Fire Protection SDP – Application Training for New Analysis Procedure

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Outline

Day 1:

- Module 1: Overview of the changes
- Module 2: Concepts and terminology
- Module 3: Overview of the new process
  - A quick once through Phases 1 and 2

Day 2:

- Module 4: Details of Phase 1
- Module 5: Details of Phase 2

Day 3:

- Module 6: Tabletops
- Discussion and Closing
  - We can go back and cover anything you want to cover in more detail

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Module 1: Overview of Changes

- Objective: Outline what hasn't changed, and what has
  - This section provides a very brief and high level comparison of the original and new processes
  - You'll see lots of changes at a detailed level

What hasn't changed

- Entry Conditions (what is a finding?)
- Risk significance (color assignment) criteria
- Duration factor plays the same role
- Focus on credible scenarios
  - You still are asked to develop one or more credible fire scenarios
- Most of the original guidance on degradations is retained
  - Enhanced guidance provided in several areas
- Use of the plant notebooks for post-fire safe shutdown
- Your use of judgment is still critical!

What has changed

- Process is tied more directly to fire PRA
  - Simplified versions of common PRA methods
  - "The equation" is the PRA equation – that just means we multiply factors directly instead of adding their exponents
  - Scenarios are tied to a timeline
    - Timing of critical events drives Phase 2 in particular
    - Time to damage versus time to suppression
- More steps, but each step is more focused
  - Each step is aimed at a specific bit of information needed to quantify risk change

What has changed (cont.)

- More aggressive efforts to identify green findings as soon as information is sufficient to justify
  - Low degradation findings are automatically green
  - "Screen to green" checks included in most steps
- Much more supporting guidance
  - That's why the "book" is so thick!
  - Most inputs come from look up tables
- The NRR Fire Dynamics Tools (FDT) are used to support fire damage timing analysis
  - Excel spreadsheets for features like plume and hot gas layer

What the changes should mean

- More quickly identify green findings
- If a finding is potentially greater than green, the Phase 2 analysis will be:
  - More systematic
  - More repeatable
  - More accurate
  - More defensible
- Reduce analysis burden at all levels (Phase 1, 2, 3)

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A word about complexity

- The new process looks complex – I hope to convince you it's really pretty straight-forward
- The original approach faced all the same analytical challenges, but with less structure and guidance
- The systematic structure and supporting guidance should improve efficiency and effectiveness
- You may not be fully convinced this week, but I hope you will come to see this as you become more expert in the process

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Module 2: Concepts and Terminology

Concepts and Terminology

- Objectives:
  - Outline the basic quantification process used in fire risk analysis
  - Define the factors that go into quantification
  - Define key terms
  - Along the way, I'll point out some "red flag" issues

Why?

- Why spend time here? Why not jump right into the SDP process?
  - The new SDP structure is the same as that used in a general fire PRA
    - If you understand this basis, life will be much easier
  - Lots of unique terminology
    - Meanings need to be clear
  - Allows us to look at the technical quantification process separate from the SDP regulatory decision making process

Risk

- Risk combines the likelihood that something undesirable will happen with the severity of resulting consequences
- In the context of the NRC's mission, risk is most correctly measured in the context of public health consequence
- Primary measure of fire risk is Core Damage Frequency (CDF)
  - CDF is a surrogate for public health consequence risk
  - We won't do fire-induced LERF for SDP

How we estimate CDF

- We calculate CDF using four basic factors:
  - Fire Frequency (F)
  - Severity Factor (SF)
  - Probability of Non-Suppression (PNS)
  - Conditional Core Damage Probability (CCDP)

How we estimate fire risk (cont.)

- For one fire scenario:

  $CDF_i = F_i * SF_i * PNS_i * CCDP_i$
- We do as many fire scenarios as we need to, add them up (carefully), and that is our risk estimate
- We can roll-up risk values at different levels:
  - One fire scenario
  - One fire ignition source – multiple scenarios
  - One fire area – multiple ignition sources
  - One building – multiple fire areas
  - Entire unit
  - Entire plant site

How we estimate fire risk (cont.)

- SDP focuses on fire area roll-up
  - Question: what is the risk impact of a specific performance deficiency?
  - Deficiency is assumed to be tied to one or two fire areas
  - We estimate risk for the impacted area(s)
- Some issues cut across fire areas – examples:
  - Post-fire manual actions
  - Manual fire brigade
  - Circuit analysis issues

Cross-cutting issues are NOT within our scope

Fire Frequency (F):

- Definition: The likelihood that a fire will occur during some time period
  - Time period is generally 12 months of at-power reactor operations
    - one reactor year (ry)
- Calculated based on past experience
  - A bunch of statistics that we won't go into
  - Database we use contains nearly 1500 reported "fires"
- General units of measure:
  - fires / ry

Pop quiz – Who is this?

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Fire Frequency (cont.)

- You often hear that not all events reported as a fire hold the potential to challenge nuclear safety – TRUE!
  - We took care of this for you
  - Events were "screened out" if there was no potential for a safety challenge
  - The values provided for SDP should not be adjusted beyond the instructions provided – leave that to Phase 3

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Event screening

- Sounds easy, but you can really cause problems if you're not careful
- Important to maintain independence
  - Other steps in analysis take credit for things you might be "counting" when you screen the events
  - Basic assumptions tend to flow from the "event set" you choose as representing your fire frequency
- Be skeptical when someone argues that particular events are not relevant to fire risk
  - They may be right, but their basis for rejecting an event cannot align with another factor credited elsewhere

Fire Frequency (cont.)

- What statistics give us is the frequency for a fire somewhere, or involving something, in the plant
  - May be a for a location or fire ignition source
  - We assume this number is the same for all plants
- What we want is the frequency for a fire involving a specific ignition source in a specific location
  - For most cases, component based fire frequencies do this directly
  - In some cases we apply a partitioning factor to reflect a critical location out of all possible locations
    - Area ratio factors – e.g., transients, welding
    - Linear feet ratio factors – e.g., cable trays, control room panels

If we need a room fire frequency

- We can use a generic room value based on average industry experience
  - SDP through step 2.3

OR

- We can add up the contribution from all the individual sources in that particular room
  - SDP beginning with Step 2.4
- Don't expect to get the same answer either way
  - For SDP, the generic values are intended to be slightly conservative
  - This won't be a universal truth, but differences should not be significant

Grouping fire ignition sources

- Sometimes you can group individual ignitions sources, and treat the group rather than each individual
  - Common example is electrical cabinets/panels
- Frequency for the group is the sum of the frequency of each individual member
  - If 10 panels, fire frequency = 10 times frequency for a single panel
- More on grouping later

Severity Factor (SF)

- General Definition: A value between 0 and 1 reflecting the fraction of all fires that are considered threatening in the context of a specific fire scenario

Severity Factors (cont.)

- SDP approach ties SF to fire intensity
  - Current PRA practice, but not same as typical IPEEE
- Why:
  - Burn an electrical panel 10 times, and you'll probably get 11 different burn profiles
  - That reflects fact that fire intensity profile is inherently uncertain
    - All things being equal, still some fires will remain small, some will get big
  - If it takes a big fire to cause problems (and it usually does) we reflect this through the severity factor

Severity Factors (cont.)

- SDP Definition: SF = the fraction of fires big enough to cause damage to at least one potential target and/or spread fire to secondary combustibles
  - We calculate "big enough" on a case-specific basis
    - How big is the fire
    - How close are the targets
  - We use two fire intensities for each fire ignition source
    - Lower value represents 90% of all fires
    - Larger value represents worst 10% of fires
  - If only the larger value leads to spread/damage, we say SF=0.1

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Severity Factor (cont.)

- One of the most widely and easily abused aspects of fire PRA
  - You can quote me – that's my professional view
  - Some cases of abusive application were seen in the IPEEEs, so take care when someone cites those to you
- You'll see severity factors crediting:
  - Prompt suppression, self-extinguished fires, fires that caused no trip, fires that did not spread, fires that did not damage secondary components, fires in non-vital areas, and … the kitchen sink

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Severity Factors (summary)

- Before you buy, remember the three "D"'s of PRA:
  - Dependency, dependency, dependency
  - The same factors may be accounted for elsewhere in the PRA – either implicitly or explicitly
  - When you see the use of one (or heaven forbid more than one) severity factor in quantification you have to ask if they are double counting somewhere

Probability of Non-Suppression

- Definition: PNS - The conditional probability that, *given the fire*, the fire will not be suppressed prior to the failure of a specific set of damage targets
  - Key 1: Specific to a particular fire ignition source scenario
    - May be a grouped set of fire ignition sources
  - Key 2: Specific to a particular targets set
  - PNS reflects the probability that given the fire, these targets will fail

Target Set

- A collection of components and/or cables that are assumed to be threatened give the postulated fire
  - This could be anything from one cable to everything in the fire area

Target Sets (cont.)

- The target set either survives or fails as a whole
  - If you need to break down a target set, you really need to define more than one target set
  - Different fire ignition sources may have the same target set(s) or different target set(s)

Target Sets (cont.)

- For any one fire ignition source:
  - Most often one target set is enough
  - You may define a series of expanding target sets reflecting growth and spread of the fire
  - Don't go overboard – one, two, or at most three, should handle most situations

Target Sets (cont.)

We'll come back to this a bit later, but…

- Poor cable routing data actually makes this step easier
  - If you don't know where specific cables are, you basically have to assume the worst
- Good cable routing data can actually complicate the choice
  - You may be tempted to define many target sets as each tray becomes involved – don't – keep it simple

Back to PNS…

- PNS is a 'probabilistic' horse race: time to damage versus time to suppression
- Time to damage depends on:
  - How close targets are to the fire
  - Target failure threshold
  - How big the fire is
  - Possibly: How quickly fire spreads
- The plant's chances of putting the fire out within this time depends on:
  - What sort of fixed fire suppression capability is available
  - Timing of manual fire response (e.g., the brigade)

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Time to Damage

- We can predict time to damage in three steps:
  - Set the damage threshold
    - Usually cables
    - Thermoset or thermoplastic
  - Predict the exposure conditions
    - Plume, radiant heating, or hot gas layer
    - Estimate temperature or heat flux at target location using Fire Dynamics Tool (FDT)
  - Convert exposure condition to damage time
    - SDP uses a look-up table

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Cables insulation/jacket types

- Thermoplastic
  - Melt if heated, solidify if cooled,
  - Drip and burn as a liquid pool
  - More wimpy
  - Examples:
    - Polyethylene (PE)
    - Polyvinylchloride (PVC)

Coaxial cables

- Thermoset
  - Don't melt
  - Burn/char in place if heated enough
  - More macho
  - Examples:
    - Cross-linked polyethylene (XLPE or XPE)
    - Ethylene-Propylene rubber (EPR)

Silicone
Rockbestos Firewall

Damage Thresholds

Screening Criteria for the Assessment of the Ignition and Damage Potential of Electrical Cables

Cable Type: Thermoplastic

Radiant Heating:	6 kW/m^2	0.5 BTU/ft^2 s
Temperature:	205°C	400°F

Cable type: Thermoset

Radiant heating:	11 kW/m^2	1.0 BTU/ft^2 s
Temperature:	330°C	625°F

"polyset" is actually worse than this ~585°

Damage Time (example)

Failure Time-Temperature Relationship for Thermoset Cables

Exposure Temperature °C	Exposure Temperature °F	Time to Failure (minutes)
330	625	28
350	660	13
370	700	9
390	735	7
410	770	5
430	805	4
450	840	3
470	880	2
490 (or greater)	915 (or greater)	1

Assumed to occur instantaneously for plume & radiant

No growth profile

No burnout

Hot gas layer is treated differently

Automatic suppression time

- We can predict the time to actuation for an automatic suppression system using a simple spreadsheet tool
  - e.g., a sprinkler head looks just like a heat detector
  - Fire Dynamics Tool (FDT) from NRR
- That give us a number
  - x:x minutes:seconds

PNS and auto suppression

- We don't want to do a straight yes/no comparison between damage time and suppression time – this can be very misleading
  - Damage time = 10 min
  - Suppression time = 9 min, 30 sec.
  - Nominally suppression wins, but what is your confidence in this answer – is it really yes/no or fail/no fail
  - We look at the margin between damage time and suppression time

Probability table

Probability of Non-suppression for Fixed Fire Suppression Systems Based on the Absolute Difference Between Damage Time and Suppression Time

Time Delta: (t_{Damage} - $t_{Suppress}$)	PNS_{Fixed}
Negative Time up to 1 Minute	1.0
> 1 Minute to 2 Minutes	.95
> 2 Minutes to 4 Minutes	.80
> 4 Minutes to 6 Minutes	.5
> 6 Minutes to 8 Minutes	.25
> 8 Minutes to 10 Minutes	.1
> 10 Minutes	0.0

PNS and Manual Suppression

- PNS for Manual suppression relies on historical fire duration curves
  - The vast majority of fires are manually suppressed
  - We get fire duration data for enough of the reported fires to develop a fire duration curve
- Pick the appropriate duration curve
- Calculate (t_{damage}- $t_{detection}$)
  - Remember that detection triggers manual response, but damage time measured from time of ignition (t = 0)
- Pick off PNS_{manual}
  - Values also available in a lookup table

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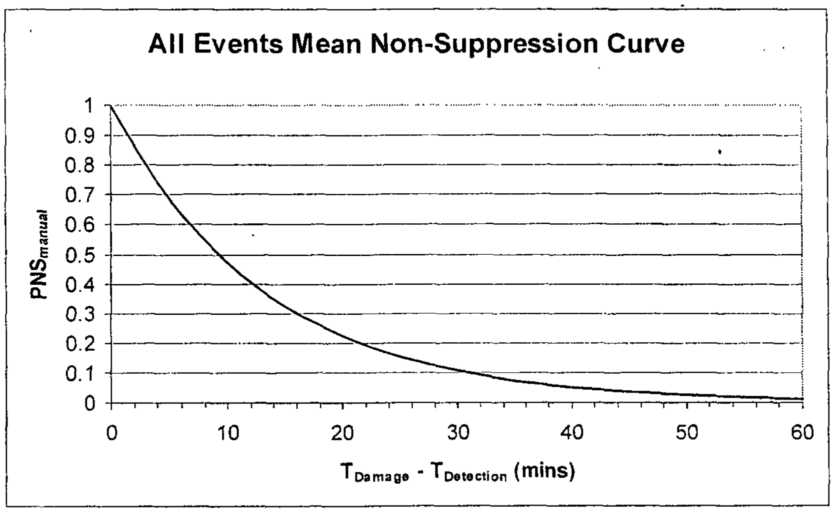
Duration curve example:



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Auto vs. Manual

- If auto is present, we assume it will be primary suppression means
- If auto fails, manual is always the backup
  - We assume that a water based automatic suppression system will fail on demand 2% of the time
  - Gaseous systems – 5% (& dry pipe water)
- If no auto system, then manual is all there is

Manual fixed systems

- Fixed fire suppression systems that have no automatic actuation mechanism – human action is required
- No hard/fast rule possible – use following:
  - Estimate detection time
  - Estimate physical response time
  - Review decision criteria and estimate decision making time
    - nominal value is 2 minutes
    - increase if circumstances warrant
  - Actuation time is sum of these three

Combining manual/auto

- Again, if auto present, it is assumed first line of defense
- Auto systems don't always work:
  - Water based system ~2% failure on demand
  - Gaseous systems ~5% failure on demand
- Manual is always available as a backup

Combining manual/auto (cont.)

For water-based systems:

$$PNS_{scenario} = (0.98 \times PNS_{fixed\text{-}scenario}) + (0.02 \times PNS_{manual\text{-}scenario})$$

For Gaseous systems: & Dry pipe water

$$PNS_{scenario} = (0.95 \times PNS_{fixed\text{-}scenario}) + (0.05 \times PNS_{manual\text{-}scenario})$$

** $PNS_{scenario} \geq PNS_{manual\text{-}scenario}$

Conditional Core Damage Probability (CCDP)

- Definition: The conditional probability that, *given fire-induced loss of a target set*, safe shutdown efforts will fail to achieve a safe and stable state thus resulting in some core damage
  - Safe and stable generally means hot shutdown
  - Risk analyses don't generally look at ability to achieve cold shutdown

CCDP (cont.)

- CCDP is calculated using a post-fire safe shutdown plant response model
  - Screening estimates may only credit the designated post-fire safe shutdown path
  - For more detail, we use a broader plant response model that may credit components and systems beyond Appendix R
  - SDP uses the plant notebooks

CCDP (cont.)

- We won't go into depth on this topic, but some high level rules:
  - To credit a system or function, you must have reasonable assurance that it will not be damaged by the fire - your judgment counts
  - We do credit manual actions – guidance is provided – but complex sets of actions will likely get little credit in Phase 2
  - Spurious operations may be a part of CCDP calculation – you may need help here

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That's pretty much it.

$$CDF_i = F_i * SF_i * PNS_i * CCDP_i$$

Of course, the devil's in the details…

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Module 2b – Fire Scenarios

More on fire scenarios

- Definition: A fire scenario is a postulated sequence of events starting with the ignition of a fire and ending either in plant safe shutdown or core damage.

Fire Scenario (cont.)

- What is a Fire Scenario:

  (Fire Scenario) = (fire ignition source scenario)

  + (fire growth and damage scenario)
  + (fire suppression scenario)
  + (plant SSD response scenario)

Change any element and you have a new fire scenario!

Fire Ignition Source Scenario

- Definition: Defines the physical characteristics of the fire that will develop in a particular fire ignition source – key factors:
  - Placement of fire "origin"
  - Heat release rate
- SDP bins fire sources by type, and ties characteristics to each type
  - Six HRR values used to characterize all fires

Fire origin

- The fire origin is a conceptual point at which we will assume the fire originates.
  - Horizontal placement determines what is overhead and therefore in the fire plume
  - Vertical placement will affect plume temperature for exposure of overhead targets
- Choice depends on the nature of the fire source
  - We'll come back to this later

Heat Release Rate (HRR)

- HRR characterizes the fire intensity or the amount of heat generated by a fire per unit time
  - Typical units are either KW or BTU/hr
- This is generally the most critical of all fire characterization input values
- Remember – SDP ties fire intensity to severity factor

Convective / Radiative Fractions

- Heat comes off in two primary forms:
  - Convective heat – The mixing of hot fire products with ambient air resulting in direct heating of the surrounding air that in turn causes buoyancy and fire plume behaviors
  - Radiative heat – the luminosity of a fire's flame zone results in direct radiant heating of opaque targets (including soot-laden air)
- Recommended split fractions are:

  0.7 convective, 0.3 radiative
  - Paired values should add to 1.0

Fire Growth and Damage Scenario

- Definition: characteristics of fire spread to secondary combustibles if such occurs, and the behaviors leading to failure of an identified thermal damage target set
  - You must define a target set – we already covered this
  - Damage may occur due to burning of the ignition source alone, or due to fire spread

SDP Fire Damage States (FDS)

- FDS0 – loss of only the fire ignition source
  - Not analyzed as a risk contributor
- FDS1 – localized damage near (especially directly above) the fire ignition source
  - Keys factors: plume heating, upward spread of fire, and direct radiant heating
- FDS2 – widespread damage within a single fire area
  - Key factors: horizontal fire spread, hot gas layer, and failure of degraded raceway fire barriers
- FDS3 – fire damage impacting two (or more) fire area (room-to-room)
  - Key factor: failure of an inter-compartment fire barrier element

Fire Detection and Suppression

- We credit all available means of fire detection and suppression
- Detection is important mainly because it triggers the manual response
  - Plant personnel become aware of the fire
  - Fire procedures may kick in (check plant process for when this really happens)
  - The fire brigade is activated
- Fixed automatic suppression systems require no prior detection signal, but usually are tied to alarm circuits

Fire Suppression (cont.)

- Remember, in PRA space, it's a horse race
  - Question is not so much "does suppression fail?"
  - But rather, "does suppression fail to put out the fire before damage occurs?"
- All fires are put out (or go out) eventually – we want to know if suppression is timely in the context of our specific target set

CCDP

- CCDP characterized plant/operator response to the fire
- Objective is safe shutdown (hot shutdown)
- This part can be complex – you will likely want to get your SRA involved to support this effort

Developing a fire time line

- Key events on the time line
  - Fire ignites (define this as time = 0)
  - Fire is detected ($t_{detection}$)
    - Manual/operator response begins
    - Fire brigade is activated
  - Target set fails (t_{damage})
  - Automatic suppression activates (t_{supp_auto})
  - Manual suppression is successful (t_{supp_man})
- Order of these events is TBD!

Module 3: Process Overview

- A quick once-through – flow chart style
- Objective: familiarize you with the process
  - Its structure
  - Steps and tasks
  - How the pieces fit together

Module 3 - Process Overview 1

Ground rules for this section

- Process questions are OK
- Please hold questions on Step/Task details
  - We'll come back and cover the details of both Phase 1 and Phase 2
  - There will be plenty of time for questions

Module 3 - Process Overview 2

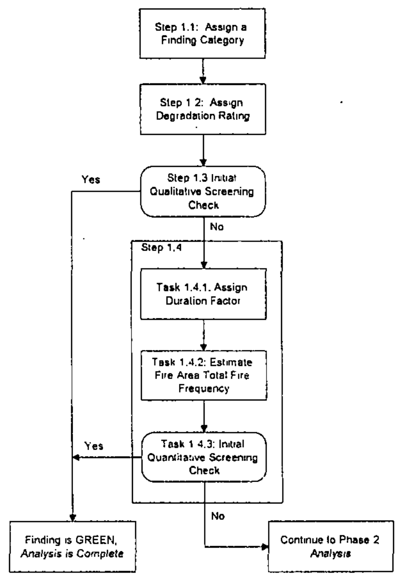
Process Overview – Scope

- We are talking about Phase 1 and 2 only
- Phase 3 is still out there, and as with today, anything goes for Phase 3 – that's not our job!

Phase 1 – Objective and Basis

- Phase 1 objective: identify findings that can be categorized as Green without detailed analysis
- Phase 1 basis: combines concepts of "qualitative screening" and very preliminary "quantitative screening" from fire PRA

Figure 4.1: Phase 1 Flow Chart



Phase 2 – Objective and Basis

- Objective: Estimate the risk change associated with a finding
- Basis: Simplified versions of current fire PRA methods – we borrow:
  - Structure
  - Assumptions
  - Numerical values
  - Analysis Tools
  - Quantification approach

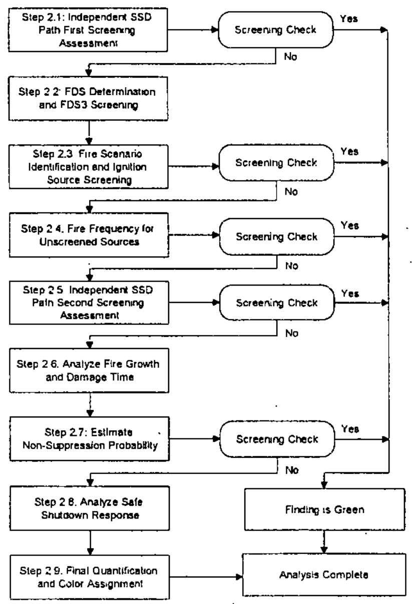


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Figure 4.2.1: Phase 1 Flow Chart

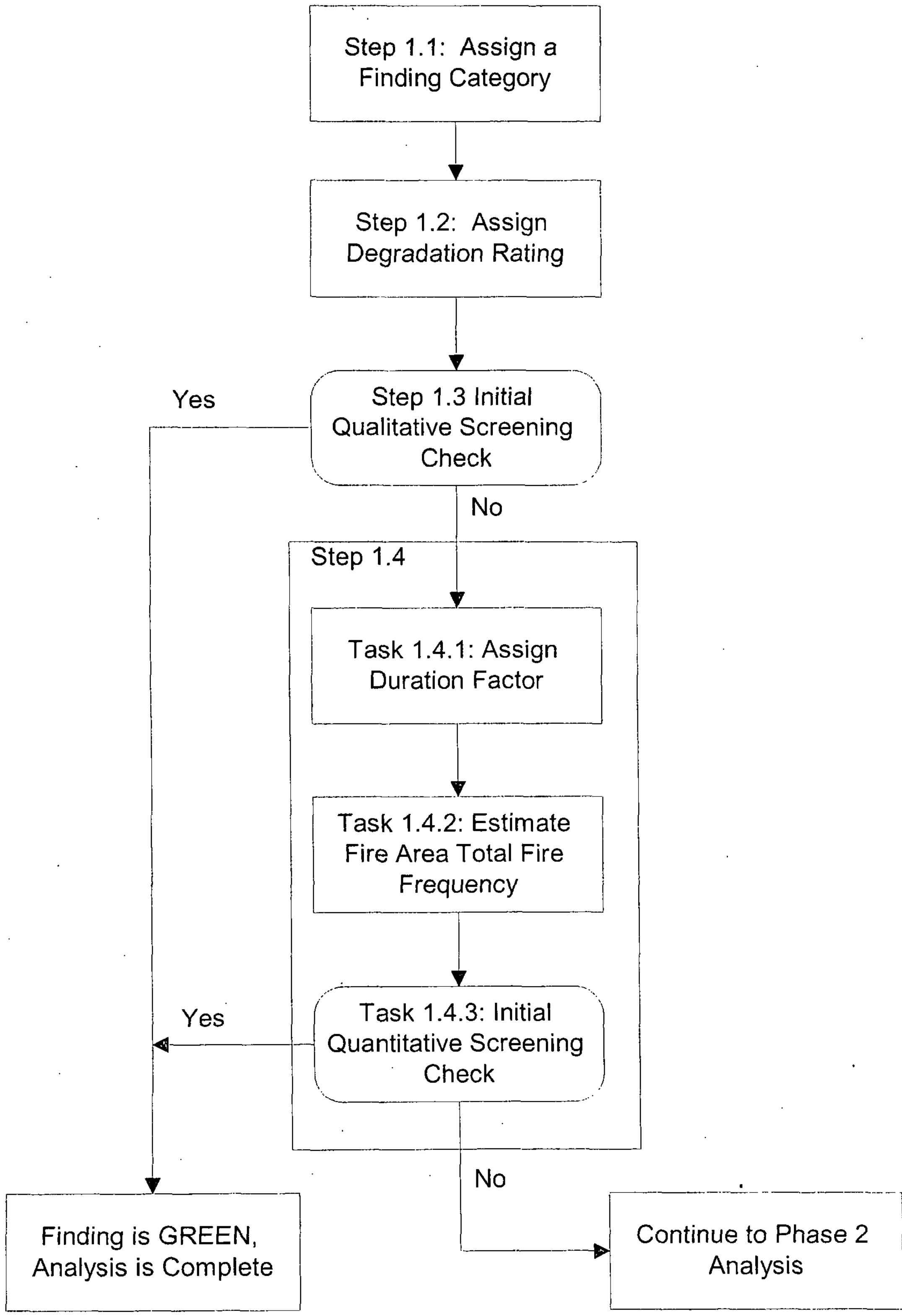
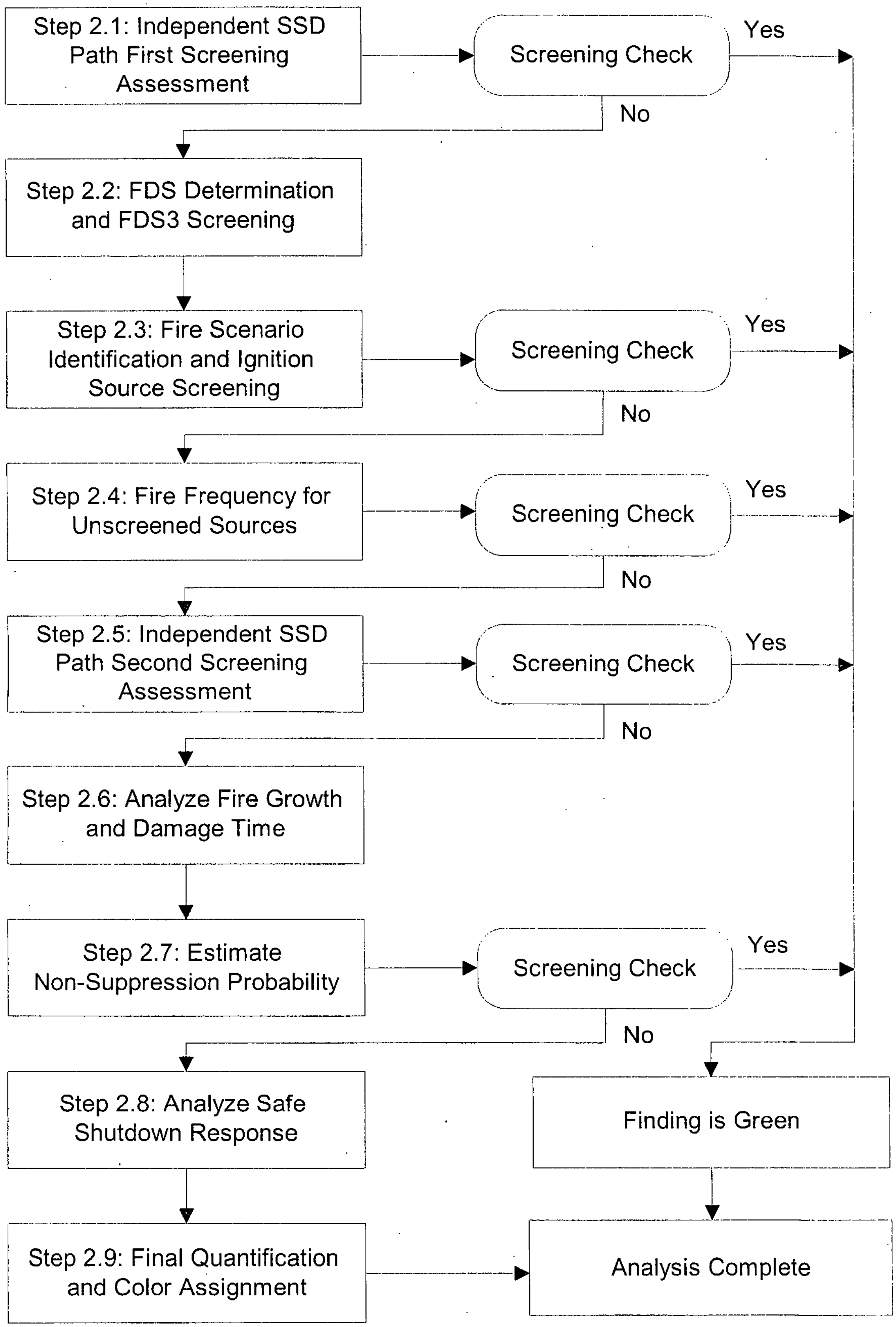


Figure 4.2.2: Phase 2 Flow Chart



Module 4: Phase 1 Details

Module 4 - Phase 1 Details 1

Phase 1 Details

- We will cover each step and task in Phase 1:
  - Purpose/objective
  - What, why, how
  - Input/output
  - Supporting guidance

Module 4 - Phase 1 Details 2

Phase 1- Step 1.1

- Assign a finding category
  - A convenient way to bin (classify) findings
- Later decisions will depend on the assigned category:
  - Degradation ratings
  - Quantitative screening criteria
  - The types of fire scenarios that are relevant

And the categories are...

- Cold Shutdown
- Fire Prevention and Administrative Controls
- Fixed Fire Protection Systems
- Fire Confinement
- Localized Cable or Component Protection
- Post-Fire Safe Shutdown

Cold Shutdown Findings

- Findings associated with systems and features only required to support or achieve cold shutdown
- Examples:
  - An issue related to RHR so long as:
    - RHR is not needed/relied upon to support post-fire hot shutdown
    - Spurious operation of RHR component(s) cannot compromise the hot shutdown capability

Fire prevention and administrative controls

- Findings relating to combustible control programs, training, permit processes, activity specific fire watches, etc.
- Examples:
  - Violation of combustible control limits
  - Failure to follow hot work permitting requirements
  - Failure to properly execute hot work fire watches
  - Deficiencies in fire-protection related training
  - Records keeping issues

Fixed fire protection systems

- Findings related to active fire protection systems or a fire watches posted as a compensatory measure for a degraded fixed fire protection system
- Fixed fire protection systems are:
  - Fixed fire suppression
  - Fixed fire detection

Fire Confinement

- Findings related to fire barriers and barrier elements that separate fire areas
  - Walls/floors/ceilings
  - Penetration seals
  - Doors
  - Dampers
  - Water curtains

Localized Cable or Component Protection

- Passive fire protection features meant to protect cables and/or components from fire damage given fires within the same fire area
  - Cable and raceway fire wraps
  - Radiant energy shields
  - Spatial separation
  - Fire barriers between fire zones within a fire area

Post-Fire Safe Shutdown (SSD)

- Findings that directly impact systems or functions identified in the post-fire SSD analysis
  - Circuit analysis related issues (e.g., spurious operation)
  - Completeness of the post-fire SSD equipment list or post-fire SSD analysis
  - Post-Fire safe shutdown procedures
  - Manual actions
  - Remote/alternate shutdown

Fire Barriers versus Safe Shutdown

- Example: A hole in a raceway fire barrier (made during maintenance) was not properly sealed upon completion of maintenance activities. The barrier protects a cable associated with the designated post-fire safe shutdown path.
  - This one should be obvious - a localized cable or component protection issue

Fire Barriers versus Safe Shutdown (cont.)

- Example 2: The licensee committed to providing fire-wraps for certain post-fire safe shutdown cables. In one case, the wrong cable tray was wrapped, and the correct tray was left un-protected
  - This is a Localized Fire Barrier issue
  - The underlying issue is failure to provide the barrier that was committed to
  - Treat as highly degraded raceway fire barrier

Barriers versus Safe Shutdown (cont.)

- A cable associated with the designated post-fire safe shutdown path is found to be exposed (with no fire wrap) in a fire area where it is required to support safe shutdown. Further review reveals that the licensee failed to identify the cable as a required component.
  - This is a Safe Shutdown Finding – failure to identify a required component is the underlying issue.

Barriers versus Safe Shutdown (cont.)

- It is determined that spurious operation on a particular circuit could compromise the designated post-fire safe shutdown path (open a diversion path) for the area being inspected. A cable that could cause the spurious operation is found to be exposed (with no fire wrap) in the fire area being inspected. The licensee did not identify the circuit as an associated circuit, hence, the cable is not on the post-fire SSD component list.
  - This is a Safe Shutdown Finding – failure to identify an associated circuit is the underlying issue.

Finding Categories (cont.)

- Categories map to elements of the analysis process:
  - Fire prevention and administrative controls –> changes in fire frequency
  - Fixed Fire Protection –> longer time to fire suppression
  - Fire Confinement –> focus on FDS3 Scenarios
  - Localized Cable or Component Protection –> Focus on scenarios that damage protected component
  - Post-Fire Safe Shutdown – changes in CCDP

Finding Categories – a final note

- Once assigned, category does not change

Phase 1 – Step 1.2

- Assign a degradation rating
  - In general pick one: High – Moderate – Low
  - Exceptions:
    - No Moderate for Fire Prevention and Administrative Controls (call it either high or low)
    - For Fire Confinement and Localized cable and Component Protection (fire barriers) Moderate is split into "Moderate A" and "Moderate B"
- Degradation rating criteria depend on finding category (from Step 1.1)
  - See Attachment 2

Questions on the degradation rating guidance?

- Don't intend to cover Attachment 2 guidance in detail, but open to questions and/or discussion

Degradation Rating – final note:

- Once set, degradation rating doesn't change

Phase 1 – Step 1.3

- Initial Qualitative Screening
  - Based on a series of yes/no questions
  - Questions are phrased so that a "yes" will mean screen to green
- Two Tasks:
  - Task 1.3.1 applies to all findings
  - Task 1.3.2 applies to only Fire Confinement findings

Phase 1, Task 1.3.1

- Two Question only
- Any finding Screens to Green if:
  - Degradation rating is LOW

  OR

  - Finding only effects the ability to achieve and maintain COLD SHUTDOWN
    - Example: RHR system issue so long as RHR is not required for post-fire hot shutdown

A note on Low and Green

- A finding does not have to be rated LOW degradation to be GREEN
  - If degradation is Low, finding is Green, but…
  - Even if degradation is greater than Low, finding may still be Green
- Even a high degradation may be Green
  - Moderate and High degradation findings tend to pass forward to Phase 2 (some exceptions)
  - Phase 2 may still conclude that finding is Green
  - We don't re-assign the degradation rating to Low just because Phase 2 screens the finding to Green

Phase 1, Task 1.3.2

- Fire Confinement findings <u>only</u>
  - Recall: fire barriers separating fire areas
- Screen to green if inter-area fire scenarios will not be risk significant even given the degradation
  - No unique targets in adjacent room
  - Low likelihood of fire barrier failure:
    - Adequate performance time even given degradation
    - DID – fire suppression capability
    - DID – additional passive fire protection
  - No substantive fire hazards present
    - cannot challenge barrier

Fire Confinement – a note on terminology

- PRA practice is a bit loose on terminology here
- You may see reference to:
  - Inter-area fires
  - Inter-compartment fires
  - Room-to-room fires
  - Multi-room fires
- They all mean basically the same thing
- For SDP Fire Confinement relates only to the fire barriers that separate one fire area from another

Exposing versus Exposed Compartment

- Remember: Fire confinement findings always involve two fire areas
  - "Exposing compartment" is fire area where you will assume that fire starts
  - "Exposed compartment" is the fire area on the other side of the degraded fire barrier
- Remember to look both ways...
  - Pick one orientation for actual analysis
  - Pick orientation where fire in exposing compartment will create greatest challenge to the degraded fire barrier

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Exposing versus Exposed (cont.)

- Indicators for choosing exposing compartment:
  - More challenging fire ignition sources
    - Higher intensity (e.g., a source of big oil fires makes for an obvious choice)
  - Fire ignition sources adjacent to degraded barrier
  - Lacks automatic fire suppression coverage
- Point is that you need to develop a fire scenario leading to spread through the degraded barrier so you need a significant fire source in the Exposing compartment

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Task 1.3.2, Question 1

Q: Will the barrier in its degraded condition provide a 2-hour or greater fire endurance rating?

- If Yes – Screen to Green, no further analysis required
- If No – Continue to next question

- Degraded fire endurance rating is based on degradation rating and nominal rating
  - Moderate A means 66% of nominal rating
  - Moderate B means 33% of nominal rating
  - High means no credit or zero endurance rating
- This one won't help very often
  - Mod. A on a 3 hour barrier
  - Non-rated barrier judged equivalent to two hours endurance

Task 1.3.2, Question 2

Q: Is there a non-degraded automatic gaseous room-flooding fire suppression system in the exposing compartment?

- If Yes – Screen to Green, no further analysis required
- If No – Continue to next question

- We are crediting Defense In Depth measures
- Gaseous systems must be non-degraded – no performance issues
- We are looking at a feature that will disrupt the initial fire growth

Task 1.3.2, Question 3

Q: Is there a non-degraded or no more than moderately degraded automatic full area water-based fire suppression system in the exposing compartment?

- If Yes – Screen to Green, no further analysis required
- If No – Continue to next question

- Again, a defense in depth credit
- For water-based system, we do allow credit given a moderate degradation
- Again, looking for something that disrupts initial fire growth

Task 1.3.2, Question 4

Q: Can it be determined that the exposed compartment contains no potential damage targets that are unique from those in the exposing fire area (damage targets may include post-fire safe shutdown components or other plant components whose loss might lead to a demand for safe shutdown (e.g., a plant trip))?

- If Yes – Screen to Green, no further analysis required
- If No – Continue to next question

- Wording may be awkward – we wanted 'yes = green'
- Point is you need unique targets in exposed room to make a room-to-room fire scenario significant

Task 1.3.2, Question 5

Q: Are all potential damage targets in the exposed fire area (as described in question 4) provided with passive fire barrier protection with no more than a moderate degradation that will provide a minimum of 20 minutes fire endurance?

- If Yes – Screen to Green, no further analysis required
- If No – Continue to next question

- Credit for passive fire barrier elements as a DID element so long as barrier is good for at least 20 minutes
  - Fire would need to breach two passive barriers

Task 1.3.2, Question 6

Q: Is a non-degraded or no more than moderately degraded partial-coverage automatic water based fire suppression system installed in the exposing compartment and are all the fixed or *in-situ* fire ignition sources included within the zone of coverage for this system?

- If Yes – Screen to Green, no further analysis required
- If No – Continue to next question

- A lot like Question 3, but we relax full coverage requirement
  - As long as all possible fire sources are covered, we credit

Task 1.3.2, Question 7

Q: Does the degraded barrier provide a minimum of 20 minutes fire endurance protection and are the fixed or *in situ* fire ignition sources and combustible or flammable materials positioned such that, even considering fire spread to secondary combustibles, the degraded barrier or barrier element will not be subject to direct flame impingement?

- If Yes – Screen to Green, no further analysis required
- If No – Continue to Step 1.4

- We relax the performance requirement on the degraded barrier if we won't have direct flame impingement on the barrier

Phase 1 – Step 1.4

- Initial Quantitative Screening
- Uses two factors:
  - Duration factor (DF)
  - Room fire frequency (F_{area})
- If product of these two is "low enough", screen to green

Task 1.4.1 – Duration Factor

Duration of the Degradation	**Duration Factor (DF)**
< 3 days	0.01
3 - 30 days	0.1
> 30 days	1.0

- same as it ever was

Task 1.4.2 – Area Fire Frequency

- F_{area} Directly from look-up table – see Pg F-8,9
- Intended to be somewhat conservative, but this won't be universally true
  - If a fire area contains a particular concentration of fire ignition sources, the component-based fire frequency for the full fire area as calculated in Phase 2 may be higher!
- Differences should be minor
  - You need to cross an order of magnitude boundary for difference to be significant
  - You may use the Phase 2 approach if table value does not fit your case - use your judgment

Task 1.4.3

- Task 1.4.3 sets Phase 1 quantitative screening criteria
- Screening criteria imply an implicit level of risk credit for non-impacted DID elements
  - Criteria depend on the finding category assigned in Step 1.1
  - Remember, if you ever get below 1E-6, finding is green so no screening criteria is ever more stringent than 1E-6

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Task 1.4.3 – Screening Check

- $\Delta(CDF)_{1.4} = DF * F_{area}$

Phase 1 Quantitative Screening Criteria

Assigned Finding Category (from Step 1.1):	$\Delta CDF_{1.4}$ Screening Criteria Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	1E-4	
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	1E-6
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

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Module 5: Phase 2 Details

Steps 2.1-2.4

Module 5: Phase 2 Details

- We will cover each step and task in Phase 2:
  - Purpose/objective
  - What, why, how
  - Input/output
  - Supporting guidance
  - Some Examples – focus on a step/task

Step 2.1: SSD path first check

- This step involves a course assessment of the designated post-fire safe shutdown path
  - Can we credit SSD path prior to development of scenarios
  - If so, what is appropriate screening CCDP value
- If we can show that the path is independent of any fire scenarios we might develop, we will credit that path right away
- Analysis gets refined after development of scenarios and in Step 2.8
  - This is just a first rough cut

Task 2.1.1: Identify SSD Path

- Path should be documented:
  - Designated SSD path under fire protection program
  - Must have supporting post-fire SSD analysis
  - Must be covered by procedures
- BTW: If the answer to any one of these is no, then you may well have a SSD finding to deal with

Task 2.1.2 – SSD nominal unavailability

- SSD path is assigned a nominal unavailability factor
  - Possible values are limited to:
    - 1.0, 0.1, 0.01, or 0.001
- 1.0 means no credit – appropriate if there are questions as to adequacy of SSD
  - e.g., given a SSD finding
- Other cases, guidance on Pg F-11

Unavailability factors (cont.)

- Automatic steam-driven (ASD) train … including a single turbine-driven component to provide 100% of a specified function…
  - $CCDP_{2.1} = 0.1$
- One train made up of a collection of equipment that together provide 100% of a specified function…
  - $CCDP_{2.1} = 0.01$
- Major operator actions required to support SSD…
  - $CCDP_{2.1} = 0.1$ OR 0.01 depending on actions

Task 2.1.3 – SSD path independence

- Independence has special context here:
  - SSD path should not be lost in <u>any</u> of the fire scenarios we might later develop
  - Because fire scenarios come later, this requires a bit of foresight
- If path might be compromised in any one fire scenario, we don't credit the path yet
  - We still want unavailability, because later we may credit for those scenarios where the path does survive
- List of criteria on Pg F-11-13

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Independence Criteria:

- These should be assured by virtue of Appendix R compliance:
  - The licensee has identified and analyzed the SSD SSCs required to support successful operation of the SSD path.
  - The licensee has identified and analyzed SSCs that may cause mal-operation of the SSD path (e.g., the required and associated circuits).
  - The licensee has evaluated any manual actions required to support successful operation of the SSD path and has determined that the actions are feasible.

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Independence Criteria (cont.)

- This one might be an issue for plants taking credit for long term actions after the fire is out:
  - All manual actions take place outside the fire area under analysis
- We don't ask you to evaluate such actions in Phase 2 – they will not be credited
  - Can be reconsidered during Phase 3 so make a note of these in your documentation

Independence Criteria (cont.)

- These three relate to circuit analysis:
  - The licensee has conducted an acceptable circuit analysis
    - Should be a given
  - Any known unresolved circuit analysis issues that could adversely impact the operability of the designated SSD path are identified.
  - No known circuit analysis issues (e.g., a known spurious operation issue) for <u>exposed cables</u> should hold the potential to compromise operability of the identified SSD path.

Independence Criteria (cont.)

- "Exposed cables" guidance:
  - Cables within the fire area under analysis are not considered exposed if
    - they are protected by a non-degraded raceway fire barrier with a minimum 3-hour fire endurance rating.

    OR
    - they are protected by a raceway fire barrier with a minimum one-hour fire endurance rating, the area is provided with automatic detection and suppression capability, and none of these elements is found to be degraded.

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Independence Criteria (cont.)

- "Exposed cables" guidance (cont.)
  - Cables in an adjoining fire area are not considered exposed if the fire barrier separating adjoining fire area from the fire area under analysis is not degraded.
  - If the finding category assigned in Step 1.1 was "Fire Confinement," cables located in the adjacent fire area are considered exposed unless they are protected by a non-degraded localized fire barrier with a minimum 1-hour fire endurance rating.

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Independence Criteria (cont.)

- These items relate to Appendix R III.G.2 Separation strategy – basically:
  - We do credit 3 hour separation as long as barrier is not degraded
  - We do credit 1 hour separation with auto detection and suppression as long as these features/systems are not degraded
  - We do not credit spatial separation within the same fire area
  - We do not credit exemptions or remote shutdown at this stage of analysis

Task 2.1.4 – Screening check

- $\Delta CDF_{2.1} = DF \times (F_{Area}) \times CCDP_{2.1}$

Phase 2 Screening Step 1 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	$\Delta CDF_{2.1}$ screening value	
	Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	1E-4	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

- If $\Delta CDF_{2.1}$ is lower than the corresponding value in the table, the finding screens to Green and the analysis is complete.
- If $\Delta CDF_{2.1}$ is greater than or equal to the corresponding value in the table, then the finding does not screen to Green, and the analysis continues to Step 2.2

Step 2.2 – FDS determination

- The nature of the finding determines which types of fire scenarios MAY be relevant to risk change
  - If nothing about a scenario changes as a result of the degradation, then the scenario is not relevant
- This step is a quick decision process to decide which FDS's need to be considered as you develop fire scenarios
- The most complex part of this step is Task 2.2.2, FDS3 screening

Task 2.2.1: Initial FDS Assignment

- Simple look up table:

FDS/Finding Category Matrix			
Finding Type or Category:	**FDS1**	**FDS2**	**FDS3**
Fire Prevention and Administrative Controls	Yes	Yes	Yes
Fixed Fire Protection Systems	Yes	Yes	Yes
Fire Confinement	No	No	Yes
Localized Cable or Component Protection Given a High degradation Given a Moderate degradation	 Yes[1] No	 Yes Yes	 Yes Yes
Post-fire SSD	Yes	Yes	Yes

Note 1: For a highly degraded local barrier, the protected components/cables are treated as fully exposed and may be assumed damaged in FDS1 scenarios, depending on their proximity to the fire ignition source.

Task 2.2.2 – FDS3 screening

- We would really like to drop FDS3 if we can – most of the time you will
  - Multi-room scenarios are rarely risk important so long as the barriers are intact
  - FDS3 is the equivalent of the multi-room term in the old SDP
- If the inter-area barrier is degraded, you're stuck
  - This screening task only applies to findings that are not Fire Confinement category

FDS3 screening (cont.)

- Given that the finding is anything other than fire confinement, the fire area you are inspecting is always the exposing fire area
  - The fire starts in the exposing fire area
- The exposed fire area may be any adjacent fire area
  - The fire may spread to an exposed fire area
- You are going to look for a fire in the exposing fire area that is substantial enough to challenge the fire barriers

FDS3 screening (cont.)

- Series of yes/no questions
  - Apply questions to each adjacent area and see if any can give you a credible scenario
  - Look for one area to act as the exposing fire area – pick the worst case and go with it
- Virtually identical to questions posed in Task 1.3.2
  - Same general intent and basis
  - Only difference is we assume the barrier between the fire areas is not degraded
  - Words relating to fire endurance rating of the barrier "in it's degraded condition" are dropped

You are going to drop FDS3 if:

- Fire area boundaries for the exposing fire area have minimum 2 hour fire performance
  - You may have a mixed bag of barriers – some 2-hour, some not
  - Drop any room combinations that are separated by a 2-hour barrier
  - For the rest of the questions, focus only on those combinations that don't have 2-hour separation
- The exposing fire area has:
  - Non-degraded gaseous suppression, OR
  - No more than moderately degraded full coverage water suppression
  - Partial coverage water system that covers in-situ fire ignition sources

(Meeting any one of these conditions is enough)

You will drop FDS3 if (cont):

For these three conditions, remember to focus on specific combinations of fire areas that lack 2-hour separation

- There are no unique targets in any exposed compartment
- Targets in any exposed compartment are at least 20 feet from the separating fire barrier and/or have passive protection with a one-hour fire endurance
- The fire barrier between fire area has at least 20 minutes fire endurance, AND in situ material won't subject barrier to direct flame impingement
  - i.e., Fire ignition sources are well away from the barrier

(Meeting any one of these conditions is enough)

If you end up retaining FDS3 you must have found:

- A somewhat wimpy barrier to at least one adjacent fire area
- Questionable or non-existent fixed suppression capability in exposing compartment
- Unique and exposed targets in at least one adjoining room
- The potential for fire that can directly challenge the fire barrier

It's not hard to develop a fire scenario out of that situation!

Step 2.2 – Summary

- At the end of this step you will be left with one, two, or three FDS's to <u>consider</u> in the development of fire scenarios
- If you drop one or more FDS's, they never come back

Step 2.2 – One Last Point

- Step 2.2 only tells you that you need to <u>consider</u> the possibility of one or more fire scenarios for each FDS retained
- It does NOT say you MUST develop at lease one fire scenario for each FDS
  - Some FDS states may simply not be credible
  - e.g., FDS2 in a fire area with inadequate combustibles to create a hot gas layer
- It also does not say every fire ignition source will lead to at least one scenario for each FDS retained
  - Some fire ignition sources might contribute to only one FDS and not to other FDS's even though the other FDS's were retained

Illustrative example

Finding: A cable tray associated with the Designated Train B SSD path should have been wrapped but was not (licensee wrapped the wrong tray)

- Finding Category: Localized Cable and Component Protection
- Degradation: High
- Task 2.2.1 says nominally retain FDS1, FDS2, FDS3

- To fill out example, let's assume:
  - FDS3 screened out in 2.2.2
  - Un-wrapped tray is second up in a stack

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Illustrative Example (cont.)

- Our targets of interest are:
  - The cables in the un-wrapped Train B tray
    - Can cause loss of the post-fire SSD capability
  - Various Train A cables in exposed trays throughout the room
    - Specifics lacking
- Given available information we don't know specifically where the Train A cables are
  - Assume the worst
  - Loss of any exposed tray causes loss of Train A

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Illustrative example (cont.)

- For those fire ignition sources directly below the unwrapped tray:
  - We only need damage the first two tray in the stack, and we lose Trains A and B
  - FDS1 scenarios get us there
  - FDS2 scenarios don't add anything new
    - We already lost both trains including the SSD train
  - For these sources, FDS1 scenarios are enough to characterize the risk change

Illustrative example (cont.)

- For fire sources remote from un-wrapped tray:
  - FDS1 scenarios will only damage Train A
    - Question to ask yourself: Does the lack of a wrap on the train B cable tray change these FDS1 scenarios in any way?
    - Answer in this case: NO.
    - Result: FDS1 scenarios are not relevant and can be dropped
  - FDS2 scenarios can damage both the Train A and Train B cables (due to either fire spread or hot gas layer)
  - For these fire ignition sources the FDS2 scenarios characterize risk change

Step 2.3 – Scenario and Ignition Sources

- Purpose of this step is to begin defining fire scenarios
- Focus is on identification of fire ignition sources to be retained for further analysis
  - Identify and count fire ignition sources
  - Screen out non-threatening fire ignition sources
  - Revised room fire frequency based on retained fire ignition sources
  - Screening check using new room fire frequency

Task 2.3.1 – Count sources

- For most cases, we use a component-based fire frequency so first task is to count fire ignition sources
  - If you use spreadsheet, entering counting results automatically updates the fire frequency
- For transients and hot work fires, the area is ranked as High – Moderate – Low
- Any questions on counting/ranking guidance??

Task 2.3.1 – Special cases

- For some findings, only a specific subset of potential fire ignition sources are considered
  - High degradation finding against combustible material controls – only transient fire ignition sources are relevant
  - High degradation finding against hot work fire watch – only hot work fires are relevant

Focus on what changes

- You want to focus on fire ignition sources where a scenario will change given the finding – example:
  - If a portion of a fire sprinkler is out of service, focus on sources that would normally be covered but now are not
  - Given a lack of detection within a beam pocket, focus on fire ignition sources that are also within/under that same beam pocket
- Use your judgment and limit your search as appropriate
  - No different than what you are already doing

Focus on what might prove to be credible

- Don't waste time worrying about fire ignition sources that will clearly not yield a credible fire scenario – Example:
  - If you have an issue in one corner of a reactor building, and there is a small fire source isolated at the opposite end of the building, Don't waste time worrying about that source
    - If it's obvious that the fire cannot spread enough to create a damaging hot gas layer, then you have no FDS2 and the scenario is not going to be credible
- Document your logic and move on.

Task 2.3.2: Characterize Sources

- We talk about simple and non-simple fire ignition sources
  - Simple: panels, other electrical fires, transformers, engines, heaters, transients
  - Non-simple: self-ignited cable fires, energetic arcing faults, transients that exceed nominal size, hot work fires, liquids, hydrogen
- We are going to talk about simple sources now, we will cover non-simple sources in Module 6 (with examples)

Task 2.3.2 – Simple sources

- For simple sources, pull HRR values from the lookup table for each fire ignition source
- Two values for each source:
  - Lower value represents 90% of fires
  - Higher value represents upper 10% of fires

Fire Characteristics Table

Mapping of General Fire Scenario Characterization Type Bins to Fire Intensity Characteristics

Fire Size Bins	Generic Fire Type Bins with Simple Predefined Fire Characteristics					
	Small Electrical Fire	Large Electrical Fire	Indoor Oil-Filled Transformers	Very Large Fire Sources	Engines and Heaters	Solid and Transient Combustibles
70 kW	50th Percentile Fire				50th Percentile Fire	50th Percentile Fire
200 kW	95th Percentile Fire	50th Percentile Fire			95th Percentile Fire	95th Percentile Fire
650 kW		95th Percentile Fire	50th Percentile Fire	50th Percentile Fire		
2 MW			95th Percentile Fire			
10 MW				95th Percentile Fire		

Task 2.3.2 – Simple Sources (cont.)

- Assign a location for the fire origin
  - Most are on top of the fire source
  - Exceptions:
    - Cabinets/Panels: 1 foot below the top of the panel
    - Pool fires: on floor at center of pool
    - Transients: 2 feet above the floor are desired location
    - Hydrogen fires: at the point of gas release

Tasks 2.3.3 and 2.3.4

- We need to screen ignition sources:
  - If we can ignite or damage any secondary target, we keep the ignition source
  - If we cannot damage/ignite nearest target, we drop that ignition source
- Three considerations:
  - Plume exposure
  - Radiant heating
  - Hot gas layer
- Screening is done in two tasks…

Task 2.3.3 – Nearest target

- In this task you identify the nearest and/or most vulnerable target to each fire source
  - Don't need to define a full target set, just find the one most likely to fail/ignite
- Target can be either a damage or ignition target
  - Target's function does not matter – does not need to be a SSD component for example

Task 2.3.3 – Nearest target (cont.)

- Look for targets directly above fire
  - Plume heating
- Look for targets off to the side
  - Radiant heating target
- If nothing else, you will have some target for hot gas layer exposure
- If you can't find a target, you should not be in that room

Task 2.3.3 (cont.)

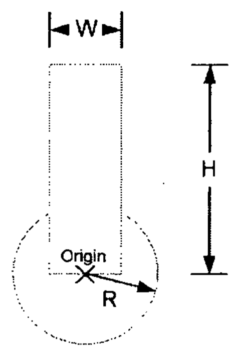
- Note location of target(s) relative to source
  - Height above source
  - Horizontal distance
- Targets are almost always cables
  - Find out if you are dealing with thermoplastic or thermoset cables

Task 2.3.4 – Screening sources

- This task decides if a given fire ignition source can spread fire and/or damage the most vulnerable target
- We do two checks:
  - Zone of Influence (Ball and Column)
    - Column = Plume
    - Ball = Radiant heating
  - Hot gas layer

Ball and Column Diagrams

- Graphical zone of influence chart
  - Height (H) and radius (R) are from look up tables
  - Width (W) corresponds to footprint of the source



Ball and Column Diagrams – Typical look-up table

For fires in an open area away from walls or corners:

Calculated Values (in feet) for Use in the Ball and Column Zone of Influence Chart for Fires in an Open Location Away from Walls				
Fire HRR	Thermoplastic Cables		Thermoset Cables	
	H	R	H	R
70 kW	4 8	1.8	3.5	1.3
200 kW	7.3	3.0	5.3	2.1
650 kW	11.6	5.4	8.5	3.8
2 MW	18.2	9.5	13.3	6.7
10 MW	34.7	21.3	25.3	15.0

Calculations are based on the following damage criteria:
Thermoplastic Cables: 400°F (325°F rise above ambient) and 0.5 BTU/ft²sec
Thermoset Cables: 625°F (550°F rise above ambient) and 1 BTU/ft²sec

Ball and Column Diagrams (cont.)

- Fire location can make a difference
  - Fires in the open (away from walls)
  - Fires near a wall
  - Fires near a corner
- Near a wall = within 2 feet
- Near a corner = within 2 feet of both walls forming the corner

Ball and Column Diagrams (cont.)

- If there is at least one target within the zone of influence, then:
  - We have the potential for fire spread and damage due to plume and radiant heating effects
  - The fire ignition source is retained
- If there are no targets within the zone of influence, then:
  - Fire cannot spread from that particular ignition source to any secondary fuels
  - Plume and radiant heating effect cannot cause damage to any of the potential targets in the room
  - Need to check hot gas layer to determine if source must be retained

Ball and Column Diagrams (cont.)

- Essentially, the ball and column is a visual check
  - Have your table handy when you do your walkdown, and you can quickly perform this screening check for most of the sources in the room.

Ball and Column Diagrams (cont.)

- If you are dealing with a HRR value not included in the tables (i.e., any one of the standard values) you will have to re-calculate the H and R values for your fire
- FDT spreadsheets can do this
  - You enter the appropriate values, and look for distances where temperature equals the damage threshold for your targets
  - Unless it's a pool fire, use a standard fire surface area of 6 square feet
  - Recommend you seek guidance if you are not sure

Task 2.3.4 – Hot gas layer

- If a fire source was retained based on the ball and column, it is retained – period
  - Only need one condition met to retain
- If a source is retained based on the zone of influence check, don't bother checking hot gas layer for that source
  - Could save you some time
  - Won't hurt if you check anyway, but it is really a waste of time at this point

Hot gas layer (cont.)

- Check the hot gas layer temperature for any fire ignition sources that had no targets within their zone of influence
  - For these sources, we don't get fire spread
  - That means for damage, fire source in and of itself has to be enough to create damaging hot gas layer
- If such sources can create a hot gas layer temperature above the failure threshold of the weakest target, the source is retained

Hot gas layer (cont)

- The hot gas layer check requires use of the FDT spreadsheet tool
- Plug in required inputs (room dimensions and ventilation conditions)
- Plug in fire HRR
- Record the hot gas layer temperature at 30 minutes
- Repeat last two steps for each unique HRR value that you identified in Task 2.3.2

Hot gas layer (cont.)

- Fire location makes no difference for hot gas layer
- That means you don't have to repeat the temperature analysis for each and every fire ignition source
- Do the calc once for each unique HRR
- The answer is the same for all fires sources at that particular HRR

Task 2.3.4 – Summary

- You end up with a screening result for each fire ignition source
  - May be retained due to ball and column or due to hot gas layer (or may screen out)
  - Is the source retained at its lower HRR value?
  - Is the source retained at the higher HRR value?
- Note that if the source is retained at the lower HRR value, it is also retained (by definition) at its higher HRR value

Task 2.3.5 – Screening check

- If no fire ignition sources were retained, then you failed to identify a credible fire scenario
  - In this case you are done – finding is green
- This requires the all sources screened out at both their lower and higher HRR values
  - If even one source at one HRR value is retained, you continue to next step

Step 2.4 – Refined fire frequency

- In this step a new refined fire frequency for the fire area is calculated
  - We remove the contribution associated with fire ignition sources screened out in Step 2.3
  - We apply severity factors for sources retained only at their higher HRR value
- We then do a screening check to see if the refined fire frequency provides sufficient evidence to call the finding green

Task 2.4.1 – Nominal fire freq.

- In this step you enter the results of Task 2.3 into a fire frequency worksheet/spreadsheet
  - Counting results for retained fire ignition sources
  - Severity factors as applicable

Task 2.4.2 – Findings that increase fire frequency

- Certain findings result in an increase in the fire frequency being applied
  - High degradation findings against combustible material control programs – multiply nominal transient fire frequency by 3
  - High degradation findings against hot work fire watch – multiply nominal hot work fire frequency by 3

Module 5 - Phase 2 57

Task 2.4.3 – Freq reductions

- Two cases where frequency may be reduced:
  - Transients
  - Hot work

Module 5 - Phase 2 58

Reduction to transient freq.

- Transient fire frequency is reduced by a factor of 3 if verifiable measures are in place to promptly identify and remove transients from the area under analysis
  - If finding is against the combustible controls program this provision will not apply – do not reduce fire frequency

Module 5 - Phase 2 59

Reductions to hot work freq.

- If it can be verified that no hot work was performed in the fire area during the finding exposure period, the hot work fire frequency may be set to zero
  - That means no hot work fire scenarios
  - If finding is against hot work control requirements (e.g., fire watch) this provision will not apply – do not reduce fire frequency

Module 5 - Phase 2 60

Task 2.4.4 – Update frequency and screening check

- The fire frequency for the fire area is re-calculated considering
  - Elimination of fire ignition sources that were not retained in Step 2.3
  - Application of severity factors for ignition sources retained only at their higher fire HRR value
  - Adjustment factors as applicable for transients and hot work fires
- May be done using hand worksheet or using an electronic spreadsheet

Module 5 - Phase 2 61

Task 2.4.4 – screening check

- Screening check is essentially identical to that from Step 2.1, but the updated fire frequency is applied
- Screening criteria are unchanged EXCEPT for moderate degradation of fire prevention and administrative findings
  - We have now done about all we will with fire frequency so we tighten that screening criteria from 1E-4 to 1E-5
  - Recall that we have a conflict here we need to resolve – there are no moderate degradations for this category

Module 5 - Phase 2 62

Screening Criteria for Step 2.4

- $\Delta CDF_{2.4} = DF \ X \ (F_{Area2.4}) \ X \ CCDP_{2.1}$

Phase 2, Screening Step 4 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	$\Delta CDF_{2.4}$ screening value	
	Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	1E-5	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

[1] This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier

- If the value of $\Delta CDF_{2.4}$ is lower than the corresponding value in the table above, then the finding Screens to Green, and the analysis is complete.

Module 5B – Phase 2 details continued

Steps 2.5-2.9

Step 2.5 – Fire growth and damage scenarios and 2nd check on SSD

- In this step the process of defining specific fire scenarios continues
  - Fire growth and damage scenarios are defined for each combination of a fire ignition source and FDS that we are retaining
- This step includes identification of scenario specific target sets
- Once fire growth and damage scenarios are defined, we re-assess survival of the designated safe shutdown path in context of each fire ignition source

Step 2.5 – Targets and Target sets

- We need to identify targets by both location and function
  - We want to know where important targets are with as much accuracy as possible
  - Don't start routing cables, but use information made available by licensee
- We are going to group individual targets into target sets
  - Sets correspond to fire ignition source/FDS combination

Step 2.5 – target sets (cont.)

- We would like to know what function is lost given failure of each target
  - If possible, tie specific targets to specific functions
- As a minimum it is sufficient to know what functions are lost given loss of the entire target set
  - In practice, this is how we use information
  - The greater level of detail is still good information to record as available

Step 2.5 – Target sets

- If location information is lacking or uncertain, targets are placed in worst plausible location
  - Lacking any other information, assume all target cables are in the tray right above the source
- Some rules of thumb may be applied
  - Power cables tend to be routed in upper trays
  - Control cables are often in lower or mid-level trays
  - Instrument cables usually in the lowest trays
- When uncertain, err towards conservatism, but use available information

Task 2.5.1 – Fire growth and damage scenarios

- Define fire growth and damage scenarios for each combination of an unscreened fire source and FDS
  - Define the fire ignition source
  - Define the applicable path for fire growth at each applicable FDS
  - Define the associated target set

Defining FDS1 Scenarios

- Start with a fire ignition source
- Was the source retained based on potential for hot gas layer damage (not plume/radiant damage)
  - If yes, then there will be no FDS1 for that source – might still have FDS2 or FDS3
- Was source retained based on ball and column
  - If yes then we consider FDS1 scenarios

Defining FDS1 scenarios

- FDS1 involves localized damage including vertical fire spread
- Define logical path of fire spread if one exists
  - Allow fire to grow vertically (i.e. through a stack of cable trays or up a vertical cable riser)
  - Do not postulate substantial horizontal spread – that is for FDS2
- Note: we will cover specifics on cable fire spread rules in Module 6

Defining FDS1 scenarios

- Given your fire spread path, define FDS1 Target set
  - Targets within zone of influence for radiant heating (remember ball and column?)
  - Targets above the fire source and in the path of fire spread
    - Include targets outside/above zone of influence if fire spread is possible (e.g., lowest tray in a stack may be ignited, but target is in higher tray)
  - Include any unprotected cables and components
  - Include cable and components "protected" by a highly degraded localized fire barrier system (e.g. a non-functional cable wrap)

Defining FDS2 fire scenarios

- Again, start with a fire ignition source
- Define fire spread path if needed
  - If fire source alone is enough to cause damaging hot gas layer, then fire spread is moot – just worry about the source
  - If fire ignition source is not enough to cause hot gas layer damage without fire spreading, then we again postulate a path of fire spread
    - This time we allow for more extensive horizontal fire spread
    - Define the fire spread path
    - Define in particular, maximum extent of fire possible

Defining FDS2 fire scenarios (cont.)

- Define the fire damage target set
  - FDS2 involves widespread damage within the fire area
  - We include consideration of more extensive fire spread, and hot gas layer damage
  - Any exposed target within the room may be damaged
  - Anything damaged in the corresponding FDS1 scenario for the same fire source is also included in the FDS2 target set
  - Cables protected by a moderately degraded localized cable or component fire barrier element are also damaged in FDS2
    - These targets will likely drive the overall damage time

Defining FDS3 fire scenarios

- The FDS3 scenarios depend a bit on what your finding is
  - If the finding is <u>not</u> fire confinement, you are looking for a fire in the fire area that you are inspecting that might spread into an adjacent fire area
  - If the finding <u>is</u> fire confinement, the fire could start in either area and spread to the second area

FDS3 – Fire is not fire confinement

- Remember, the inspected area is the exposing area, an adjacent area is the exposed area
- For this case, something in the fire area that you are inspecting is degraded, but it is not the fire area boundaries
- In developing FDS3 scenarios, we are presuming that a fire in the inspected compartment might be more likely to spread to an adjacent compartment
  - i.e., it might go unsuppressed for a longer time than one would normally expect

If you Step 2.2 didn't drop FDS3 you must have found:

- A somewhat wimpy barrier to at least one adjacent fire area
- Questionable or non-existent fixed suppression capability in exposing compartment
- Unique and exposed targets in at least one adjoining room
- The potential for fire that can directly challenge the fire barrier

It's not hard to develop a fire scenario out of that situation!

FDS3 – Finding is fire confinement

- In this case you have a degraded fire barrier between two fire areas
- Fire spreading through the degraded barrier IS the scenario
- Fire might go in either direction, so you may have two scenarios
  - Hopefully the screening question would eliminate fire in one direction or the other
  - e.g., if one fire area has a non-degraded fire sprinkler system, that should not be the exposing fire compartment

Defining the FDS3 scenarios

- Focus only on fire getting through the barrier(s) that did not meet the screening rules
  - If endurance rating is greater than 20 minutes, but less than 2 hours, your targets in the exposed room should be right near the barrier
  - If it's less than 20 minutes or barrier is degraded, could be anywhere
- Focus on the fire ignition sources that could challenge the fire barrier
  - High hazard
  - Near barrier
  - Direct path for fire spread through the barrier

Defining FDS3 scenarios (cont.)

- Again start with a fire ignition source
  - Pick the worst one an let it represent the whole set
  - You want one that can spread fire or fire effects into the adjacent area
    - If you applied the screening rules in step 2.2 correctly, then you should have verified at least one such source existed
- Characterize the conditions that lead to fire spread into the adjacent fire area
  - Fire spread along cable trays that penetrate the barrier is typical
  - If you have a high hazard fire source (e.g., oil-filled transformer or other large oil source), it could be a hot gas layer impacting both fire areas

Defining the FDS3 Scenarios

- Target set should be pretty obvious
- Minimum set:
  - Everything within reach of your fire source
  - Everything in the path of fire spread
  - The unique targets in the exposed fire area
- Maximum:
  - Everything in both fire areas
- Use your judgment, pick a target set

Task 2.5.2 – Fire damage state

- For each fire growth and damage scenario determine what failure of target set means in the context of plant safe shutdown response
  - What functions/systems are lost
  - What is the nature of the failure
    - loss of function, spurious operation, operable but with loss of indication....
  - What is function/system state given failure
    - System may be running
    - Valve may be open or closed...

Fire Damage State (cont.)

- Also define what <u>survives</u>
  - What functions/systems can be credited for safe shutdown
  - Assume systems are lost unless it can be verified with reasonable confidence that the system will survive
- Identify any manual actions needed to support safe shutdown
  - Focus on actions outside the main control room or complex actions within the main control room

Task 2.5.3 – Re-check SSD path

- In this task the independence of the designated SSD path is re-assessed based on the specific plant damage states
  - Plant damage state will define whether or not the SSD path is available – no more rules/questions needed
- You look at the worst case target set for each fire ignition source
  - If the SSD path survives in this worst case, the CCDP from Step 2.1 can be applied to all scenarios for that fire ignition source

Step 2.5.4 – Screening check

- In this case, the SSD path is credited, or not credited, on a fire ignition source specific basis
  - The CCDP for each ignition source is either 1.0 or $CCDP_{2.1}$ depending on results of 2.5.3
- If the SSD path is lost for at least one fire scenario for each fire ignition source, then this step is skipped
  - You can only improve screening result if you are going to credit the SSD path for at least one fire ignition source
- If you decided earlier that $CCDP_{2.1}$ applied in general, then there is no benefit to be gained

Screening check:

$$\Delta CDF_{2.5} = DF \times \sum \{(F_{source})_i \times (CCDP_{2.1})_i\}$$

*SF_i

- Sum over all fire ignition sources (i=1 to n)

Phase 2, Screening Step 5 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	$\Delta CDF_{2.5}$ screening value	
	Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	1E-5	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

Step 2.6: Damage time

- Analyze the fire growth and damage time for each fire scenario
- Separate "rules" for FDS1, 2, and 3
  - Task 2.6.1 – FDS1
  - Task 2.6.2 – FDS2
  - Task 2.6.3 – FDS3
- FDS1 and FDS2 require use of Fire Dynamics tools (plume, radiant, hot gas layer)
- Fire spread rules also apply

Task 2.6.1: FDS1

- If the target set is within the zone of influence then plume/radiant heating is enough
  - Calculate plume temperature or radiant flux level at target
  - Pick damage time off the table
- If fire is spreading into a cable tray stacks and target tray is outside the zone of influence use the cable tray fire growth rules (attachment 3)

Fire spread in a tray stack:

- If you can ignite the first tray (within zone of influence) fire can spread according to the following rules:
  - Assume first tray ignites using plume temperature and time to damage/ignition table - call this t_1
    - Guidance says use five minutes but <u>this was an error</u>
  - Second tray 4 minutes later (elapsed time t_1 + 4 min.)
  - Third tray 3 minutes later (elapsed time t_1 + 7 min.)
  - Fourth tray 2 minutes later (elapsed time t_1 + 9 min.)
  - Fifth tray 1 minute later (elapsed time t_1 + 10 min.)
  - Higher trays 1 minute later (elapsed time t_1 + 11 min.)
- Cables fail when the tray they are in ignites

Task 2.6.2 – FDS2 damage time

- Begin with the corresponding FDS1 damage time if there is one for the fire ignition source
  - FDS2 can't be any faster
- Then you need to go after the hot gas layer, and consider time to damage for degraded raceway fire barriers

FDS2 damage time (cont.)

- Targets with no barrier protection are damaged based on exposure temperature and time to damage table
- If FDS2 target sets include cables or components within a moderately degraded local fire barrier system, add in the remaining performance time given the degradation to get total damage time

FDS2 – how to do the HGL

- First decide how big a fire it takes to get a damaging HGL using FDT
- Start with the HRR of the fire ignition source
- If HGL temperature at 10 minutes is greater than or equal to the damage threshold, then ignition source alone is enough to cause damage
  - Use damage time table for the calculated temperature – analysis is done

FDS2 – doing the HGL (cont.)

- If temperature is not high enough, then fire spread is needed to create the damaging hot gas layer
  - If fire spread is not possible (no ignition targets within zone of influence), then this in not a credible FDS2 scenario – drop scenario
- If fire spread is possible (at least one ignition target within zone of influence), increase fire size in FDT until the temperature at 10 minutes reaches the damage threshold and record required HRR
  - Don't try to get too fine an answer, steps of 50 kW is fine

FDS2 – Doing the HGL (cont.)

- Now we have to figure out how far the fire has to spread to create a fire this big:
  - Cable trays are assumed to burn at 400 kW/m^2
  - Calculate square feet of tray required to get fire size needed
    - Remember – the ignition source is also burning, trays only have to make up the difference
  - Determine if there are enough trays in the area to get a fire this big
    - If no, then the FDS2 scenario is not credible
    - If yes, need to estimate time for fire to grow this far using cable tray fire spread rules

Task 2.6.3: FDS3 Scenarios

- If you have a highly degraded fire barrier as the finding, combine the two areas and treat just like FDS2
  - Inter-area barrier gets no credit
  - Credit only one fire suppression system if more than one exist (i.e. you might have had some coverage in both rooms

Task 2.6.3 – FDS3 (cont.)

- If you have a moderate degraded barrier or a finding that is not fire confinement
  - Use one scenario to estimate time for direct fire spread to and through the fire barrier
    - Estimate time for fire to spread to the barrier
  - Use one scenario (same or other) to try to get a damaging hot gas layer
    - Use FDS2 approach to estimate time to reach a damaging hot gas layer in the exposing fire area
  - Pick the shorter time from these two cases to represent all FDS3 fires
    - This is the fire growth time

Task 2.6.3 – FDS3 (cont.)

- Moderate degradation fire confinement or non-confinement finding (cont.)
  - Add in the fire endurance time allowed for the degraded barrier (e.g., 65% or 35% of nominal if barrier is degraded or full credit if not)
  - If targets in exposed fire area have raceway fire barrier protection, add in the fire endurance rating of this protection

Total fire damage time = (fire growth time) + (endurance of degraded barrier) + (endurance of raceway barriers is present in exposed compartment)

Step 2.7 – Non suppression probability analysis

- This step estimates the probability that suppression fails in the time available before our target set is damaged
- Credit is given to both fixed fire suppression and manual fire suppression
- For the fire brigade, we also need the detection time
  - Detection activates the human response including the fire fighting response

Task 2.7.1 – Fire detection time

Detection time is a race – shortest time wins:

- Fixed fire detection is estimated using FDT spreadsheet
- Other means of detection
  - Continuous fire watch – $t_{detection} = 0$
  - Roving fire watch – $t_{detection} = ½$ repeat time
  - General plant personnel:
    - $t_{detection} = 5$ minutes if continuously manned
    - $t_{detection} = 15$ if not manned
  - Maximum detection time is 15 minutes

Task 2.7.2 – Fixed fire suppression

- Activation of a fixed fire suppression system that is considered effective against the fire ignition source is assumed to end the fire scenario
  - Inspector decides on effectiveness
  - Timing needs to be determined
- Skip this task is no fixed suppression of installed system is highly degraded

Fixed suppression (cont)

- Use the fire detector tool in FDT to estimate actuation time
  - Sprinkler head is just a fancy heat detector
- Watch for cross-zoned actuation logic
  - Common for auto gas systems and deluge
  - Need to ensure both zones actuate so analyze the detector that is farthest from the fire source
- Add discharge delay time for gaseous systems
  - Minimum of 30 seconds, 1-2 minutes is typical

Fixed suppression (cont)

- If the suppression system is moderately degraded:
  - If issue is head spacing – model as found
  - If some subset of discharge heads are degraded then assume nearest head won't work, second closest head is modeled
  - If system does not provide adequate coverage to some fire ignition sources, credit only for those source that are covered

Fixed suppression (cont)

- If fixed system is manually actuated
  - Estimate the fire brigade response time
  - If fire brigade member have full decision making authority to actuate system, allow additional 2 minutes for assessment and decision making process
  - If fire brigade must get authorization (e.g., from MCR, shift supervisor, plant manager) you must assess the time required for such authorization
  - Don't forget delay time for gaseous system discharge applies even when manually actuated

Task 2.7.1 – PNS_{fixed}

- Now that you have a time to actuation and a time to damage the two are weighed to assess the value of PNS_{fixed}
  - Take the difference:
    - t_{damage} - t_{supp_fixed}
  - Refer to lookup table for PNS
- Point is that both values have uncertainty
  - If difference is small, we don't allow as much credit as when difference is large

The PNS_{fixed} lookup table

Probability of Non-suppression for Fixed Fire Suppression Systems Based on the Absolute Difference Between Damage Time and Suppression Time	
Time Delta: (t_{Damage} - $t_{Suppress}$)	**PNS_{Fixed}**
Negative Time up to 1 Minute	1.0
> 1 Minute to 2 Minutes	.95
> 2 Minutes to 4 Minutes	.80
> 4 Minutes to 6 Minutes	.5
> 6 Minutes to 8 Minutes	.25
> 8 Minutes to 10 Minutes	.1
> 10 Minutes	0.0

Task 2.7.2 – Manual suppression

- Manual suppression is based on fire duration curves
  - Analysis of historical event
- Several curves for various fire ignition sources
  - Pick the curve that fits you ignition source
  - Example: If fire spreads from a panel to cable trays, the ignition source was the panel, use the electrical fire curve

Manual suppression

- "Curves" are available in three forms
  - Graphical
  - Lookup table
  - Equation:

$$PNS_{manual} = \exp[-\lambda \times t]$$

  - Values of constant are in lookup table

Task 2.7.4: Final combined PNS

For water-based systems:

$$PNS_{scenario} = (0.98 \times PNS_{fixed\text{-}scenario}) + (0.02 \times PNS_{manual\text{-}scenario})$$

For Gaseous systems:

$$PNS_{scenario} = (0.95 \times PNS_{fixed\text{-}scenario}) + (0.05 \times PNS_{manual\text{-}scenario})$$

** $PNS_{scenario} \geq PNS_{manual\text{-}scenario}$

For moderate degradation needs to be adjusted if there's a degradation in the gas systems soak time capability (Must depend on manual suppression) Gas system "buys" some extra time for brigade.

Step 2.7.5 – screening check

- We now have scenario specific PNS
- Combine with duration factor, scenario specific frequency, scenario specific credit for SSD path to get new screening result
- Screen to green if change in CDF is less than 1E-6

Step 2.8 – SSD / CCDP analysis

- I won't go into detail
  - Task 2.8.1 – select plant initiating event worksheet
  - Task 2.8.2 – identify credited systems and fucntions
  - Task 2.8.3 – identify ex-control room actions
  - Task 2.8.4 – assess failure probability for manual actions
  - Task 2.8.5 – assess CCDP

Step 2.9 – final quantification

- In this step you take all your best information that now includes a specific CCDP for each individual scenario
- Run them through the risk equation
- Sum scenarios
- Assign a preliminary color

Module 6A – High energy arcing faults in electrical distribution and switching equipment

Arcing faults

- Arcing faults are not your typical fire
  - High energy discharge at the outset – essentially a small explosive discharge
  - Usually started due to either phase-to-phase or phase-to-ground shorts and arcing
    - Often following a maintenance activity
  - Electrical energy is converted to heat – lots of heat – for a very short time
  - Copper electrical contacts get vaporized
  - Arcs can burn through steel in very short order

Our prototypical event

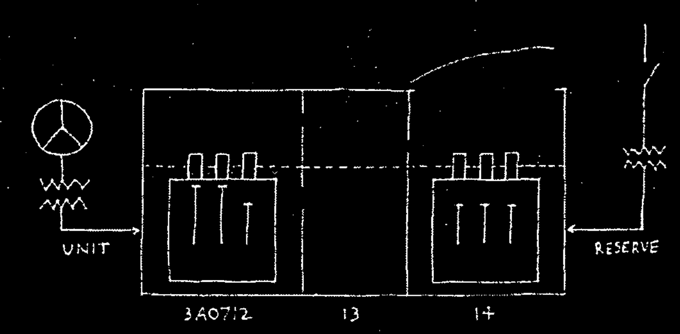
- San Onofre, Unit 3, Feb. 3, 2001
  - Discussion based largely on presentation by Bob Richter at 10/01 NEI FP Forum
- Picture at right shows panel after the fire
  - Some damage was done during fire fighting (large mass bottom center pulled free of panel)
  - Note extensive burn marks

So what happened

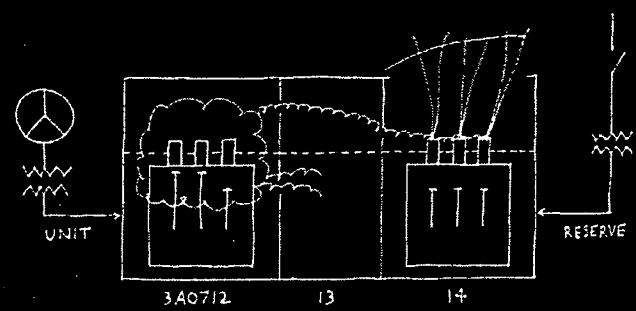
- While "racking in" one of the two main input breakers for one train of switchgear, the "stabs" for one phase did not make proper/full contact
- Arcing vaporized the copper contacts
- Arcing burned a hole through the side of the panel
- The ionized smoke and copper plasma propagated to the second main input breaker in an adjoining panel
- Arcing in the second breaker cubical caused a catastrophic arcing fault and explosion

What happened (cont.)

- The door to the second panel was blown open
- The ensuing fire caused loss of overhead cable trays, adjoining switchgear breaker cubicles, and panels located across the aisle from the initially faulting switchgear



Sketch 1: C Contact arcing and Phase to Phase to ground arcing in Cabinet 3A0712.



Sketch 2: Ionized gas transits from 12 to 14 and into 13. Conductive bridge across 14 Reserve stabs causes flash.

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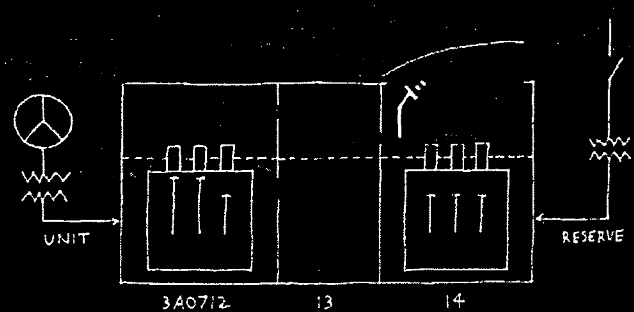

Sketch 3: Main Generator continues to feed A-B-C-Ground arcing in 12. A-phase arcs to ground in 14 causing Differential trip.

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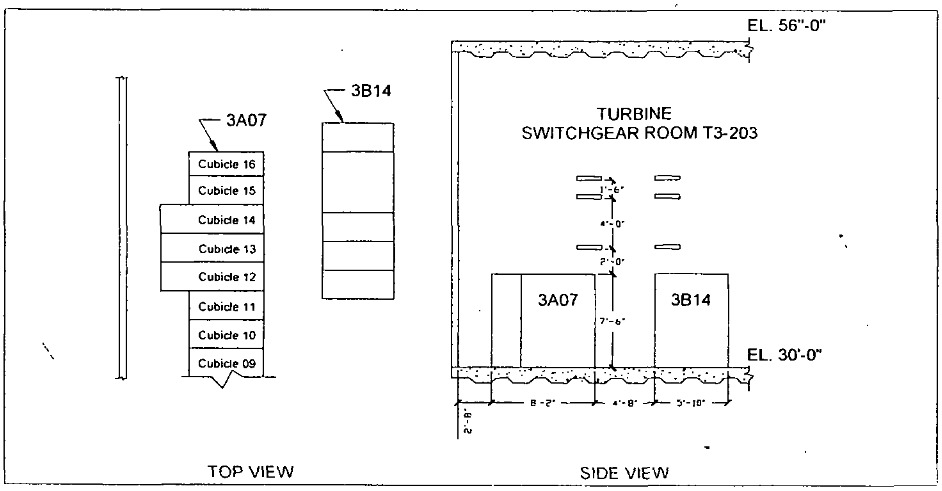
Plant assessment of causes

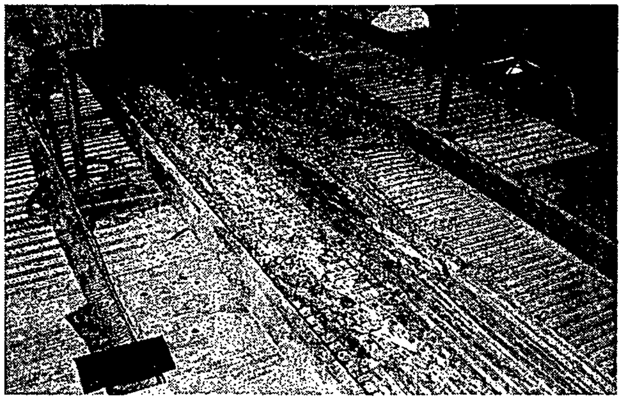
- Most Likely Causes For A07 Fire
  - 1. Mis-positioning of stud to pushrod interface among the 3 phases.
  - 2. Improper bridge pivot joint pressure
  - 3. Arc chute degradation leading to foreign material between breaker contacts

U3 AO7 30' Switchgear Room Bus & Cable Tray Arrangement

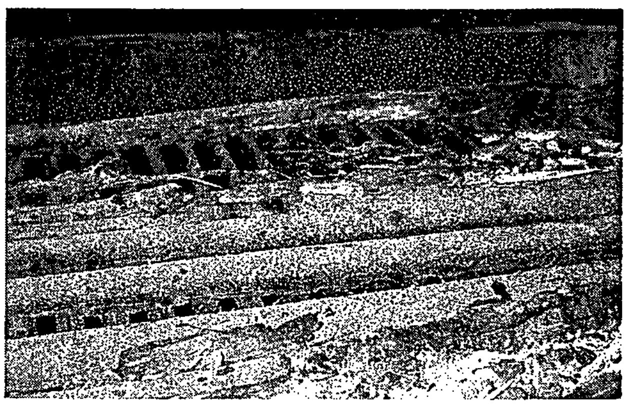


U3 AO7 30' Switchgear Room Cable Trays

Cable
Tray
Directly
Above
Bus
A07



U3 AO7 30' Switchgear Room Cable Trays



Cable Tray Directly Above Bus A07

U3 AO7 30' Switchgear Room Cable Trays

Second Level Cable Tray above Bus A07

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U3 AO7 30' Switchgear Room Cable Trays

Second Level Cable Tray

Above Bus A07

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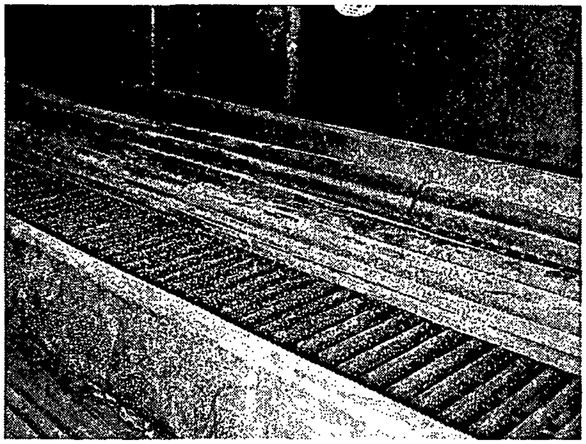
U3 AO7 30' Switchgear Room Cable Trays



Third Level Cable Tray Above Bus A07

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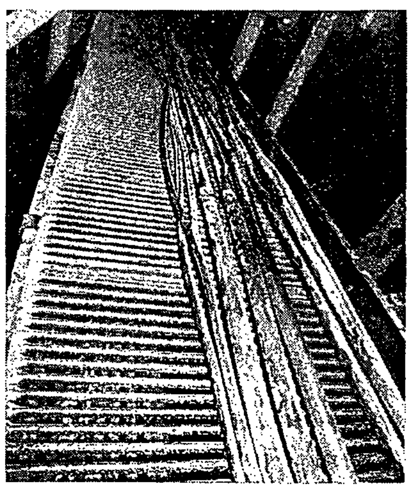
U3 AO7 30' Switchgear Room Cable Trays

Third Level
Cable Tray
above Bus A07



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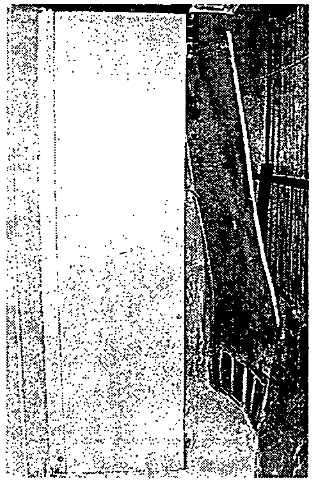
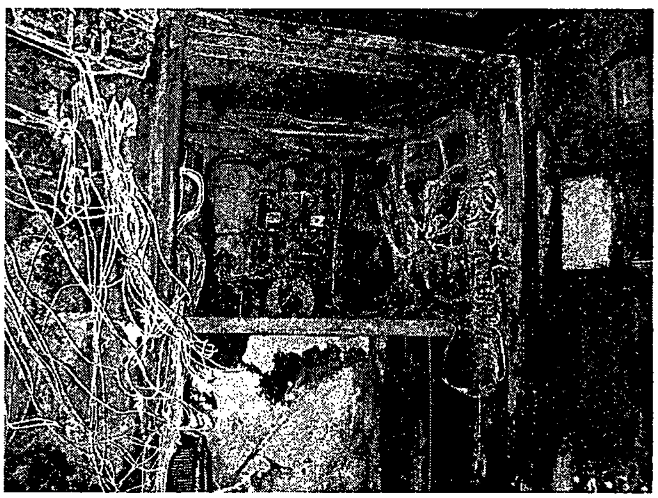
Effects of the initial pressure spike

- Back door of Cubicle 14 blown off by high pressure pulse.
- Soot pattern shows that the pulse originated in the lower right corner at the Phase A input.



Module 6A Arcing Faults 17



- Upper section of panel

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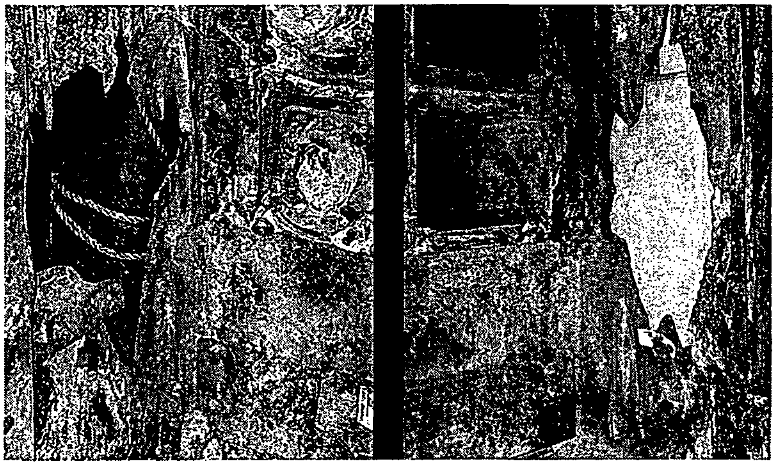

- Holes in the sides of the 3A0712 cubicle from the arcing. Left A phase to ground, right C phase to ground.

Fire characterization rules for SDP

- We will do arcing faults for certain types of equipment
  - 480V and up only
  - Switchgear, breakers, motor control centers
  - Frequency is given in worksheet for applicable fire ignition sources
  - The frequency is per panel section just like any other fire frequency

Initial energetic release

- Assume that the door(s) to the faulting cubicle are blown open (creates an open panel fire)
- Assume that equipment in the first neighboring cubicle/panel in each direction will also be damaged
  - An empty panel section will not stop propagation of initial fault (as shown by the San Onofre event)
  - Go to the first occupied section
- Initial fault will trip out next higher level of circuit protection
  - A fault in one switchgear cubicle will cause a loss of power to the entire bank because the input power will trip offline
  - Not recoverable (until the initial fault is isolated)

Enduring fire

- The enduring fire is treated using only one fire size for this case – 200 kW
  - Severity factor is 1
- If there are any trays above the faulting panel, the first/lowest tray in each stack will be ignited at time 0 so long as it is within 5 feet of the top of the panel
  - Propagate fire through additional trays using general rules for cable tray fire growth
- Any combustible materials within 3 feet horizontally of the front or rear surface of the panel will ignite at time 0
  - Damage targets in the same region fail at time zero

Module 6B – Cable tray fires

Fires in cable tray stacks

- Fire spread is rules-based
- Two specific pieces of info used:
  - Fires will burn at a rate of 400 kW per square meter of cable tray
  - Fires will propagate horizontally at a rate of 10 feet per hour
- We don't distinguish between cable types

Exposure fires and ignition of the first tray

- First decide if you can ignite the first tray
  - Is first tray within zone of influence?
  - Yes says fire can spread to the trays
- Us FDT to calculate plume temperature at location of the first tray
  - Use distance to tray bottom
- Assume first tray ignites using plume temperature and time to damage/ignition table - call this t1
  - Guidance says use five minutes but this was an error

Spread to subsequent trays

- Additional trays are ignited as follows:
  - Second tray 4 minutes later (elapsed time t1 + 4 min.)
  - Third tray 3 minutes later (elapsed time t1 + 7 min.)
  - Fourth tray 2 minutes later (elapsed time t1 + 9 min.)
  - Fifth tray 1 minute later (elapsed time t1 + 10 min.)
  - Higher trays 1 minute later (elapsed time t1 + 11 min.)
- Cables fail when the tray they are in ignites

More than one stack?

- Ignite lowest tray in adjacent stack at time that third tray in initial stack ignites
- Fire spread in the second stack then follows the tray by tray spread of the initial stack, always lagging by two trays until entire stack is involved

Self-ignited cable fires

- Fire starts within a cable tray due to a fault in the cables
- Only applies to cables that do not meet IEEE-383 low flame spread standard
  - Most industry cables meet this standard
  - Watch for the PE/PVC cables
- Meeting the flame spread standard is enough in this case – don't need all the additional EQ environmental exposure stuff

Self-ignited cable fires continued

- Find: of all the places the fire might ignite, what are the critical locations
  - The place or set of places where the fire will do the worst damage
- We apply a weighting factor to fire frequency to reflect percentage of trays represented by the critical location
  - WF = (Linear feet of tray in critical location) / (Total linear feet of tray in the room)
  - ESTIMATE – don't pull out the tape measure

Self-ignited cable fires

- From there the same fire spread rules apply as for other fire scenarios

Module 6C – Reverse engineering the hot gas layer

Hot gas layer

- FDS2 involves hot gas layer damage
- In few cases will any single fire ignition source burning by itself be enough to create a hot gas layer
  - Check your case, but you need a big fire in a small room
  - Exceptions might be large oil fires, oil filled transformers
- That usually means the fire has to spread to create a damaging hot gas layer
- Fire spread takes time, and the question boils down to how much time?

HGL (cont.)

- We work this problem backwards
  - Use the FDT hot gas layer tool to estimate the fire size required to cause a damaging hot gas layer
  - Figure out how much fire spread is need to create a fire that big
  - Figure out how much time is needed to spread fire that far

HGL (cont.)

- First decide how big a fire it takes to get a damaging HGL using FDT
- Start with the HRR of the fire ignition source
- If HGL temperature at 10 minutes is greater than or equal to the damage threshold, then ignition source alone is enough to cause damage
  - Use damage time table for the calculated temperature
  - Analysis is done

HGL (cont.)

- If temperature is not high enough, then fire spread is needed to create the damaging hot gas layer
  - If fire spread is not possible (no ignition targets within zone of influence), then this in not a credible FDS2 scenario – drop scenario
- If fire spread is possible (at least one ignition target within zone of influence), increase fire size in FDT until the temperature at 10 minutes reaches the damage threshold and record required HRR
  - Don't try to get too fine an answer, steps of 50 kW is fine

HGL (cont.)

- Now we have to figure out how far the fire has to spread to create a fire this big:
  - You will look for a fire spreading into cable trays
  - Cable trays are assumed to burn at 400 kW/m^2
  - Calculate square meters (or square feet) of tray required to get fire size needed
    - Remember – the ignition source is also burning, trays only have to make up the difference
  - Determine if there are enough trays in the area to get a fire this big
    - If no, then the FDS2 scenario is not credible
    - If yes, need to estimate time for fire to grow this far using cable tray fire spread rules

HGL (cont.)

- Once we have extent of fire needed, we have to reverse engineer the cable tray spread model
  - Time to ignite first tray come from plume temperature and time to damage/ignition – FDS1
  - Remaining trays propagate as normal:
    - First tray – elapsed time 5 min.
    - Two trays – elapsed time 9 min.
    - Three trays – elapsed time 12 min.
    - Four trays – elapsed time 14 min
    - Five trays – elapsed time 15 min.
    - Rest of stack – elapsed time 16 min.

HGL (cont.)

- This is one we will probably work on a bit more
- Should be easy to make this a bit more of a lookup
- Given following information its cookbook:
  - How many trays in the stack
  - How many stacks
  - Time to first tray ignition
  - Width of trays

SDP Appendix F Training

Tabletop example #1:

Background:

The licensee's fire protection program included a commitment to install a Halon fire extinguishing system in the cable spreading room. The system was to achieve a design concentration between 5-7% and a with minimum hold time of 15 minutes. Licensee testing documents show the system could achieve a delivered Halon concentration of 6% and hold that concentration for 4 minutes. Based on this result, the licensee showed by calculation that at about 10 minutes the concentration would drop to below the 5% design goal.

Finding:

The Halon system, as installed, fails to meet the design requirements and cannot maintain adequate concentration to assure the extinguishment of a deep-seated cable fire.

Other relevant facts:

The system design configuration has not changed since originally installed in 1981. Halon actuation is controlled by a cross-zone smoke detection system. The two zones are configured with alternating detectors spaced in a 10 foot grid.

The cable spreading room contains cables for all trains of safe shutdown systems. The safe shutdown path for this fire area involves use of critical functions from one equipment train. The cables associated with this safe shutdown path are protected by a 1-hour fire wrap. The fire wrap is not degraded.

The fire area is provided with automatic fire detection (cross-zone smoke detectors). The Halon system is the only installed fixed fire suppression system. Fire extinguishers and manual hose stations are available to support manual fire fighting.

The fire area is a limited access / access controlled space. Hot work is disallowed during at power operations and transient combustibles are strictly controlled. No violations of these measures are evident.

In addition to the cables, the following electrical components are also identified in the fire area:

- 1 bank of electrical switchgear containing 4 individual panels
- 2 dry transformers

A stack of 6 cable trays is routed above and parallel to the switchgear panels. The lowest tray is approximately 18 inches above the tops of the switchgear panels. The height of the trays above the panel is consistent for all panels.

Thermoplastic cables

Similarly, a stack of 5 cable trays is routed above each of the two transformers. The lowest tray is approximately 60 inches above the top of each transformer.

In other portions of the fire area, the lowest cable trays are all located approximately 8 feet above floor level. Such trays exist in several locations.

The boundaries of the fire area are rated at all rated at a minimum of two hours fire endurance. No deficiencies are noted.

Room dimensions are 50'x35'x20'(H).

Assume that a safe shutdown path is routed in the adjacent swtichgear fire area. The unavailability is estimated at 0.1.

EXAMPLE #2

Location: Relay room

Finding: Three cables, each of which could result in opening of one PORV, have been identified as unprotected in the fire area. Spurious operation of more than one PORV would compromise the designated SSD path for this fire area due to an inadequate makeup capacity. (The licensee analysis only considered the potential opening of one PORV at a time. Based on the guidance of the RIS, the potential for spurious operations arising from two cables concurrently will be considered.)

Other information:

Cables are thermoplastic jacketed, thermoset insulated armored cables. Each cable is associated with one PORV circuit. Analysis has verified that spurious operation is possible give conductor-to-conductor hot shorts within each of these cables. The cables have been certified as low fire spread based on the IEEE 383 test.

Cables are housed in 24 inch wide cable trays routed in two stacks. One stack of eight trays is mounted directly to the eastern wall. The second stack of two trays is mounted to the western wall. The lowest tray in each stack is 6 feet above the floor. The exact location of the cables of interest is not known beyond the fact that ther are in the fire area.

The room is provided with fixed smoke detection on a 15 foot grid.

Room Dimensions: 15'x20'x12'(H)

All boundaries are three-hour rated and no degradations are noted.

Fixed fire suppression: none.

SSD Path: Transfer of plant control to a dedicated shutdown facility. This path compromised if two or more PORVs open spuriously.

Fixed fire ignition sources: There are 10 general control/relay panels. Eight are located in a bank parallel to the eastern wall at a distance of about 7 feet from the wall. The other two are located as a pair about 3 feet from the western wall. Each panel measures 8 feet tall.

Attachment 1

Part 1: Fire Protection SDP Phase 1 Worksheet

Facility: Example #1

Performance Issue: Halon Broke (Degraded) Forever (> 30 days)

Step 1.1

Assign a finding category:

- O Cold Shutdown
- O Fire Prevention and Administrative Controls
- ☒ Fixed Fire Protection Systems
- O Fire Confinement
- O Localized Cable or Component Protection
- O Post-fire SSD

Basis for selection/comments:

Step 1.2

Assign a degradation rating:

- O Low
- ● Moderate
- O Moderate A (applies only to Fire Confinement and Localized Cable or Component Protection Issues)
- O Moderate B (applies only to Fire Confinement and Localized Cable or Component Protection Issues)
- O High

Basis for selection/comments: App F Att 2

Step 1.3

Task 1.3.1: Qualitative Screening for All Finding Categories

Question 1: Was the finding assigned a Low degradation rating?

- O Yes – Screens to Green, no further analysis required
- O No – Continue to next question

Question 2: Does the finding only affect ability to reach and maintain cold shutdown conditions?

- O Yes - Screen to Green, no further analysis required
- O No – Continue to Step 1.4, unless the finding category was "Fire Confinement," in which case, proceed to Task 1.3.2

Task 1.3.2: Supplemental Screening for Fire Confinement Findings

If the finding category assigned in Step 1.1 is "Fire Confinement" and the degradation rating assigned in Step 1.2 is "Moderate," perform a supplemental ~~qualitative~~ screening check based on the following questions. Otherwise, proceed to Step 1.4.

N/A

Question 1: Will the barrier in its degraded condition provide a 2-hour or greater fire endurance rating?

- O Yes – Screens to Green, no further analysis required
- O No – Continue to next question

Question 2: Is there a non-degraded automatic gaseous room-flooding fire suppression system in the exposing compartment?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 3: Is there a non-degraded or no more than moderately degraded automatic full area water-based fire suppression system in the exposing compartment?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 4: Can it be determined that the exposed compartment contain no potential damage targets that are unique from those in the exposing fire area (damage targets may include post-fire safe shutdown components or other plant components whose loss might lead to a demand for safe shutdown (e.g., a plant trip))?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 5: Are all potential damage targets in the exposed fire area (as described in question 4) provided with passive fire barrier protection with no more than a moderate degradation that will provide a minimum of 20 minutes fire endurance?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 6: Is a non-degraded or no more than moderately degraded partial-coverage automatic water based fire suppression system installed in the exposing compartment and are all the fixed or *in-situ* fire ignition sources included within the zone of coverage for this system?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 7: Does the degraded barrier provide a minimum of 20 minutes fire endurance protection and are the fixed or *in situ* fire ignition sources and combustible or flammable materials positioned such that, even considering fire spread to secondary combustibles, the degraded barrier or barrier element will not be subject to direct flame impingement?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to Step 1.4

Step 1.4 - Initial Quantitative Screening:

Task 1.4.1 - Assign a duration factor (DF):

O	< 3 Days	(0.01)
O	3 – 30 Days	(0.10)
●	> 30 Days	(1.00)

Task 1.4.2 - Estimate the fire frequency for the fire area (from Generic Fire Area Fire Frequency Table):

$f_A =$

AREA	F_{AREA}
CSR	6E-3
(ΣF_{AREA}) =	6E-3

Task 1.4.3 – Screening Assessment:

$\Delta CDF_{1.4} = (\Sigma F_{AREA}) \times DF =$ 6E-3

Phase 1 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	**Δ CDF1.4 Screening Value**	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	1E-4	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

O $\Delta CDF_{1.4}$ is lower than the corresponding value in the table above - the finding screens to Green and the analysis is complete (no Phase 2 analysis is required)

● $\Delta CDF_{1.4}$ is greater than or equal to the corresponding value in the table above - the finding does not screen to Green, and the analysis continues to Phase 2

Part 2: Fire Protection SDP Phase 2 Worksheet

Facility: Drojac

Results from FP SDP Phase 1 Review: $\Delta CDF_{1.4} = (\Sigma F_{AREA}) \times DF =$ 6E-3

Request and review the following licensee documents:

- The fire hazards analysis for the fire areas to be evaluated
- The post-fire safe shutdown analysis for the fire areas to be evaluated
- The licensee's lists of required and associated circuits
- Post-fire operating procedures applicable to the fire areas to be assessed
- Documentation for any USNRC approved deviations or exemptions relevant to the fire areas to be assessed.

Step 2.1 - Independent SSD Path First Screening Assessment:

Task 2.1.1 - Identify the Designated Post-fire SSD Path:
The identified SSD path must meet the following criteria in order to be considered at this stage of the Phase 2 analysis:

- The SSD path must be identified as the designated post-fire SSD path in the plant's fire protection program.
- The SSD path must be supported by a documented post-fire SSD analysis consistent with regulatory requirements.
- Use of the SSD path must be documented and included in the plant operating procedures.

Need info

SSD Path: Train protected by 1 hr Fire Wrap

Task 2.1.2 - Assess the Unavailability Factor for the Identified SSD Path:

$CCDP_{2.1}$ = (SSD Unavailability Factor) = 0.1 (Credited as either 1.0, 0.1, or 0.01)

Basis for selection/comments:

If $CCDP_{2.1}$ = 1.0, proceed to Step 2.2.

Task 2.1.3 - Assess Independence of the Identified SSD Path:

Criteria satisfied: $CCDP_{2.1}$ = Value assigned in Task 2.1.2 0.1

Criteria not satisfied: ~~$CCDP_{2.1}$ = 1.0. Proceed to Step 2.2~~

Basis for criteria not met/comments:

Task 2.1.4 - Screening Check:

$\Delta CDF_{2.1}$ = DF X (ΣF_{Area}) X $CCDP_{2.1}$ = 6E-4

1 6E-3 0.1

Phase 2 Screening Level 1 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	Δ $CDF_{2.1}$ Screening Value	
	Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	1E-4	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

O Δ $CDF_{2.1}$ is lower than the corresponding value in the table above - the finding screens to Green and the analysis is complete.

☒ Δ $CDF_{2.1}$ is greater than or equal to the corresponding value in the table above. The analysis continues to Step 2.2

Step 2.2 - Fire Damage State Determination:

Task 2.2.1 - Initial FDS Assignment

(Check all that apply)

☒ FDS1

☒ FDS2

☒ FDS3

Basis for selection(s)/FDS3 assessment/comments: See Table 2.2.1

Task 2.2.2 - Screening Assessment for FDS3 Scenarios

If the finding category assigned in Step 1.1 is "Fire Confinement," retain the FDS3 scenarios and continue the analysis with Step 2.3. For all other finding categories, conduct a screening check for the FDS3 scenarios based on the following questions:

Question 1: Does the fire barrier separating the exposed and the exposing fire areas have a non-degraded 2-hour or greater fire endurance rating?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 2: Is there a non-degraded automatic gaseous room-flooding fire suppression system either in the exposed or in the exposing fire area?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 3: Is there a non-degraded or no more than moderately degraded automatic full area water-based fire suppression system either in the exposed or in the exposing fire area?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 4: Can it be determined that the exposed compartment contain no potential damage targets that are unique from those in the exposing fire area (damage targets may include post-fire safe shutdown components or other plant components whose loss might lead to a demand for safe shutdown (e.g., a plant trip))?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 5: If the exposed fire area does contain post-fire safe shutdown components or components whose fire-induced failure might lead to a demand for safe shutdown, are all such components located at least 20 feet from the intervening fire barrier, and/or provided with passive fire protection with a minimum one-hour fire endurance rating?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 6: Is a partial-coverage automatic water based fire suppression system installed in the exposing fire area and are all the fixed or *in-situ* fire ignition sources included within the zone of coverage for this system?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 7: Does the fire barrier provide a minimum of 20 minutes fire endurance protection and are the fixed or *in situ* fire ignition sources and combustible or flammable materials in the exposing fire area positioned such that, even considering fire spread to secondary combustibles, the barrier will not be subject to direct flame impingement?

- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Retain the FDS3 scenarios and continue the analysis with Step 2.3:

Step 2.3 - Fire Scenario Identification and Ignition Source Screening:

Task 2.3.1 - Identify and Count Fire Ignition Sources

(Use the worksheet on the following pages)

Fire Frequency Evaluation Worksheet						
Nuclear Power Plant:						
Description of the Plant Area of Interest:			CSR			
Identifier/Designator of the Plant Area:						
Ignition Source Bin		# of Items or Level	Associated Frequency	Comments	Base Frequency	Associated HHRs
Cables - Non-Qualified (Low/Medium/High)		H	1.4E-3		1.6E-05/4.8E-05/ 1.4E-03	See Attachment 6
Electrical Cabinets:						
Switchgear Cabinets	Thermal	4	2.2E-4		5.5E-05	70kW, 200kW
	High Energy	4	1.88E-5		4.7E-06	See Attachment 6
General Electrical Cabinets					6.0E-05	70kW, 200kW
General Control Cabinets					6.0E-05	200kW, 650kW
MCR and MCR Service Cabinets					4.8E-03	200kW, 650kW
Electric Motors:						
Electric Motors (<100HP)					6.5E-04	70kW, 200kW
Electric Motors (≥ 100HP)					6.5E-04	200kW, 650kW
Generators - General:						
Diesel Generators					5.6E-03	70kW, 200kW
Gas Turbine Generators					3.2E-04	70kW, 200kW
Reactor Protection System MG Sets					6.7E-04	70kW, 200kW
Total from Sheet 1:			1.64E-3			
Total from Sheet 2:		2.7E-4	~~2.2E-4~~			
Total from Sheet 3:			0			
Total for Area of Interest:			~~1.86E-3~~ ~2E-3			

Ignition Source Bin		# of Items or Level	Associated Frequency	Comments	Base Frequency	Associated HHRs
Hydrogen Sources:						
Hydrogen Recombiner (BWR)					5.5E-03	See Attachment 6
Hydrogen Storage Tanks (Yes / No)					6.5E-04	See Attachment 6
Hydrogen Piping - Charged (Yes / No)					9.7E-04	See Attachment 6
Hot Work (Low/Medium/High)					2.3E-05/6.9E-05/ 6.9E-04	See Attachment 6
Main Turbine- Generator Set:						
T/G Exciter Fire (Yes / No)					1.4E-03	70kW, 200kW
T/G Oil Fires (Yes / No)					1.7E-03	See Attachment 6
T/G Hygrogen Fire (Yes / No)					1.4E-03	See Attachment 6
Miscellaneous Components:						
Air Compressors (<100HP)	Motor Fire				1.5E-04	70kW, 200kW
	Oil Fire				1.0E-04	See Attachment 6
Air Compressors (≥ 100HP)	Motor Fire				1.5E-04	200kW, 650kW
	Oil Fire				1.0E-04	See Attachment 6
Battery Banks					1.9E-04	70kW, 200kW
Boiler Heating Units					9.7E-04	See Attachment 6
Bus Bars	(Energetic Faults)				4.7E-06	See Attachment 6
Electric Dryers					5.4E-04	70kW, 200kW
Ventilation Subsystems					6.0E-05	70kW, 200kW
Total from Sheet 2:			0			

Ignition Source Bin		# of Items or Level	Associated Frequency	Comments	Base Frequency	Associated HHRs
Pumps:						
Reactor Coolant Pump (PWR)	Motor Fire				6.2E-04	200kW, 600kW
	Oil Fire				3.1E-04	See Attachment 6
Reactor Feed Pump (BWR)	Motor Fire				8.4E-05	200kW, 650kW
	Oil Fire				8.4E-04	See Attachment 6
Main Feedwater Pumps	Motor Fire				2.7E-04	200kW, 650kW
	Oil Fire				2.7E-03	See Attachment 6
Other Pumps (<100HP)	Motor Fire				5.0E-05	70kW, 200kW
	Oil Fire				5.0E-05	See Attachment 6
Other Pumps (≥ 100HP)	Motor Fire				5.0E-05	200kW, 650kW
	Oil Fire				5.0E-05	See Attachment 6
Transformers:						
Transformers - Outdoor/Yard	(Energetic Faults)				4.2E-03	650kW, 10MW
Transformers - Indoor Dry	(Energetic Faults)	2	2.2E-4		1.1E-04	70kW, 200kW
Transformers - Indoor Oil-Filled	(Energetic Faults)				1.1E-04	650kW, 2MW
Transients (Low/Medium/High)		L	5.5E-5		5.5E-05/1.7E-04/ 1.7E-03	70kW, 200kW or See Attachment 6
Total from Sheet 3:			~~2.2E-4~~ 2.7E-4			

Task 2.3.2 - Characterize Fire Ignition Sources: and
Task 2.3.3 - Identify Nearest and Most Vulnerable Ignition or Damage Targets:
Task 2.3.4 - Fire Ignition Source Screening: (Using NUREG-1805 or Zone of Influence Chart)

Source #	Source - Description/Location	Number of Sources	Expected HRR / High Confidence HRR	Identify Nearest Target	Target Distance (ft) H	Target Distance (ft) R	Critical Distance (ft) H	Critical Distance (ft) R	Number of Sources Remaining (i.e., Did not screen out)
1	Switchgear Large Electrical	4	70 kW	Tray #1	2.5		4.5	2.1	Keep
			200kW	Tray #1	2.5		6.6	3.5	Keep
2	Large Electrical Transformer	2	70 kW		5.0		4.5	2.1	Keep
			200KW		5.0		6.6	3.5	Keep
3	Cables	DROP							
4	Transients	DROP							

Fire Area Dimensions: Width(ft) ________ Depth (ft) ________ Height (ft) ________

Highest HRR Results in Hot Gas Layer: ○ Yes ○ No

(Attach printouts of any spreadsheet calculations utilized from NUREG-1805.)

Xfmr Screens out for Expected HRR

Task 2.3.5 - Finding Screening Check:

- ○ All identified fire ignition sources screened out in Task 2.3.4. The Phase 2 analysis is complete and the finding should be assigned a Green significance determination rating. Subsequent analysis tasks and steps need not be completed.

- ● One or more of the fire ignition sources is retained, even if only at the higher severity value. The analysis continues to Step 2.4.

Step 2.4 - Fire Frequency for Unscreened Fire Sources:

Task 2.4.1 - Nominal Fire Frequency Estimation:
Task 2.4.2 - Findings Quantified Based on Increase in Fire Frequency: and
Task 2.4.3 - Credit for Compensatory Measures that Reduce Fire Frequency:

(Use the worksheet on the following page)

Source #	Unscreened Fire Source at Specified HRR Value	Number of Sources Remaining from 2.3.4	Base Fire Frequency	Severity Factor (SF)	Adjustment Factor for Fire Frequency Increase or Compensatory Measures or Weighting Factors * ($AF_{i2.4}$)	Base Frequency Increase **	Revised Fire Frequency for Unscreened Source
	Switchgear	4	70kW 5.5E-5	0.9			
	Switchgear	4	200kW 5.5E-5	0.1			
	Switchgear	4	Energetic 4.7E-6	1.0			
	Xfmr	2	1.1E-4	0.1			
Total ($\Sigma F_{Source\ i} \times SF_i \times \Pi AF_{i2.4}$):							2.1E-2

Table title: Step 2.4 - Fire Frequency for Unscreened Fire Sources

* Adjustment Factor for Fire Frequency Increase applies only to "Fire Prevention and Administrative Controls" findings (see discussion under Task 2.4.2). Credit for Compensatory Measures applies only to transient or hot work sources (see discussion under Task 2.4.3). Weighting factors apply only to transient and hot work sources (see Attachment 6).

** Base frequency increases apply only to "Fire Prevention and Administrative Controls" findings within the combustible controls programs (see discussion under Task 2.4.2).

Assumptions/Comments/Remarks:

$$\Delta CDF_{2.4} = (\Sigma F_{Source\ i} \times SF_i \times \Pi AF_{i2.4}) \times DF \times CCDP_{2.1}$$

= 2.1E-2 1 0.1 = 2.1E-3

Task 2.4.4 - Finding Screening Check:
Compare the updated change in CDF value, given the newly calculated fire frequency reflecting only the unscreened fire sources, with the values in the table below.

Phase 2, Screening Step 4 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	**$\Delta CDF_{2.4}$ screening value**	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	1E-5	
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	1E-6
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

[1] This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier.

O Δ $CDF_{2.4}$ is lower than the corresponding value in the table above - the finding screens to Green and the analysis is complete.

● Δ $CDF_{2.4}$ is greater than or equal to the corresponding value in the table above. The analysis continues to Step 2.5

Step 2.5 - Definition of Specific Fire Scenarios and Independent SSD Path Second Screening Assessment:

Task 2.5.1 - Identify Specific Fire Growth and Damage Scenarios:
Task 2.5.2 - Identify Specific Plant Damage State Scenarios: and
Task 2.5.3 - Assess Fire Scenario-Specific SSD Path Independence:

(Use the worksheet on the following page)

FDS1 Burns Train A (Loss of Train A)

FDS2 Need 1 hr Fire to Damage Train B

Source #	Unscreened Fire Source at Specified HRR Value	FDS State	Plant Damage State Scenarios	Scenario-Specific SSD Path Independence (Yes / No)	Worst Case FDS (√)	Revised Fire Frequency for Unscreened Fire Sources (from Step 2.4)	CCDPi (from task 2.1.2 or 2.1.3)	Revised Fire Frequency x CCDPi
Total ($\Sigma F_{Source\,i}$ X SF_i X $\Pi AF_{i\,2.4}$ X $CCDP_{i\,2.1}$):								

Attach printouts of any spreadsheet calculations utilized from NUREG-1805.

Assumptions/Comments/Remarks:____

____

____

$$\Delta CDF_{2.5} = (\Sigma F_{Source\,i} \text{ X } SF_i \text{ X } \Pi AF_{i\,2.4} \text{ X } CCDP_{i\,2.1}) \text{ X } DF$$

= ____

Task 2.5.4 - Screening Check:

If the SSD path cannot be credited for any of the identified fire ignition sources given its worst-case damage state, then Step 2.5.4 is complete, and the analysis continues with Step 2.6.

If the SSD path can be credited for at least one fire ignition source, then the screening check is performed based on the values and criteria provided in the table below:

Phase 2, Screening Step 5 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	$\Delta CDF_{2.5}$ screening value	
	Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	1E-5	
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	1E-6
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

[1] This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier.

- O The value of $\Delta CDF_{2.5}$ is lower than the corresponding value in the table above. The finding Screens to Green, and the analysis is complete.
- O The value of $\Delta CDF_{2.5}$ exceeds the corresponding value in the table above. The analysis continues to Step 2.6.

Step 2.6 -
Fire Growth and Damage Time Analysis:

and

Step 2.7 -
Non-Suppression Probability Analysis

Attach printouts of any spreadsheet calculations utilized from NUREG-1805.

(All times in nearest whole minute - damage times rounded down, detection/suppression and manual response times up)

Source #	Unscreened Fire Damage State Scenarios	Time to Damage	Detection Time	(T_{Damage} - $T_{Detection}$)	Fixed Suppression Actuation Time	(T_{Damage} - $T_{Suppression}$)

Assumptions/Comments/Remarks:____

____

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Task 2.7.4 - Probability of Non-Suppression:

Source #	Unscreened Fire Damage State Scenarios	PNS_{fixed}	PNS_{manual}	$PNS_{scenario\ i}$

Assumptions/Comments/Remarks:____

Task 2.7.5 - Finding Screening Check:
The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

Source #	Unscreened Fire Damage State Scenarios$_i$	Revised Fire Frequency x CCDP$_i$ ($F_{Source\ i}$ X SF_i X $\Pi AF_{i\ 2.4}$ X $CCDP_{i\ 2.1}$)	PNS_i	Revised Fire Frequency
Total ($\Sigma\ F_{Source\ i}$ x SF_i x $\Pi AF_{i\ 2.4}$ x $CCDP_{i\ 2.1}$ x $PNS_{scenario\ i}$):				

$$\Delta CDF_{2.7} = DF \times (\Sigma\ F_{Source\ i} \times SF_i \times \Pi AF_{i\ 2.4} \times CCDP_{i\ 2.1} \times PNS_{scenario\ i})$$

$\Delta CDF_{2.7}$ = ______________________________

If $\Delta CDF_{2.7}$ is less than or equal to 1E-6, then the finding screens to Green, and the analysis is complete. If $\Delta CDF_{2.7}$ is greater than 1E-6, then the analysis continues to Step 2.8.

Step 2.8 - Plant Safe Shutdown Response Analysis

Using the appropriate plant initiating event worksheet(s) from the plant risk-informed inspection notebook, carry out the guidance provided under Step 2.8 of Appendix F, to account for the plant SSD response and required human recovery actions in order to quantify the factor "$CCDP_i$" for each fire growth and damage scenario of interest.

Attach any internal event worksheets and manual action evaluation table determinations used to quantify each $CCDP_i$.

(Use the worksheet on the following page)

Step 2.8 - Plant Safe Shutdown Response Analysis							
Source #	Unscreened Fire Damage State Scenarios	HEP_i	P_{SPi}	CCDP (given successful manual action)	CCDP (given manual action fails and spurious actuation)	CCDP (given manual action fails and no spurious actuation)	$CCDP_i$

$$CCDP_i = [(1-HEP_i) \times CCDP(\text{given successful manual action})] + [HEP_i \times P_{SPi} \times CCDP(\text{given manual action fails and spurious actuation})] + [HEP_i \times (1 - P_{SPi}) \times CCDP(\text{given manual action fails and no spurious actuation})]$$

where: HEP_i is the true value of the human error probability for scenario i (not the exponent value derived from the HEP tables), and
P_{SPi} is the probability of a spurious actuation for scenario i.

Step 2.9 - Quantification and Preliminary Significance Determination

Calculate a final quantification of the FDS scenarios of interest and assign a preliminary determination of a findings significance.

Step 2.9 - Quantification of the FDS Scenarios					
Source #	Unscreened Fire Damage State Scenarios	Revised Fire Frequency for Unscreened Source (from Step 2.4) ($F_{Source\ i}$ x SF_i x $\Pi AF_{i\ 2.4}$)	Probability of Non-Suppression (PNS_i)	CCDPi	Revised Fire Frequency for Unscreened Source
Total ($\Sigma F_{Source\ i}$ X SF_i X $\Pi AF_{i\ 2.4}$ X PNS_i X $CCDP_i$):					

Assumptions/Comments/Remarks:____

The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

$$\Delta CDF_{2.8} = DF \times \sum_{i=1}^{n}\left[F_i \times SF_i \times \Pi AF_{i\,2.4} \times PNS_i \times CCDP_i\right]_{\text{All Scenarios}}$$

$\Delta CDF_{2.8}$ = ______________________________

Where:

n	=	number of fire scenarios evaluated for a given finding (covering all relevant FDSs)
DF	=	Duration factor from Step 1.4
F_i	=	Fire frequency for the fire ignition source i from Task 2.4.1
SF_i	=	Severity factor for scenario i from Task 2.4.1
$AF_{i\,2.4}$	=	Ignition source specific frequency adjustment factors from Step 2.4
PNS_i	=	Probability of non-suppression for scenario i from Step 2.7
$CCDP_i$	=	Conditional core damage probability for scenario i from Step 2.8

If $\Delta CDF_{2.8}$ is less than or equal to 1E-6, then the finding screens to Green, and the analysis is complete. If $\Delta CDF_{2.8}$ is greater than 1E-6, then the finding is potential safety significant.

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