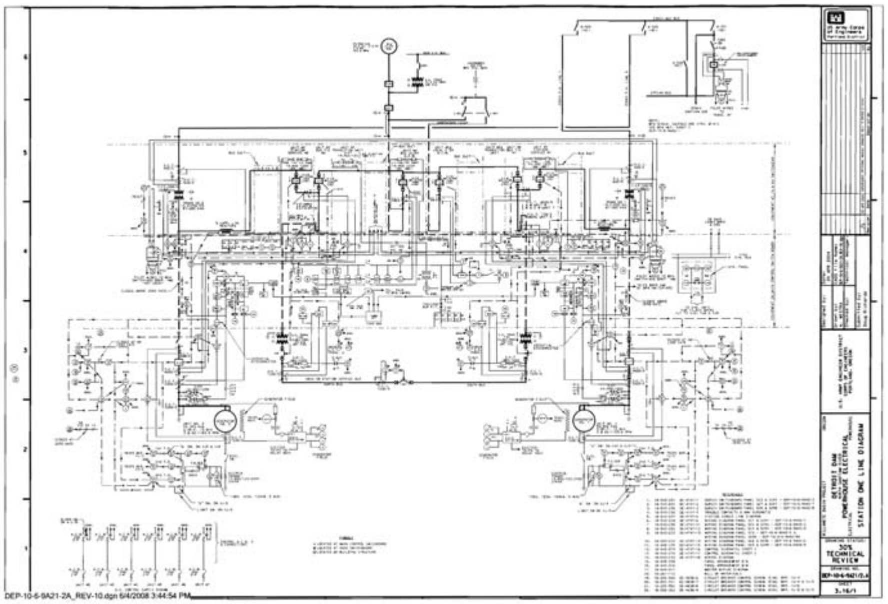

- Fire Prevention: Electrical Protective System Certification
  - Verifying the drawings
  - Revisiting the design
  - Coordinating relay settings
  - Testing relay settings and systems

HDC FIRE SYSTEM RECOMMENDATIONS

- Fire Prevention:
  - Revisit clearance procedures
  - Increased staff training before major modernization projects

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HDC FIRE SYSTEM RECOMMENDATIONS

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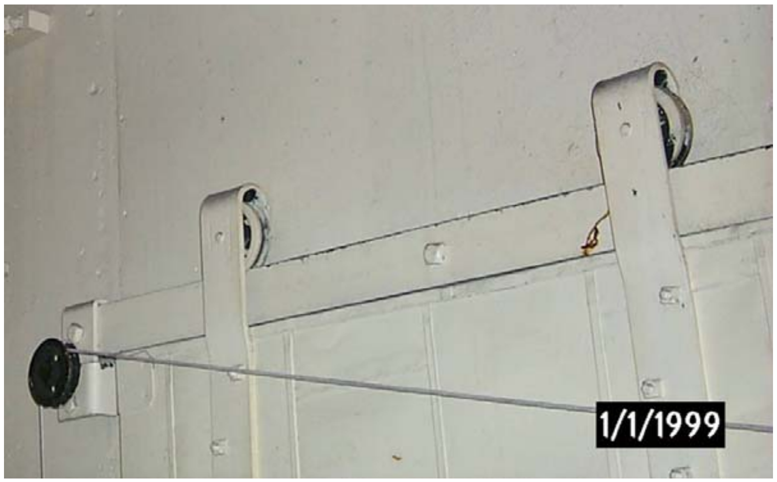
- Fire Detection
  - Manned vs. unmanned plants
  - Importance of designing detection systems to insure future support

HDC FIRE SYSTEM RECOMMENDATIONS



Fire Mitigation:

- Smoke exhaust system
- Compartmentalize
  - Doors and dampers
  - Automatic and manual

HDC Fire System Recommendations: Begin With a Fire Survey

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- Every plant is different. There is no one-sized solution. Survey each plant to identify:
  - Life safety issues
  - Specific hazards
  - Effect of loss of power on reservoir operation
  - Estimated probability of a fire occurring
  - Status of protective system drawing and periodic review/testing
  - Status of operator training

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A Challenge: Don't Procrastinate

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- It is easy to do because even though they can be very costly, hydropower fires are low frequency events.
- If you have not done so, start with a fire survey
- Decide on an acceptable level of risk
  - Personnel safety
  - Financial
    - Clean up
    - Equipment
    - Loss of revenue
- Build a prioritized steps-of-action plan
- You can't do it all at once - start somewhere

Detroit Dam

Electrical Failure and Fire

Some Illustrative Lessons Learned
– Southwestern Regional Hydropower Conference
Ft. Worth, TX
June 11, 2008

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Portland District

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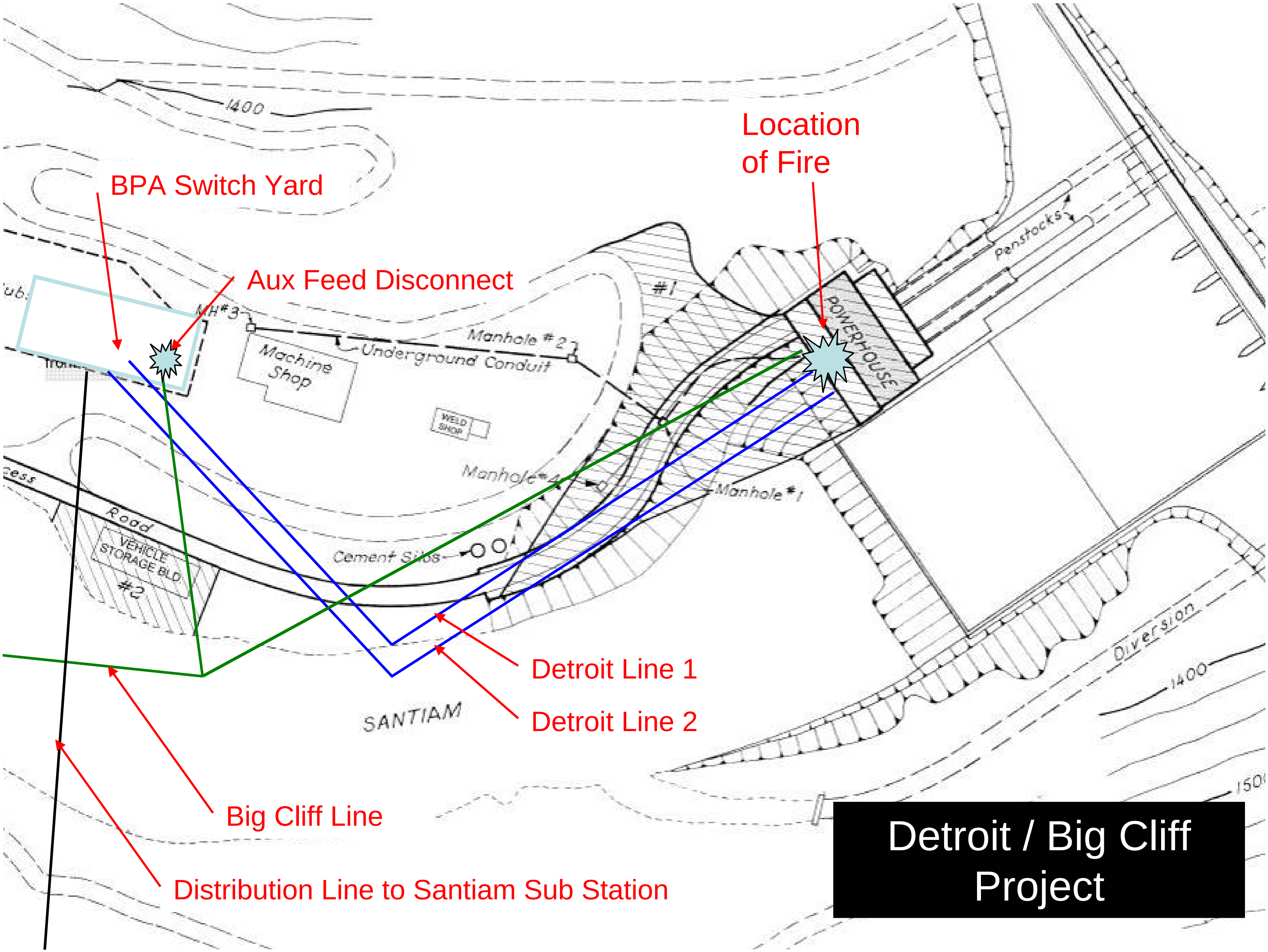
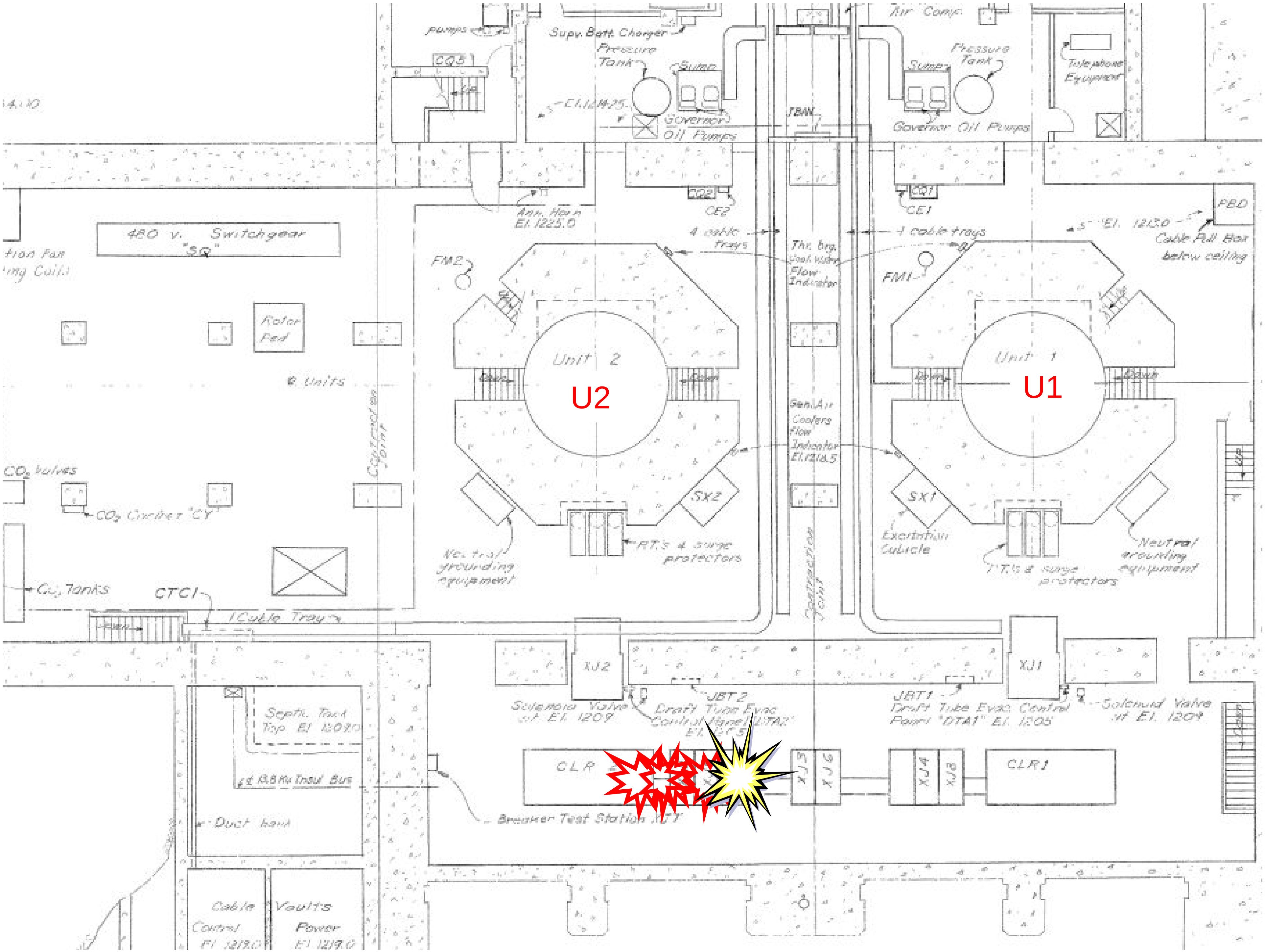
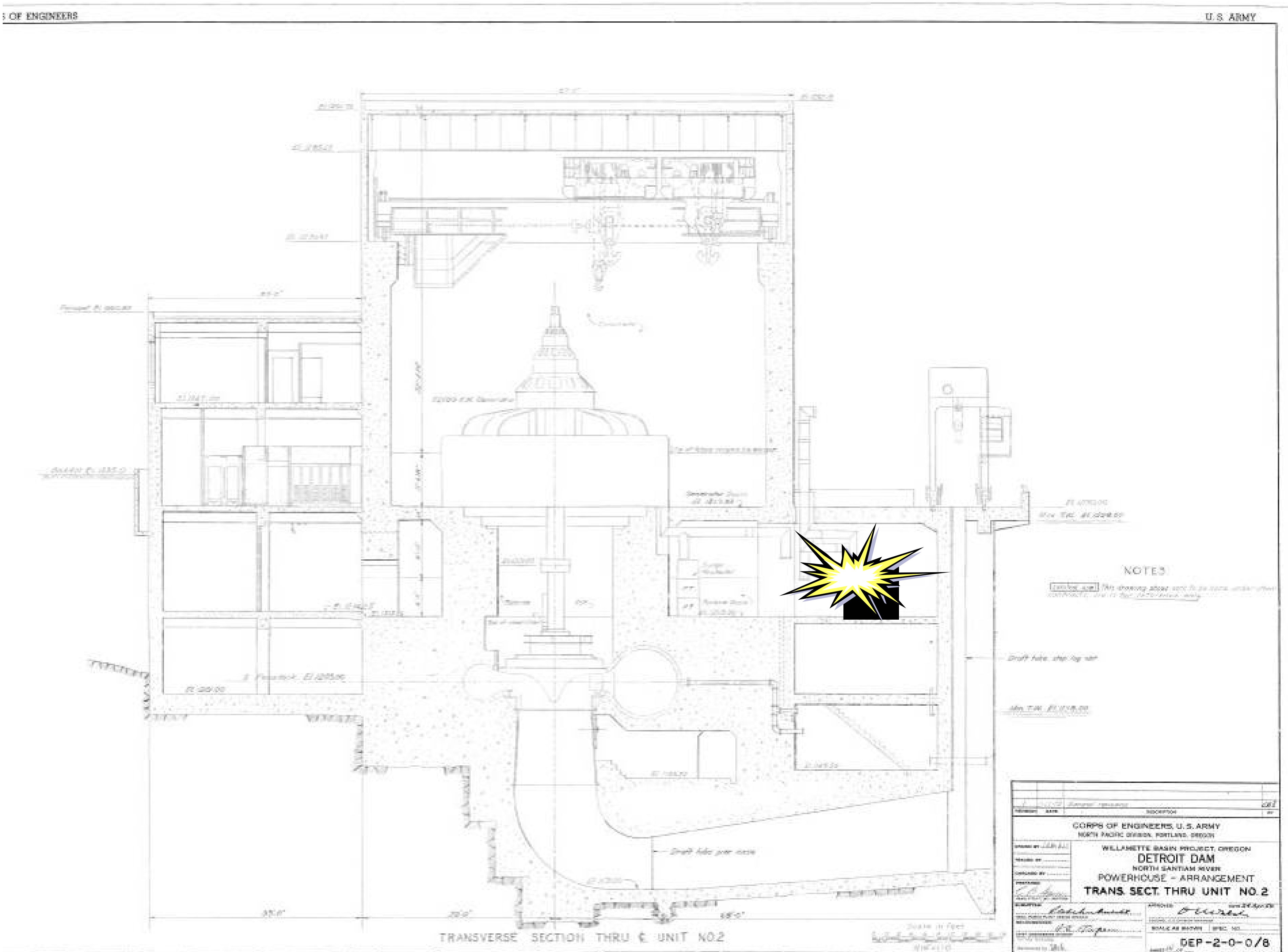
Detroit Dam



Location of Fire
BPA Switch Yard
Aux Feed Disconnect
Machine Shop
Underground Conduit
Manhole #2
MH#3
WELD SHOP
Manhole #4
Manhole #1
POWERHOUSE
Penstocks
#1
Cement Silos
VEHICLE STORAGE BLD
#2
Road
1400
SANTIAM
Diversion
Detroit Line 1
Detroit Line 2
Big Cliff Line
Distribution Line to Santiam Sub Station
Detroit / Big Cliff Project



U2
U1
Unit 2
Unit 1
480 v. Switchgear "SQ"
Rotor Pad
CO2 Valves
CO2 Cardox "CY"
CO2 Tanks
CTC1
1 Cable Tray
Supv. Batt. Charger
Pressure Tank
Sump
Governor Oil Pumps
Air Comp.
Telephone Equipment
Ann. Horn El. 1225.0
4 cable trays
Thr. brg. cool. water Flow Indicator
FM2
FM1
CE2
CE1
CQ2
CQ1
FBD
El. 1213.0
Cable Pull Box below ceiling
Gen. Air Coolers Flow Indicator El. 1218.5
SX2
SX1
Neutral grounding equipment
P.T.'s & surge protectors
Excitation Cubicle
Contraction Joint
XJ2
XJ1
JBT2
JBT1
Solenoid Valve at El. 1209
Draft Tube Evac. Control Panel "DTA2" El. 1205
Draft Tube Evac. Control Panel "DTA1" El. 1205
CLR 2
CLR 1
XJ3
XJ6
XJ4
XJ8
Breaker Test Station "XFT"
Septic Tank Top El. 1202.0
13.8 Kv Insul. Bus
Duct bank
Cable Vaults
Control El. 1219.0
Power El. 1219.0



RASTER# DEP-2-0-0-08_REV-1.tif

Detroit Fire: Context

- Project was undergoing a phased but piece-meal multi-year modernization program:
  - Bridge crane
  - Main Unit Breaker replacement completed in 2004
  - Rewinding Detroit generators
    - Unit 1 was almost complete – but was still out of service
  - SCADA control upgrades
  - 13.8 kV station service breaker replacement project just completed
  - Station service distribution transformer and 480 volt switchgear replacement planned but not yet started

Detroit Fire Immediate Cause Under-rated Surge Arresters 2004

- A contract modification added arresters to temporarily protect several old transformers that would not be replaced until the next phase.
- 12.7kV MCOV proposed and approved.
- 10.2kV MCOV installed (10 sec @13.8kV).

Detroit Fire Causal Analysis
18 June Event Sequence

- Ground fault comes in hard.
- Big Cliff unit trips as designed.
- XJ2, XJ3, XJ5 trip as designed.
- Lights go out.
- Operator gets help.
- Lighting restored.

Detroit Fire Causal Analysis - Start of Fire

- Operator re-closed the circuit breaker energizing the firmly faulted bus.
- 13.8kV ground fault still there.
- Surge Arresters see high voltage.
- Surge Arresters burn.
- Reactor limits fault current
- No relay action since operator did not restart the tripped generator

Detroit Fire Causal Analysis
Relay Power Tagged Out, May 07

- Fire burns into XJ5 activating other protective devices – but:
  - A clearance had been taken for the purpose of performing some work on T1 before U1 was returned to service
  - This unknowingly disabled the secondary protective system trip
  - No line lock out relay function.

Detroit Fire Causal Analysis
Original Design – 1950's

- Unrealized plans for second yard breaker.
- Yard breaker only tripped by T1 pilot wires or 86L1
- T2 pilot wires do nothing.
- 86L2 must trip 86L1 to trip yard Breaker
- Compromise at the time based on best practices, costs, assumptions.

Detroit Fire Causal Analysis
Fire Propagation

- XJ5 Burns
- Still No Relay Action

Detroit Fire Causal Analysis
Fire Propagation

- XJ9 Burns
- Still No Relay Action

Detroit Fire Causal Analysis
Energy Source Removed

- Bus burns to current limiting reactor.
- Current increases
- BPA over-current relay trips.

Failure Events: Summary

- BPA ground fault
- New under-rated surge arresters burn
- 2 circuit breakers burn
- BCL bus melted
- Fault bypasses reactor
- Substation breaker clears the fault
- Soot and smoke everywhere

Damage Assessment

- XJ5, XJ9 circuit breakers
- Surge arresters & capacitors
- Metering PTs, CTs
- Switchgear enclosures
- Portions of the isolated phase bus work
- Soot everywhere (environmental clean up $2+M)
- Current estimate - $6.5m


764
99% ISOPROPYL
ALCOHOL


TURBINE BEARING
OIL PRESSURE
DEGREES CENTIGRADE
EMERGENCY
HEAD GATE CONTROL
OFF
LOWER
LOWER
SCROLL CASE

Electrical System Lessons Learned

- The critical need to keep electrical drawings up to date
- The critical need to carefully evaluate every modification phase in the full context of the protection system operation
- The very high value of prevention from periodically revisiting electrical protection schemes for each project
- The need to revisit clearance procedures to insure they actually do not do more than expected

Other Lessons Learned

- The need to provide more comprehensive operating staff training, especially during time of modernization
- The higher risk of multi-year phased piece-meal modifications to operating electrical distribution systems.
- The lower risk of a holistic system replacement strategy

Things We Are Doing Different

- Redesigning the protective relay systems to automatically isolate problems
  - Reducing the steps an operator needs to take to safely troubleshoot a station service power problem
  - Decreasing the amount of special knowledge needed to operate safely
- Adding new levels of protection that were not cost effective in the past
  - New multipurpose digital devices allow levels of protection not affordable in the past

Things We Are Doing Different

- Carefully coordinating our protective relay settings with our power marketer’s substation relays
- Implementing a system wide program to revisit protective systems at each project
- Implementing a comprehensive program to update critical project drawings

Things We Are Doing Different

- Improving station service control panel switch labeling
- Improving the event recording part of our SCADA

QUESTIONS/DISCUSSION