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> April 25, 2003 LIC-03-0063

U.S. Nuclear Regulatory Commission ATTN: Document Control Desk Washington, DC 20555

Reference:

- 1. 2.
- Docket No. 50-285
- Letter from OPPD (R. T. Ridenoure) to NRC (Document Control Desk) Dated November 8, 2002 (LIC-02-0118)

### SUBJECT: Omaha Public Power District (OPPD) Fire Modeling Analysis – Fire Area 32

As discussed on April 22, 2003, in a telephone conversation between G. R. Cavanaugh of the Fort Calhoun Station (FCS) and A. B. Wang of the Nuclear Regulatory Commission (NRC), OPPD is submitting the following sections from a technical analysis for Fire Area 32 for the FCS docket: Section 3 - Fire Scenarios, Section 5 - References, and Attachment B - Fire Modeling Worksheets. No commitments are made to the NRC in this letter.

Sincerely, R/T. Rid¢noure

Division Manager Nuclear Operations

RTR/HPM/epm

Enclosure

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| SECTION 3<br>FIRE SCENARIOS   | A bounding fire in this compartment would involve postulated failure of the systems identified above. This fire would result in unacceptable results. Therefore, fire modeling was performed to refine the analysis as discussed below.   |  |
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|   | In the discussions below, no differentiation is made between sections of a cable tray. Therefore, if a tray is partially within the fire zone of influence, all associated trays are assumed damaged.   |  |
| AFW pump FW-10 large oil fire.  | 1. Steam Driven AFW Pump FW-10 – Large Fire   |  |
| 18% conditional probability of<br>large spill.  | A postulated 'large' auxiliary feedwater pump fire is assumed to occur with a conditional probability of 0.18. The fire was characterized as a spill of the entire oil inventory from the pump, 5.5 gallons. This fire has the potential to damage cable trays located directly above. The FIVE Inside Plume worksheet (Attachment B, Sheet "FW-10 Large – In-Plume") was used to determine whether target damage occurs. This situation was further evaluated using the Outside Plume and Radiant Exposure worksheets (Attachment B, Sheets "FW-10 Large – Out-Plume" and "FW-10 Large – Radiant", respectively).                          |  |
| Unconfined spill results in high<br>heat rate, but 10 second fire<br>duration not credible. | Using the FIVE methodology, an unconfined large spill involving 5.5 gallons of<br>oil would cover 660 sq.ft. and have a fire duration of 10 seconds. However, a<br>credible fire event would require some time to ignite the oil spill, would involve<br>a fire growth phase, then continued combustion until available fuel is depleted.<br>Such a fire can be expected to burn for several minutes. For the purposes of the<br>Fire Risk Analysis, it will be conservatively assumed that the minimum credible<br>fire duration is 2.5 minutes. This 2.5 minute assumption is based on several<br>parameters as discussed below.          |  |
| Assumed fire duration is 2.5 minutes.   | In order to provide realistic results, the analysis considers a confined oil spill so that the fire duration can be extended. The selection of a 2.5 minute minimum fire duration is based on the following considerations.   |  |
|   | <ol> <li>A short fire duration is conservative. However, the 10 seconds associated with an ideal unconfined spill fire is unrealistic.</li> <li>The Fire PRA Implementation Guide [5] indicates that ignition of IEEE 383 qualified cables would require fire exposure for 5 to 10 minutes.</li> <li>A realistic oil pool fire can be expected to experience some degree of oxygen depletion which would reduce the overall combustion rate (longer fire duration). This reduction can be modeled by considering a smaller pool surface area.</li> <li>The cable damage times (Appendix G of [5]) range from 2 to 19 minutes for</li> </ol> |  |
| Adjust spill surface area to obtain 2.5 minute duration fire.                               | temperatures of 700 °F and higher.<br>Using the 2.5 minute fire duration, the resulting fire characteristics are provided in<br>Attachment B, Sheet "FW-10 Large – Fuel": The postulated 5.5 gallon oil spill<br>fire has a fire intensity of 4528 Btu/s and a surface area of 45.7 sq. ft.   |  |
| ,<br>!  | A number of physical parameters for the fire compartment are needed in order to<br>assess the response of the 'nearest' target and the automatic fire suppression<br>system. The determination of these parameters is based on the postulated oil spill<br>originating from FW-10.  |  |



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|   | The fire is of sufficient magnitude that damage to targets in the fire plume will occur. Therefore, an outside of plume worksheet was used to evaluate the extent of damage to targets beyond the fire plume.  |
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| Trays 2S, 17S, and 18S potentially impacted.    | <u>Height to Target = 14.5 feet</u> – The nearest target above FW-10 is cable tray 2S, which is 14.5 feet above the floor. Other trays above FW-10 include the following: 18S at 15.5 feet high; and 17S at 16.5 feet high and 8 feet laterally.   |
|   | Trays 3S, 4S, 5S, 6S, 19S, and 20S are also near FW-10. However, the 1-hour radiant barrier partially surrounding FW-10 prevents the oil spill from spreading in their direction and provides some measure of shielding from the radiant heat effects.   |
|   | Room Height = 20 feet – FCS Fire Hazards Analysis [2].   |
|   | <u>Floor Dimensions = 207.8 x 27 feet</u> – This is based on a floor area of 5,610 ft <sup>2</sup> and an approximate room width of 27 feet near the pump.   |
|   | <u>Radial Distance to Targets = 7.6 feet</u> - The postulated oil spill has a surface area of 45.7 $ft^2$ . This equates to a diameter of 7.6 feet for a circular spill. Since the spill can occur anywhere around the pump, a 7.6 foot radius around the pump is assumed for determining potential targets impacted.  |
|   | <u>Fire Intensity</u> = $4,528$ <u>Btu/s</u> – the assumed fire intensity is based on the assumptions discussed earlier. Attachment B provides a worksheet which develops this value.  |
|   | <u>Fire Location Factor = 1</u> - the fire is assumed to be in the 'center' of the room.   |
|   | <u>Ambient Temperature = <math>90  {}^{\circ}F</math></u> - this assumed value is used for the maximum expected ambient temperature during normal plant operations.  |
| Outside of plume damage distance<br>– 4.8 feet. | The outside of plume worksheet (Attachment B, Sheet "FW-10 Large – Out-<br>Plume") predicts a radial damage distance of 4.8 feet. Therefore, if a target is<br>located in the jet region, but more than 4.8 feet from the fire plume, target damage<br>is not expected.  |
| Radiant exposure damage distance<br>– 12 feet.  | Additionally, the radiant exposure worksheet (Attachment B, Sheet "FW-10<br>Large – Radiant") predicts a critical radiant flux distance of 12 feet. The only<br>critical component within this distance is FW-6, however it is separated from FW-<br>10 by a 1-hour radiant barrier. Therefore, no additional targets are assumed to be<br>damaged due to radiant effects. |
| · · · · · · · · · · · · · · · · · · ·           | This scenario was evaluated further to determine the target damage time versus<br>suppression system actuation time. Successful actuation of the suppression system<br>prior to the predicted target damage time would prevent such damage. The<br>additional parameters needed for this analysis are discussed below.   |
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|  | <u>Height to Target = 11.5 feet</u> – Although the actual target height is approximately 14.5 feet, the height used in the analysis was reduced to 11.5 feet, which is the lowest height which would yield a target damage time greater than the suppression system actuation time.   |
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|  | <u><b>Radial Distance to Target = 0.1 feet</b></u> – The target is conservatively assumed to be located above the fire source.  |
|  | <u>Fire Location Factor (Target) = 1</u> – The fire is assumed to be in the 'center' of the room.   |
|  | <u>Radiant Fraction = <math>0.40</math></u> - this value is based on guidance in FIVE [4].  |
|  | <u>Rated Detector Temperature = <math>165  {}^{\circ}F</math></u> - this value is based on the device setpoint [7].   |
|  | <u>Ambient Temperature = <math>75 {}^{\circ}F</math></u> - The assumed ambient temperature for this case is assumed to be 75 °F. This has the effect of increasing the detector response time.  |
| Sprinklers approximately 8 feet<br>above floor.  | <u>Distance to Detector = 10 feet vertical, 1 foot horizontal</u> – There are two sprinkler heads located directly above AFW pump FW-10, approximately 8 feet above the floor. Other detectors and sprinkler heads are located throughout the room. For conservatism, a vertical distance of 10 feet and a horizontal distance of 1 foot are assumed.   |
|  | <u>Fire Location Factor (Detector) = 1</u> - the fire is assumed to be in the 'center' of the room. This provides the most conservative result with respect to detector response.   |
|  | <u><i>Target Location = 1 (in-plume)</i></u> . The targets are inside the postulated fire plume.  |
|  | <u>Target Thermal Response Parameter = <math>34</math></u> - This represents a nominal value for XPE/XPE cables with 0.43 inch diameter [4].  |
|  | <u>Detector Time Constant</u> = $120$ - this assumed value is based on the highest (slowest) detector in the reference tables [4].  |
| Targets greater than 11.5 feet<br>above the pump will not be<br>damaged if suppression is<br>successful. | The results of the suppression system actuation analysis are provided in<br>Attachment B, Sheet "FW-10 Large – Suppression". Assuming a 'virtual' target<br>11.5 feet above the pump and inside the fire plume, the analysis conservatively<br>predicts a cable damage time of 7 seconds and a suppression system actuation time<br>of 6.95 seconds. The expected damage time for the actual targets, since they are<br>located higher than 11.5 feet, would be greater than 7 seconds. |
| :  | Based on this analysis, it is concluded that successful actuation of the suppression<br>system during a postulated large oil spill fire will limit damage in this fire<br>compartment such that only the pump itself will be damaged.   |
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| AFW pump FW-10 small oil fire.  | 2. Steam Driven AFW Pump FW-10 – Small Fire  |
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| 82% conditional probability of small spill.   | A postulated 'small' auxiliary feedwater pump fire is assumed to occur with a conditional probability of 0.82. The fire was characterized as a spill of 10% of the entire oil inventory, or 0.55 gallons. This spill is assumed to occur with an 82% conditional probability [5]. The characterization of such a fire is based on the same fundamental parameters as that considered for the large oil spill fire. The resulting fire has a surface area of 4.6 sq.ft., a duration of 2.5 minutes, and an intensity of 453 Btu/s.  |
| Targets greater than 8.3 feet above<br>the pump will not be damaged.                        | The analysis of this postulated fire was evaluated using the FIVE worksheets for<br>the Inside Plume and Radiant exposure cases (Attachment B, Sheets "FW-10<br>Small – In-Plume" and "FW-10 Small - Radiant", respectively). The completed<br>analysis worksheets are based on the same input parameters as the FW-10 large<br>fire. The analysis shows that targets located 8.3 feet or more above the postulated<br>fire would not be damaged.  |
|   | The radiant exposure case performed using 1 Btu/s/ft <sup>2</sup> critical flux limit yields a critical flux distance of approximately 3.8 feet. Given the 1-hour radiant shield between FW-10 and FW-6, as well as the spacing between FW-10 and the air ompressors, this heating mechanism is not a concern with respect to target damage.   |
|   | Based on this analysis, a postulated small oil spill fire should be assumed to result<br>in damage to only the pump itself.  |
| AFW pump FW-6 large oil fire.   | 3. Motor Driven AFW Pump FW-6 – Large Fire   |
| 18% conditional probability of<br>large spill.  | A postulated 'large' auxiliary feedwater pump fire is assumed to occur with a conditional probability of 0.18. The fire was characterized as a spill of the entire oil inventory from the pump, 3.5 gallons. This fire has the potential to damage cable trays located directly above. The FIVE Inside Plume worksheet (Attachment B, Sheet "FW-6 Large – In-Plume") was used to determine whether target damage occurs. This situation was further evaluated using the Outside Plume and Radiant Exposure worksheets (Attachment B, Sheets "FW-6 Large – Out-Plume" and "FW-6 Large - Radiant", respectively).                    |
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| Unconfined spill results in high<br>heat rate, but 10 second fire<br>duration not credible. | Using the FIVE methodology, an unconfined large spill involving 3.5 gallons of<br>oil would cover 420 sq.ft. and have a fire duration of 10 seconds. However, a<br>credible fire event would require some time to ignite the oil spill, would involve<br>a fire growth phase, then continued combustion until available fuel is depleted.<br>Such a fire can be expected to burn for several minutes. For the purposes of the<br>Fire Risk Analysis, it will be conservatively assumed that the minimum credible<br>fire duration is 2.5 minutes. This 2.5 minute assumption is based on several<br>parameters as discussed below. |

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| Assumed fire duration is 2.5 minutes.                                | In order to provide realistic results, the analysis considers a confined oil spill so that the fire duration can be extended. The selection of a 2.5 minute minimum fire duration is based on the following considerations.  |
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|  | <ol> <li>A short fire duration is conservative. However, the 10 seconds associated with an ideal unconfined spill fire is unrealistic.</li> <li>The Fire PRA Implementation Guide [5] indicates that ignition of IEEE 383 qualified cables would require fire exposure for 5 to 10 minutes.</li> <li>A realistic oil pool fire can be expected to experience some degree of oxygen depletion which would reduce the overall combustion rate (longer fire duration). This reduction can be modeled by considering a smaller pool surface area.</li> <li>The cable damage times (Appendix G of [5]) range from 2 to 19 minutes for temperatures of 700 °F and higher.</li> </ol> |
| <i>Adjust spill surface area to obtain 2.5 minute duration fire.</i> | Using the 2.5 minute fire duration, the resulting fire characteristics are provided in Attachment B, Sheet "FW-6 Large – Fuel". The postulated 3.5 gallon oil spill fire has a fire intensity of 2882 Btu/s and a surface area of 29.1 sq. ft.   |
|  | A number of physical parameters for the fire compartment are needed in order to<br>assess the response of the 'nearest' target and the automatic fire suppression<br>system. The determination of these parameters is based on the postulated oil spill<br>originating from FW-6.  |
|  | The fire is of sufficient magnitude that damage to targets in the fire plume will occur. Therefore, an outside of plume worksheet will be used to evaluate the extent of damage to targets beyond the fire plume.  |
| Trays 2S, 3S, 4S, 18S, and 19S potentially impacted.                 | <u>Height to Target = 14.5 feet</u> – The nearest target above FW-6 is cable tray 2S, which is 14.5 feet above the floor. Other trays above FW-6 include the following: 18S at 15.5 feet high; 19S at 14.5 feet high and 8 feet laterally; 3S at 18.5 feet high and 6.5 feet laterally; and 4S at 14.5 feet high and 11.5 feet laterally.  |
|  | <u>Room Height = 20 feet</u> – FCS Fire Hazards Analysis [2].  |
|  | <u>Floor Dimensions</u> = 207.8 x 27 feet – This is based on a floor area of 5,610 ft <sup>2</sup> and an approximate room width of 27 feet near the pump.   |
|  | <u>Radial Distance to Targets = 7.6 feet</u> - The postulated oil spill has a surface area of 29.1 ft <sup>2</sup> . This equates to a diameter of 6.1 feet for a circular spill. Since the spill can occur anywhere around the pump, a 6.1 foot radius around the pump is assumed for determining potential targets impacted.   |
|  | <u>Fire Intensity</u> = $2,882$ <u>Btu/s</u> – the assumed fire intensity is based on the assumptions discussed earlier. Attachment B provides a worksheet which develops this value.  |
|  | <u>Fire Location Factor = 1</u> - the fire is assumed to be in the 'center' of the room.   |
|  | <u>Ambient Temperature = <math>90  {}^{\circ}F</math></u> - this assumed value is used for the maximum expected ambient temperature during normal plant operations.  |
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| <i>Outside of plume damage distance<br/>– 2.6 feet.</i> | The outside of plume worksheet (Attachment B, Sheet "FW-6 Large – Out-<br>Plume") predicts a radial damage distance of 2.6 feet. Therefore, if a target is<br>located in the jet region, but more than 2.6 feet from the fire plume, target damage<br>is not expected.  |
| Radiant exposure damage distance<br>–9.6 feet.          | Additionally, the radiant exposure worksheet (Attachment B, Sheet "FW-6 Large – Radiant") predicts a critical radiant flux distance of 9.6 feet. The only critical component within this distance is FW-10, however it is separated from FW-6 by a 1-hour radiant barrier. Therefore, no additional targets are assumed to be damaged due to radiant effects. |
|   | This scenario was evaluated further to determine the target damage time versus<br>suppression system actuation time. Successful actuation of the suppression system<br>prior to the predicted target damage time would prevent such damage. The<br>additional parameters needed for this analysis are discussed below.  |
|   | <u>Height to Target = <math>12.7 feet</math></u> – Although the actual target height is approximately 14.5 feet, the height used in the analysis was reduced to 12.7 feet, which is the lowest height which would yield a target damage time greater than the suppression system actuation time.  |
|   | <u>Radial Distance to Target = <math>0.1</math> feet</u> – The target is conservatively assumed to be located above the fire source.  |
| *   | <u>Fire Location Factor (Target) = 1</u> – The fire is assumed to be in the 'center' of the room.   |
|   | <u>Radiant Fraction = <math>0.40</math></u> - this value is based on guidance in FIVE [4].  |
|   | <u>Rated Detector Temperature = <math>165 {}^{\circ}F</math></u> - this value is based on the device setpoint [7].  |
|   | <u>Ambient Temperature = <math>75 {}^{\circ}F</math></u> - The assumed ambient temperature for this case is assumed to be 75 ${}^{\circ}F$ . This has the effect of increasing the detector response time.  |
| Sprinklers assumed to be near ceiling.                  | <u>Distance to Detector = 20 feet vertical, I foot horizontal</u> – There are sprinkler heads located near the ceiling above AFW pump FW-6. Other detectors and sprinkler heads are located throughout the room. For conservatism, a vertical distance of 20 feet and a horizontal distance of 1 foot are assumed.  |
|   | <u>Fire Location Factor (Detector) = 1</u> - the fire is assumed to be in the 'center' of $-$ the-room.—This provides the most conservative result with respect to detector response.   |
| · · · ·   | <u>Target Location = 1 (in-plume)</u> - The targets are inside the postulated fire plume.   |
|   | <u>Target Thermal Response Parameter</u> = $34$ - This represents a nominal value for XPE/XPE cables with 0.43 inch diameter [4].   |
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Targets greater than 12.7 feet above the pump will not be damaged if suppression is successful.

AFW pump FW-6 small oil fire.

82% conditional probability of small spill.

Targets greater than 8.0 feet above the pump will not be damaged.

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Air compressor large oil fire.

18% conditional probability of large spill.

<u>Detector Time Constant</u> = 120 - this assumed value is based on the highest (slowest) detector in the reference tables [4].

The results of the suppression system actuation analysis are provided in Attachment B, Sheet "FW-6 Large – Suppression". Assuming a 'virtual' target 12.7 feet above the pump and inside the fire plume, the analysis conservatively predicts a cable damage time of 26 seconds and a suppression system actuation time of 25.7 seconds. The expected damage time for the actual targets, since they are located higher than 12.7 feet, would be greater than 26 seconds.

Based on this analysis, it is concluded that successful actuation of the suppression system during a postulated large oil spill fire will limit damage in this fire compartment such that only the pump itself will be damaged.

4. Motor Driven AFW Pump FW-6 - Small Fire

A postulated 'small' auxiliary feedwater pump fire is assumed to occur with a conditional probability of 0.82. The fire was characterized as a spill of 10% of the entire oil inventory, or 2 quarts, whichever is greater. In this case, with an oil inventory of 3.5 gallons, a 2 quart spill is considered more limiting. This spill is assumed to occur with an 82% conditional probability [5]. The characterization of such a fire is based on the same fundamental parameters as that considered for the large oil spill fire. The resulting fire has a surface area of 4.2 sq.ft., a duration of 2.5 minutes, and an intensity of 412 Btu/s.

The analysis of this postulated fire was evaluated using the FIVE worksheets for the Inside Plume and Radiant exposure cases (Attachment B, Sheets "FW-6 Small – In-Plume" and "FW-6 Small – Radiant", respectively). The completed analysis worksheets are based on the same input parameters as the FW-6 large fire. The analysis shows that targets located 8.0 feet or more above the postulated fire would not be damaged.

The radiant exposure case performed using 1 Btu/s/ft<sup>2</sup> critical flux limit yields a critical flux distance of approximately 3.6 feet. Given the 1-hour radiant shield between FW-6 and potential targets, this heating mechanism is not a concern with respect to target damage.

Based on this analysis, a postulated small oil spill fire should be assumed to result in damage to only the pump itself.

#### 5. Air Compressor Large Fire

A postulated 'large' air compressor fire is assumed to occur with a conditional probability of 0.18. The fire was characterized as a spill of the entire oil inventory from one compressor, 7 gallons. This fire has the potential to damage cable trays located directly above. The FIVE Inside Plume worksheet (Attachment B, Sheet "IA Large – In-Plume") was used to determine whether target damage occurs. This situation was further evaluated using the Outside Plume and Radiant Exposure worksheets (Attachment B, Sheets "IA Large – Out-Plume" and "IA Large - Radiant", respectively). Since the compressors are expected to have similar target impacts, only one scenario is developed for all three compressors.



Using the FIVE methodology, an unconfined large spill involving 7 gallons of oil would cover 840 sq.ft. and have a fire duration of 10 seconds. However, a

| duration not credible.   | credible fire event would require some time to ignite the oil spill, would involve<br>a fire growth phase, then continued combustion until available fuel is depleted.<br>Such a fire can be expected to burn for several minutes. For the purposes of the<br>Fire Risk Analysis, it will be conservatively assumed that the minimum credible<br>fire duration is 2.5 minutes. This 2.5 minute assumption is based on several<br>parameters as discussed below.  |
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| Assumed fire duration is 2.5 minutes.                                | In order to provide realistic results, the analysis considers a confined oil spill so that the fire duration can be extended. The selection of a 2.5 minute minimum fire duration is based on the following considerations.  |
|  | <ol> <li>A short fire duration is conservative. However, the 10 seconds associated with an ideal unconfined spill fire is unrealistic.</li> <li>The Fire PRA Implementation Guide [5] indicates that ignition of IEEE 383 qualified cables would require fire exposure for 5 to 10 minutes.</li> <li>A realistic oil pool fire can be expected to experience some degree of oxygen depletion which would reduce the overall combustion rate (longer fire duration). This reduction can be modeled by considering a smaller pool surface area.</li> <li>The cable damage times (Appendix G of [5]) range from 2 to 19 minutes for temperatures of 700 °F and higher.</li> </ol> |
| <i>Adjust spill surface area to obtain 2.5 minute duration fire.</i> | Using the 2.5 minute fire duration, the resulting fire characteristics are provided in Attachment B, Sheet "IA Large – Fuel". The postulated 7 gallon oil spill fire has a fire intensity of 5763 Btu/s and a surface area of 58.2 sq. ft.   |
|  | A number of physical parameters for the fire compartment are needed in order to<br>assess the response of the 'nearest' target and the automatic fire suppression<br>system. The determination of these parameters is based on the postulated oil spill<br>originating from the air compressor.  |
|  | The fire is of sufficient magnitude that damage to targets in the fire plume will occur. Therefore, an outside of plume worksheet will be used to evaluate the extent of damage to targets beyond the fire plume.  |
| Trays 1S, 16S, and 16S-1 potentially impacted.                       | <u>Height to Target = <math>16.5</math> feet</u> – The nearest target above the air compressors is cable tray 1S, which is 16.5 feet above the floor. Other trays near the compressors include 16S (16.5 feet high, 2 feet laterally) and 16S-1 (16.5 feet high, 2 feet laterally).  |
|  | Room Height = 20 feet - FCS Fire Hazards Analysis [2].   |
|  | <u>Floor Dimensions</u> = 207.8 x 27 feet – This is based on a floor area of 5,610 ft <sup>2</sup><br>and an approximate room width of 27 feet near the pump.  |
|  | <u>Radial Distance to Targets <math>\stackrel{!}{=}</math> 8.6 feet - The postulated oil spill has a surface area of 58.2 ft<sup>2</sup>. This equates to a diameter of 8.6 feet for a circular spill. Since the spill can occur anywhere around the compressor, a 8.6 foot radius around the compressor is assumed for determining potential targets impacted.</u>  |



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Unconfined spill results in high

heat rate, but 10 second fire

Fire Intensity = 5,763 Btu/s - the assumed fire intensity is based on the

assumptions discussed earlier. Attachment B provides a worksheet which develops this value. *Fire Location Factor* = 1 - the fire is assumed to be in the 'center' of the room. Ambient <u>Temperature = 90 "F</u> - this assumed value is used for the maximum expected ambient temperature during normal plant operations. The outside of plume worksheet (Attachment B, Sheet "IA Large - Out-Plume") Outside of plume damage distance predicts a radial damage distance of 6.4 feet. Therefore, if a target is located in the - 6.4 feet. jet region, but more than 6.4 feet from the fire plume, target damage is not expected. Additionally, the radiant exposure worksheet (Attachment B, Sheet "IA Large -Radiant exposure damage distance Radiant") predicts a critical radiant flux distance of 13.5 feet. Depending on the -12 feet. compressor which is the source of the fire, two or three of the compressors may be damaged due to radiant effects. For conservatism, all three are assumed damaged. This scenario was evaluated further to determine the target damage time versus suppression system actuation time. Successful actuation of the suppression system prior to the predicted target damage time would prevent such damage. The additional parameters needed for this analysis are discussed below. <u>Height to Target = 16 feet</u> - Although the actual target height is approximately 16.5 feet, the height used in the analysis was reduced to 16 feet, which is the lowest height which would yield a target damage time greater than the suppression system actuation time. Radial Distance to Target = 0.1 feet – The target is conservatively assumed to be located above the fire source. Fire Location Factor (Target) = 1 - The fire is assumed to be in the 'center' ofthe room. Radiant Fraction = 0.40 - this value is based on guidance in FIVE [4]. <u>Rated Detector Temperature =  $165 \,^{\circ}F$  - this value is based on the device setpoint</u> [7]. Ambient Temperature =  $75 \,^{\circ}F$  - The assumed ambient temperature for this case is assumed to be 75 °F. This has the effect of increasing the detector response time. Distance to Detector = 20 feet vertical, 1 foot horizontal - There are sprinkler Sprinklers assumed to be near heads located near the ceiling above AFW pump FW-6. Other detectors and ceiling. sprinkler heads are located throughout the room. For conservatism, a vertical distance of 20 feet and a horizontal distance of 1 foot are assumed.

<u>Fire Location Factor (Detector)</u> = I - the fire is assumed to be in the 'center' of the room. This provides the most conservative result with respect to detector

*Target Location = 1 (in-plume)* - The targets are inside the postulated fire plume. Target Thermal Response Parameter = 34 - This represents a nominal value for XPE/XPE cables with 0.43 inch diameter [4] Detector Time Constant = 120 - this assumed value is based on the highest (slowest) detector in the reference tables [4] The results of the suppression system actuation analysis are provided in Targets greater than 11.5 feet Attachment B, Sheet "IA Large - Suppression". Assuming a 'virtual' target 16 above the pump will not be feet above the pump and inside the fire plume, the analysis conservatively predicts damaged if suppression is a cable damage time of 16 seconds and a suppression system actuation time of 15.5 successful. seconds. The expected damage time for the actual targets, since they are located higher than 16 feet, would be greater than 16 seconds. Based on this analysis, it is concluded that successful actuation of the suppression system during a postulated large oil spill fire will limit damage in this fire compartment such that only the pump itself will be damaged. 6. Air Compressor Small Fire AFW pump FW-10 small oil fire. A postulated 'small' air compressor fire is assumed to occur with a conditional 82% conditional probability of probability of 0.82. The fire was characterized as a spill of 10% of the entire oil small spill. inventory, or 0.7 gallons. This spill is assumed to occur with an 82% conditional probability [5]. The characterization of such a fire is based on the same fundamental parameters as that considered for the large oil spill fire. The resulting fire has a surface area of 5.8 sq.ft., a duration of 2.5 minutes, and an intensity of 576 Btu/s. The analysis of this postulated fire was evaluated using the FIVE worksheets for Targets greater than 9.1 feet above the Inside Plume and Radiant exposure cases (Attachment B, Sheets "IA Small the pump will not be damaged. In-Plume" and "IA Small - Radiant", respectively). The completed analysis worksheets are based on the same input parameters as the air compressor large fire. The analysis shows that targets located 9.1 feet or more above the postulated fire would not be damaged. The radiant exposure case performed using 1 Btu/s/ft<sup>2</sup> critical flux limit yields a critical flux distance of approximately 4.3 feet. Given the 8.6 foot spill radius, this radiant exposure distance is sufficient to potentially damage all three compressors. Based on this analysis, a postulated small oil spill fire should be assumed to result in damage to only the three compressors.

response.

### Fire IPEEE Tier 2 Documentation Scenario No. FA32, Revision 2

| SECTION 5<br>REFERENCES | <ol> <li>"Safe Shutdown Analysis," EA-FC-89-055, Rev. 3.</li> <li>Fire Hazards Analysis for Fort Calhoun Station, Rev. 6.</li> <li>Individual Plant Examination of External Events for Fort Calhoun,<br/>Enclosure to LIC 95-0130.</li> <li>EPRI Report TR-100370s, "Fire-Induced Vulnerability Evaluation<br/>(FIVE)", Final Report, April 1992</li> <li>EPRI Report TR-105928, "EPRI Fire PRA Implementation Guide," Final<br/>report, December 1995.</li> <li>Fire Compartment Close-out Strategy, Scenario No. GEN.</li> <li>FCS Fire PRA Fire Modeling Analysis, 0139-00534-RPT-001, Rev. 0,<br/>VECTRA.</li> </ol> |
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Attachment B

### Fire Modeling Worksheets

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## OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

#### COMBUSTIBLE MATERIAL WORKSHEET

### FUEL PROPERTIES - UNCONFINED SPILL

| DESCRIPTION            |   |       |
|------------------------|---|-------|
| VOLUME (QUARTS)        |   | 22    |
| NET HEAT OF COMBUSTION | - | 17111 |
| COMBUSTION EFFICIENCY  |   | 90%   |
| UNIT HEAT RELEASE RATE |   | 110   |
| DENSITY                |   | 60    |

#### FLOW CHARACTERISTICS

| DESCRIPTION         |       |
|---------------------|-------|
| SPECIFIC SPILL AREA | 120.0 |

| SPILL AREA          | 660   | SQ-FT |
|---------------------|-------|-------|
| PEAK FIRE INTENSITY | 65340 | BTU/S |
| FIRE DURATION       | 10    | SEC   |
|                     | 0.173 | MIN   |

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#### FUEL PROPERTIES - CONFINED SPILL

| DESCRIPTION            |       |
|------------------------|-------|
| VOLUME (QUARTS)        | 22    |
| NET HEAT OF COMBUSTION | 17111 |
| COMBUSTION EFFICIENCY  | 1     |
| UNIT HEAT RELEASE RATE | 110   |
| DENSITY                | 60    |

#### FLOW CHARACTERISTICS

:

| DESCRIPTION<br>SPILL AREA | <b>45.7</b> | SQ-FT        |
|---------------------------|-------------|--------------|
| PEAK FIRE INTENSITY       | 4528<br>150 | BTU/S<br>SEC |
|                           | 2.500       | MIN          |



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### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

## FIXED COMBUSTIBLE / TARGET IN PLUME

ENGLISH UNITS VERSION

| 1          | TARGET DAMAGE THRESHOLD TEMPERATURE                      | 700        | F        |
|------------|--|------------|----------|
|            | (USE TABLE 1E FOR GUIDANCE)                              |            |          |
| 2          | HEIGHT OF TARGET ABOVE FIRE SOURCE                       | 20         | ft       |
|            | (BASED ON SCENARIO GEOMETRY)                             |            |          |
| 3          | HEIGHT FROM FIRE SOURCE TO CEILING                       | 20         | ft       |
|            | (BASED ON SCENARIO GEOMETRY)                             |            |          |
| 3a         | FLOOR DIMENSIONS - LENGTH                                | 207.777778 | ft       |
|            | - WIDTH  | 27         | ft       |
| 3b         | FLOOR AREA (LENGTH) X (WIDTH)                            | 5610       | ft2      |
| Зc         | ESTIMATED DURATION OF FIRE                               | 2.5        | min      |
| 4          | PEAK FIRE INTENSITY                                      | 4528.22374 | Btu/s    |
| ·          | USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)                 |            |          |
| 5          | FIRE LOCATION FACTOR                                     | 1          |          |
| -          | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)                 |            |          |
| 6          | EFFECTIVE HEAT RELEASE RATE                              | 4528.22374 | Btu/s    |
| ÷          | ([BOX 4] X [BOX 5])                                      |            |          |
| • 7.       | PLUME TEMPERATURE RISE AT TARGET                         | 631.51     | F        |
| ··· ·· • • | (LOOK UP VALUE FROM TABLE 5E)                            |            |          |
| 8a         | MAXIMUM AMBIENT TEMPERATURE                              | 90         | F        |
| 8b         | CRITICAL TEMPERATURE RISE AT TARGET                      | 610        | F        |
|            | ((BOX 1] - MAXIMUM AMBIENT TEMPERATURE)                  |            |          |
| 9          | CRITICAL - PLUME TEMPERATURE RISE                        | -21.51     | F        |
|            | ([BOX 8] - [BOX 7])                                      |            |          |
|            | IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE  |            |          |
|            | TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO     |            |          |
|            | RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT             |            |          |
| 10         | Qnet/V TO ACHIEVE TEMP RISE IN BOX 9                     | 0.00       | Btu/ft3  |
|            | (LOOK UP VALUE FROM TABLE 7E)                            |            |          |
| 11         | CALCULATED ENCLOSURE VOLUME, V                           | 0          | ft3      |
|            | ([BOX 3] X FLOOR AREA OF SPACE)                          |            |          |
| 12         | CALCULATED CRITICAL Qnet                                 | 0          | Btu      |
|            | ([BOX 10] X [BOX11])                                     |            |          |
| 13         | ESTIMATED HEAT LOSS FRACTION                             | 0.7        |          |
|            | (REPRESENTATIVE VALUE: 0.7)                              |            |          |
| 14         | ESTIMATE OF CRITICAL Qtot                                | 0          | Btu      |
|            | ([BOX 12]/(1 - [BOX13]))                                 |            |          |
| 15         | ESTIMATE OF ACTUAL Qtot                                  | 0          | Btu      |
| -          | ([HRR] X [TIME]) = [BOX 4] X [TIME]                      |            | <u> </u> |
| <b></b>    | IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14, |            |          |
| 1          | CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   |            |          |
|            | BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PAS    | s          |          |
|            | THIS SCREENING PROCEDURE. FURTHER ANALYSIS REQUIRED.     |            |          |

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#### **OPPD - Fort Calhoun Station** Fire Risk Analysis Refinement Project

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#### 1. FIXED COMBUSTIBLE / TARGET OUTSIDE PLUME

ENGLISH UNITS VERSION

| 1        | TARGET DAMAGE THRESHOLD TEMPERATURE                         | 760       | F                                       |
|----------|---|-----------|---|
|          | (LOOK UP VALUE FROM TABLE 1E)                               |           |   |
| 2        | HEIGHT OF TARGET ABOVE FIRE SOURCE                          | 18        | ft                                      |
|          | (BASED ON SCENARIO GEOMETRY)                                |           |   |
| 3        | HEIGHT FROM FIRE SOURCE TO CEILING                          | 20        | ft                                      |
|          | (BASED ON SCENARIO GEOMETRY)                                |           | <u> </u>                                |
| 3a       | FLOOR DIMENSIONS - LENGTH                                   | 207.77778 | ft                                      |
|          | - WIDTH   | 27        | <u>ft</u>                               |
| 3b       | FLOOR AREA [LENGTH] X [WIDTH]                               | 5610      | ft2                                     |
| 3c       | ESTIMATED DURATION OF FIRE                                  | 2.5       | min                                     |
| 4        | RATIO OF TARGET HEIGHT/CEILING HEIGHT                       | 0.90      |   |
|          |   | <u>. </u> | • |
|          | IF THE VALUE IN BOX 4 IS > 0.85, COMPLETE BOXES 5-11;       |           |   |
|          | OTHERWISE, ENTER A VALUE OF U IN BOX 14 AND CONTINUE        |           |   |
|          | WITH BOX 15   |           | A                                       |
| 5        | LONGITUDINAL DISTANCE FROM FIRE SOURCE TO TARGET, L         | 000000    | ic.                                     |
|          | (BASED ON SCENARIO GEOMETRY)                                | - 0.24    |   |
| 6        | LONGITUDINAL DISTANCE TO HEIGHT RATIO, L/H                  | 0.24      |   |
|          | ([BOX 5]/[BOX 3])   | ┼──╤╤──┼  |   |
| 7        | ENCLOSURE WIDTH, W  | 27        | π                                       |
|          | (BASED ON SCENARIO GEOMETRY)                                |           |   |
| 8        | HEIGHT TO WIDTH RATIO, H/W                                  | 0.74      |   |
|          | ([BOX 3]/[BOX 7])   |           |   |
| 9 -      | PEAK FIRE INTENSITY   | 4528,2237 | Btu/s                                   |
|          | (USE TABLE 2E FOR GUIDANCE)                                 |           |   |
| • 10     | FIRE LOCATION FACTOR  | 1         |   |
|          | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)                    |           |   |
| 11       | EFFECTIVE HEAT RATE RELEASE                                 | 4528.2237 | Btu/s                                   |
|          | ((BOX 9] X (BOX 10])  |           |   |
| 12       | PLUME TEMPERATURE RISE AT CEILING                           | 631.51    | F                                       |
|          | (LOOK LIP VALUE FROM TABLE SE)                              | 1         |   |
| 13       | CET ING IFT TEMPERATURE RISE FACTOR AT TARGET               |           |   |
| 10       | (IE (BOX 4) < 0.85, ENTER 0, ELSE                           | 0.777     |   |
|          | LOOK HE VALLE FROM TABLE 64 OR 6B)                          |           |   |
| 14       |   | 490.56    | F                                       |
| 7.4      |   |           | -                                       |
| 15-      |   | ne        | F                                       |
| 158      | MAXIMUM AMBIENT TEMPERATURE                                 |           |   |
| 15b      | CRITICAL TEMPERATURE RISE AT TARGET                         | 610       | F                                       |
|          | ([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)                     |           | <u> </u>                                |
| 16       | CRITICAL - CEILING JET TEMP. RISE AT TARGET                 | 119.44    | F                                       |
|          | ([BOX 15] - [BOX 14])                                       |           |   |
|          | IF THE ENTRY IN BOX 16 IS <= 0, STOP. OTHERWISE CONTINUE TO |           |   |
|          | CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO RAISE     |           |   |
|          | THE AVERAGE TEMPERATURE BY THE AMOUNT INDICATED IN BOX 16   |           |   |
| 17       | Qnet/V TO ACHIEVE TEMP RISE IN BOX 16                       | 1.88      | Btu/i                                   |
|          | (LOOK UP VALUE FROM TABLE 7E)                               |           |   |
| 18       | CALCULATED ENCLOSURE VOLUME, V                              | 112,200   | ft3                                     |
|          | ([BOX 3B] X [BOX 3])  |           | <u> </u>                                |
| 19       | CALCULATED CRITICAL Quet                                    | 210,466   | Btı                                     |
|          | ([BOX 17] X [BOX18])  |           | I                                       |
| 20       | ESTIMATED HEAT LOSS FRACTION (RANGE: 0-1)                   | 0.7       | -                                       |
| 1        | (REPRESENTATIVE VALUE : 0.7)                                |           | I                                       |
| 21       | ESTIMATE OF CRITICAL Otot                                   | 701,554   | Bb                                      |
|          | (IBOX 191/(1 - (BOX201))                                    | 1         | 1                                       |
| 1 22     |   | 679.234   | Bt                                      |
| 1 22     |   |           | 1                                       |
| <b> </b> | (BASED ON ENERGY CONTENT OF FIRE SOURCE)                    | ·         | <u> </u>                                |
|          | IF THE ENTRY IN BOX 22 IS LESS THAN THE VALUE IN BOX 21,    |           |   |
| ll.      | CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO      |           |   |
|          | BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS      |           |   |
|          | THIS SCREENING PROCEDURE. FURTHER ANALYSIS REQUIRED.        |           |   |

# FIXED COMBUSTIBLE / RADIANT EXPOSURE

ENGLISH UNITS VERSION

| 1   | CRITICAL RADIANT FLUX TO TARGET                      | 1          | Btu/s/ft2 |
|---|--|------------|-----------|
|   | (REPRESENTATIVE CONSERVATIVE VALUE = 1)              |            |           |
|   | (LOOK UP VALUE FROM TABLE 1E)                        |            |           |
| 2   | PEAK FIRE INTENSITY                                  | 4528.22374 | Btu/s     |
|   | (USE TABLE 2E FOR GUIDANCE)                          |            |           |
| 3   | RADIANT FRACTION OF HEAT RELEASE                     | 0.4        |           |
|   | (REPRESENTATIVE VALUE = 0.4)                         |            | <u> </u>  |
| 4   | RADIANT HEAT RELEASE RATE                            | 1811.2895  | Btu/s     |
|   | ([BOX2]X[BOX3])                                      |            |           |
| 5   | CRITICAL RADIANT FLUX DISTANCE                       | 12.01      | ft        |
|   | (LOOK UP VALUE FROM TABLE 10E)                       |            |           |
| 6   | ACTUAL DISTANCE BETWEEN SOURCE/TARGET                | 0          | ft        |
|   | (FROM FIRE COMPARTMENT CCDS)                         |            |           |
|   | IF THE EXPOSURE FIRE IS LOCATED WITHIN THIS DISTANCE |            |           |
| (INDICATED IN BOX 5) OF THE TARGET, CRITICAL CONDITIONS CAN |  |            |           |
| OCCUR. OUTSIDE THIS RANGE, CRITICAL CONDITIONS ARE NOT      |  |            |           |
|   | INDICATED FOR THE SCENARIO UNDER CONSIDERATION.      |            |           |

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## OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

#### SUPPRESSION

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#### THERMALLY THICK TARGETS

ENGLISH UNITS VERSION

| <u></u>    | ARGET INFO     | DRMATION   |                               |            |
|------------|----------------|--|-------------------------------|------------|
| Γ          | 1a             | HEIGHT OF TARGET ABOVE FIRE SOURCE                   | ANA\$1.5.64                   | ft         |
|            |                | (BASED ON SCENARIO GEOMETRY)                         |                               |            |
|            | 1b             | RADIAL DISTANCE FROM FIRE SOURCE TO TARGET           | 0.1                           | ft         |
|            |                | LINE OF SIGHT DISTANCE FROM FIRE SOURCE TO TARGET    |                               | TT         |
| ļ          | 2              | PEAK FIRE INTENSITY                                  | 4528,22374                    | Btu/s      |
| L          |                | FROM BASIC SCREENING METHODOLOGY                     |                               |            |
|            | 3              | FIRE LOCATION FACTOR                                 |                               | **         |
| <b>6</b> - |                | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)             |                               | Dhula      |
|            | 4              | EFFECTIVE HEAT RELEASE RATE                          | 4528.223/4                    | Btu/s      |
|            |                | ([BOX 2] X [BOX 3])                                  |                               |            |
|            | 6              | MAXIMUM AMBIENT TEMPERATURE                          | 0000043.0000                  | F          |
| -          |                |  | 1588.31                       | F          |
|            | ,              |  |                               | -          |
| -          | 8              | RADIANT FRACTION OF HEAT RELEASE                     | 0.4                           | -          |
|            | •              | (REPRESENTATIVE VALUE = 0.4)                         |                               |            |
| t i        | 9              | RADIANT HEAT RELEASE RATE                            | 1811.2895                     | Btu/s      |
|            |                | (FROX 2 TXTBOX 81)                                   |                               |            |
| li.        |                | NEOD MATION  |                               |            |
| r i        | LECTOR         |  | in the second                 | F          |
| 8          | 1              | RATED ACTUATION TEMPERATURE OF DETECTOR              | 0000 <b>49</b> 44.0000        | •          |
|            |                | (MANUFACIURERS DATA)                                 | SSSS 4 0 1000                 | ft         |
|            | 2              | HEIGHT FROM FIRE SOURCE TO CELLING                   | 19000 <b>19</b> 00 <b>1</b> 9 |            |
|            |                | (BASED ON SCENARIO GEOMETRY)                         |                               | <b>f</b> + |
| 1          | 3              | HOOR DIMENSION - WIDTH                               | 0000 <b>×</b> 60000           |            |
| ŀ          | 4              | LONGTUDINAL DISTANCE FROM FIRE SOURCE TO DETECTOR. 1 | 1                             | ft         |
|            | т              | (PASED ON SCENARIO GEOMETRY)                         |                               |            |
|            | 5              | LONGTUDINAL DISTANCE TO HEIGHT RATIO. UH             | 0.10                          |            |
|            |                | (TEOX 41/TEOX 21)                                    |                               |            |
| · · ·      | 6              | HEIGHT TO WITTH PATTO, HW                            | 0.37                          |            |
|            | Ŭ              | (IBOX 2]/(BOX 3])                                    |                               |            |
| 1          | 7              | PEAK FIDE INTENSITY                                  | 4528.22374                    | Btu/s      |
| 1          |                | (LISE TARLE OF FOR CLIDANCE)                         |                               |            |
|            | 8              |  |                               |            |
|            |                | A FOR CORNER 2 FOR WALL 1 FOR CENTER)                |                               |            |
|            |                | EFECTIVE FIDE INTENSITY                              | 4528.22374                    | Btu/s      |
|            |                |  |                               |            |
|            | 10             |  | 1600.00                       | F          |
|            | 10             | A DOX IN VALUE FROM TABLE 55                         |                               | -          |
| ļ          | - 11           | CERTING IET TEMPERATIRE PISE FACTOR AT DELECTOR      | 1.00                          |            |
|            |                | ( LOOK IN VALUE FROM TABLE 64 OR 68)                 |                               |            |
|            | 12             | CETTING SET TEMPEDATI DE DISE AT DETECTOR            | 1600.00                       | F          |
|            | 12             | (BOX 101X BOX 111)                                   |                               |            |
| Ì          | TIMETOI        | TARGET DAMAGE  |                               |            |
|            | 1              | PADIATIVE HEAT BUX AT TARGET                         | 1 09                          | Btu/s/     |
|            | 1              | (TABLE A-3E)   | 1                             |            |
|            | 22             | TARGET LOCATION                                      | 1                             |            |
|            | 1 <sup>4</sup> | IN-PLUME(1): OUT-PLUME (2)                           |                               | 1          |
|            | 2h             | CONVECTIVE HEAT FLUX AT TARGET                       | 10.27                         | Btu/s/     |
|            | 20             | (TABLES A-F AND A-5)                                 |                               | 1          |
|            |                | TOTAL HEAT FILM AT TARGET                            | 11.36                         | Btu/s/     |
|            | 1              | (fBOX1) + FBOX 2bT)                                  |                               | 1          |
|            | -              | TARGET THERMAL RESPONSE PARAMETER                    | 34                            | -          |
|            |                | (TABLE A-7E)   |                               |            |
|            | 5              | ESTIMATED TIME TO TARGET DAMAGE                      | 7                             | 5          |
|            |                | (TABLE A-2E)   |                               |            |
|            | TIME TO        | DETECTOR ACTUATION                                   |                               |            |
|            | 6              | DETECTION DEVICE RATED TEMPERATURE RISE              | 90                            | F          |
|            | 1              |  |                               |            |
|            | 7              | GAS TEMPERATURE RISE AT DETECTOR                     | 1600                          | F          |
|            |                | (USE BASIC SCREENING METHODOLOGY)                    |                               | 1          |
|            | 8              | DETECTOR TEMPERATURE RISE/GAS TEMPERATURE RISE       | 0.06                          | -          |
|            |                | ([BOX 6]/[BOX 7])                                    |                               |            |
|            | 9              | DIMENSIONLESS DETECTOR ACTUATION TIME                | 0.06                          | -          |
|            |                | (TABLE A-1)  |                               |            |
|            | 10             | TIME CONSTANT OF DETECTION DEVICE                    | 12000                         | () S       |
|            | L              | (TABLE A-6E OR MFG. DATA)                            |                               |            |
|            | 11             | ESTIMATED TIME TO DETECTOR ACTUATION                 | 6.95                          | s          |
|            |                | Annual and a her many and h                          | 1                             | 1          |

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#### COMBUSTIBLE MATERIAL WORKSHEET

#### FUEL PROPERTIES - UNCONFINED SPILL

| \$\$\$\$ <b>2</b> \$\$\$\$\$ |
|------------------------------|
| 17111                        |
| 90%                          |
| 110                          |
| 60                           |
|                              |

#### FLOW CHARACTERISTICS

| DESCRIPTION         |       |
|---------------------|-------|
| SPECIFIC SPILL AREA | 120,0 |

| SPILL AREA          | 66    | SQ-FT |
|---------------------|-------|-------|
| PEAK FIRE INTENSITY | 6534  | BTU/S |
| FIRE DURATION       | 10    | SEC   |
|                     | 0.173 | MIN   |

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#### FUEL PROPERTIES - CONFINED SPILL

| DESCRIPTION            |       |
|------------------------|-------|
| VOLUME (QUARTS)        | 2     |
| NET HEAT OF COMBUSTION | 17111 |
| COMBUSTION EFFICIENCY  | 1     |
| UNIT HEAT RELEASE RATE | 110   |
| DENSITY                | 60    |

#### FLOW CHARACTERISTICS

| DESCRIPTION<br>SPILL AREA | 4.6   | SQ-FT |
|---------------------------|-------|-------|
| PEAK FIRE INTENSITY       | 453   | BTU/S |
| FIRE DURATION             | 2.500 | MIN   |

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### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

## FIXED COMBUSTIBLE / TARGET IN PLUME

ENGLISH UNITS VERSION

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### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

## FIXED COMBUSTIBLE / RADIANT EXPOSURE

ENGLISH UNITS VERSION

| 1   | CRITICAL RADIANT FLUX TO TARGET                 | 1          | Btu/s/ft2 |
|---|---|------------|-----------|
|   | (REPRESENTATIVE CONSERVATIVE VALUE = 1)         |            |           |
|   | (LOOK UP VALUE FROM TABLE 1E)                   |            |           |
| 2   | PEAK FIRE INTENSITY                             | 452.912776 | Btu/s     |
|   | (USE TABLE 2E FOR GUIDANCE)                     |            |           |
| 3   | RADIANT FRACTION OF HEAT RELEASE                | 0.4        |           |
|   | (REPRESENTATIVE VALUE = 0.4)                    |            |           |
| 4   | RADIANT HEAT RELEASE RATE                       | 181.165111 | Btu/s     |
|   | ([BOX2]X[BOX3])                                 |            |           |
| 5   | CRITICAL RADIANT FLUX DISTANCE                  | 3.80       | ft        |
|   | (LOOK UP VALUE FROM TABLE 10E)                  |            |           |
| 6   | ACTUAL DISTANCE BETWEEN SOURCE/TARGET           | 0          | ft        |
|   | (FROM FIRE COMPARTMENT CCDS)                    | • •        |           |
| IF THE EXPOSURE FIRE IS LOCATED WITHIN THIS DISTANCE        |   |            |           |
| (INDICATED IN BOX 5) OF THE TARGET, CRITICAL CONDITIONS CAN |   |            |           |
| OCCUR. OUTSIDE THIS RANGE, CRITICAL CONDITIONS ARE NOT      |   |            |           |
|   | INDICATED FOR THE SCENARIO UNDER CONSIDERATION. |            |           |

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## **OPPD - Fort Calhoun Station** Fire Risk Analysis Refinement Project

#### COMBUSTIBLE MATERIAL WORKSHEET

#### FUEL PROPERTIES - UNCONFINED SPILL

| DESCRIPTION            |             |
|------------------------|-------------|
| VOLUME (QUARTS)        | <u>)</u> 14 |
| NET HEAT OF COMBUSTION | 17111       |
| COMBUSTION EFFICIENCY  | 90%         |
| UNIT HEAT RELEASE RATE | 110         |
| DENSITY                | 60          |

#### FLOW CHARACTERISTICS

| DESCRIPTION         |  |
|---------------------|--|
| SPECIFIC SPILL AREA |  |

SPILL AR PEAK FIF FIRE DU

120.0

| REA ·          | 420   | SQ-FT |
|----------------|-------|-------|
| RE INTENSITY · | 41580 | BTU/S |
| RATION         | 10    | SEC   |
|                | 0.173 | MIN   |

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#### **FUEL PROPERTIES - CONFINED SPILL**

| DESCRIPTION            |       |   |
|------------------------|-------|---|
| VOLUME (QUARTS)        | 14    | ~ |
| NET HEAT OF COMBUSTION | 17111 |   |
| COMBUSTION EFFICIENCY  | 1     |   |
| UNIT HEAT RELEASE RATE | 110   |   |
| DENSITY                | 60    |   |

#### FLOW CHARACTERISTICS

| DESCRIPTION<br>SPILL AREA            |   | 29.1                 | SQ-FT               |
|--------------------------------------|---|----------------------|---------------------|
| PEAK FIRE INTENSITY<br>FIRE DURATION | - | 2882<br>150<br>2.500 | BTU/S<br>SEC<br>MIN |

#### COMMENTS

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### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

## FIXED COMBUSTIBLE / TARGET IN PLUME

ENGLISH UNITS VERSION

| (USE TABLE 1E FOR GUIDANCE)       18.2         2       HEIGHT OF TARGET ABOVE FIRE SOURCE       18.2         3       HEIGHT OF TARGET ABOVE FIRE SOURCE       18.2         4       HEIGHT FROM FRE SOURCE TO CELLING       20         6ASED ON SCENARIO GEOMETRY)       207/777778         3a       FLOOR AREA (LENGTH) X (WIDTH)       201         3c       ESTIMATED DURATION OF FIRE       225         3c       ESTIMATED DURATION OF FIRE       225         4       PEAK FIRE INTENSITY       2852/39611         5       FIRE LOCATION FACTOR          (4 FOR CONTENE, 2 FOR WALL, 1 FOR CENTER)          6       EFFECTIVE HEAT RELEASE RATE       2882/39611         (IDOX A) FUNCTION FACTOR          (IDOX A) FUNCTION FACTOR          (IDOX A) FUNCTION FACTOR          7       PUIME TEMPERATURE RISE AT TARGET       546.84         6       EFFECTIVE HEAT RELEASE AT TARGET       610         7       PUIME TEMPERATURE RISE AT TARGET       610         8b       CRITICAL TEMPERATURE RISE AT TARGET       610         9       CRITICAL TEMPERATURE RISE AT TARGET       610         116 (IBOX 1) - MAXIMUM AMBIENT TEMPERATURE       900      1   | • 1 | TARGET DAMAGE THRESHOLD TEMPERATURE                      | 700                                   | F       |  |  |
|---|-----|--|---------------------------------------|---------|--|--|
| 2       HEIGHT OF TARGET ABOVE FIRE SOURCE<br>(BASED ON SCENARIO GEOMETRY)       18:2       ft         3       HEIGHT FROM FIRE SOURCE TO CELLING<br>(BASED ON SCENARIO GEOMETRY)       20       ft         3a       FLOOR DIMENSIONS - LENGTH<br>- WIDTH       207:772778       ft         3b       FLOOR AREA (LENGTH) X (WIDTH)       5610       ft2         3c       ESTIMATED DURATION OF FIRE       225:5       min         4       PEAK FIRE INTENSITY<br>USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)       1   |     | (USE TABLE 1E FOR GUIDANCE)                              |                                       | ]       |  |  |
| (BASED ON SCENARIO GEOMETRY)       20       ft         3       HEIGHT FROM FIRE SOURCE TO CELLING       20       ft         3a       FLOOR DIMENSIONS - LENGTH       207,777778       ft         3b       FLOOR AREA (LENGTH) X (WIDTH)       5610       ft2         3c       ESTIMATED DURATION OF FIRE       215,500       min         4       PEAK FIRE INTENSITY       2882,3951.       Btu/s         uSE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)       5       FIRE LOCATION FACTOR          6       EFFECTIVE HEAT RELEASE RATE       2882,3961.       Btu/s         (IBOX 4) X (BOX 5))            7  | 2   | HEIGHT OF TARGET ABOVE FIRE SOURCE                       | 18.2                                  | ft      |  |  |
| 3       HEIGHT FROM FIRE SOURCE TO CELLING<br>(BASED ON SCENARIO GEOMETRY)       20       ft         3a       FLOOR DIMENSIONS - LENGTH<br>- WIDTH       217,777778       ft         3b       FLOOR AREA (LENGTH) X (WIDTH)       5610       ft2         3c       ESTIMATED DURATION OF FIRE       215       min         4       PEAK FIRE INTENSITY<br>USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)       288239513       Btu/s         5       FIRE LOCATION FACTOR<br>(4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)       2882.3961       Btu/s         6       EFFECTIVE HEAT RELEASE RATE<br>(IDOX UP VALUE FROM TABLE 5E)       546.84       F         10       CRITICAL - PLIME TEMPERATURE RISE AT TARGET<br>(IBOX 1] - MAXIMUM AMBIENT TEMPERATURE<br>9       63.16       F         10       QREVY TO ACHIEVE TEMP RATURE RISE IN ENSPERATURE)       1.04       Btu/ft3<br>(IBOX 2)       Ft         10       QREVY TO ACHIEVE TEMP RATE       1.04       Btu/ft3<br>(IBOX 3) X FLOOR AREA OF SPACE)       110200       ft3<br>(IBOX 10) X [BOX11)         11       CALCULATED ENCLOSURE VOLUME, V<br>(IBOX 10) X [BOX11])       1116,421       Btu<br>/ft3<br>(IBOX 10) X [BOX11])       1116,421       Btu<br>/ft3<br>(IBOX 112)       ESTIMATE OF CRITICAL CONT         12       CALCULATED CRITICAL QOAL<br>(IBOX 10) X [BOX11])       13       60,7  |     | (BASED ON SCENARIO GEOMETRY)                             |                                       |         |  |  |
| (BASED ON SCENARIO GEOMETRY)207.777778ft3aFLOOR DIMENSIONS - LENGTH207.777778ft3bFLOOR AREA (LENGTH) X (WIDTH)5610ft23cESTIMATED DURATION OF FIRE22.5min4PEAK FIRE INTENSITY2882/3961.Btu/s5FIRE LOCATION FACTOR2882.3961.Btu/s6EFFECTIVE HEAR RELEASE RATE2882.3961.Btu/s7PLUME TEMPERATURE RISE AT TARGET2482.3961.Btu/s7PLUME TEMPERATURE RISE AT TARGET546.84F10(IGOX 4) X (BOX 5)F8aMAXIMUM AMBIENT TEMPERATURE90F8bCRITICAL FULME TEMPERATURE RISE AT TARGET610F10(IGOX 1) - MAXIMUM AMBIENT TEMPERATURE)63.16F9CRITICAL FULME TEMPERATURE RISE63.16F10IF THE ENTRY IN BOX 9 15 <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT10.410QREVY TO ACHIEVE TEMP RISE IN BOX 91.04Btu/ft311CALCULATED ENCLOSURE VOLUME, V112200ft312CALCULATED CRITICAL Quet<br>(IBOX 13) X FLOOR AREA OF SPACE)10.60.713ESTIMATED CRITICAL Quet<br>(IBOX 12) X IDOR AREA OF SPACE)388,070Btu14ESTIMATED CRITICAL Quet<br>(IBOX 12) X IDOR AREA OF SPACE)388,070Btu15ESTIMATED CRITICAL Quet<br>(IHRR) X (TIME)) = [BOX 4) X [TIME]432,359Btu<   | 3   | HEIGHT FROM FIRE SOURCE TO CEILING                       | 20                                    | ft      |  |  |
| 3a       FLOOR DIMENSIONS - LENGTH<br>- WIDTH       207/77778       ft         3b       FLOOR AREA (LENGTH) X (WIDTH)       5610       ft2         3c       ESTIMATED DURATION OF FIRE       2282/3961       Btu/s         4       PEAK FIRE INTENSITY<br>USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)       2882/3961       Btu/s         5       FIRE LOCATION FACTOR<br>(4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)       2882.3961       Btu/s         6       EFFECTIVE HEAT RELEASE RATE<br>(LOOK UP VALUE FROM TABLE 5E)       2882.3961       Btu/s         7       PLUME TEMPERATURE RISE AT TARGET<br>(LOOK UP VALUE FROM TABLE 5E)       546.84       F         8a       MAXIMUM AMBIENT TEMPERATURE       90       F         8b       CRITICAL TEMPERATURE RISE AT TARGET<br>(LOOK UP VALUE FROM TABLE 5E)       610       F         9       CRITICAL TEMPERATURE RISE AT TARGET<br>(LOOK UP VALUE FROM TABLE 5E)       63.16       F         90       CRITICAL - PLUME TEMPERATURE RISE<br>(IGOX 3) - INOX 3) IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT       10       Quety V TO ACHEVE TEMP RISE IN BOX 9       1.04       Btu/ft3<br>(IGOX 3) X LOOR AREA OF SPACE)         11       CALCULATED ENCLOSURE VOLUME, V<br>(IGOX 3) X LOOR AREA OF SPACE)       112200       ft3<br>(IGOX 10) X [BOX11])       11       11       116,421   |     | (BASED ON SCENARIO GEOMETRY)                             |                                       |         |  |  |
| -WIDTH       27,000       ft         3b       FLOOR AREA (LENGTH) X (WIDTH)       5610       ft2         3c       ESTIMATED DURATION OF FIRE       28.500       min         4       PEAK FIRE INTENSITY       28.82:3961       Btu/s         use table 22.6 FIGURES 4-5 FOR GUIDANCE)       28.82:3961       Btu/s         5       FIRE LOCATION FACTOR   | 3a  | FLOOR DIMENSIONS - LENGTH                                | 207.777778                            | ft      |  |  |
| 3bFLOOR AREA (LENGTH) X (WIDTH)5610ft23cESTIMATED DURATION OF FIRE2882/3961min4PEAK FIRE INTENSITY<br>USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)2882/3961Btu/s5FIRE LOCATION FACTOR<br>(4 FOR CONNER, 2 FOR WALL, 1 FOR CENTER)2882.3961Btu/s6EFFECTIVE HEAT RELEASE RATE<br>(BOX 4) X [ROX 5])2882.3961Btu/s7PLUME TEMPERATURE RISE AT TARGET<br>(LOOK UP VALUE FROM TABLE 5E)546.84F8aMAXIMUM AMBIENT TEMPERATURE90F8bCRITICAL TEMPERATURE RISE AT TARGET<br>(IBOX 1) - MAXIMUM AMBIENT TEMPERATURE)610F9CRITICAL - PLUME TEMPERATURE RISE<br>(IBOX 1) - MAXIMUM AMBIENT TEMPERATURE)63.16F9CRITICAL - PLUME TEMPERATURE RISE<br>(IBOX 1) - MAXIMUM AMBIENT TEMPERATURE)63.16F9CRITICAL - PLUME TEMPERATURE RISE<br>(IBOX 3) - IOAT IN IBOX 9 IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT10010QnetV TO ACHIEVE TEMP RISE IN BOX 91.04Btu/ft311CALCULATED ENCLOSURE VOLUME, V<br>(IBOX 3) X FLOOR AREA OF SPACE)112.200ft3112CALCULATED CRITICAL Quet<br>(IBOX 10) X (BOX11)13ESTIMATE OF CRITICAL Quet<br>(IBOX 12) X IEDX 11)1313ESTIMATE OF CRITICAL Quet<br>(IBOX 12) X IEDX 14,<br>(IHRR) X TIME) = [BOX 4) X [TIME]432,359Btu15ESTIMATE OF CRUTICAL Quet<br>(IHRR) X TIME) = ESTIMATE OF CRUTICAL Quet<br>(IHRR) X TIME) = [BOX 4) X [TIME]432,359   |     | - WIDTH  | 27                                    | ft      |  |  |
| 3c       ESTIMATED DURATION OF FIRE       2.5       min         4       PEAK FIRE INTENSITY       2.882.3961.8       Btu/s         USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)       2       82.3961.8       Btu/s         5       FIRE LOCATION FACTOR       1          (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)       2       82.3961.8       Btu/s         6       EFFECTIVE HEAT RELEASE RATE       2882.3961       Btu/s         (IBOX 4] X [BOX 5])       7        4400 KULE FROM TABLE 5E)       546.84       F         8a       MAXIMUM AMBIENT TEMPERATURE       90       F       610       F         8b       CRITICAL TEMPERATURE RISE AT TARGET<br>(IBOX 1] - MAXIMUM AMBIENT TEMPERATURE)       63.16       F         9       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         (IBOX 1] - MAXIMUM AMBIENT TEMPERATURE       1.04       Btu/ft3         (IBOX 1] - MAXIMUM AMBIENT TEMPERATURE       1.04       Btu/ft3      <  | 3b  | FLOOR AREA (LENGTH) X (WIDTH)                            | 5610                                  | ft2     |  |  |
| 3c       ESTIMATED DURATION OF FIRE       235       min         4       PEAK FIRE INTENSITY       2882/3961///////////////////////////////////  |     |  |                                       |         |  |  |
| 4       PEAK FIRE INTENSITY<br>USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)       2882/3961       Btu/s         5       FIRE LOCATION FACTOR<br>(4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)  | 3c  | ESTIMATED DURATION OF FIRE                               | 2.5                                   | min     |  |  |
| USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)       DED/05         5       FIRE LOCATION FACTOR  | 4   |  | 2882 3961                             | Btu/s   |  |  |
| 50:E       FIRE LOCATION FACTOR   | т   | LISE TARIE 25 & FIGURES 4.5 FOR GUIDANCE)                |                                       | 200/0   |  |  |
| 3       FIRE EXOLUTION FACTOR         (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)       2882.3961         6       EFFECTIVE HEAT RELEASE RATE<br>(IBOX 4] X [BOX 5])       Btu/s         7       PLUME TEMPERATURE RISE AT TARGET<br>(LOOK UP VALUE FROM TABLE 5E)       546.84       F         8a       MAXIMUM AMBIENT TEMPERATURE       90       F         8b       CRITICAL TEMPERATURE RISE AT TARGET<br>(IBOX 1] - MAXIMUM AMBIENT TEMPERATURE)       610       F         9       CRITICAL - PLUME TEMPERATURE RISE AT TARGET<br>(IBOX 8] - [BOX 7])       63.16       F         9       CRITICAL - PLUME TEMPERATURE RISE<br>(IBOX 8] - [BOX 7])       63.16       F         10       Qnet/V TO ACHIEVE TEMPERATURE BY THIS AMOUNT       70       RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         11       CALCULATED ENCLOSURE VOLUME, V<br>(IBOX 3] X FLOOR AREA OF SPACE)       112200       ft3         12       CALCULATED CRITICAL Qnet<br>(IBOX 10] X [BOX11])       116,421       Btu         13       ESTIMATE OF CRITICAL Qnet<br>(IBOX 12]/(1 - [BOX13]))       388,070       Btu         14       ESTIMATE OF CRITICAL Quot<br>(IHRR] X [TIME])       388,070       Btu         15       ESTIMATE OF ACTUAL Quot<br>(IHRR] X [TIME])       432,359       Btu </td <td></td> <td></td> <td>1005.0001</td> <td></td>  |     |  | 1005.0001                             |         |  |  |
| 6       EFFECTIVE HEAT RELEASE RATE       2882.3961       Btu/s         (IBOX 4] X [BOX 5])       2882.3961       Btu/s         7       PLUME TEMPERATURE RISE AT TARGET       546.84       F         (LOOK UP VALUE FROM TABLE 5E)       546.84       F         8a       MAXIMUM AMBIENT TEMPERATURE       90       F         8b       CRITICAL TEMPERATURE RISE AT TARGET       610       F         (IBOX 1] - MAXIMUM AMBIENT TEMPERATURE)       63.16       F         9       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         (IBOX 8] - [BOX 7])       IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE   | 5   |  |                                       |         |  |  |
| 0       EFFECTIVE FIENT NELLINGE WITE       20020501       Ditly's         ([B0X 4] X [B0X 5])       7.       PLUME TEMPERATURE RISE AT TARGET       546.84       F         (LOOK UP VALUE FROM TABLE 5E)       8a       MAXIMUM AMBIENT TEMPERATURE       90       F         8b       CRITICAL TEMPERATURE RISE AT TARGET       610       F         ([B0X 1] - MAXIMUM AMBIENT TEMPERATURE)       63.16       F         9       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         ([B0X 8] - [B0X 7])       IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE  | 5   | CEECTIVE HEAT DELEASE DATE                               | 2882 3961                             | Btu/s   |  |  |
| 7.7       PLUME TEMPERATURE RISE AT TARGET       546.84       F         8a       MAXIMUM AMBIENT TEMPERATURE       90       F         8b       CRITICAL TEMPERATURE RISE AT TARGET       610       F         (IBOX 1] - MAXIMUM AMBIENT TEMPERATURE       63.16       F         9       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         (IBOX 8] - (BOX 7])       IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT       10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         11       CALCULATED ENCLOSURE VOLUME, V       112200       ft3         (IBOX 3] X FLOOR AREA OF SPACE)       116,421       Btu         12       CALCULATED CRITICAL QNEt       07          13       ESTIMATE OF CRITICAL Quet       388,070       Btu         (IBOX 12)/(1 - [BOX13]))       15       ESTIMATE OF ACTUAL Quet       432,359       Btu         15       ESTIMATE OF ACTUAL Quet       432,359       Btu       IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14, CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO       632,359       Btu  | Ö   |  | 2002.3301                             | Diajo   |  |  |
| Image: Section of the intervention of the section of the secentral of the sectin of the section of the secentral of the secen |     |  | 546.84                                | F       |  |  |
| 8a       MAXIMUM AMBIENT TEMPERATURE       90       F         8b       CRITICAL TEMPERATURE RISE AT TARGET       610       F         ([B0X 1] - MAXIMUM AMBIENT TEMPERATURE)       93       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         9       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         ([B0X 8] - [B0X 7])       IF THE ENTRY IN B0X 9 IS <= 0, STOP. OTHERWISE CONTINUE   |     |  | J 10.01                               | •       |  |  |
| Od       PRALIPORT AURIPLEAT TEMPERATURE       610       F         8b       CRITICAL TEMPERATURE RISE AT TARGET       610       F         ([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)       63.16       F         9       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         ([BOX 8] - [BOX 7])       IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE   | 0-  |  | n                                     | F       |  |  |
| 8b       CRITICAL TEMPERATURE RISE AT TARGET<br>([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)       610       F         9       CRITICAL - PLUME TEMPERATURE RISE<br>([BOX 8] - [BOX 7])       63.16       F         IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9<br>(LOOK UP VALUE FROM TABLE 7E)       1.04       Btu/ft3<br>(LOOK UP VALUE FROM TABLE 7E)         11       CALCULATED ENCLOSURE VOLUME, V<br>([BOX 3] X FLOOR AREA OF SPACE)       1112200       ft3         12       CALCULATED CRITICAL Qnet<br>([BOX 10] X [BOX11])       116,421       Btu<br>([BOX 10] X [BOX11])         13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)       388,070       Btu<br>([BOX 12]/(1 - [BOX13]))         15       ESTIMATE OF CRITICAL Qtot<br>([BOX 12]/(1 - [BOX13]))       432,359       Btu<br>([HRR] X [TIME]) = [BOX 4] X [TIME]         15       ESTIMATE OF ACTUAL Qot<br>([HRR] X [TIME]) = [BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  | bo  |  |                                       | I I     |  |  |
| ([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)         9       CRITICAL - PLUME TEMPERATURE RISE       63.16       F         ([BOX 8] - [BOX 7])       IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT       10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         (LOOK UP VALUE FROM TABLE 7E)       112200       ft3         11       CALCULATED ENCLOSURE VOLUME, V       112200       ft3         ([BOX 3] X FLOOR AREA OF SPACE)       116,421       Btu         12       CALCULATED CRITICAL Qnet       116,421       Btu         ([BOX 10] X [BOX11])            13       ESTIMATE D FC RITICAL Quot       388,070       Btu         ([BOX 12]/(1 - [BOX13]))            14       ESTIMATE OF ACTUAL Quot       432,359       Btu         15       ESTIMATE OF ACTUAL Quot       432,359       Btu         1       ([HRR] X [TIME]) = [BOX 4] X [TIME]       IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  | 8b  | CRITICAL TEMPERATURE RISE AT TARGET                      | 610                                   | F       |  |  |
| 9       CRITICAL - PLUME TEMPERATURE RISE<br>([BOX 8] - [BOX 7])       63.16       F         IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT       10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         11       CALCULATED ENCLOSURE VOLUME, V       112200       ft3         ([BOX 3] X FLOOR AREA OF SPACE)       116,421       Btu         12       CALCULATED CRITICAL Qnet<br>([BOX 10] X [BOX11])       116,421       Btu         13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)       388,070       Btu         14       ESTIMATE OF CRITICAL Qtot<br>([BOX 12]/(1 - [BOX13]))       388,070       Btu         15       ESTIMATE OF ACTUAL Qtot<br>([HRR] X [TIME]) = [BOX 4] X [TIME]       432,359       Btu         15       ESTIMATE OF ACTUAL Qtot       432,359       Btu         16       THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO       CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   |     | ([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)                  |                                       |         |  |  |
| I[BOX 8] - [BOX 7])       IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE   | 9   | CRITICAL - PLUME TEMPERATURE RISE                        | 63.16                                 | F       |  |  |
| IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9<br>(LOOK UP VALUE FROM TABLE 7E)       1.04       Btu/ft3         11       CALCULATED ENCLOSURE VOLUME, V<br>(IBOX 3] X FLOOR AREA OF SPACE)       112200       ft3         12       CALCULATED CRITICAL Qnet<br>(IBOX 10] X [BOX11])       116,421       Btu         13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)   |     | ([BOX 8] - [BOX 7])                                      |                                       |         |  |  |
| TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9<br>(LOOK UP VALUE FROM TABLE 7E)       1.04       Btu/ft3         11       CALCULATED ENCLOSURE VOLUME, V<br>(IBOX 3] X FLOOR AREA OF SPACE)       112200       ft3         12       CALCULATED CRITICAL Qnet<br>(IBOX 10] X [BOX11])       116,421       Btu         13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)       0.7          14       ESTIMATE OF CRITICAL Qtot<br>(IBOX 12]/(1 - [BOX13]))       388,070       Btu         15       ESTIMATE OF ACTUAL Qtot<br>(IHRR] X [TIME]) = [BOX 4] X [TIME]       432,359       Btu         15       ESTIMATE OF ACTUAL Qtot<br>(IHRR] X [TIME]) = [BOX 4] X [TIME]       HOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  |     | IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE  |                                       |         |  |  |
| RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT         10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         (LOOK UP VALUE FROM TABLE 7E)       112200       ft3         11       CALCULATED ENCLOSURE VOLUME, V       112200       ft3         ([BOX 3] X FLOOR AREA OF SPACE)       116,421       Btu         12       CALCULATED CRITICAL Qnet       116,421       Btu         ([BOX 10] X [BOX11])       13       ESTIMATED HEAT LOSS FRACTION  |     | TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO     |                                       |         |  |  |
| 10       Qnet/V TO ACHIEVE TEMP RISE IN BOX 9       1.04       Btu/ft3         (LOOK UP VALUE FROM TABLE 7E)       112200       ft3         11       CALCULATED ENCLOSURE VOLUME, V       112200       ft3         (IBOX 3] X FLOOR AREA OF SPACE)       116,421       Btu         12       CALCULATED CRITICAL Qnet       116,421       Btu         (IBOX 10] X [BOX11])       13       ESTIMATED HEAT LOSS FRACTION       07          14       ESTIMATE OF CRITICAL Qtot       388,070       Btu         (IBOX 12]/(1 - [BOX13]))       15       ESTIMATE OF ACTUAL Qtot       432,359       Btu         15       ESTIMATE OF ACTUAL Qtot       432,359       Btu         (IHRR] X [TIME]) = [BOX 4] X [TIME]       IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  |     | RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT             |                                       |         |  |  |
| (LOOK UP VALUE FROM TABLE 7E)       112200         11       CALCULATED ENCLOSURE VOLUME, V       112200         ([BOX 3] X FLOOR AREA OF SPACE)       116,421         12       CALCULATED CRITICAL Quet       116,421         ([BOX 10] X [BOX11])       13         13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)       07.         14       ESTIMATE OF CRITICAL Quot<br>([BOX 12]/(1 - [BOX13]))       388,070         15       ESTIMATE OF ACTUAL Quot<br>([HRR] X [TIME]) = [BOX 4] X [TIME]       432,359         15       IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  | 10  | Qnet/V TO ACHIEVE TEMP RISE IN BOX 9                     | 1.04                                  | Btu/ft3 |  |  |
| 11       CALCULATED ENCLOSURE VOLUME, V       112200       ft3         ([BOX 3] X FLOOR AREA OF SPACE)       116,421       Btu         12       CALCULATED CRITICAL Qnet       116,421       Btu         ([BOX 10] X [BOX11])       13       ESTIMATED HEAT LOSS FRACTION       0.7         13       ESTIMATED HEAT LOSS FRACTION       0.7          (REPRESENTATIVE VALUE : 0.7)       14       ESTIMATE OF CRITICAL Qtot       388,070       Btu         15       ESTIMATE OF ACTUAL Qtot       432,359       Btu         ([HRR] X [TIME]) = [BOX 4] X [TIME]       IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO       CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   |     | (LOOK UP VALUE FROM TABLE 7E)                            |                                       |         |  |  |
| ([BOX 3] X FLOOR AREA OF SPACE)       116,421         12       CALCULATED CRITICAL Qnet       116,421         ([BOX 10] X [BOX11])       116,421         13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)  | 11  | CALCULATED ENCLOSURE VOLUME, V                           | 112200                                | ft3     |  |  |
| 12       CALCULATED CRITICAL Quet<br>([BOX 10] X [BOX11])       116,421       Btu         13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)   |     | ([BOX 3] X FLOOR AREA OF SPACE)                          |                                       |         |  |  |
| ([BOX 10] X [BOX11])          13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)          14       ESTIMATE OF CRITICAL Qtot<br>([BOX 12]/(1 - [BOX13]))       388,070       Btu         15       ESTIMATE OF ACTUAL Qtot<br>([HRR] X [TIME]) = [BOX 4] X [TIME]       432,359       Btu         IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO       CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   | 12  | CALCULATED CRITICAL Qnet                                 | 116,421                               | Btu     |  |  |
| 13       ESTIMATED HEAT LOSS FRACTION<br>(REPRESENTATIVE VALUE : 0.7)       0.7         14       ESTIMATE OF CRITICAL Qtot<br>([BOX 12]/(1 - [BOX13]))       388,070       Btu         15       ESTIMATE OF ACTUAL Qtot<br>([HRR] X [TIME]) = [BOX 4] X [TIME]       432,359       Btu         1F THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO       CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  |     | ([BOX 10] X [BOX11])                                     |                                       |         |  |  |
| (REPRESENTATIVE VALUE : 0.7)         14       ESTIMATE OF CRITICAL Qtot         ([BOX 12]/(1 - [BOX13]))         15       ESTIMATE OF ACTUAL Qtot         432,359       Btu         ([HRR] X [TIME]) = [BOX 4] X [TIME]         IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,         CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   | 13  | ESTIMATED HEAT LOSS FRACTION                             | 0.7                                   |         |  |  |
| 14       ESTIMATE OF CRITICAL Qtot       388,070       Btu         ([BOX 12]/(1 - [BOX13]))       ([BOX 12]/(1 - [BOX13]))       432,359       Btu         15       ESTIMATE OF ACTUAL Qtot       432,359       Btu         ([HRR] X [TIME]) = [BOX 4] X [TIME]       IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  | 1   | (REPRESENTATIVE VALUE: 0.7)                              |                                       |         |  |  |
| ([BOX 12]/(1 - [BOX13]))       15         15       ESTIMATE OF ACTUAL Quot         ([HRR] X [TIME]) = [BOX 4] X [TIME]         IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,         CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  | 14  | ESTIMATE OF CRITICAL Qtot                                | 388,070                               | Btu     |  |  |
| 15       ESTIMATE OF ACTUAL Quot       432,359       Btu         ([HRR] X [TIME]) = [BOX 4] X [TIME]       IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,       CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  |     | ([BOX 12]/(1 - [BOX13]))                                 |                                       |         |  |  |
| ([HRR] X [TIME]) = [BOX 4] X [TIME]         IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,         CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   | 15  | ESTIMATE OF ACTUAL Quot 432,359 Btu                      |                                       |         |  |  |
| IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  |     | ([HRR] X [TIME]) = [BOX 4] X [TIME]                      |                                       |         |  |  |
| CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO  |     | IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14. | · · · · · · · · · · · · · · · · · · · |         |  |  |
|   |     | CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   |                                       |         |  |  |
| BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS  |     | BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS   | 5                                     |         |  |  |
| THIS SCREENING PROCEDURE. FURTHER ANALYSIS REQUIRED.  | ÷.  | THIS SCREENING PROCEDURE. FURTHER ANALYSIS REQUIRED.     |                                       |         |  |  |

#### FIXED COMBUSTIBLE / TARGET OUTSIDE PLUME

ENGLISH UNITS VERSION

| -  |                 |   |  |           |
|--|-----------------|---|--|-----------|
| Γ  | 1               | TARGET DAMAGE THRESHOLD TEMPERATURE                         | 700  | F         |
| Ļ  |                 | (LOOK UP VALUE FROM TABLE 1E)                               |  |           |
|  | 2               | HEIGHT OF TARGET ABOVE FIRE SOURCE                          | 18,2   | ft        |
|  |                 | (BASED ON SCENARIO GEOMETRY)                                |  |           |
|  | 3               | HEIGHT FROM FIRE SOURCE TO CEILING                          | 20   | ft        |
|  |                 | (BASED ON SCENARIO GEOMETRY)                                |  |           |
| 1  | 3a              | FLOOR DIMENSIONS - LENGTH                                   | 207,77778  | ft        |
| L  |                 | - WIDTH   | 27   | <u>ft</u> |
|  | Зb              | FLOOR AREA [LENGTH] X [WIDTH]                               | 5610   | ft2       |
|  | 3c              | ESTIMATED DURATION OF FIRE                                  | 2.5  | min       |
|  | 4               | RATIO OF TARGET HEIGHT/CEILING HEIGHT                       | 0.91   | -         |
| ╟  |                 |   | 11   |           |
| l  |                 | IF THE VALUE BY BOX 4 15 > 0.05, COMPLETE BOXES JAN,        |  |           |
| ľ  |                 | UTTERWISE, ENTER & VALUE OF U IN BOX 14 AND CONTINUE        |  |           |
| ŀ  | 5               |   | 1000 n 20000   |           |
|  | 5               | LONGITUDINAL DISTANCE FROM FIRE SOURCE TO TARGET, L         |  | 11        |
| ╟  | <u> </u>        | (BASED ON SCENARIO GEOMETRY)                                | 0.12   |           |
|  | D               | LUNGITUDINAL DISTANCE TO HEIGHT RATIO, UH                   | 0.13   |           |
|  |                 | ((BOX 5)/(BOX 3))   | <u>-</u>   |           |
| l  | 7               | ENCLOSURE WIDTH, W  | 2/   | π         |
|  |                 | (BASED ON SCENARIO GEOMETRY)                                |  |           |
|  | 8               | HEIGHT TO WIDTH RATIO, H/W                                  | 0.74   |           |
|  |                 | ([BOX 3]/[BOX 7])   |  |           |
|  | 9 -             | PEAK FIRE INTENSITY   | 2882.3961  | Btu/s     |
|  |                 | (USE TABLE 2E FOR GUIDANCE)                                 |  |           |
|  | •• 10           | FIRE LOCATION FACTOR  | 1  |           |
| l  |                 | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)                    |  |           |
|  | 11              | EFFECTIVE HEAT RATE RELEASE                                 | 2882.3961  | Btu/s     |
| I  |                 | ([BOX 9] X [BOX 10])  |  |           |
| l  | 12              | PLUME TEMPERATURE RISE AT CEILING                           | 467.30   | F         |
| 1  |                 | (LOOK UP VALUE FROM TABLE 5E)                               |  |           |
|  | 13              | CEILING JET TEMPERATURE RISE FACTOR AT TARGET               | •  |           |
|  |                 | (IF [BOX 4] < 0.85, ENTER 0, ELSE                           | 1.169  |           |
|  |                 | LOOK UP VALUE FROM TABLE 6A OR 6B)                          | 1  |           |
|  | 14              | CEILING JET TEMPERATURE RISE AT TARGET                      | 546.29   | F         |
|  |                 | ((BOX 12] X (BOX 13])                                       |  |           |
|  | 15a             | MAXIMUM AMBIENT TEMPERATURE                                 | 90   | F         |
|  |                 |   | P  |           |
|  | 15b             | CRITICAL TEMPERATURE RISE AT TARGET                         | 610  | F         |
|  |                 | (TBOX 11 - MAXIMUM AMBIENT TEMPERATURE)                     |  |           |
|  | 16              | CRITICAL - CEILING JET TEMP. RISE AT TARGET                 | 63.71  | F         |
|  |                 | ([BOX 15] - [BOX 14])                                       |  |           |
|  | l               | IF THE ENTRY IN BOX 16 IS <= 0. STOP. OTHERWISE CONTINUE TO |  |           |
|  |                 | CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO RAISE     |  |           |
|  |                 | THE AVERAGE TEMPERATURE BY THE AMOUNT INDICATED IN BOY 16   |  |           |
|  | 17              | One AVERAGE FEMPERATORE ST THE ANOONT INDICATED IN DOA 10.  | 1 1 05   | Bhilft    |
|  | 1 <sup>1</sup>  |   | 1.05   |           |
|  | 10              |   | 112 200  | 83        |
|  | 10              | CALCULATED ENCLOSURE VOLUME, V                              | 112,200  |           |
|  | 10              |   | 117 295  | Btu       |
|  | 1 <sup>12</sup> |   | 11,000   |           |
|  |                 |   | -  |           |
|  | 20              | ESTIMATED HEAT LOSS FRACTION (RANGE: 0-1)                   | - Faile - Carlos - C | 1 -       |
|  |                 | (REPRESENTATIVE VALUE : 0.7)                                | 201 202  | Dhi       |
|  | 21              | ESTIMATE OF CRITICAL Quot                                   | 391,282  |           |
|  | I               | ([BOX 19]/(1 - [BOX20]))                                    |  |           |
|  | 22              | ESTIMATE OF ACTUAL Qtot                                     | 432,359  | Btu       |
| (BASED ON ENERGY CONTENT OF FIRE SOURCE) |                 |   |  | 1         |
|  |                 | IF THE ENTRY IN BOX 22 IS LESS THAN THE VALUE IN BOX 21,    |  |           |
|  | l.              | CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO      |  |           |
|  |                 | BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS      |  |           |
|  | 1               | THIS SCREENING PROCEDURE. FURTHER ANALYSIS REQUIRED.        |  |           |

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## FIXED COMBUSTIBLE / RADIANT EXPOSURE

ENGLISH UNITS VERSION

| 1   | CRITICAL RADIANT FLUX TO TARGET         | 1          | Btu/s/ft2 |  |
|---|---|------------|-----------|--|
|   | (REPRESENTATIVE CONSERVATIVE VALUE = 1) |            |           |  |
|   | (LOOK UP VALUE FROM TABLE 1E)           |            |           |  |
| 2   | PEAK FIRE INTENSITY                     | 2882.3961  | Btu/s     |  |
|   | (USE TABLE 2E FOR GUIDANCE)             |            |           |  |
| 3   | RADIANT FRACTION OF HEAT RELEASE        | 0.4        |           |  |
|   | (REPRESENTATIVE VALUE = 0.4)            |            |           |  |
| 4   | RADIANT HEAT RELEASE RATE               | 1152.95844 | Btu/s     |  |
|   | ([BOX2]X[BOX3])                         |            |           |  |
| 5   | CRITICAL RADIANT FLUX DISTANCE          | 9.58       | ft        |  |
|   | (LOOK UP VALUE FROM TABLE 10E)          |            |           |  |
| 6   | ACTUAL DISTANCE BETWEEN SOURCE/TARGET   | 0          | ft        |  |
| (FROM FIRE COMPARTMENT CCDS)                                |   |            |           |  |
| IF THE EXPOSURE FIRE IS LOCATED WITHIN THIS DISTANCE        |   |            |           |  |
| (INDICATED IN BOX 5) OF THE TARGET, CRITICAL CONDITIONS CAN |   |            |           |  |
| OCCUR. OUTSIDE THIS RANGE, CRITICAL CONDITIONS ARE NOT      |   |            |           |  |
| INDICATED FOR THE SCENARIO UNDER CONSIDERATION.             |   |            |           |  |

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#### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

#### SUPPRESSION

#### THERMALLY THICK TARGETS

ENGLISH UNITS VERSION

| TARGET INF    | ORMATION  |  |           |
|---------------|---|--|-----------|
| <b>1</b> a    | HEIGHT OF TARGET ABOVE FIRE SOURCE                    | 12.7   | ft        |
|               | (BASED ON SCENARIO GEOMETRY)                          |  |           |
| 1b            | RADIAL DISTANCE FROM FIRE SOURCE TO TARGET            | 0.1  | ft        |
|               | UNE OF SIGHT DISTANCE FROM FIRE SOURCE TO TARGET      | 12.70  | ft        |
| 2             | PEAK FIRE INTENSITY                                   | 2882,3961  | Btu/s     |
|               | FROM BASIC SCREENING METHODOLOGY                      |  |           |
| 3             | FIRE LOCATION FACTOR                                  |  | -         |
|               | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)              |  |           |
| 4             | EFFECTIVE HEAT RELEASE RATE                           | 2882.3961  | Btu/s     |
|               | ([ECX 2] X [BOX 3])                                   |  |           |
| 6             | MAXIMUM AMBIENT TEMPERATURE                           |  | F         |
| 7             | PLUME TEMPERATURE RISE AT TARGET                      | 996.11   | F         |
|               | (LOOK UP VALUE FROM TABLE SE)                         |  |           |
| 8             | RADIANT FRACTION OF HEAT RELEASE                      | 0.4  | 1         |
|               | (REPRESENTATIVE VALUE = 0 4)                          |  |           |
| 9             | RADIANT HEAT RELEASE RATE                             | 1152.95844   | Btu/s     |
|               | (TEOX 2)X[BOX 8])                                     |  |           |
| DETECTOR      | INFORMATION   |  |           |
| 1             | RATED ACTUATION TEMPERATURE OF DETECTOR               | 165  | F         |
|               | (MANUFACTURERS DATA)                                  |  |           |
| 2             | HEIGHT FROM FIRE SOURCE TO CEILING                    | 20   | ft        |
| _             | (BASED ON SCENARIO GEOMETRY)                          |  |           |
| 3             | PLOOR DIMENSION - WIDTH                               | 27   | ft        |
| L             |   |  |           |
| 4             | LONGITUDINAL DISTANCE FROM FIRE SOURCE TO DETECTOR, L | 2000 ¥   | п         |
| <u>-</u>      | (EASED ON SCENARIO GEOMETRY)                          | - 0.05   |           |
| <u>ک</u> ـټ ا | LONGITUDINAL DISTANCE TO HEIGHT RATIO, L/R            | 0.05   |           |
| <u> </u>      |   | 0.74   |           |
|               | HEIGHT TO WIDTH KATIO, N/W                            | 0.74   |           |
| <u> </u>      |   | 2882 3961  | Btu/s     |
| 1 '           | PEAK FIKE INTENSIT                                    | 2002.5501  | 000/5     |
| <b>—</b>      |   |  |           |
| °             | FIRE EDUCATION FACTOR                                 | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~  |           |
|               | REFECTIVE FIRE INTENSITY                              | 2882,3961  | Btu/s     |
|               |   |  | ,-        |
| 10            | IN UME TEMPERATURE RISE AT CELLING                    | 467.30   | F         |
| 10            | (I OOK UP VALUE FROM TABLE SE)                        |  |           |
| 11            | CETLING JET TEMPERATURE RISE FACTOR AT DETECTOR       | 1.00   |           |
|               | ( LOOK UP VALUE FROM TABLE 5A OR 5B)                  |  | 1         |
| 12            | CEILING JET TEMPERATURE RISE AT DETECTOR              | 467,30   | F         |
|               | (120X 10] X (BOX 11])                                 |  |           |
| TIME TO       | TARGET DAMAGE   |  |           |
| 1             | RADIATIVE HEAT FLUX AT TARGET                         | 0.57   | Btu/s/ft2 |
| 1             | (TABLE A-3E)  |  |           |
| 2a            | TARGET LOCATION                                       |  |           |
|               | IN-PLUME(1); OUT-PLUME (2)                            |  | ļ         |
| 2b            | CONVECTIVE HEAT FLUX AT TARGET                        | 5.36   | Btu/s/ft2 |
|               | (TABLES A-4E AND A-5)                                 |  | ļ         |
| 3             | TOTAL HEAT FLUX AT TARGET                             | 5.93   | Btu/s/ft2 |
| L             | ([BOX1] + [BOX 2b])                                   |  | <u> </u>  |
| 4             | TARGET THERMAL RESPONSE PARAMETER                     | 39.000   | a - T     |
|               | (TABLE A-7E)  |  |           |
| 5             | ESTIMATED TIME TO TARGET DAMAGE                       | 26   | 5         |
| L             | (TABLE A-2E)  |  | 1         |
| TIME TO       | DETECTOR ACTUATION                                    |  | 1         |
| 6             | DETECTION DEVICE RATED TEMPERATURE RISE               | 90   |           |
|               |   | 467  | -         |
| 7             | GAS TEMPERATURE RISE AT DETECTOR                      | -10/   | 1         |
| <u> </u>      | USE BASIC SURTENING METHODOLOGT                       | 0 10   |           |
| 8             | DETECTOR TEMPERATURE RISE/GAS TEMPERATURE RISE        | 0.13   |           |
|               |   | 0.21   | +         |
| 9             | DIMENSIONLESS DETECTOR ACTUATION TIME                 | J.2.1  |           |
|               | THE CONSTANT OF DETECTION DEVICE                      | S  |           |
| 1 10          | (TABLE A-6F OR MEG. DATA)                             |  | ~1 -      |
|               | ESTIMATED TIME TO DETECTOR ACTUATION                  | 25.67  | s         |
|               | (TROX 9] X FBOX 10T)                                  |  | 1         |
|               | · · · · · · · · · · · · · · · · · · ·                 | and the second |           |

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## OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

#### COMBUSTIBLE MATERIAL WORKSHEET

#### FUEL PROPERTIES - UNCONFINED SPILL

| DESCRIPTION            |       |
|------------------------|-------|
| VOLUME (QUARTS)        | 2/2/  |
| NET HEAT OF COMBUSTION | 17111 |
| COMBUSTION EFFICIENCY  | 90%   |
| UNIT HEAT RELEASE RATE | 110   |
| DENSITY                | 60    |

#### FLOW CHARACTERISTICS

| DESCRIPTION         |       |
|---------------------|-------|
| SPECIFIC SPILL AREA | 120.0 |

| SPILL AREA          | 60    | SQ-FT |
|---------------------|-------|-------|
| PEAK FIRE INTENSITY | 5940  | BTU/S |
| FIRE DURATION       | 10    | SEC   |
|                     | 0.173 | MIN   |

#### 

#### FUEL PROPERTIES - CONFINED SPILL

| DESCRIPTION            |       |
|------------------------|-------|
| VOLUME (QUARTS)        | 2     |
| NET HEAT OF COMBUSTION | 17111 |
| COMBUSTION EFFICIENCY  | 1     |
| UNIT HEAT RELEASE RATE | 110   |
| DENSITY                | 60    |

#### FLOW CHARACTERISTICS

| DESCRIPTION<br>SPILL AREA              | 4.2                 | SQ-FT               |
|--|---------------------|---------------------|
| PEAK FIRE INTENSITY .<br>FIRE DURATION | 412<br>150<br>2.500 | BTU/S<br>SEC<br>MIN |
|  |                     |                     |



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## OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

## FIXED COMBUSTIBLE / TARGET IN PLUME

ENGLISH UNITS VERSION

| USE TABLE 1E FOR GUIDANCE)         2       HEIGHT OF TARGET ABOVE FIRE SOURCE<br>(BASED ON SCENARIO GEOMETRY)         3       HEIGHT FROM FIRE SOURCE TO CEILING<br>(BASED ON SCENARIO GEOMETRY) |
|--|
| 2       HEIGHT OF TARGET ABOVE FIRE SOURCE<br>(BASED ON SCENARIO GEOMETRY)       8       ft         3       HEIGHT FROM FIRE SOURCE TO CEILING<br>(BASED ON SCENARIO GEOMETRY)       20       ft |
| (BASED ON SCENARIO GEOMETRY)  3 HEIGHT FROM FIRE SOURCE TO CEILING (BASED ON SCENARIO GEOMETRY)  |
| 3 HEIGHT FROM FIRE SOURCE TO CEILING 20 ft<br>(BASED ON SCENARIO GEOMETRY)   |
| (BASED ON SCENARIO GEOMETRY)   |
|  |
| 3a FLOOR DIMENSIONS - LENGTH 247.1/17/8 TT   |
| - WIDTH 27 ft  |
| 3b FLOOR AREA (LENGTH) X (WIDTH) 5610 ft2  |
|  |
| 3C ESTIMATED DURATION OF FIRE 2.5 min  |
|  |
| 4 PEAK FIRE INTENSITY 411.720064 Btu/  |
| USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)   |
| 5 FIRE LOCATION FACTOR   |
| (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)   |
| 6 EFFECTIVE HEAT RELEASE RATE 411.720064 Btu/  |
| ([BOX 4] X [BOX 5])  |
| 7 PLUME TEMPERATURE RISE AT TARGET 588.03 F  |
| (LOOK UP VALUE FROM TABLE 5E)  |
| 8a MAXIMUM AMBIENT TEMPERATURE 90 F  |
|  |
| 8b CRITICAL TEMPERATURE RISE AT TARGET 610 F   |
| ([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)  |
| 9 CRITICAL - PLUME TEMPERATURE RISE 21.97 F  |
| ([BOX 8] - [BOX 7])  |
| IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE  |
| TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO   |
| RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT   |
| 10 Qnet/V TO ACHIEVE TEMP RISE IN BOX 9 0.37 Btu/  |
| (LOOK UP VALUE FROM TABLE 7E)  |
| 11 CALCULATED ENCLOSURE VOLUME, V 112200 ft  |
| ([BOX 3] X FLOOR AREA OF SPACE)  |
| 12 CALCULATED CRITICAL Qnet 41,956 Bt  |
| ([BOX 10] X [BOX11])   |
| 13 ESTIMATED HEAT LOSS FRACTION -  |
| (REPRESENTATIVE VALUE: 0.7)  |
| 14 ESTIMATE OF CRITICAL Qtot 139,854 Bt  |
| ([BOX 12]/(1 - [BOX13]))   |
| 15 ESTIMATE OF ACTUAL Qtot 61,758 Bt   |
| ([HRR] X [TIME]) = [BOX 4] X [TIME]  |
| IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,   |
| CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   |
| BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS   |
| THIS SCREENING PROCEDURE. FURTHER ANALYSIS REQUIRED.   |

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## FIXED COMBUSTIBLE / RADIANT EXPOSURE

ENGLISH UNITS VERSION

| 1 | CRITICAL RADIANT FLUX TO TARGET                         | 1          | Btu/s/ft2 |
|---|---|------------|-----------|
|   | (REPRESENTATIVE CONSERVATIVE VALUE = 1)                 |            |           |
|   | (LOOK UP VALUE FROM TABLE 1E)                           |            |           |
| 2 | PEAK FIRE INTENSITY                                     | 411.720064 | Btu/s     |
|   | (USE TABLE 2E FOR GUIDANCE)                             |            |           |
| 3 | RADIANT FRACTION OF HEAT RELEASE                        | 0.4        |           |
|   | (REPRESENTATIVE VALUE = 0.4)                            |            |           |
| 4 | RADIANT HEAT RELEASE RATE                               | 164.688026 | Btu/s     |
|   | ([BOX2]X[BOX3])   |            |           |
| 5 | CRITICAL RADIANT FLUX DISTANCE                          | 3.62       | ft        |
|   | (LOOK UP VALUE FROM TABLE 10E)                          |            |           |
| 6 | ACTUAL DISTANCE BETWEEN SOURCE/TARGET                   | 0          | ft        |
|   | (FROM FIRE COMPARTMENT CCDS)                            |            |           |
|   | IF THE EXPOSURE FIRE IS LOCATED WITHIN THIS DISTANCE    |            |           |
|   | (INDICATED IN BOX 5) OF THE TARGET, CRITICAL CONDITIONS | CAN        |           |
|   | OCCUR. OUTSIDE THIS RANGE, CRITICAL CONDITIONS ARE NO   | Г          |           |
|   | INDICATED FOR THE SCENARIO UNDER CONSIDERATION.         |            |           |

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### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

#### COMBUSTIBLE MATERIAL WORKSHEET

#### **FUEL PROPERTIES - UNCONFINED SPILL**

| 28    |
|-------|
| 17111 |
| 90%   |
| 110   |
| 60    |
|       |

#### FLOW CHARACTERISTICS

| DESCRIPTION         |
|---------------------|
| SPECIFIC SPILL AREA |

120,0

| SPILL AREA          | 840   | SQ-FT |
|---------------------|-------|-------|
| PEAK FIRE INTENSITY | 83160 | BTU/S |
| FIRE DURATION       | 10    | SEC   |
|                     | 0.173 | MIN   |

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#### FUEL PROPERTIES - CONFINED SPILL

| DESCRIPTION            |       |
|------------------------|-------|
| VOLUME (QUARTS)        | 28 💊  |
| NET HEAT OF COMBUSTION | 17111 |
| COMBUSTION EFFICIENCY  | 1     |
| UNIT HEAT RELEASE RATE | 110   |
| DENSITY                | 60    |

#### FLOW CHARACTERISTICS

| DESCRIPTION<br>SPILL AREA            | 58:2                 | SQ-FT               |
|--------------------------------------|----------------------|---------------------|
| PEAK FIRE INTENSITY<br>FIRE DURATION | 5763<br>150<br>2,500 | BTU/S<br>SEC<br>MIN |

#### COMMENTS

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### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

## FIXED COMBUSTIBLE / TARGET IN PLUME

ENGLISH UNITS VERSION

| TARGET DAMAGE THRESHOLD TEMPERATURE                      | 700  | F  |
|--|--|--|
| (USE TABLE 1E FOR GUIDANCE)                              |  |  |
| HEIGHT OF TARGET ABOVE FIRE SOURCE                       | 20   | ft   |
| (BASED ON SCENARIO GEOMETRY)                             |  |  |
| HEIGHT FROM FIRE SOURCE TO CEILING                       | 20   | ft   |
| (BASED ON SCENARIO GEOMETRY)                             |  |  |
| FLOOR DIMENSIONS - LENGTH                                | 207.777778   | ft   |
| - WIDTH  | 27   | ft   |
| FLOOR AREA (LENGTH) X (WIDTH)                            | 5610   | ft2  |
| ESTIMATED DURATION OF FIRE                               | 2.5  | min  |
| PEAK FIRE INTENSITY                                      | 5763.48787   | Btu/s  |
| USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)                 | 7~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~  |  |
| FIRE LOCATION FACTOR                                     | 1  |  |
| (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)                 |  |  |
| EFFECTIVE HEAT RELEASE RATE                              | 5763.48787   | Btu/s  |
| ([BOX 4] X [BOX 5])                                      |  | /-   |
| PLUME TEMPERATURE RISE AT TARGET                         | 741.68   | F  |
| (LOOK UP VALUE FROM TABLE 5E)                            |  | •  |
| MAXIMUM AMBIENT TEMPERATURE                              | 90   | F  |
| CRITICAL TEMPERATURE RISE AT TARGET                      | 610  | F  |
| ([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)                  |  |  |
| CRITICAL - PLUME TEMPERATURE RISE                        | -131.68  | F  |
| ([BOX 8] - [BOX 7])                                      |  | -  |
| IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE  |  |  |
| TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO     |  |  |
| RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT             |  |  |
| Qnet/V TO ACHIEVE TEMP RISE IN BOX 9                     | 0.00   | Btu/ft3  |
| (LOOK UP VALUE FROM TABLE 7E)                            |  | •  |
| CALCULATED ENCLOSURE VOLUME, V                           | 0  | ft3  |
| ([BOX 3] X FLOOR AREA OF SPACE)                          |  |  |
| CALCULATED CRITICAL Qnet                                 | 0  | Btu  |
| ([BOX 10] X [BOX11])                                     |  |  |
| ESTIMATED HEAT LOSS FRACTION                             | 0.7  |  |
| (REPRESENTATIVE VALUE: 0.7)                              |  |  |
| ESTIMATE OF CRITICAL Quot                                | 0  | Btu  |
| ([BOX 12]/(1 - [BOX13]))                                 |  |  |
| ESTIMATE OF ACTUAL Qtot                                  | 0  | Btu  |
| $([HRR] \times [TIME]) = [BOX 4] \times [TIME]$          | _  |  |
| IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14. | 1  | L <u></u>  |
| CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   |  |  |
| BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS   |  |  |
| THIS SCREENING PROCEDURE. FURTHER ANALYSIS REOUIRED.     |  |  |
|  | TARGET DAMAGE THRESHOLD TEMPERATURE<br>(USE TABLE 1E FOR GUIDANCE)<br>HEIGHT OF TARGET ABOVE FIRE SOURCE<br>(BASED ON SCENARIO GEOMETRY)<br>HEIGHT FROM FIRE SOURCE TO CEILING<br>(BASED ON SCENARIO GEOMETRY)<br>FLOOR DIMENSIONS - LENGTH<br>- WIDTH<br>FLOOR AREA (LENGTH) X (WIDTH)<br>ESTIMATED DURATION OF FIRE<br>PEAK FIRE INTENSITY<br>USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)<br>FIRE LOCATION FACTOR<br>(4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)<br>EFFECTIVE HEAT RELEASE RATE<br>((BOX 4) X (BOX 5))<br>PLUME TEMPERATURE RISE AT TARGET<br>(LOOK UP VALUE FROM TABLE 5E)<br>MAXIMUM AMBIENT TEMPERATURE<br>CRITICAL TEMPERATURE RISE AT TARGET<br>((BOX 1) - MAXIMUM AMBIENT TEMPERATURE)<br>CRITICAL - PLUME TEMPERATURE RISE<br>((BOX 3) - (BOX 7))<br>IF THE ENTRY IN BOX 9 IS <= 0, STOP. OTHERWISE CONTINUE<br>TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT<br>Quet/V TO ACHIEVE TEMP RISE IN BOX 9<br>(LOOK UP VALUE FROM TABLE 7E)<br>CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO<br>RAISE THE AVERAGE TEMPERATURE BY THIS AMOUNT<br>QUETV TO ACHIEVE TEMP RISE IN BOX 9<br>(LOOK UP VALUE ROM TABLE 7E)<br>CALCULATED ENCLOSURE VOLUME, V<br>((BOX 3) X FLOOR AREA OF SPACE)<br>CALCULATED CRITICAL QUE<br>((BOX 10) X (BOX11))<br>ESTIMATE OF CRITICAL QUE<br>((BOX 12)/(1 - (BOX13)))<br>ESTIMATE OF CRITICAL QUE<br>((BOX 12)/(1 - (BOX13)))<br>ESTIMATE OF ACTUAL QUE<br>IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,<br>CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO<br>BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS<br>THIS SCREENING PROCEDURE, FURTHER ANALYSIS REQUIRED. | TARGET DAMAGE THRESHOLD TEMPERATURE       700         (USE TABLE 1E FOR GUIDANCE)       20         HEIGHT OF TARGET ABOVE FIRE SOURCE       20         (BASED ON SCENARIO GEOMETRY)       20         HEIGHT FROM FIRE SOURCE TO CEILING       20         (BASED ON SCENARIO GEOMETRY)       20         FLOOR DIMENSIONS - LENGTH       207.777778         - WIDTH       27         FLOOR AREA (LENGTH) X (WIDTH)       5610         ESTIMATED DURATION OF FIRE       2.5         PEAK FIRE INTENSITY       57/63.48787         USE TABLE 22 & FIGURES 4-5 FOR GUIDANCE)       57/63.48787         FIRE LOCATION FACTOR       1         (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)       57/63.48787         (IBOX 4] X (BOX 5])       741.68         PLUME TEMPERATURE RISE AT TARGET       741.68         (IBOX 4] X (BOX 5])       741.68         PLUME TEMPERATURE RISE AT TARGET       610         (IBOX 1] - MAXIMUM AMBIENT TEMPERATURE       90         CRITICAL TEMPERATURE RISE AT TARGET       610         (IBOX 2])       15 <= 0, STOP. OTHERWISE CONTINUE |

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#### OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

### FIXED COMBUSTIBLE / TARGET OUTSIDE PLUME

ENGLISH UNITS VERSION

| ſ | 1       | TARGET DAMAGE THRESHOLD TEMPERATURE  | 700       | F        |
|---|---------|--|-----------|----------|
|   |         | (LOOK UP VALUE FROM TABLE 1E)  |           |          |
|   | 2       | HEIGHT OF TARGET ABOVE FIRE SOURCE   | 18        | ft       |
| L |         | (BASED ON SCENARIO GEOMETRY)   |           |          |
|   | 3       | HEIGHT FROM FIRE SOURCE TO CEILING   | 20        | ft       |
|   |         | (BASED ON SCENARIO GEOMETRY)   |           |          |
|   | За      | FLOOR DIMENSIONS - LENGTH  | 207.7778  | π        |
|   |         | - WIDTH  | E610      | <u>π</u> |
|   | 30      | FLOOR AREA [LENGTH] X [WLDTH]  | 2010      | 11.2     |
|   | 3c      | ESTIMATED DURATION OF FIRE   | 2.5       | min      |
| ľ | 4       | RATIO OF TARGET HEIGHT/CEILING HEIGHT  | 0.90      |          |
|   |         | ((BOX2)/(BOX3))  | II.       |          |
|   |         | IF THE VALUE IN BOX 4 IS > 0.85, COMPLETE BOXES 5-11;<br>CONFERVATES ENTER A VALUE OF 0 IN BOX 14 AND CONTINUE |           |          |
|   |         | WITH BOY 15  |           |          |
|   | 5       | LONGTHIDINAL DISTANCE FROM FIRE SOURCE TO TARGET 1   | 6.4       | ft       |
|   | 2       | (BASED ON SCENARIO GEOMETRY)   |           |          |
|   | 6       | LONGTUDINAL DISTANCE TO HEIGHT BATIO, 1/H  | 0.32      |          |
|   | U       | (IBOY STITBOX 31)  |           |          |
|   | 7       |  | 27        | ft       |
|   | •       | (BASED ON SCENARIO GEOMETRY)   |           |          |
| Í | 8       | HEIGHT TO WIDTH RATIO, H/W   | 0.74      |          |
|   | -       | ((BOX 3)/(BOX 7))  |           |          |
|   | 9 -     | PEAK FIRE INTENSITY  | 5763.4879 | Btu/s    |
|   |         | (USE TABLE 2E FOR GUIDANCE)  |           |          |
|   | • 10    | FIRE LOCATION FACTOR   | 1         | -        |
|   |         | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)   |           |          |
|   | 11      | EFFECTIVE HEAT RATE RELEASE  | 5763.4879 | Btu/s    |
|   |         | ([BOX 9] X [BOX 10])   |           |          |
|   | 12      | PLUME TEMPERATURE RISE AT CEILING  | 741.68    | F        |
|   |         | (LOOK UP VALUE FROM TABLE SE)  |           |          |
|   | 13      | CEILING JET TEMPERATURE RISE FACTOR AT TARGET  |           |          |
|   | Ï       | (IF [BOX 4] < 0.85, ENTER 0, ELSE  | 0.641     |          |
|   |         | LOOK UP VALUE FROM TABLE 6A OR 6B)   |           |          |
|   | 14      | CEILING JET TEMPERATURE RISE AT TARGET   | 475.60    | F        |
|   |         | ([BOX 12] X [BOX 13])  |           |          |
|   | 15a     | MAXIMUM AMBIENT TEMPERATURE  | 90        | F        |
|   | 15b     | CRITICAL TEMPERATURE RISE AT TARGET  | 610       | F        |
|   |         | ([BOX 1] - MAXIMUM AMBIENT TEMPERATURE)  |           |          |
|   | 16      | CRITICAL - CEILING JET TEMP. RISE AT TARGET  | 134.40    | F        |
|   |         | ([BOX 15] - [BOX 14])  |           | -        |
|   |         | IF THE ENTRY IN BOX 16 IS <= 0, STOP. OTHERWISE CONTINUE TO  |           |          |
|   |         | CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO RAISE  |           |          |
|   |         | THE AVERAGE TEMPERATURE BY THE AMOUNT INDICATED IN BOX 16.   |           |          |
|   | 17      | Qnet/V TO ACHIEVE TEMP RISE IN BOX 16  | 2.09      | Btu/ft3  |
|   | <b></b> | (LOOK UP VALUE FROM TABLE 7E)  |           |          |
|   | 18      | CALCULATED ENCLOSURE VOLUME, V   | 112,200   | 13       |
|   |         | ([BOX 3B] X [BOX 3])   |           |          |
|   | 19      | CALCULATED CRITICAL Qnet   | 234,141   | Btu      |
|   |         | ([BOX 17] X (BOX18])   |           |          |
|   | 20      | ESTIMATED HEAT LOSS FRACTION (RANGE: 0-1)  |           |          |
|   |         | (REPRESENTATIVE VALUE: 0.7)  | 700 471   | Dhu      |
|   | 21      | ESTIMATE OF CRITICAL Quot  | /80,4/1   | BU       |
|   | <b></b> | ([BOX 19]/(1 - [BOX20]))   | 064 532   |          |
|   | 22      | ESTIMATE OF ACTUAL Quot  | 004,523   |          |
|   |         | (BASED ON ENERGY CONTENT OF FIRE SOURCE)   |           | 1        |
|   |         | IF THE ENTRY IN BOX 22 IS LESS THAN THE VALUE IN BOX 21,   |           |          |
|   |         | CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIO   |           |          |
|   | 1       | BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PASS   |           |          |
|   | 1       | ITID SUKEENING PROLEDUKE, FURTHER ANALTSIS REQUIRED.   |           |          |

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## FIXED COMBUSTIBLE / RADIANT EXPOSURE

ENGLISH UNITS VERSION

| 1   | CRITICAL RADIANT FLUX TO TARGET         | 1          | Btu/s/ft2 |  |
|---|---|------------|-----------|--|
|   | (REPRESENTATIVE CONSERVATIVE VALUE = 1) |            |           |  |
| •   | (LOOK UP VALUE FROM TABLE 1E)           |            |           |  |
| 2   | PEAK FIRE INTENSITY                     | 5763.48787 | Btu/s     |  |
|   | (USE TABLE 2E FOR GUIDANCE)             |            |           |  |
| 3   | RADIANT FRACTION OF HEAT RELEASE        | 0.4        |           |  |
|   | (REPRESENTATIVE VALUE = 0.4)            |            |           |  |
| 4   | RADIANT HEAT RELEASE RATE               | 2305.39515 | Btu/s     |  |
|   | ([BOX2]X[BOX3])                         |            |           |  |
| 5   | CRITICAL RADIANT FLUX DISTANCE          | 13.54      | ft        |  |
|   | (LOOK UP VALUE FROM TABLE 10E)          |            |           |  |
| 6   | ACTUAL DISTANCE BETWEEN SOURCE/TARGET   | 0          | ft        |  |
|   | (FROM FIRE COMPARTMENT CCDS)            |            |           |  |
| IF THE EXPOSURE FIRE IS LOCATED WITHIN THIS DISTANCE        |   |            |           |  |
| (INDICATED IN BOX 5) OF THE TARGET, CRITICAL CONDITIONS CAN |   |            |           |  |
| OCCUR. OUTSIDE THIS RANGE, CRITICAL CONDITIONS ARE NOT      |   |            |           |  |
| INDICATED FOR THE SCENARIO UNDER CONSIDERATION.             |   |            |           |  |

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#### **OPPD - Fort Calhoun Station** Fire Risk Analysis Refinement Project

#### SUPPRESSION

#### THERMALLY THICK TARGETS

ENGLISH UNITS VERSION

| <u>, 1</u>                            | ARGET INFO | RMATION   |  |                                   |
|---------------------------------------|------------|---|--|-----------------------------------|
| Γ                                     | 1a         | HEIGHT OF TARGET ABOVE FIRE SOURCE                    | 25                                     | ft                                |
|                                       |            | (BASED ON SCENARIO GEOMETRY)                          |  |                                   |
|                                       | 1b         | RADIAL DISTANCE FROM FIRE SOURCE TO TARGET            | 0,1                                    | ft                                |
| 1                                     |            | LINE OF SIGHT DISTANCE FROM FIRE SOURCE TO TARGET     | 16.00                                  | ft                                |
| l l                                   | 2          | PEAK FIRE INTENSITY                                   | 5763,48787                             | Btu/s                             |
| 1                                     |            | FROM BASIC SCREENING METHODOLOGY                      |  |                                   |
| ſ                                     | 3          | FIRE LOCATION FACTOR                                  |  |                                   |
| k.                                    |            | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)              |  |                                   |
|                                       | 4          | EFFECTIVE HEAT RELEASE RATE                           | 5763.48787                             | Btu/s                             |
| l.                                    |            | ([BOX 2] X [BOX 3])                                   |  |                                   |
|                                       | 6          | MAXIMUM AMBIENT TEMPERATURE                           | 75                                     | F                                 |
|                                       |            |   |  |                                   |
|                                       | 7          | PLUME TEMPERATURE RISE AT TARGET                      | 1075.81                                | F                                 |
| 1. I.                                 |            | (LOOK UP VALUE FROM TABLE 5E)                         |  |                                   |
|                                       | 8          | RADIANT FRACTION OF HEAT RELEASE                      | /////0;4/////                          | -                                 |
|                                       |            | (REPRESENTATIVE VALUE = 0 4)                          |  |                                   |
|                                       | 9          | RADIANT HEAT RELEASE RATE                             | 2305.39515                             | 8tu/s                             |
| L                                     |            | ([BOX 2]X[BOX 6])                                     |  |                                   |
| Ĩ                                     | DETECTOR I | NFORMATION  |  |                                   |
| l l l l l l l l l l l l l l l l l l l | 1          | RATED ACTUATION TEMPERATURE OF DETECTOR               | 165                                    | F                                 |
|                                       |            | (MANUFACTURERS DATA)                                  |  |                                   |
| 8                                     | 2          | HEIGHT FROM FIRE SOURCE TO CEILING                    | 20                                     | ft                                |
| l l                                   |            | (BASED ON SCENARIO GEOMETRY)                          |  |                                   |
|                                       | 3          | FLOOR DIMENSION - WIDTH                               | 27                                     | ft                                |
|                                       |            |   |  |                                   |
|                                       | 4          | LONGITUDINAL DISTANCE FROM FIRE SOURCE TO DETECTOR, L |  | ft                                |
|                                       |            | (BASED ON SCENARIO GEOMETRY)                          |  |                                   |
| t i                                   | 5          | LONGITUDINAL DISTANCE TO HEIGHT RATIO, L/H            | 0.05                                   | ••                                |
|                                       |            | (TBOX 4)/TBOX 21)                                     |  |                                   |
| · · ~ ~ · ]                           | 6          | HEIGHT TO WIDTH RATIO, HAW                            | 0.74                                   |                                   |
|                                       | -          | (IBOX 21/IBOX 31)                                     |  |                                   |
|                                       | 7          | PEAK FIRE INTENSITY                                   | 5763.48787                             | Btu/s                             |
|                                       | ·          | (USE TABLE 2E FOR GUIDANCE)                           |  | -                                 |
|                                       | 8          | FIRE LOCATION FACTOR                                  | 1                                      |                                   |
|                                       | -          | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)              |  |                                   |
|                                       | 9          | EFFECTIVE FIRE INTENSITY                              | 5763.48787                             | Btu/s                             |
|                                       | -          | (TBOX 71 X [BOX BT)                                   | 1                                      |                                   |
|                                       | 10         | PLUME TEMPERATURE RISE AT CEILING                     | 741.68                                 | F                                 |
| 1                                     |            | (LOOK UP VALUE FROM TABLE SE)                         |  |                                   |
|                                       | 11         | CEILING JET TEMPERATURE RISE FACTOR AT DETECTOR       | 1.00                                   |                                   |
|                                       |            | ( LOOK UP VALUE FROM TABLE 6A OR 6B)                  |  |                                   |
|                                       | 12         | CEILING JET TEMPERATURE RISE AT DETECTOR              | 741.68                                 | F                                 |
|                                       |            | (TBOX 10] X (BOX 11])                                 | 1                                      |                                   |
| 1                                     | TIME TO T  | ADGET DAMAGE  | *****                                  | <del></del>                       |
|                                       | 1          | PADIATIVE HEAT FILM AT TARGET                         | 0.72                                   | Btu/s/ft                          |
|                                       | 1          | (TABLE A-RE)  | 1                                      | ,-,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, |
|                                       | 22         |   | 1.000                                  |                                   |
|                                       | 24         | IN-DUME(1) OUT-DUME (7)                               |  | 1                                 |
|                                       | 24         | CONVECTIVE HEAT FILM AT TARGET                        | 6.75                                   | Btu/s/ft                          |
|                                       | 20         | (TAB! ES A-4F AND A-5)                                | 1                                      | ,•,"                              |
|                                       |            | TOTAL HEAT FUN AT TARGET                              | 7.47                                   | Btu/s/fi                          |
|                                       |            | (TBOY1) + (BOY 2h)                                    |  |                                   |
|                                       |            | TADGET THEDMAL DESDONGE DADAMETED                     |  | - 1                               |
|                                       | 1 7        | TARGET THERMAL RESPONSE PARAMETER                     | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | 1                                 |
|                                       | <u> </u>   |   | 16                                     |                                   |
|                                       | 2          |   |  |                                   |
|                                       |            |   |  | <u> </u>                          |
| •                                     | TIME TO L  | DETECTOR ACTUATION                                    |  | F                                 |
|                                       | °          | DETECTION DEVICE RATED TEMPERATORE RISE               |  | 1                                 |
|                                       | <b></b>    |   | 747                                    |                                   |
| 1                                     | 1 1        | GAS TEMPERATURE RISE AT DETECTOR                      | 1 174                                  | 1                                 |
| ł                                     | <b></b>    |   | 0.17                                   |                                   |
|                                       | 8          | DETECTOR TEMPERATURE RISE/GAS TEMPERATURE RISE        | 0.12                                   | 1 -                               |
|                                       | I          |   | 0.12                                   | +                                 |
|                                       | 9          | DIMENSIONLESS DETECTOR ACTUATION TIME                 | 0.13                                   | 1 -                               |
|                                       |            | (TABLE A-1)   |  | d                                 |
|                                       | 10         | TIME CONSTANT OF DETECTION DEVICE                     | 1988 - 19 Ali                          | া হ                               |
|                                       |            | (TABLE A-GE OR MFG, DATA)                             |  |                                   |
|                                       | 1 11       | ESTIMATED TIME TO DETECTOR ACTUATION                  | 15.52                                  | 5                                 |
|                                       | 1          |   |  | 1                                 |

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### COMBUSTIBLE MATERIAL WORKSHEET

### FUEL PROPERTIES - UNCONFINED SPILL

| DESCRIPTION            |       |
|------------------------|-------|
| VOLUME (QUARTS)        | 3     |
| NET HEAT OF COMBUSTION | 17111 |
| COMBUSTION EFFICIENCY  | 90%   |
| UNIT HEAT RELEASE RATE | 110   |
| DENSITY                | 60    |

#### FLOW CHARACTERISTICS

| DESCRIPTION         | ···· ···· ··· ···· |
|---------------------|--------------------|
| SPECIFIC SPILL AREA | 120,0              |

| SPILL AREA          | 84    | SQ-FT |
|---------------------|-------|-------|
| PEAK FIRE INTENSITY | 8316  | BTU/S |
| FIRE DURATION       | 10    | SEC   |
|                     | 0.173 | MIN   |

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### FUEL PROPERTIES - CONFINED SPILL

| DESCRIPTION            |       |
|------------------------|-------|
| VOLUME (QUARTS)        | 3     |
| NET HEAT OF COMBUSTION | 17111 |
| COMBUSTION EFFICIENCY  | 1     |
| UNIT HEAT RELEASE RATE | 110   |
| DENSITY                | 60    |

#### FLOW CHARACTERISTICS

| DESCRIPTION<br>SPILL AREA            | ۲ | 5.8                 | SQ-FT               |
|--------------------------------------|---|---------------------|---------------------|
| PEAK FIRE INTENSITY<br>FIRE DURATION |   | 576<br>150<br>2.500 | BTU/S<br>SEC<br>MIN |

#### COMMENTS

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# FIXED COMBUSTIBLE / TARGET IN PLUME

ENGLISH UNITS VERSION

|             |  | 200 200           | F                  |
|-------------|--|-------------------|--------------------|
| 1           | TARGET DAMAGE THRESHOLD TEMPERATURE                            | 700               |                    |
|             | (USE TABLE 1E FOR GUIDANCE)                                    |                   |                    |
| 2           | HEIGHT OF TARGET ABOVE FIRE SOURCE                             | A'T               | 1C                 |
|             | (BASED ON SCENARIO GEOMETRY)                                   |                   |                    |
| 3           | HEIGHT FROM FIRE SOURCE TO CEILING                             | 20                | π                  |
| -           | (BASED ON SCENARIO GEOMETRY)                                   |                   |                    |
| 3a          | FLOOR DIMENSIONS - LENGTH                                      | 207.77778         | π                  |
|             | - WIDTH  | 2/                | $-\frac{\pi}{\pi}$ |
| Зb          | FLOOR AREA (LENGTH) X (WIDTH)                                  | 5610              | ft2                |
| 3c          | ESTIMATED DURATION OF FIRE                                     | 2:5               | min                |
| 4           | PEAK FIRE INTENSITY  | 576.401067        | Btu/s              |
| -           | USE TABLE 2E & FIGURES 4-5 FOR GUIDANCE)                       |                   |                    |
| 5           | FIRE LOCATION FACTOR   | 1                 |                    |
| -           | (4 FOR CORNER, 2 FOR WALL, 1 FOR CENTER)                       |                   |                    |
| 6           | EFFECTIVE HEAT RELEASE RATE                                    | 576.401067        | Btu/s              |
| U           | ((BOX 41 X (BOX 51)  |                   |                    |
| 7           | DI IME TEMPERATURE RISE AT TARGET                              | 593.69            | F                  |
| - 11        | II OOK UP VALUE FROM TABLE 5E)                                 |                   |                    |
| 8a          | MAXIMUM AMBIENT TEMPERATURE                                    | 90                | F                  |
| 8h          | CRITICAL TEMPERATURE RISE AT TARGET                            | 610               | F                  |
| 00          | (TROX 11 - MAXIMUM AMBIENT TEMPERATURE)                        |                   |                    |
| q           | CRTTICAL - PLUME TEMPERATURE RISE                              | 16.31             | F                  |
| 5           |  |                   |                    |
|             | IE THE ENTRY IN BOX 9 IS $\leq = 0$ , STOP, OTHERWISE CONTINUE | <u>_</u> ,,,,,,,, |                    |
|             | TO CALCULATE THE CRITICAL COMBUSTIBLE LOAD NEEDED TO           |                   |                    |
|             | PATSE THE AVERAGE TEMPERATURE BY THIS AMOUNT                   |                   |                    |
| 10          | OperA/ TO ACHIEVE TEMP RISE IN BOX 9                           | 0.28              | Btu/ft3            |
| 10          | (LOOK UP VALUE FROM TABLE 7E)                                  |                   |                    |
| 11          |  | 112200            | ft3                |
| 11          | (IBOY 31 X EL OOR AREA OF SPACE)                               |                   |                    |
| 12          |  | 31,299            | Btu                |
| 12          |  |                   |                    |
| 12          | ILIBOA 10 A (BOATT)  | 0.7               |                    |
| 15          |  |                   | ]                  |
|             | ICEPRESENTATIVE VALUE . 0.7)                                   | 104,329           | Btu                |
| 14 III      |  |                   | Į                  |
|             |  | 86,460            | Btu                |
| 15          |  |                   |                    |
| <u>  _'</u> | [([HRR] X [TIME]) = [BOX 4] X [TIME]                           | l                 |                    |
|             | IF THE ENTRY IN BOX 15 IS LESS THAN THE VALUE IN BOX 14,       |                   |                    |
|             | CRITICAL CONDITIONS ARE NOT INDICATED FOR THE SCENARIC         |                   |                    |
|             | BEING EVALUATED. OTHERWISE, THE SCENARIO DOES NOT PAS          | 5                 |                    |
| 11          | THIS SCREENING PROCEDURE. FURTHER ANALYSIS REQUIRED.           |                   |                    |

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## OPPD - Fort Calhoun Station Fire Risk Analysis Refinement Project

## FIXED COMBUSTIBLE / RADIANT EXPOSURE

ENGLISH UNITS VERSION

| 1   | CRITICAL RADIANT FLUX TO TARGET                 | I          | Btu/s/ft2 |  |
|---|---|------------|-----------|--|
|   | (REPRESENTATIVE CONSERVATIVE VALUE = 1)         |            |           |  |
|   | (LOOK UP VALUE FROM TABLE 1E)                   | ļ          |           |  |
| 2   | PEAK FIRE INTENSITY                             | 576.401067 | Btu/s     |  |
|   | (USE TABLE 2E FOR GUIDANCE)                     | ļ          | <u></u>   |  |
| 3   | RADIANT FRACTION OF HEAT RELEASE                | D.4        |           |  |
|   | (REPRESENTATIVE VALUE = 0.4)                    |            |           |  |
| 4   | RADIANT HEAT RELEASE RATE                       | 230.560427 | Btu/s     |  |
|   | ([BOX2]X[BOX3])                                 | ļ          |           |  |
| 5   | CRITICAL RADIANT FLUX DISTANCE                  | 4.28       | ft        |  |
|   | (LOOK UP VALUE FROM TABLE 10E)                  |            |           |  |
| 6   | ACTUAL DISTANCE BETWEEN SOURCE/TARGET           | 0          | ft        |  |
|   | (FROM FIRE COMPARTMENT CCDS)                    | <u> </u>   |           |  |
| IF THE EXPOSURE FIRE IS LOCATED WITHIN THIS DISTANCE        |   |            |           |  |
| (INDICATED IN BOX 5) OF THE TARGET, CRITICAL CONDITIONS CAN |   |            |           |  |
| OCCUR. OUTSIDE THIS RANGE, CRITICAL CONDITIONS ARE NOT      |   |            |           |  |
|   | INDICATED FOR THE SCENARIO UNDER CONSIDERATION. |            |           |  |

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