Redmond
WASHINGTON

City Contract Routing Form

City Contract #: 9559

Section 1 – Attach Contract Documents *(multiple files can be uploaded)*

Is an insurance certificate attached?

☐ Yes

☒ No/Not applicable

Comments: Insurance Addendum referenced in Exhibit D

Section 2 – Fill Out Contract Details

Date: 12/04/2020 Department: Fire Division: Admin Mail Stop: FDADM

Project Administrator Name: Dawn DeLoach Extension: 2244

Project Manager Name (if different than above): Rich Gieseke Extension: 2204

Contract Type: Consulting Services If other, please indicate:

Contract Title: Building X Professinal Fire Engineering Services

Contractor/Consultant Business Name: AEGIS Engineering

Contract Description: Performance based design review and technical assistance

Project ID #: Budget/Account #: TBD

Council Approval Date: 12/01/2020 Council Agenda Memo #: 20-160 RFP/IFB/RFQ #: NIGP #:

☒ New Contract

Total Amount: $200,000.00

Start Date: Upon execution End Date: 12/31/2023

Renewal Option (Y/N): N If yes, how many? N/A

☐ Amendment/Renewal/Change Order #: Original CC #:

New Start Date: New End Date:

Current Contract Amount (including all previous amendments/change orders):

Amount of this Amendment/Change Order (proposed increase/decrease):

New/Cumulative Contract Amount:

Section 3 – Route Contract for Signatures and Approvals

☒ Department Director: DocuSigned by: Todd Short CDD8096AE0E54C8... Date: 12/10/2020 Comments:

☐ TIS Director: Date: Comments:

☒ City Attorney: DocuSigned by: Jim Haney 85394CE968994B5... Date: 12/10/2020 Comments:

☒ Risk Manager: DocuSigned by: Malisa Files 581CDD1AF985491... Date: 12/10/2020 Comments:

☒ Mayor or Designee: DocuSigned by: Malisa Files (Mayor Designee) 5D9FC672714C4E4... Date: 12/10/2020 Comments:

☒ City Clerk's Office: DocuSigned by: Cheryl Xanthos E725E589816E4E1... Date: 12/10/2020 Comments: Electronic Original - in Hummingbird

☒ Purchasing: *no signature required – for copy only*

Three Party Consultant Agreement
Non-Public Work

PROJECT TITLE & IDENTIFICATION NUMBER (if # is known) Building X - Professional Fire Engineering Services - Performance Based Design Review and Technical Assistance 10301 Willows Road, Redmond, WA 98052	***WORK DESCRIPTION*** ***(reference & list all attached exhibits)*** Consulting Services Agreement Exhibit A, Scope of Work Exhibit B, Work Schedule Exhibit C, Payment Schedule Exhibit D, Insurance Addendum Exhibit E, Building X Atrium Smoke Control Modeling Parameters Exhibit F, Building X Structural Fire Engineering Parameters Report
CONSULTANT AEGIS Engineering Mukilteo, Washington 13024 Beverly Park Road, Suite 202 Mukilteo, WA 98275	***CITY PROJECT ADMINISTRATOR*** ***(Name, address, phone #)*** City of Redmond 15670 NE 85th Street Redmond, WA PO Box 9710 Redmond, WA 98073-9710
CONSULTANT CONTACT ***(Name, address, phone #)*** Brian Thompson AEGIS Engineering 13024 Beverly Park Road, Suite 202 Mukilteo, WA 98275 (425)745-4700 X105 BrianT@AEGISengineering.com	***BUDGET OR FUNDING SOURCE*** Applicant reimbursed technical review Account number to be determined
FEDERAL ID # Federal ID# 20-4435033	***MAXIMUM AMOUNT PAYABLE, IF ANY*** $200,000
SUPPLIER/CONTRACTOR'S REDMOND BUSINESS LICENSE ID # Redmond Business License ID # RED06-000113	***COMPLETION DATE*** December 31, 2023
APPLICANT NAME Willow Run, LLC 251 Little Falls Drive Wilmington, DE 19808	***APPLICANT CONTACT*** ***(Name, address & phone #)*** Rory O'Brien Senior Project Manager, Facebook Redmond, WA 650.313.4821 roryob@fb.com

THIS AGREEMENT is entered into on December 10, 20 20 between the City of Redmond, Washington, hereinafter called "the CITY", and the above-referenced person, firm or organization, hereinafter called "the CONSULTANT", and the above- referenced person, firm or organization, hereinafter called "the APPLICANT", referenced individually as "Party" and collectively as "Parties".

WHEREAS, the APPLICANT has applied to the CITY for certain development approvals in connection with the above-referenced project, and

WHEREAS, the CITY does not have sufficient staff or expertise to conduct certain technical portions of the project review and therefore deems it advisable and desirable to engage the assistance of a CONSULTANT to provide the necessary services for the project review; and

WHEREAS, the CONSULTANT has represented to the CITY that the CONSULTANT is in compliance with the professional registration statutes of the State of Washington, if applicable, and has signified a willingness to furnish consulting services to the CITY, now, therefore,

IN CONSIDERATION OF the terms and conditions set forth below, or attached and incorporated and made a part hereof, the parties agree as follows:

1. **Retention of Consultant - Scope of Work**. The CITY hereby retains the CONSULTANT to provide professional services as defined in this agreement and as necessary to accomplish the scope of work attached hereto as Exhibit A and incorporated herein by this reference as if set forth in full. The CONSULTANT shall furnish all services, labor and related equipment necessary to conduct and complete the work, except as specifically noted otherwise in this agreement.

2. **Completion of Work**. The CONSULTANT shall not begin any work under the terms of this agreement until authorized in writing by the CITY. The CONSULTANT shall complete all work required by this agreement according to the schedule attached as Exhibit B and incorporated herein by this reference as if set forth in full. A failure to complete the work according to the attached schedule, except where such failure is due to circumstances beyond the control of the CONSULTANT, shall be deemed a breach of this agreement. The established completion time shall not be extended because of any delays attributable to the CONSULTANT, but may be extended by the CITY, in the event of a delay attributable to the CITY or APPLICANT, or because of unavoidable delays caused by circumstances beyond the control of the CONSULTANT. All such extensions shall be in writing and shall be executed by both CITY and CONSULTANT.

3. **Payment to CONSULTANT**. The CONSULTANT shall be paid for satisfactorily completed work and services satisfactorily rendered under this agreement at the rates provided in Exhibit C, attached hereto and incorporated herein by this reference as if set forth in full. Such payment shall be full compensation for work performed or services rendered and for all labor, materials, supplies, equipment, and incidentals necessary to complete the work specified in the Scope of Work attached. When work is performed or services rendered, the CONSULTANT shall submit invoices to the CITY (with a copy to the APPLICANT) at least,

and no more frequently than, once per month during the course of the completion of work and services by the CONSULTANT. Invoices shall detail the work performed or services rendered, the time involved (if compensation is based on an hourly rate) and the amount to be paid. The CITY shall pay all undisputed amounts of an invoice within 30 days of its submittal, and the CITY shall give notice with justification to the CONSULTANT for any invoice amount that is in dispute.

4. **Payment by APPLICANT**. The CITY shall be reimbursed by the APPLICANT for all invoices received from the CONSULTANT for satisfactorily completed work and services satisfactorily rendered under this agreement at the rates provided in Exhibit C. Such payment by the APPLICANT shall be full compensation for the work performed or services rendered for all labor, materials, supplies, equipment and incidentals necessary to complete the work specified in the Scope of Work attached. The invoices submitted to the APPLICANT shall detail the work performed or services rendered, the time involved (if compensation is based on an hourly rate) and the amount to be paid. When work is performed or services rendered, the CITY shall submit invoices to the APPLICANT at least, and no more frequently than, once per month. The APPLICANT shall pay all such invoices within 30 days of submittal, unless the APPLICANT gives notice to the CITY that the invoice is in dispute. The APPLICANT shall give notice with justification to the CITY within 15 days of receipt of the copy of the invoice from the CONSULTANT if any amount of the invoice is in dispute. If the CITY receives notice that APPLICANT disputes an invoice, the parties will seek to resolve the dispute rapidly and in good faith, before exercising rights under Section 15. APPLICANT shall not be responsible for the disputed amounts until the dispute is resolved. Unless otherwise agreed in writing by the APPLICANT, in no event will the APPLICANT pay the CITY more than one hundred thousand dollars ($100,000). Notwithstanding anything to the contrary in this Agreement, APPLICANT's sole responsibility in this agreement is to reimburse the CITY consistent with this Section 4.

5. **Changes in Work**. The CONSULTANT shall make such changes and revisions in the complete work provided by this agreement as may be necessary to correct errors made by the CONSULTANT and appearing therein when required to do so by the CITY. The CONSULTANT shall make such corrective changes and revisions without additional compensation from the CITY. Should the CITY find it desirable for its own purposes to have previously satisfactorily completed work or parts thereof changed or revised, the CONSULTANT shall make such revisions as directed by the CITY. This work shall be considered as Extra Work and will be paid for as provided in Section 6.

6. **Extra Work**.

a. The CITY may, at any time, by written order, make changes within the general scope of the agreement in the services to be performed. If any such change causes an increase or decrease in the estimated cost of, or the time required for, performance of any part of the work or services under this agreement, whether or not changed by the order, or otherwise affects any other terms or conditions of the agreement, the CITY shall make an equitable adjustment in the (1) maximum amount payable; (2) delivery or completion schedule or both; and (3) other affected terms, and shall modify the agreement accordingly.

b. The CONSULTANT must submit any "proposal for adjustment" under this clause within 30 days from the date of receipt of the written order to make changes. However, if the CITY decides that the facts justify it, the CITY may receive and act upon a proposal submitted before final payment of the agreement.

c. Failure to agree to any adjustment shall be a dispute under the Disputes clause of this agreement, as provided in Section 14. Notwithstanding any such dispute, the CONSULTANT shall proceed with the agreement as changed.

d. Notwithstanding any other provision in this section, the maximum amount payable for this agreement shall not be increased or considered to be increased except by specific written amendment of this agreement.

7. **Ownership of Work Product**. Any and all documents, drawings, reports, and other work product produced by the CONSULTANT under this agreement shall become the property of the CITY upon payment of the CONSULTANT'S fees and charges therefore. The CITY shall have the complete right to use and re-use such work product in any manner deemed appropriate by the CITY, provided, that use on any project other than that for which the work product is prepared shall be at the CITY'S risk unless such use is agreed to by the CONSULTANT. APPLICANT shall a receive a copy of all work product prepared under this agreement.

8. **Independent Contractor**. The CONSULTANT is an independent contractor for the performance of services under this agreement. The CITY shall not be liable for, nor obligated to pay to the CONSULTANT, or any employee of the CONSULTANT, sick leave, vacation pay, overtime or any other benefit applicable to employees of the CITY, nor to pay or deduct any social security, income tax, or other tax from the payments made to the CONSULTANT which may arise as an incident of the CONSULTANT performing services for the CITY. The CITY shall not be obligated to pay industrial insurance for the services rendered by the CONSULTANT.

9. **Indemnity**. The CONSULTANT agrees to hold harmless and indemnify the CITY, its officers, agents and employees, from and against any and all claims, losses, or liability, including reasonable attorney's fees and costs expended by the City in defense thereof for injuries, sickness or death of persons, including employees of the CONSULTANT, or damage to property, arising out of any willful misconduct or negligent act, error, or omission of the CONSULTANT, its officers, agents, subconsultants or employees, in connection with the services required by this agreement, provided, however, that:

a. The CONSULTANT's obligations to indemnify, defend and hold harmless shall not extend to injuries, sickness, death or damage caused by or resulting from the misconduct or sole negligence of the CITY, its officers, agents or employees, or of the APPLICANT, its officers, agents, or employees; and

b. The CONSULTANT's obligations to indemnify, defend and hold harmless for injuries, sickness, death or damage caused by or resulting from the concurrent negligence or willful misconduct of the CONSULTANT and the CITY, or of the CONSULTANT and a third party other than an officer, agent, subconsultant or employee of the CONSULTANT, shall apply only to the extent of the negligence or willful misconduct of the CONSULTANT.

10. **Insurance**. The CONSULTANT shall provide the following minimum insurance coverages:

a. Worker's compensation and employer's liability insurance as required by the State of Washington;

b. General public liability and property damage insurance in an amount not less than a combined single limit of two million dollars ($2,000,000) for bodily injury, including death, and property damage per occurrence.

c. Professional liability insurance, if commercially available in CONSULTANT's field of expertise, in the amount of one million dollars ($1,000,000) each occurrence or two million dollars ($2,000,000) in the aggregate against claims arising out of work provided for in this agreement.

The amounts listed above are the minimum deemed necessary by the CITY to protect the CITY'S interests in this matter. The CITY has made no recommendation to the CONSULTANT as to the insurance necessary to protect the CONSULTANT'S interests and any decision by the CONSULTANT to carry or not carry insurance amounts in excess of the above is solely that of the CONSULTANT.

All insurance shall be obtained from an insurance company authorized to do business in the State of Washington. Excepting the professional liability insurance, the CITY will be named on all insurance as an additional insured. The CONSULTANT shall submit a certificate of insurance to the CITY evidencing the coverages specified above, together with an additional insured endorsement naming the CITY, within fifteen (15) days of the execution of this agreement. The additional insured endorsement shall provide that to the extent of the CONSULTANT's negligence, the CONSULTANT's insurance shall be primary and non-contributing as to the City, and any other insurance maintained by the CITY shall be excess and not contributing insurance with respect to the CONSULTANT's insurance. The certificates of insurance shall cover the work specified in or performed under this agreement. No cancellation of the foregoing policies shall be effective without thirty (30) days prior written notice to the CITY.

11. **Compliance and Governing Law**. The CONSULTANT shall at all times comply with all applicable federal, state, and local laws, rules, ordinances, and regulations. This Agreement shall be governed by and construed in accordance with the laws of the State of Washington.

12. **Records**. The CONSULTANT shall keep all records related to this agreement for a period of three years following completion of the work for which the CONSULTANT is retained. The CONSULTANT shall permit any authorized representative of the CITY, and any person authorized by the CITY for audit purposes, to inspect such records at all reasonable times

during regular business hours of the CONSULTANT. Upon request, the CONSULTANT will provide the CITY with reproducible copies of any such records. The copies will be provided without cost if required to substantiate any billing of the CONSULTANT, but the CONSULTANT may charge the CITY for copies requested for any other purpose.

13. **Notices**. All notices required to be given by any party to another under this Agreement shall be in writing and shall be given in person or by mail to the addresses set forth in the box for the same appearing at the outset of this Agreement. Notice by mail shall be deemed given as of the date the same is deposited in the United States mail, postage prepaid, addressed as provided in this paragraph.

14. **Project Administrator**. The Project Administrator shall be responsible for coordinating the work of the CONSULTANT, for providing any necessary information for and direction of the CONSULTANT's work in order to ensure that it meets the requirements of this Agreement, and for reviewing, monitoring and approving the quality and quantity of such work. The CONSULTANT shall report to and take any necessary direction from the Project Administrator.

15. **Disputes**. Any dispute concerning questions of fact in connection with the work not disposed of by agreement between the CONSULTANT, the APPLICANT and the CITY shall be referred for resolution to a mutually acceptable mediator, provided that the parties first attempt to resolve the dispute through good faith negotiations and the reasonable exchange of relevant information. If the dispute is between two parties, the parties shall each be responsible for one-half of the mediator's fees and costs unless or until the mediation warrants a different proportional responsibility. If the dispute is between all three parties, each party shall be responsible for one-third (1/3) of the mediator's fees and costs unless or until the mediation warrants a different proportional responsibility.

16. **Termination**. The CITY reserves the right to terminate this agreement at any time upon ten (10) days written notice to the CONSULTANT. Any such notice shall be given to the address specified above. In the event that this agreement is terminated by the City other than for fault on the part of the CONSULTANT, a final payment shall be made to the CONSULTANT for all services performed. No payment shall be made for any work completed after ten (10) days following receipt by the CONSULTANT of the notice to terminate. In the event that services of the CONSULTANT are terminated by the CITY for fault on part of the CONSULTANT, the amount to be paid shall be determined by the CITY, after receiving the written approval of the APPLICANT, with consideration given to the actual cost incurred by the CONSULTANT in performing the work to the date of termination, the amount of work originally required which would satisfactorily complete it to date of termination, whether that work is in a form or type which is usable to the CITY at the time of termination, the cost of the CITY of employing another firm to complete the work required, and the time which may be required to do so. Prior to terminating this agreement, the CITY will meet and confer with the APPLICANT, and the agreement shall not be terminated without the written consent of the APPLICANT, which shall not be unreasonably withheld, conditioned, or delayed.

17. **Non-Discrimination**. The CONTRACTOR agrees not to discriminate against any customer, employee or applicant for employment, subcontractor, supplier or materialman,

because of race, creed, color, national origin, sex, religion, honorable discharged veteran or military status, familial status, sexual orientation, age, or the presence of any sensory, mental, or physical disability or the use of a trained dog or service animal by a person with a disability, except for a bona fide occupational qualification. The CONTRACTOR understands that if it violates this provision, this Agreement may be terminated by the CITY and that the CONTRACTOR may be barred from performing any services for the CITY now or in the future.

18. **Subcontracting or Assignment**. The CONSULTANT may not assign or subcontract any portion of the services to be provided under this agreement without the express written consent of the CITY. Any subconsultants approved by the CITY at the outset of this agreement are named on Exhibit D attached hereto and incorporated herein by this reference as if set forth in full.

19. **Non-Waiver**. Payment for any part of the work or services by the CITY shall not constitute a waiver by the CITY of any remedies of any type it may have against the CONSULTANT for any breach of the agreement by the CONSULTANT, or for failure of the CONSULTANT to perform work required of it under the agreement by the CITY. Waiver of any right or entitlement under this agreement by the CITY shall not constitute waiver of any other right or entitlement.

20. **Litigation**. In the event that any party deems it necessary to institute legal action or proceedings to enforce any right or obligation under this agreement, the parties agree that such actions shall be initiated in the Superior Court of the State of Washington, in and for King County. The parties agree that all questions shall be resolved by application of Washington law and that parties to such actions shall have the right of appeal from such decisions of the Superior Court in accordance with the law of the State of Washington. The CONSULTANT and APPLICANT hereby consents to the personal jurisdiction of the Superior Court of the State of Washington, in and for King County. The prevailing party/parties in any such litigation shall be entitled to recover their costs, including reasonable attorney's fees, in addition to any other award.

21. **Taxes**. The CONSULTANT will be solely responsible for the payment of any and all applicable taxes related to the services provided under this agreement and if such taxes are required to be passed through to the CITY by law, the same shall be duly itemized on any billings submitted to the CITY by the CONSULTANT.

22. **City Business License**. The CONSULTANT has obtained, or agrees to obtain, a business license from the CITY prior to commencing to perform any services under this agreement. The CONSULTANT will maintain the business license in good standing throughout the term of this Agreement.

23. **Entire Agreement**. This agreement represents the entire integrated agreement between the CITY, the APPLICANT and the CONSULTANT, superseding all prior negotiations, representations or agreements, written or oral. This agreement may be modified, amended, or added to, only by written instrument properly signed by all parties hereto.

IN WITNESS WHEREOF, the parties hereto have executed this agreement as of the day and year first above written.

CONSULTANT DocuSigned by: Signed: Brian Thompson 82AD27A84E8F442... By: Brian Thompson Its: for AEGIS Engineering; Principal	**CITY OF REDMOND** DocuSigned by: Signed: Malisa Files (Mayor Designee) 5D9FC072714C4E4... By: Angela Birney Its: Mayor
APPLICANT DocuSigned by: Signed: Rory O'Brien 22046946D1C8402... By: Rory O'Brien Its: Senior Project Manager	APPROVED AS TO FORM: DocuSigned by: Signed: Jim Haney 85394CE968994B5... By: Jim Haney Its: City Attorney

EXHIBIT A

SCOPE OF WORK

Building X – Performance Based Design

Alternate methods and material engineering review

The Consultant shall perform all services and provide all goods as described below:

Consultant will provide technical assistance to the Redmond Building and Fire departments in the evaluation of an alternate methods and materials proposal for unprotected structural steel and performance-based design of high-rise and atrium smoke control systems with Building X. The technical assistance will consist of the following:

1. Participate in a kick-off meeting with project team and/or City of Redmond and review meeting minutes provided by others. It is anticipated that this meeting would occur remotely via common virtual platform and/or telephone conference.

2. Review the performance methodology and criteria such as presented in the Smoke Control Parameters Memo dated March 2, 2020 addressing both exhaust of the atrium and pressurization of high-rise shafts. Evaluate and report on the acceptability of such criteria based on generally accepted and well-established principles of fire engineering relevant to the design.

3. Review submittal of revisions to the report in Item 2 and provide a written response; up two (2) such submittals are included for budgeting purposes.

4. Review the performance methodology and criteria with regard to design fires and CFD analysis, such as presented in the Structural Fire Engineering Parameters Report dated November 19, 2019. Evaluate and report on the acceptability of such criteria based on generally accepted and well-established principles of fire engineering relevant to the design.

5. Review submittal of revisions to the report in Item 4 and provide a written response; up two (2) such submittals are included for budgeting purposes.

6. Review submittal of smoke control performance-based design and analysis addressing both atrium exhaust and high-rise shaft pressurization. Evaluate and report on findings relative to the approved methodology and criteria, and generally accepted and well-established principles of fire engineering relevant to the design. Review and comment on up to three (3) submittals is included for budgeting purposes.

7. Review submittal of smoke control special inspection and test requirements for the building. Evaluate and report on findings relative to building smoke control system equipment and functionality. Review and comment on up to three (3) submittals is included for budgeting purposes.

8. Review submittal of design fire scenarios and fire modeling analysis associated with identifying the temperature at the surface of building structural elements. Evaluate and report on findings relative to the approved methodology and criteria, and generally accepted and well-established principles of fire engineering relevant to the design. Review and comment on up to three (3) submittals is included for budgeting purposes.

9. Participate in up to six (6) periodic meetings with City of Redmond and/or project team and review meeting minutes provided by others. It is anticipated that these meetings would occur remotely via common virtual platform and/or telephone conference.

10. Provide up to eight (8) hours of general consulting time, including telephone or e-mail communications associated with any questions, clarifications, and/or coordination with other reviewers pertaining to project design submittals.

11. Upon request, participate in site visits to observe constructed conditions with regard to project elements reviewed in Items 6, 7, and/or 8 above. Up to three (3) site visits are included for budgeting purposes. Provide written report of items inspected and non-conforming features observed by AEGIS Engineering following each site visit.

12. Witness smoke control system commissioning, including acceptance testing and performance measurements demonstrated by others. Provide written report of items inspected and non-conforming features observed by AEGIS Engineering following each site visit. Participation in up to three (3) total site visits of testing is included for budgeting purposes.

13. Perform one (1) review of final report on smoke control testing prepared by special inspector or special inspection agency. Provide a written response presenting the findings of our review.

14. Provide up to eight (8) hours of general consulting time, including telephone or e-mail communications regarding construction period services such as to discuss expectations, observations, findings, or impressions.

Consultant shall provide the following:

A. Written letter consistent with the indicated purpose for each instance in Items 1 thru 13 above, excluding Items 1, 9, and 10, where "report", "written response", or "comment" is identified.

B. Written letter(s) upon request with Items 10 or 14 above regarding adjustments to, or modification of, approved conditions.

EXHIBIT B

WORK SCHEDULE

The contractor/consultant shall complete project milestones as identified below:

Milestone	Schedule
Kick-off meeting	Attend at mutually agreeable day and time, anticipated to occur within two (2) weeks following receipt of fully- executed contract.
Review of submitted materials.	Provide written deliverable within 3 weeks of receipt of a submittal and direction from the City to review the same, whichever is later.
Periodic meetings.	Participate in meetings when provided with advance notification, subject to Consultant availability. Review meeting minutes within one (1) week following receipt.
Site visit.	Attend site visit when provided with advance notification, subject to Consultant availability. Provide written summary within two (2) business days following site visit.
Review of certain limited supplemental, partial, additional or modified individual parameters, if needed	Respond to preliminary or select revisions involving certain individual parameters within one (1) week of receipt of informal correspondence.
Acceptance Test	Witness system commissioning, acceptance testing and meeting performance measures by others with written report on items inspected and non-conforming features.
Final Report	Review final report on the smoke control testing by the special inspector with a written response of findings.

EXHIBIT C

PAYMENT SCHEDULE

For the goods and services identified in the Scope of Work, the City shall pay Contractor/Consultant:

Position	Standard Work	Expedited Work
Fire Protection Engineer	$275 per hour	$400 per hour
Fire Protection Associate II	$215 per hour	$315 per hour
Fire Protection Associate I	$175 per hour	$255 per hour
Fire Protection Technician	$115 per hour	$170 per hour
Administrative	$90 per hour	$130 per hour

EXHIBIT D
Insurance Addendum

INSURANCE ADDENDUM

THIS ADDENDUM modifies the provisions of the (check one): General Services Agreement, _X Non-Public Work Consultant Agreement, ______ Instructional Services Agreement, ______ Social/Community Services Agreement, ______ Short Term Facility Agreement, ______ Fixed Asset Loan Agreement, ______ Three Party Consultant Agreement (hereinafter "the Agreement") or ______ Public Work Consultant Agreement entered into between the parties on ____________________________________, __________________

THE UNDERSIGNED PARTIES agree to modify paragraph 8 (if a General Services Agreement), 9 (if Non-Public Work Consultant Agreement), 7 (if Instructional Services Agreement), 6 (if Social/Community Services Agreement, 9 (if Short Term Facility Agreement), exhibit 5 (if Fixed Asset Loan Agreement), 10 (if a Three Party Consultant Agreement) or 8 (if Public Work Consultant Agreement) as follows (check all applicable items):

The general public liability and property damage insurance limit is increased/reduced to $ ____________ (insert amount).

The professional liability insurance amount is increased/reduced to $ ______________ (insert amount). This item relates to Consultant and Three Party Consultant Agreements only.

The professional liability insurance requirement is eliminated. This item relates to Consultant and Three Party Consultant Agreements only.

X The insurance provisions are otherwise modified as follows:

Professional liability insurance, if commercially available in CONSULTANT'S field of expertise, in the amount of $1,000,000 each claim, $2,000,000 in aggregate, or more for work provided outside this agreement.

Except as expressly modified above, all insurance-related terms and conditions of the Agreement will remain unchanged and in full force and effect. The City has made no recommendation to the contractor/consultant as to the insurance necessary to protect the contractor/consultant's interests and any decision by the contractor/consultant to carry or not carry insurance amounts or coverage in excess of the above is solely that of the contractor/ consultant.

DATED: 12/7/2020, ______

CONTRACTOR/CONSULTANT

DocuSigned by:
Brian Thompson
82AD27A84E8F442...

By: Brian Thompson
Title: Principal

149781034.1

CITY OF REDMOND

DocuSigned by:
Malisa Files (Mayor Designee)
5D9FC672714C4E4...
MAYOR ANGELA BIRNEY

ATTEST/AUTHENTICATED:

DocuSigned by:
Cheryl Xanthos
E725E589816E4E1...
CITY CLERK, CITY OF REDMOND

APPROVED AS TO FORM:

DocuSigned by:
Jim Haney
85394CE968994B5...
OFFICE OF THE CITY ATTORNEY

APPROVED:

DocuSigned by:
Malisa Files
581CDD1AF985491...
RISK MANAGER, CITY OF REDMOND

Building X – Atrium Smoke Control

Smoke Control Parameters Memo

Client Name: Gehry Partners

Client Address: 12541 Beatrice St, Los Angeles, CA 90066

Date: 3/2/2020

Table of Contents

1 OVERVIEW

1.1 Executive Summary

Building X is proposed as a new high-rise building of Type I-B construction. The proposed building is five stories, consisting of three stories of commercial office space over a tiered parking structure. The office area includes a series of vertical openings such that all three office levels are atmospherically connected. The office area is also atmospherically connected to an open stairway in the lobby that extends vertically to the basement parking tier (Tier 0). The vertical openings will be classified and protected as an atrium meeting the requirements of 2018 IBC §404.

Per §404.5, the three-story atrium will be protected by a smoke control system. The smoke control system will include active elements (mechanical exhaust) as well as passive elements (draft curtains with smoke reservoir containment) to maintain tenability in the means of egress.

Code Unlimited has been requested to develop the capacity of mechanical exhaust required for the smoke control system and shaft pressurization systems to meet prescriptive code requirements for performance-based design, and to provide a rational analysis of the smoke control system for the atrium. The rational analysis will discuss the performance of the smoke control system in maintaining tenability for egress of all occupants and will address the criteria outlined in 2018 IBC §909.4.

The initial step in the smoke and egress analysis is to determine the worst-case design fire locations and software input parameters. This document outlines the following parameters that will be used to evaluate the performance of the smoke control system:

- Design Fires
- Pass/Fail Criteria
- Fire Simulation Input Parameters
- Egress Analysis
- Shaft Pressurization Analysis

1.2 Applicable Codes and Standards

- 2018 International Building Code (IBC) with Washington Amendments (Adopted July 1st, 2020)
- 2018 International Fire Code (IFC) with Washington Amendments (Adopted July 1st, 2020)
- 2015 NFPA 92 – Standard for Smoke Control Systems
- 2016 NFPA 13 – Standard for the Installation of Sprinkler Systems
- 2012 Handbook of Smoke Control Engineering
- 2009 ASHRAE Handbook of Fundamentals
- 2008 NFPA Fire Protection Handbook, 20th Edition
- SFPE Handbook 3rd, 4th, and 5th Editions

1.3 Building Overview

Building X is a new corporate office building designed by Gehry Partners for Facebook, located in Redmond, Washington, and under the jurisdictional review of the City of Redmond. The building includes open office areas, conference rooms, technology laboratories, a cafeteria, and occupied roof terrace. One of the primary architectural design goals is to create an open and collaborative office plan. This is fostered by atmospheric connection of all office levels, beginning at the main lobby entrance.

As permitted by §404.6 Exception 3, all portions of the office levels will be exposed to the atrium on all three floors. All such spaces will be accounted for in the design of the smoke control system, as detailed in this report. The vertical openings that make up the atrium space in this building are illustrated in Figures 1-6.

The building will be sprinklered throughout and provided with an emergency voice/alarm communication system. To meet requirements for smokeproof enclosures, three interior exit stairways and two elevator shafts will be protected by pressurization. Emergency systems will be provided in accordance with the high-rise provisions outlined in §403.4, including a Fire Command Center off the Main Entrance Lobby.

The ceiling height on the office levels is significantly higher than the 7-foot 6-inch minimum required in accordance with §1003.2. The height above finished floor to the bottom of the exposed deck above is approximately as follows:

- Office Level 01 – 20'-1"
- Office Level 02 – 13'-4" - 15'-4"
- Office Level 03 – 15'-4"

1.4 Key Approach & Methodology

The vertical openings on the office floors are open to adjacent spaces and are not separated by fire-resistance-rated construction. Therefore, per §404.6 Exception 3, the design of the smoke control system in the atrium must account for the entirety of the office floors. The main lobby extends from the Tier 0 through the Level 3 Office and will be incorporated in the overall office atrium space and the performance-based engineering design. The lobby is separated from the parking garage on all tiers with fire-resistance-rated construction.

Due to the size of the floorplate and location of the vertical openings, the design of the smoke control system will include both active and passive elements:

- **Active Protection Zone: Mechanical Exhaust and Supply Fans**
  The portion of the atrium with vertical openings between office levels will be provided with exhaust fans in the clerestory and supply fans throughout the office spaces on each floor. These supply fans will activate upon the detection of smoke. The currently proposed exhaust system consists of four (4) dedicated fans with a total available capacity of 135,000 CFM. The required exhaust capacity of these fans will be refined as the modeling exercise provides feedback. The supply system will utilize the Dedicated Outdoor Air System (DOAS) fans which will provide approximately 98,000 CFM of supply air. Natural ventilation will be included if required as the modeling develops. Table 1 below outlines the volume of air supplied and exhausted for each office level. This system will direct smoke upwards through

the vertical openings towards the roof and exhaust the smoke to the building exterior. This system will only operate upon detection of smoke within the vertical opening space, either by activation of a spot detector or beam detector. Beam detectors will be located in evenly spaced locations in the clerestory of the vertical opening and spot detectors will be located throughout the atrium space.

Table 1: Supply and Exhaust Air Volumes per Floor

Building Level	DOAS Air Supplied (CFM)	Natural Ventilation Supplied (CFM)	% of Total Supply Volume	Available Exhaust Capacity (CFM)
Clerestory	-			135,000
Office Level 3	19,600	TBD	20%	-
Office Level 2	29,400	TBD	30%	-
Office Level 1	49,000	TBD	50%	-

- **Passive Protection Zone: Draft Curtains**
  The spaces adjacent to portion of the atrium with vertical openings will be protected by smoke reservoirs bounded by draft curtains that are constructed to resist the passage of smoke. As a baseline assumption, the draft curtains will be dimensioned to extend 6'-0" from the exposed deck above, and reduced if determined to be feasible through modeling. The atrium space contained within the draft curtains is illustrated in Figures 4-6. The primary function of this system is to provide compartmentalization between the office spaces and the atrium space. The draft curtains will utilize the natural buoyancy of the smoke to contain smoke and prevent migration between floors or adjacent spaces. The passive system will also utilize the large ceiling heights in the proposed design to create reservoirs for the smoke to collect above the 6-foot smoke layer interface required for egress, described further in Section 2. The atrium exhaust and supply fans will not operate upon detection of smoke in the office spaces adjacent to the atrium space. This is to prevent the spread of smoke into the atrium space which could adversely affect the egress of occupants throughout the building.

As part of the rational analysis, three computer simulations will be performed:

- **Fire Model: PyroSim**
  PyroSim was developed by Thunderhead Engineering Consultants, Inc., and utilizes Fire Dynamic Simulator (FDS) software from the National Institute of Standards and Technology (NIST) to model smoke generation, fire development, and air movement. See Section 3 for further discussion regarding the fire model.

- **Egress Model: Pathfinder**
  Pathfinder was developed by Thunderhead Engineering Consultants, Inc., and is an agent-based human movement simulator that accounts for occupant walking speed and path of travel to model egress behavior. See Section 4 for further discussion regarding the egress model.

- **Shaft Pressurization Model: CONTAM**
  CONTAM was developed by NIST and calculates building airflow rates and relative pressures between zones of a building. This software will be used to model the shaft pressurization systems. See Section 5 for further discussion regarding the egress model.

By analyzing the results from the smoke, egress, and pressurization models in combination, the simulations will demonstrate compliance for all integrated smoke control systems in alignment with the testing provisions of §901.6.2. The egress model will also be used to demonstrate that the proposed maximum travel distance, which exceeds the 200 feet allowed in atriums, but is within the 300 feet allowed for Group B occupancies, maintains occupant safety.

2 TENABILITY PASS/FAIL CRITERIA

Per IBC §909.8.1, a smoke control system must maintain a horizontal smoke layer interface at least 6 feet above any walking surface that forms a portion of a required egress system within the smoke zone. As part of the rational analysis, the following pass/fail criteria will be analyzed at 6 feet above the finished floor:

- Visibility of illuminated exit signs within a minimum of 30 feet (9 meters), based on an office building with occupants that are unfamiliar with the space (2012 Handbook of Smoke Control Engineering, p. 186)
- Temperatures must not exceed 160°F for a period greater than 4 minutes (2012 Handbook of Smoke Control Engineering, p. 174, Figure 6.1)
- Exposure to carbon monoxide must not exceed 1200 ppm for the duration of system operation (SFPE Handbook 5th Edition, p. 2219)

3 DESIGN FIRES

3.1 Proposed Design Fires

The analysis of the proposed design will be based on multiple design fires in accordance with §909.9. Based on a review of the Design Development progress drawings provided by Gehry Partners dated 11/22/2019, multiple design fires were evaluated as part of an initial analysis to determine the fires that would present the greatest hazard to building occupants. The analysis included several factors including fire location, fuel array, sprinkler control, smoke detection, location of vertical openings, and location of draft curtains. Six design fires were developed as potential worst-case scenarios that will be modeled to evaluate the smoke control system.

In all simulations, smoke detection and sprinkler activation times will be verified by FDS simulation results. Spot smoke detectors will be utilized at the ceilings for initial analysis. Beam detectors may be utilized if preliminary FDS results show that the detection time must decrease for the model to achieve the pass criteria described in Pass/Fail Criteria. The model will also incorporate the effects of sprinkler activation and control of the fuel array but will not assume extinguishment by the automatic fire sprinkler system. See Appendix B for full description.

The design fires selected for modeling are described below. General model parameters that apply to the building environment in all scenarios are described in Appendix A. See Appendix B, C, and D for detailed simulation input parameters for each fuel package and further description of growth rate and sprinkler control.

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Design Fire #01

Fuel Package:	Sofa (Appendix B), Chairs (Appendix C)
Location:	Lobby on Tier 01
Zone:	Combination Passive/Active Protection Zone
Floor to Deck:	27'-5" – 80'- 4"

The primary hazards for this design fire are the fuel packages (high smoke yield and rapid increase of HRR) and floor to ceiling height (potentially longer time until detection and less effective sprinkler coverage).

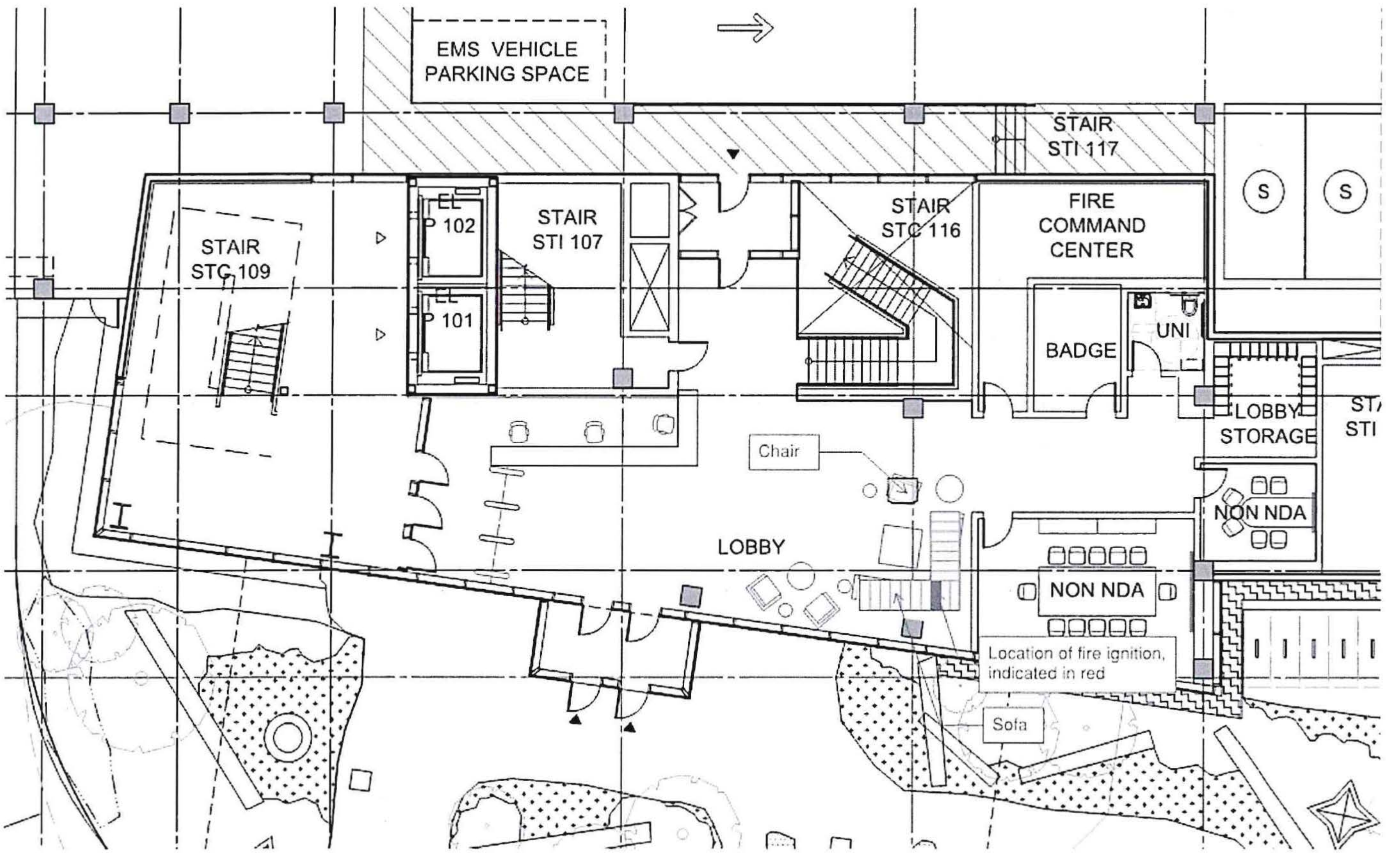
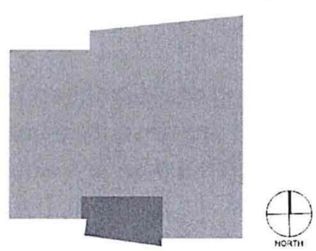
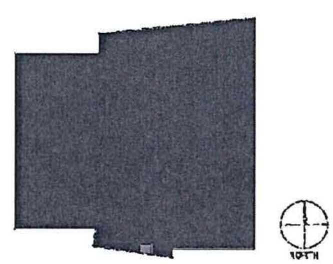


Figure 1. *Fire in the lobby on Tier 01, including ignition of one sofa and additional combustible loading of one chair.*





Design Fire #02

Fuel Package:	Sofa (Appendix B), Chairs (Appendix C)
Location:	Office Level 01
Zone:	Active Protection Zone
Floor to Deck:	52'-4"

The primary hazards for this design fire are the potential location of combustible upholstered furniture (high smoke yield and rapid increase of HRR) within the vertical opening. Due to the floor to ceiling height within the vertical opening, the smoke has a potential to migrate between floors (potentially longer time until detection and less effective sprinkler coverage).

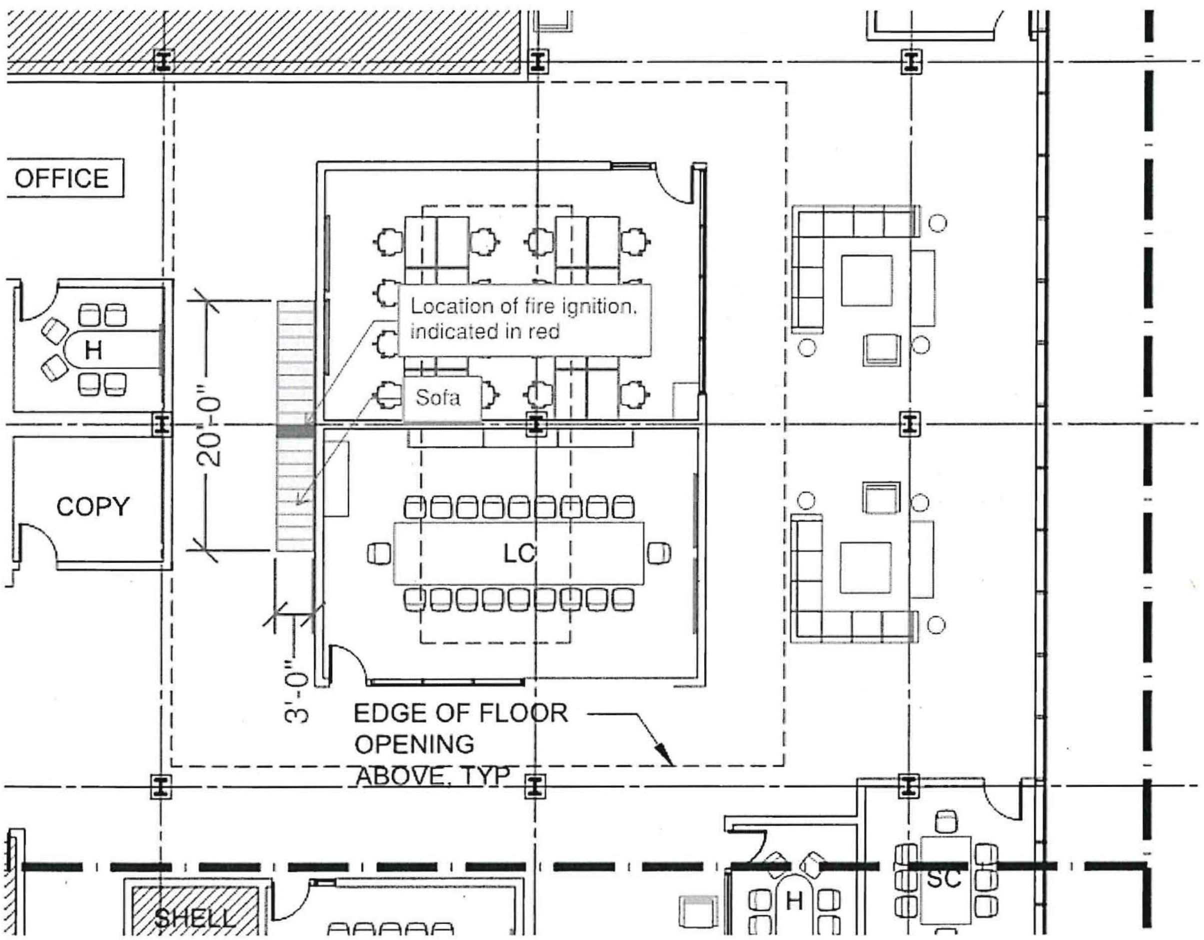
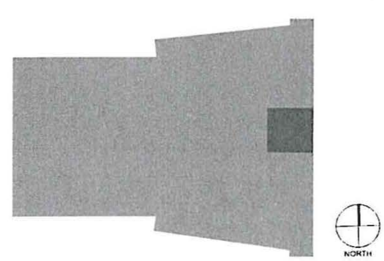


Figure 2. *Fire in a lounge area on Office Level 01, including ignition of one large sofa. (NTS)*



Design Fire #03

Fuel Package:	Sofa (Appendix B), Chairs (Appendix C), Workstation (Appendix D)
Location:	Office Level 01
Zone:	Passive Protection Zone
Floor to Deck:	20'-1"

The primary hazards for this design fire are the primary fuel package (high smoke yield and rapid increase of HRR) and potential proximity of various fuel packages. The draft curtains must be designed to maintain tenable conditions in this scenario.

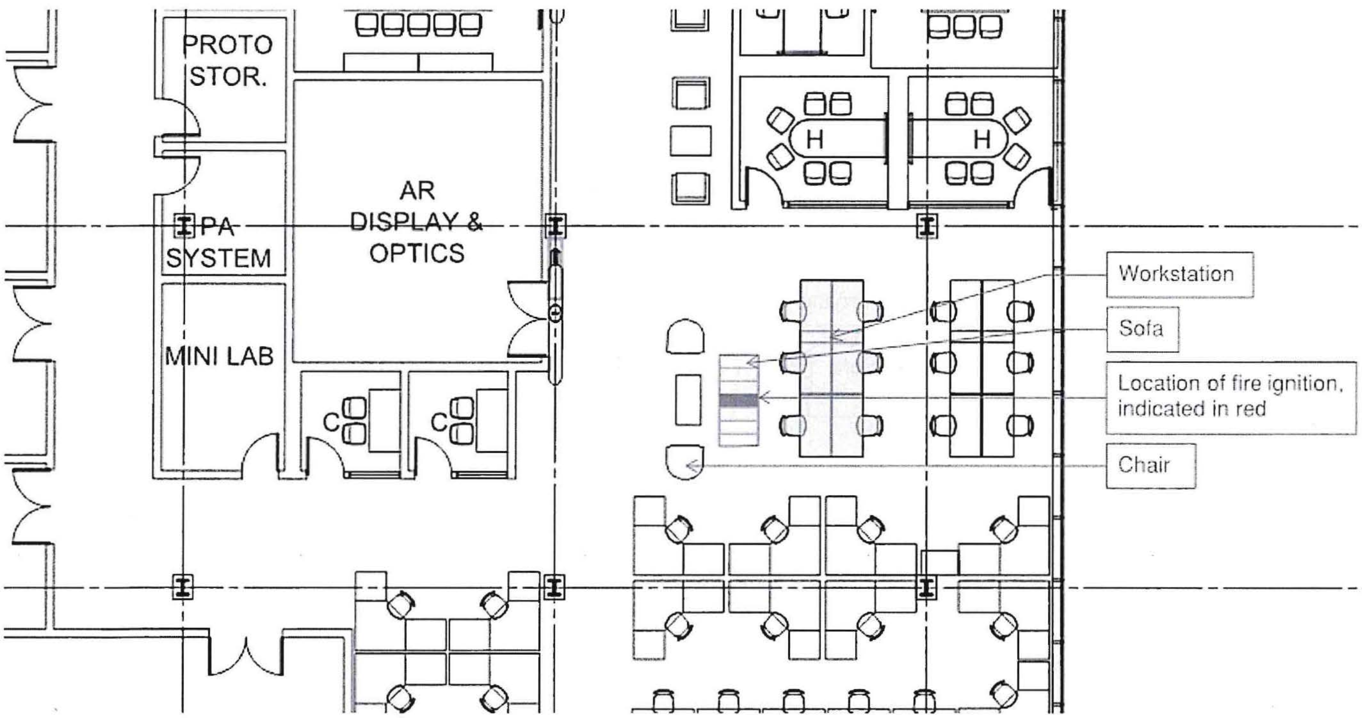
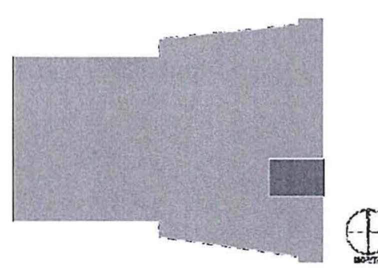


Figure 3. *Fire in an open office area on Office Level 01, including ignition of one sofa and additional combustible loading of one chair and one workstation. (NTS)*



Design Fire #04

Fuel Package:	Workstation (Appendix D)
Location:	Office Level 02
Zone:	Passive Protection Zone
Floor to Deck:	13'-4"

The primary hazards for this design fire are the fuel package (sustained HRR in a shielded fire) and lower ceiling height in the smallest volume of open office area. The draft curtains must be designed to maintain tenable conditions in this scenario.

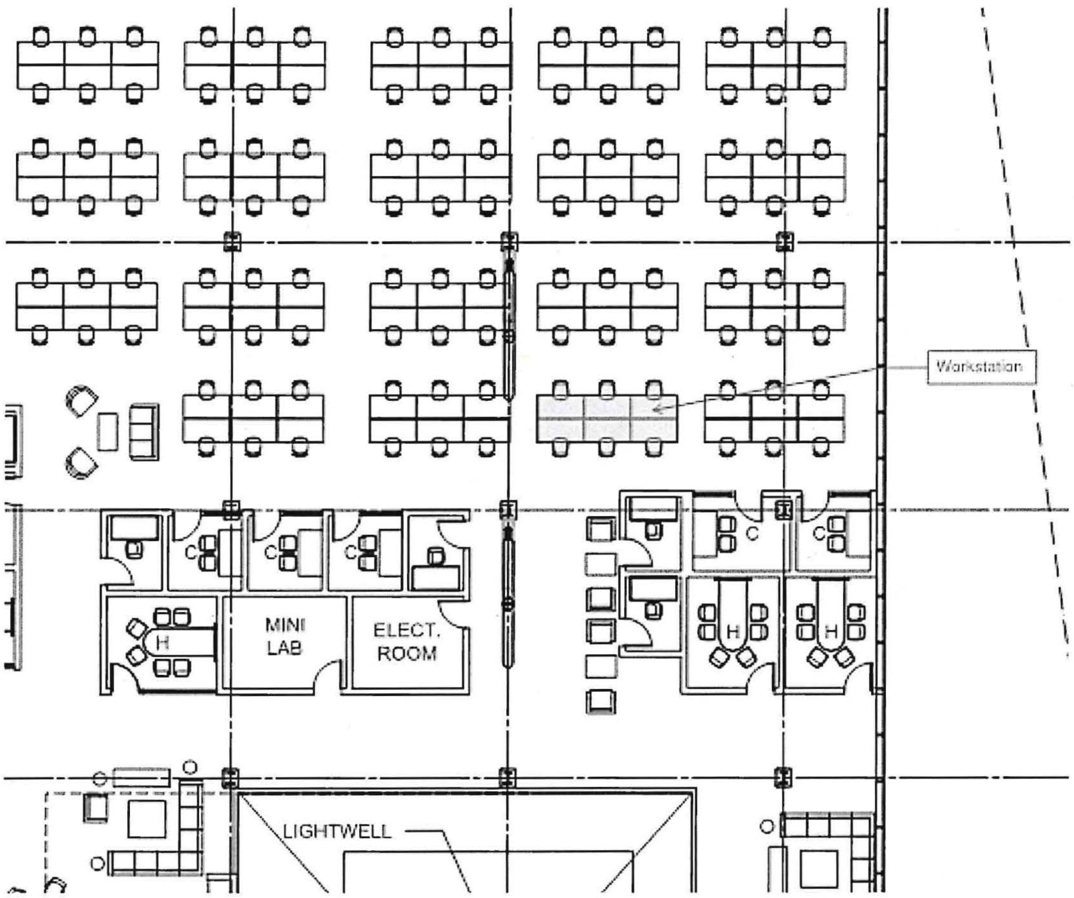
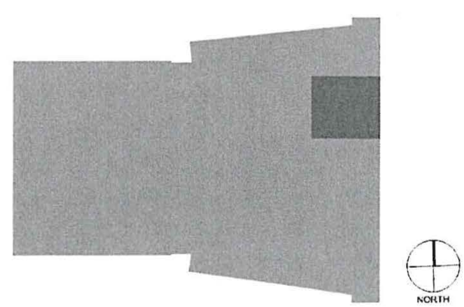


Figure 4. *Fire in an open office area on Office Level 02, including ignition of one workstation. (NTS)*



Design Fire #05

Fuel Package:	Sofa (Appendix B), Chair (Appendix C)
Location:	Office Level 02
Zone:	Passive Protection Zone
Floor to Deck:	13-4"

The primary hazards for this design fire are the fuel package (high smoke yield and rapid increase of HRR) and lower ceiling height in the smallest volume of open office area. The draft curtains must be designed to maintain tenable conditions in this scenario.

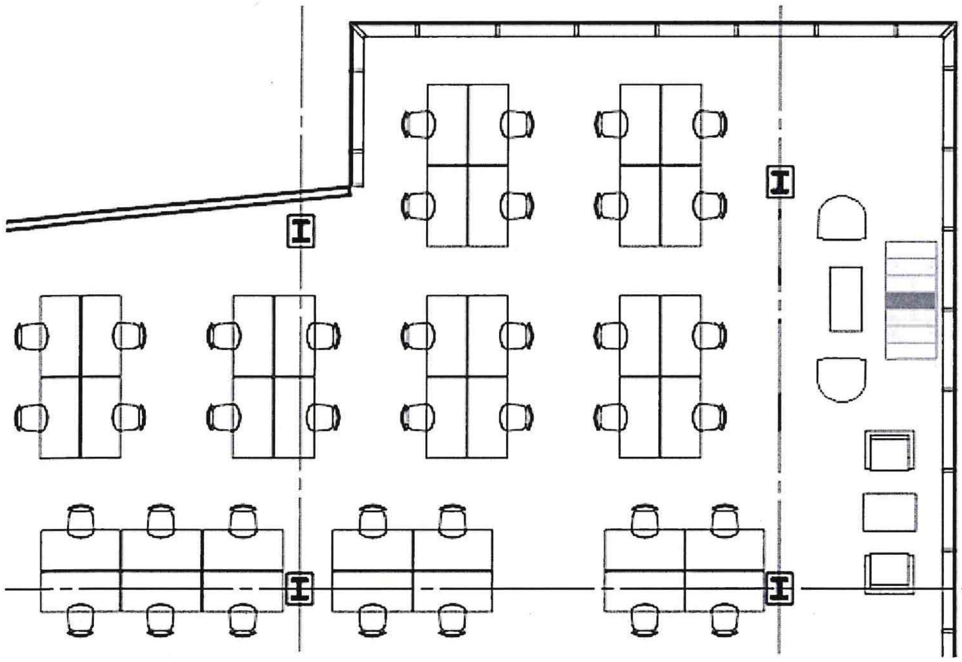
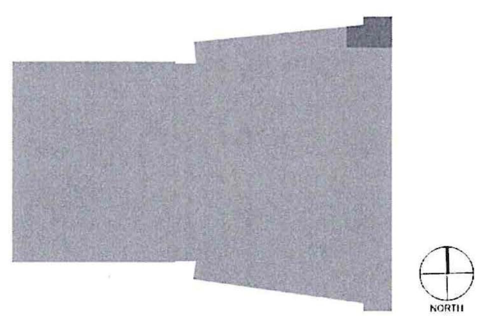


Figure 5. *Fire in an open office area on Office Level 02, including ignition of one sofa and additional combustible loading of one chair and one workstation. (NTS)*



Design Fire #06

Fuel Package:	Sofa (Appendix B), Chair (Appendix C)
Location:	Office Level 02
Zone:	Active Protection Zone
Floor to Deck:	31'-11"

The primary hazards for this design fire are the fuel package (high smoke yield and rapid increase of HRR) and the proximity to the vertical opening. The smoke has a potential to migrate between floors before the fire is controlled by sprinkler activation.

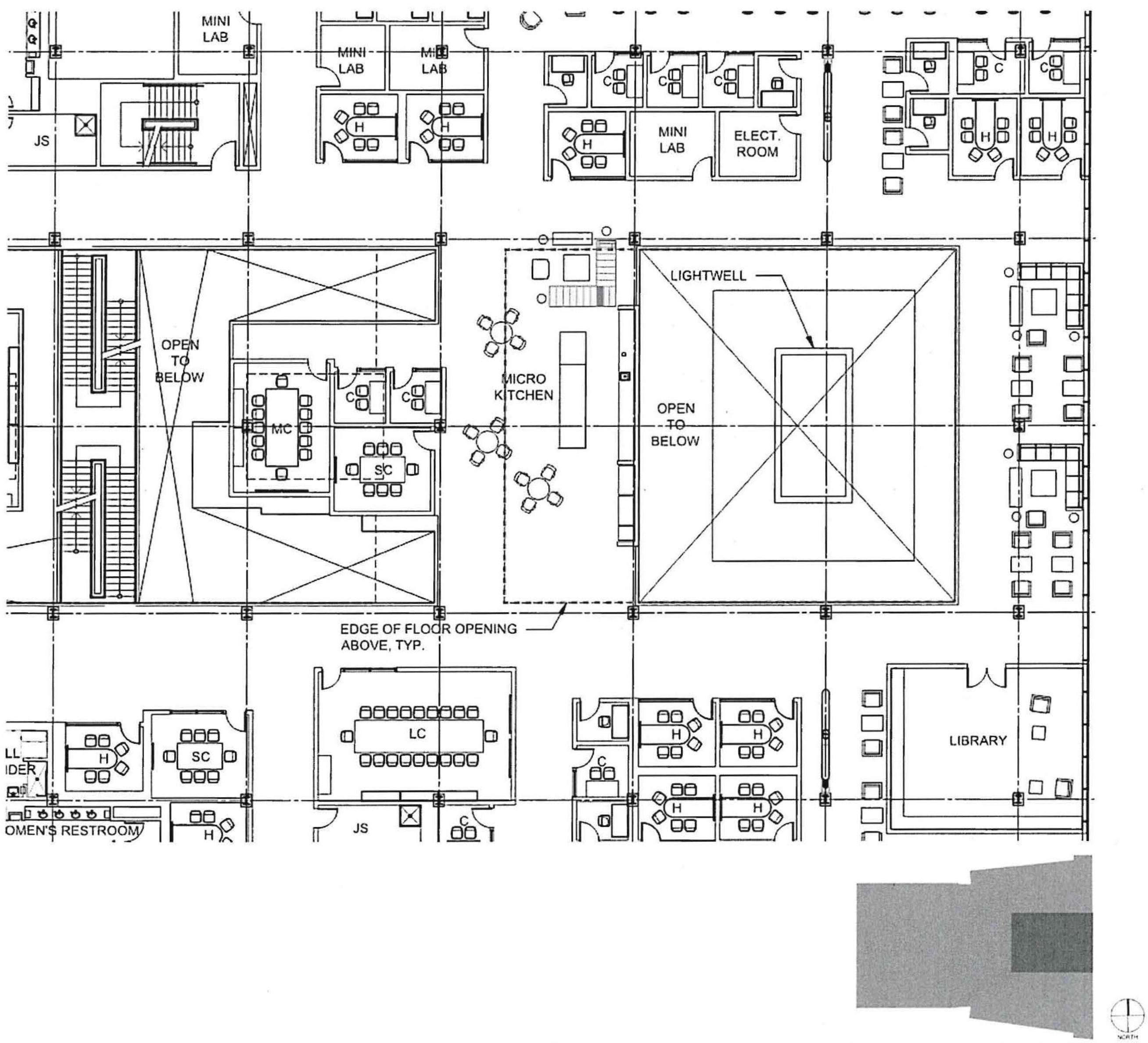


Figure 6. *Fire underneath a vertical opening (indicated by the dashed red line) on Office Level 02, including ignition of one sofa and additional combustible loading of one chair. (NTS)*

3.2 Other Considerations

Other design fires and locations were considered, but not selected as potential worst-case scenarios.

- **Conference Rooms / Technology Labs (General)**
  Fires in enclosed lab and conference rooms were considered but would result in less significant fires than design fires located in unenclosed portions of the floorplate.
  - Sprinkler activation would occur more quickly in enclosed rooms and extinguish the fire.
  - The small occupant loads of these spaces would result in quick and efficient egress of the room.
  - The room would act as a small smoke reservoir and prevent smoke from migrating to the vertical openings.

- **Kitchen Fires (General)**
  Kitchen appliances were considered as potential fuel packages but would result in less significant fires than sofas or shielded furniture.
  - Kitchens with heated surfaces are provided with localized protections as required by the International Mechanical Code, such as hoods or localized extinguishers.
  - Kitchens will have a lower quantity of combustible materials than lounge areas or open office areas.

- **Managed Event Space (Office Level 03)**
  A fire in the Managed Event Space on Office Level 03 was considered but would result in less significant smoke migration compared to fires in the open office.
  - The depth of the smoke reservoir in this space would prevent smoke from migrating to the vertical openings.
  - Sprinkler activation would extinguish the fire since the chairs do not create a shielded fire condition.
  - Sprinkler activation would maintain tenable conditions for egress of all Managed Event Space occupants.

- **Sofa in Active Zone (Office Level 03)**
  A sofa fire in the Active Protection Zone on Office Level 03 was considered but would result in less significant smoke production and migration compared to a sofa fire on Office Level 01.
  - Sprinkler activation on Office Level 03 would occur more quickly than for the same fuel package on Office Level 01.
  - A sofa fire in the Active Protection Zone on Office Level 01 will be modeled (see Design Fire #02).

4 EGRESS ANALYSIS

Pathfinder, an advanced movement simulation software, will be used to determine building evacuation times. This software is an agent-based egress simulator that uses steering behaviors to model occupant motion. The occupant movement is controlled by inputs to the simulation. These inputs will be adjusted to conservatively represent the occupant movement that is expected in the evacuation of the office building.

Occupant characteristics within the building are taken into consideration in the egress analysis. As referenced in the 4th Edition of SFPE Handbook of Fire Protection Engineering, the U.S. Census Bureau reported in 2005 that 14.9% of the U.S. population, 5 years and older, had some level of disability, excluding people living in institutions.

The SFPE Handbook provides walking speeds on horizontal surfaces. Persons without locomotive impairments are reported to walk at 4.10 ft/s (1.25 m/s). Those with locomotion disabilities are reported to move at 2.62 ft/s (0.8 m/s). A summary of walking speeds to be used in the egress simulation is provided in the Table 2 below. Walking speeds on stairs will be calculated by the software in accordance with *Engineering Guide to Human Behavior in Fire* (SFPE, 2003). Previous models have shown that walking speed, both lateral and on stairways, has a significantly smaller effect on egress time when compared to the queuing that occurs at doorways to exit stairways on floors above the level of exit discharge. We anticipate the queuing at these doorways to be the most significant component to overall egress time in Building X as well.

Table 2: *Occupant Egress Analysis.*

	Percentage of Occupants	*Walking Speed*
Locomotive Disability	15%	2.62 ft/s
No Locomotive Disability	85%	4.10 ft/s

Pre-movement time will also be accounted for in the simulation. The pre-movement time will begin after the fire is detected by smoke detectors in the model. Since the building will be equipped with an emergency voice/alarm communication system in accordance with §403.4.4 and §907.5.2.2, occupants will receive auditory direction of how to egress in a fire event. Based on Table 3-13.1 in the 3rd edition of the SFPE Handbook entry for office buildings with directives using a voice communication system, a pre-movement time of 3 minute minimum will be incorporated into the simulation, and the effects of longer pre-movement times will also be evaluated.

5 SHAFT PRESSURIZATION ANALYSIS

A CONTAM analysis will be used to identify airflow and pressure relationships for pressurized interior exit stairways and elevator hoistways. The simulation will incorporate the maximum anticipated conditions of stack effect and wind effect.

The three interior exit stairways in Building X serve Office Level 03, which is more than 75 feet above the lowest level of fire department vehicle access. To meet the §403.5.4 requirements for smokeproof enclosures in high-rise buildings, the interior exit stairways will be pressurized. The pressurization system will be sized to meet the following requirements for pressurized stairways:

- Per §909.20.5, interior exit stairways will be pressurized to maintain a minimum positive pressure of 0.10 inch of water and a maximum positive pressure of 0.35 inches of water with respect adjacent occupied spaces on all floors measured with all interior exit stairway doors closed.
- Door opening force should not exceed 30 ft-lbs per §1010.1.3

Two of the elevator hoistways in Building X connect more than three stories, are enclosed within a shaft enclosure, and are more than 75 feet in height. To meet the requirements of §3006.2 Item 5, the elevator hoistway door openings of these elevator hoistways will be protected by pressurization. The pressurization system will be sized to meet the following requirements for pressurized elevators:

- Per §909.21.1, elevator hoistways will be pressurized to maintain a minimum positive pressure of 0.10 inch of water and a maximum positive pressure of 0.25 inch of water with respect to adjacent occupied space on all floors measured with doors open on the floor of recall.

6 CONCLUSION

The atrium in Building X will be provided with a smoke control system, including mechanical exhaust fans and passive draft curtains, that will be evaluated for performance compared to the requirements of the 2018 International Building Code (IBC) with Washington Amendments (Adopted July 1st, 2020). Code Unlimited has provided the input parameters for the smoke and egress simulations, the approach for shaft pressurization, and the basis of the smoke control design.

For smoke modeling, the worst-case design fires were identified as described in Section 3 of this report. The design fires will be modeled as part of a rational analysis to determine the movement of smoke in the proposed design. The analysis will consider the concerns of sprinklers, wind effects, HVAC systems, climate, and duration of operation as required by §909.4. Subsequently, egress modeling will be performed to determine tenability based on results of the smoke model related to the amount of time it takes for occupants to egress. The smoke model will incorporate results from the shaft pressurization analysis to ensure that all the smoke control design incorporates the integration of all mechanical systems during a fire event.

The results of our analysis and any additional requirements for the proposed design will be included in a final rational analysis report. The smoke report will be stamped by a Washington State registered Fire Protection Engineer.

7 APPENDIX A: BUILDING INPUT PARAMETERS

The following simulation input parameters are related to general building and environment conditions that remain constant in every design fire scenario. The table below describes the input parameters that will be used in the FDS simulation, along with the resource used to determine each parameter.

	PARAMETER	DESIGN FIRE	SOURCE
SMOKE DETECTOR PARAMETERS			
1.	Smoke Detection	Area spot detectors	Locations based on Code Unlimited analysis in accordance with NFPA 72.
2.	Smoke Detector Obscuration Threshold	2.5%/ft (alarm verification routines for spot detectors will be included in the design)	SFPE Emerging Trends Digital Newsletter Issue 56: Challenges in Estimating Smoke Detector Response, James A. Milke, Ph.D., P.E., FSFPE.
3.	Fire Alarm Delay	10s after smoke detection	Conservative delay based on current standard smoke detection/alarm devices.
SPRINKLER PARAMETERS			
4.	Sprinkler Activation Temperature	155 °F / 165 °F	Nominal operating temperature, 2013 NFPA 13 Standard for the Installation of Sprinkler Systems Chapter 6.
5.	Sprinkler Response Time Index (RTI)	181 $\sqrt{m/s}$	Quick response links in accordance with 2013 NFPA 13 Standard for the Installation of Sprinkler Systems §3.6.1(b).
6.	Sprinkler Type	1/2" quick-response heads protecting floor; 5/8" ELO (extra-large orifice) standard response heads with intermediate response temperature at clerestory.	
OTHER SYSTEM PARAMETERS			
7.	Exhaust	To be determined; activated upon smoke detection and activation of the smoke control system.	Analysis performed by Code Unlimited.

	PARAMETER	DESIGN FIRE	SOURCE
8.	*Make-up Air*	*Mechanical ventilation will be provided from AHU systems connected to each floor by a plenum; activated upon smoke detection and activation of the smoke control system.*	*Analysis performed by Code Unlimited.*
GENERAL MODEL PARAMETERS			
9.	*Mesh size*	*1 ft x 1 ft x 1 ft*	*Preliminary mesh size; to be based on FDS simulation.*
10.	*Duration Factor*	*1.5 X calculated egress time or 20 minutes, whichever is greater.*	*2018 IBC, §909.4.6. Egress analysis will be performed to determine the required duration of operation.*
11.	*Visibility Factor*	*8*	*Based on illuminated exit signs. Klote, J. (2016). "Smoke Control." SFPE Handbook of Fire Protection, Fifth Edition, 1818.*
12.	*Interior Air Temperature*	*72 °F*	*ASHRAE Standard 55-2013, Thermal Environmental Conditions for Human Occupancy*
13.	*Exterior Air Temperature*	*Minimum Exterior Air Temperature: 21.4 °F* *Maximum Exterior Air Temperature: 89.6° F*	*ASHRAE. 2017. Climatic Design Conditions, Location: Seattle, WA, USA (WMO: 994014)* *The system will be modelled under the maximum and minimum temperatures to verify the effects of air temperature on the smoke management system.*
14.	*Wind Direction & Speed (July)*	*Wind Direction: 320° (Northwest)* *Wind Speed: 6.7 mph*	*ASHRAE. 2017. Climatic Design Conditions, Location: Seattle, WA, USA (WMO: 994014)* *Plan north and true north are aligned in the building drawings.*

8 APPENDIX B: SOFA FIRE INPUT PARAMETERS

BASIS OF PARAMETERS:

The following input parameters are for design fires that designate a 3-seat sofa as the fuel package. The sofa fire will be modeled based off data from a full-scale fire test conducted under a furniture calorimeter as reported by the National Bureau of Standards.

FIRE GROWTH:

The full-scale test, conducted as a non-sprinkler-controlled fire, produced a fast growth rate fire with a peak Heat Release Rate (HRR) of 3,120 kW with a published growth curve (see Figure 1).

The simulation of the sofa fire will follow the same growth curve and peak heat release rate as the tested sofa.

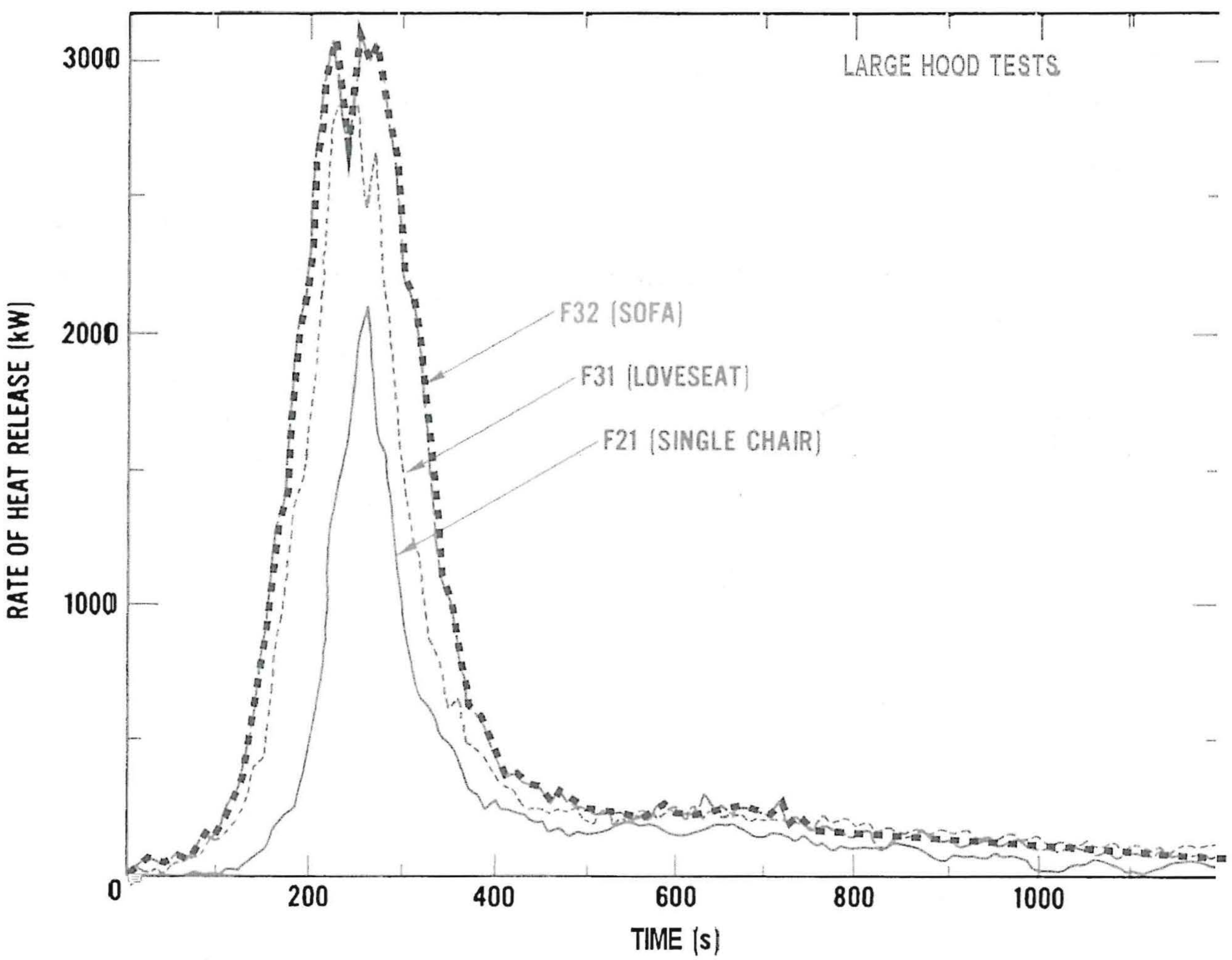


Figure 1: *The HRR curve of a three-seated sofa from a full-scale fire test performed by the National Bureau of Standards was used a basis for determining the fire parameters of a fire propagating along a large sofa.*

SPRINKLER ACTIVATION:
All atrium smoke control design fire models will incorporate the control of the fire after activation of sprinklers; at the time of sprinkler activation:

- The fire will not continue to propagate to adjacent slices.
- The HRR of actively burning slices will reduce linearly to a maximum of 30 kW HRR over a period of 30 seconds; the sofa will remain at 30 kW HRR for the remaining duration of the model run.

The reduction of HRR occurs over a period of 30 seconds to allow the discharge pattern to become fully developed and for water to pre-wet unignited areas of the fuel array. This delay is a conservative value; fire experiments show that realistically, the sprinklers would control the spread of fire within seconds after activation. This is consistent with the HRR profile of a sprinkler-controlled fire with some partially shielded areas continuing to smolder, rather than assuming complete extinguishment by the automatic fire sprinkler system.

The table below shows the input parameters that will be used in the FDS simulation along with the resource used to determine each parameter.

	PARAMETER	***DESIGN FIRE***	***SOURCE***
	Design Fire Size	*HRRPUA* *Sofa: 1400 kW/m²*	*Established based on NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, Table 2A, pg 30 (1982)*
2.	*Fire area*	*Sofa: 3ft x 20ft = 60 ft² (5.57 m²)*	*Approximate dimensions of the worst-case large sofa, based on furniture in existing office buildings owned by the same tenant.*
3.	*Auto-ignition*	*0.4 kW/m2² radiant heat flux (input into device for heat flux)*	*Based on FDS comparison testing to the full-scale fire test described in NBSIR 82-2604.* *This is significantly more conservative than other referenced standards: the SFPE 2016 indicates a heat flux of 30 kW/m² for sofas and the NFPA 92 indicates a heat flux of 10 kW/m² for sofas.* *SFPE. 2016. "Handbook of Fire Protection Engineering," Fifth Edition, pg. 586.* *NFPA 92 §5.2.5.7 Standard for Smoke Control Systems*
4.	*Design fire location*	*Locations specified in Section 3.1.*	*Analysis performed by Code Unlimited.*

	PARAMETER	DESIGN FIRE	SOURCE
5.	*Fire growth rate*	*Follows NIST test curve until sprinklers activate (based on temperature at ceiling from model) then decreases linearly over next 30 seconds to 30 kW HRR. The fire is then held at 30 kW HRR for the remainder of model run after decrease.*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, pg 23 (1982)*
6.	*Peak HRR*	*7,401 kW*	*To be based on FDS simulation.*
7.	*Reaction*	*Polyurethane*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2A, pg 32 (1982)*
8.	*Soot yield*	*0.024*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 9, pg 37 (1982)*
9.	*CO yield*	*0.0012*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2B, pg 31 (1982)*
10.	*Radiative Fraction*	*0.35*	*NFPA. 2008. "NFPA Fire Protection Handbook", Twentieth Edition, pg 3-156*
11.	*Critical Flame Temperature*	*1327 °C*	*NIST Special Publication 1019, "Fire Dynamics Simulator User's Guide", Sixth Edition. Table 17.23, p. 243*
12.	*Surface Temperature*	*300 °C*	*Conservative default parameter established by Pyrosim in edition 2018.3.1210.*

9 APPENDIX C: CHAIR FIRE INPUT PARAMETERS

BASIS OF PARAMETERS:

The following input parameters are for design fires that designate a chair as the fuel package. The chair fire will be modeled based off data from a full-scale fire test conducted under a furniture calorimeter as reported by the National Bureau of Standards.

FIRE GROWTH:

The full-scale test, conducted as a non-sprinkler-controlled fire, produced a fast growth rate fire with a peak Heat Release Rate (HRR) of 2,100 kW with a published growth curve (see Figure 1).

The simulation of the chair fire will follow the same growth curve and peak heat release rate as the tested chair.

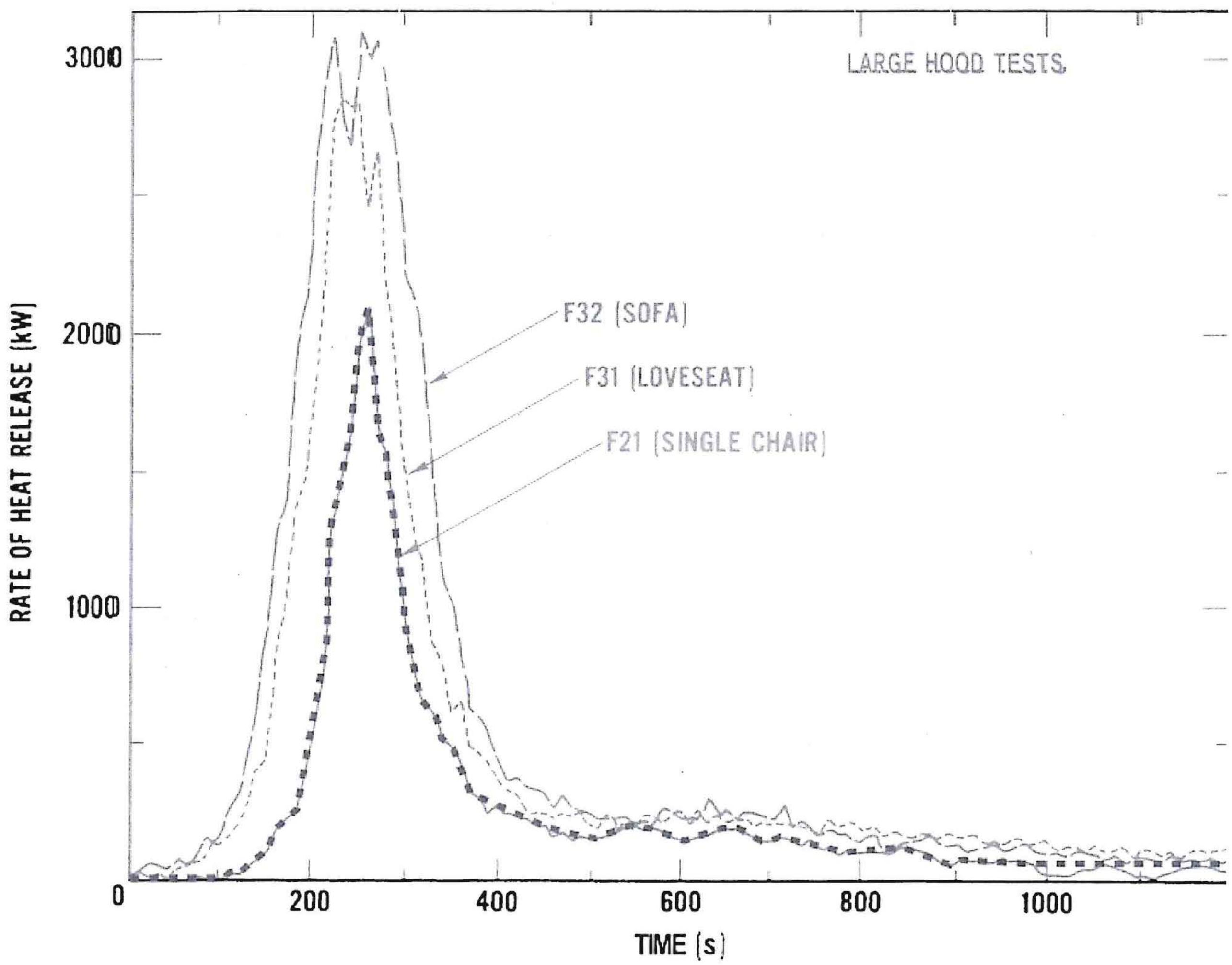


Figure 1: *The HRR curve of a three-seated sofa from a full-scale fire test performed by the National Bureau of Standards was used a basis for determining the fire parameters of a fire propagating along a large sofa.*

SPRINKLER ACTIVATION:

All atrium smoke control design fire models will incorporate the control of the fire after activation of sprinklers; at the time of sprinkler activation:

- The fire will not continue to propagate to adjacent chairs or other combustible fuel loads.
- The HRR of actively burning chairs will reduce linearly to a maximum of 30 kW HRR over a period of 30 seconds; the sofa will remain at 30 kW HRR for the remaining duration of the model run.

The reduction of HRR occurs over a period of 30 second to allow the discharge pattern to become fully developed and for water to pre-wet unignited areas of the fuel array. This delay is a conservative value; fire experiments show that realistically, the sprinklers would control the spread of fire within seconds after activation. This is consistent with the HRR profile of a sprinkler-controlled fire with some partially shielded areas continuing to smolder, rather than assuming complete extinguishment by the automatic fire sprinkler system.

The table below shows the input parameters that will be used in the FDS simulation along with the resource used to determine each parameter.

	PARAMETER	***DESIGN FIRE***	***SOURCE***
	Design Fire Size	*HRRPUA* *Chair: 3,750 kW/m²*	*Established based on NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, Table 2A, pg 30 (1982)*
14.	*Fire area*	*Chair: 6 ft² (0.56 m²)*	*Approximate dimensions of the worst-case large sofa, based on furniture in existing office buildings owned by the same tenant.*
15.	*Auto-ignition*	*0.4 kW/m2² radiant heat flux (input into device for heat flux)*	*Based on FDS comparison testing to the full-scale fire test described in NBSIR 82-2604.* *This is significantly more conservative than other referenced standards: the SFPE 2016 indicates a heat flux of 30 kW/m² for sofas and the NFPA 92 indicates a heat flux of 10 kW/m² for sofas.* *SFPE. 2016. "Handbook of Fire Protection Engineering," Fifth Edition, pg. 586.* *NFPA 92 §5.2.5.7 Standard for Smoke Control Systems*
16.	*Design fire location*	*Locations specified in Section 3.1.*	*Analysis performed by Code Unlimited.*

	PARAMETER	DESIGN FIRE	SOURCE
17.	Fire growth rate	Follows NIST test curve until sprinklers activate (based on temperature at ceiling from model) then decreases linearly over next 30 seconds to 30 kW HRR. The fire is then held at 30 kW HRR for the remainder of model run after decrease.	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, pg 23 (1982)
18.	Peak HRR	2,100 kW	To be based on FDS simulation.
19.	Reaction	Polyurethane	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2A, pg 32 (1982)
20.	Soot yield	0.024	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 9, pg 37 (1982)
21.	CO yield	0.0012	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2B, pg 31 (1982)
22.	Radiative Fraction	0.35	NFPA. 2008. "NFPA Fire Protection Handbook", Twentieth Edition, pg 3-156
23.	Critical Flame Temperature	1327 °C	NIST Special Publication 1019, "Fire Dynamics Simulator User's Guide", Sixth Edition. Table 17.23, p. 243
24.	Surface Temperature	300 °C	Conservative default parameter established by Pyrosim in edition 2018.3.1210.

10 APPENDIX D: WORKSTATION FIRE INPUT PARAMETERS

BASIS OF PARAMETERS:

The following input parameters are for design fires that designate a workstation as the fuel package. The workstation fire will be modeled based off data from a full-scale fire test conducted under an oxygen consumption calorimeter by the National Research Council of Canada (NRCC) and described in the 2012 Handbook of Smoke Control Engineering compiled by representatives of ASHRAE, SFPE, ICC, and NFPA.

The study conducted by NRCC included two desks, two chairs, multiple boxes, and empty filing cabinets (see Figure 1) and focused on open-plan office scenarios. **This study assumes that workstations are not divided by combustible partitions.**

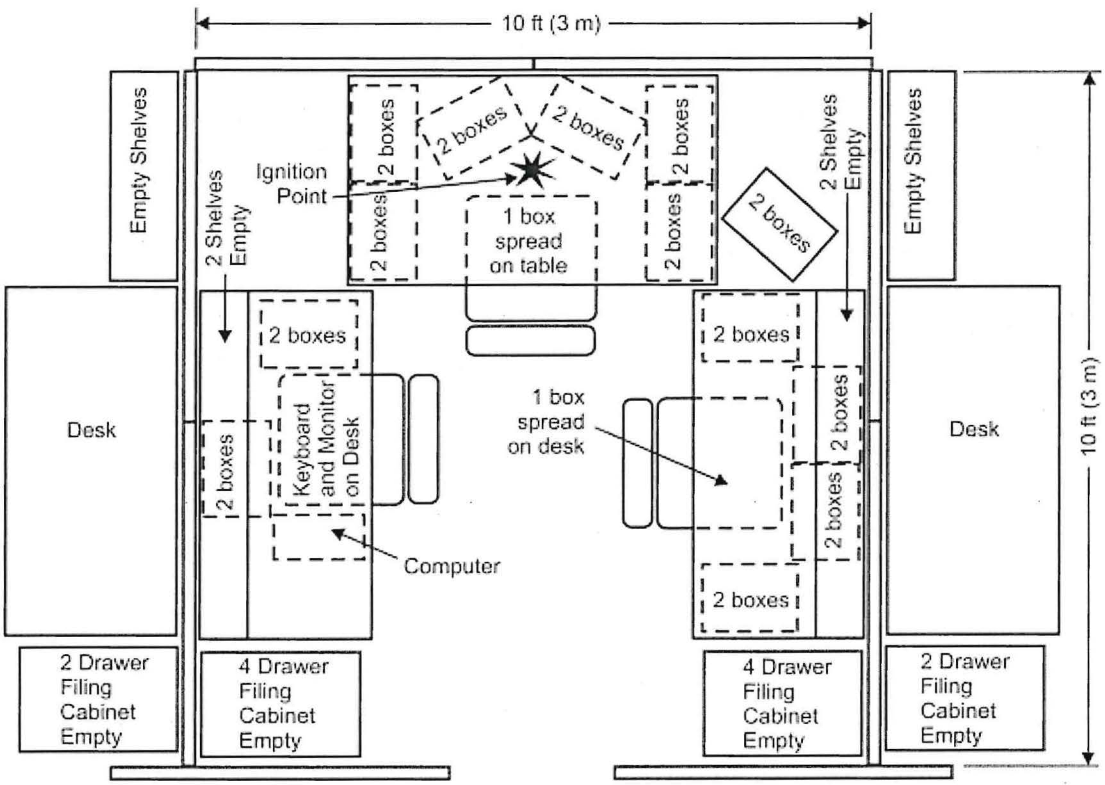


Figure 1: *Layout of the workstations tested in the NRCC shielded fire study.*

FIRE GROWTH:

The proposed design fires involving workstations include an open-office layout with series of adjacent workstations. This test, conducted as a sprinkler-controlled fire, was a shielded fire with a peak Heat Release Rate (HRR) of 1,000 kW with a published growth curve (see Figure 2). The growth curve will be input into the FDS simulation.

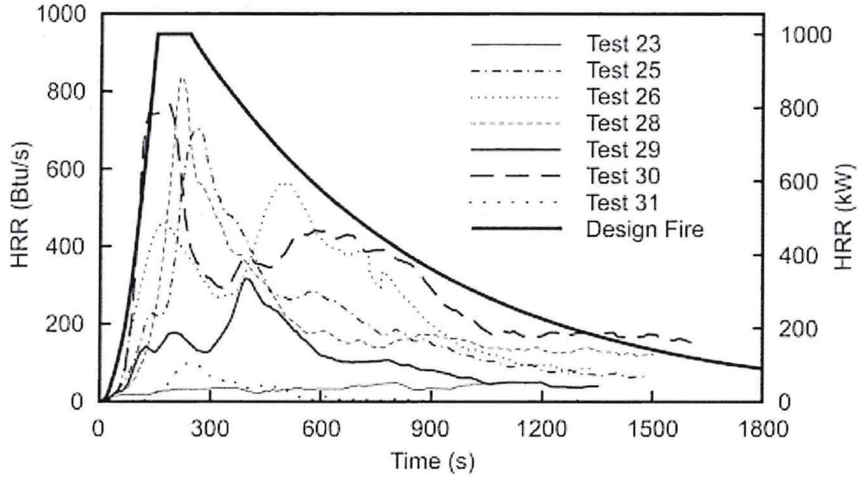


Figure 5.10 *HRR of shielded fires from the NRCC study.*

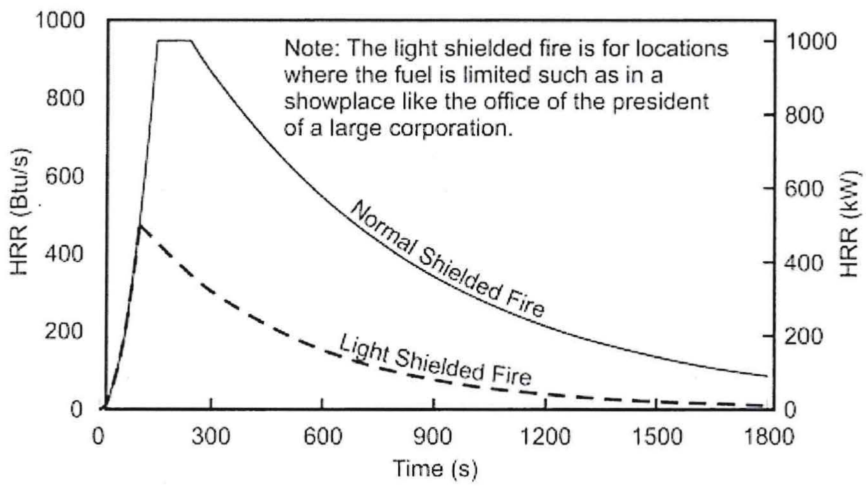


Figure 5.11 *Recommended shielded design fires.*

Figure 2: *The HRR curve of a shielded workstation fire from a full-scale fire test performed by the NRCC was used a basis for determining the fire parameters of a workstation.*

SPRINKLER ACTIVATION:

All design fire models will incorporate the control of the fire after activation of sprinklers. The NRCC workstation test fire utilized sprinklers in an open office environment with a ceiling height of 9 feet. The results of this study are appropriate for ceilings up to approximately 20 feet in height.

The activation of sprinklers is not as effective in controlling a workstation fire scenario as much of the combustible fuel load is shielded by a table or desk. Realistically, and as described in the Handbook of Smoke Control Engineering Chapter 5, sprinklers are ineffective in controlling the growth of a shielded fire where the water array is obstructed from the source of the flames.

The effects of sprinkler activation are incorporated in the following ways:

- The growth curve has a prolonged decay due to combustibles located under the table that are shielded and burn until the ignited fuel array is fully consumed.
- The sprinkler activation will prewet adjacent workstations and cool the surrounding air temperatures, preventing the propagation of fire to adjacent workstations.

The table below shows the input parameters that will be used in the FDS simulation along with the resource used to determine each parameter.

	PARAMETER	DESIGN FIRE	SOURCE
25.	*Design Fire Size*	*HRR* *Workstation: 1,000 kW*	*Handbook of Smoke Control Engineering, Chapter 5 'Fire Science and Design Fires – Shielded Fires', compiled by members of ASHRAE, SFPE, ICC, and NFPA, Figure 5.11 pg. 158 (2012)*
26.	*Fire area*	*Sofa: 150 ft^2 (15 ft x 10 ft)*	*Handbook of Smoke Control Engineering, Chapter 5 'Fire Science and Design Fires – Shielded Fires', compiled by members of ASHRAE, SFPE, ICC, and NFPA, Figure 5.9 pg. 157 (2012)*
27.	*Auto-ignition*	*0.4 kW/m2^2 radiant heat flux (input into device for heat flux) based on padded chair at workstation.*	*Based on FDS comparison testing to the full-scale fire test described in NBSIR 82-2604.* *This is significantly more conservative than other referenced standards: the SFPE 2016 indicates a heat flux of 30 kW/m^2 for sofas and the NFPA 92 indicates a heat flux of 10 kW/m^2 for sofas.* *SFPE. 2016. "Handbook of Fire Protection Engineering," Fifth Edition, pg. 586.* *NFPA 92 §5.2.5.7 Standard for Smoke Control Systems*
28.	*Design fire location*	*Locations specified in Section 3.1.*	*Analysis performed by Code Unlimited.*
29.	*Fire growth rate*	*Follows full-scale test curve, which incorporates the effects of sprinklers.*	*Handbook of Smoke Control Engineering, Chapter 5 'Fire Science and Design Fires – Shielded Fires', compiled by members of ASHRAE, SFPE, ICC, and NFPA, Figure 5.11 pg. 157 (2012)*

	PARAMETER	*DESIGN FIRE*	*SOURCE*
30.	*Reaction*	*Polyurethane* *Most conservative reaction in a simulation fire with both padded chair and wood elements.*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2A, pg 32 (1982)*
31.	*Soot yield*	*0.024* *Most conservative reaction in a simulation fire with both padded chair and wood elements.*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 9, pg 37 (1982)*
32.	*CO yield*	*0.0012* *Most conservative reaction in a simulation fire with both padded chair and wood elements.*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2B, pg 31 (1982)*
33.	*Radiative Fraction*	*0.35* *Most conservative reaction in a simulation fire with both padded chair and wood elements.*	*NFPA. 2008. "NFPA Fire Protection Handbook", Twentieth Edition, pg 3-156*
34.	*Critical Flame Temperature*	*1327 °C*	*NIST Special Publication 1019, "Fire Dynamics Simulator User's Guide", Sixth Edition. Table 17.23, p. 243*
35.	*Surface Temperature*	*300 °C*	*Conservative default parameter established by Pryosim in edition 2018.3.1210.*

Building X – Structural Fire Engineering

Fire Parameters Report

Client Name: Gehry Partners

Client Address: 12541 Beatrice St, Los Angeles, CA 90066

Date: 11/19/2019

Table of Contents

1 OVERVIEW

1.1 Executive Summary

Building X is classified as a high-rise building of Type I-B construction. Per 2018 IBC §403.2.1.1, the construction type is permitted to be Type II-A, while maintaining area, height, and stories as permitted for a building of Type I-B construction.

Code Unlimited and Magnusson Klemencic Associates (MKA) will follow the provisions of IBC §703.3 and §104.11 to provide fire analysis of the structural systems under design fire scenarios and demonstrate that structural integrity is maintained. A design per these alternative design provisions is required to meet the intent of the prescriptive provisions of the code, specifically in this case, ensuring that Life-Safety objectives are met for the building's occupants. The structural analysis will follow the framework established by "Performance-Based Design Procedures for Fire Effects on Structures" outlined in Appendix E of the 2016 ASCE-7 standard. The Fire Design Scenarios are developed based on the Building Fire Risk Analysis outlined in the SFPE Handbook and other industry standards. Computational Fluid Dynamics (CFD) is used to model the fire development and its effect on the building structure. Since the building is required to meet the requirements of Type II-A construction, the fire exposure is limited to a period of one hour.

This memo outlines the parameters used to evaluate the performance of the steel structural members when exposed to a credible fire caused by combustible materials within Building X. The fire will be simulated to burn without any consideration for the activation of sprinklers or suppression of fire.

The design fire scenarios are based on the anticipated worst-case fuel loading in the building. A building fire risk analysis determined two worst-case design fire scenarios: one for the exposed steel column and one for the exposed steel beam. The ASTM E119 fire growth curve was also considered, but not selected as a worst-case design. The design fire scenarios result in peak, critical temperatures more quickly than the ASTM E119 test curve. Introducing elevated temperatures to the steel structure earlier in the simulation creates a worse scenario for the internal strength of the steel.

Code Unlimited will model these design fires in a representative building area of 60-ft x 60-ft in size. The temperature at the surface of the steel column and beam will be documented over the duration of fire exposure. This data will be used by MKA to perform structural analysis and determine whether the structural integrity is maintained within acceptable ASCE standards for the required duration.

The floor/ceiling assembly is composite metal deck with normal weight concrete. The concrete cover will prescriptively meet the requirement for a 1-hour fire-resistance-rated floor/ceiling assembly. Therefore, it is not part of this performance-based analysis.

1.2 Applicable Codes and Standards

- 2018 International Building Code (IBC) in anticipation of Washington adoption
- 2018 International Fire Code (IFC) in anticipation of Washington adoption
- 2009 ASHRAE Handbook of Fundamentals
- 2008 NFPA Fire Protection Handbook, 20th Edition
- Society of Fire Protection Engineering (SFPE) Handbook 4th Edition
- American Society of Civil Engineer (ASCE) and Structural Engineering Institute (SCI) 7-16 Appendix E
- 2016 American Institute of Steel Construction 260 (AISC 360-16) Appendix 4
- Structural Fire Engineering Manual of Practice (ASCE/SEI-138)

1.3 Building Overview

Building X is a new corporate office building designed by Gehry Partners for Facebook, located in Redmond, Washington. The proposed building is five stories of commercial office space over a tiered parking structure. The building includes open office areas, conference rooms, research laboratories, cafeteria, and occupied green roof terrace. One of the primary architectural design goals is to have exposed steel, without fireproofing where possible, in the main office structure. The parking garage will be constructed of cast-in-place concrete and will meet the prescriptive fire-resistance-rating requirements.

1.4 Key Approach & Methodology

As described in IBC §704.2 and §704.3, individual encasement protection is required for columns and other primary structural frame members receiving tributary loads from multiple levels that are required to have protection to achieve a fire-resistance rating. This requirement assumes that the structural elements have an insufficient level of inherent fire protection to maintain structural integrity for occupant egress based on a typical building layout with the minimum code prescriptive conditions.

The performance-based design will include a rational analysis to document how the proposed design meets the IBC and ASCE codes and standards with limited or no individual encasement. The analysis will be specific to the proposed design for Building X, which has design elements that benefit the structure in a fire event compared to a typical code prescriptive building:

- **Increased Ceiling Height**
  Generally, along means of egress, the ceiling height cannot be less than 7 feet 6 inches above the finished floor. In the proposed design, the floor to ceiling heights on the Office Levels range from ~14 feet to 19 feet. For columns, this results in less significant heating along the upper region of the column where the member does not experience direct flame impingement. For beams, this means the fire is significantly further away from the flame than in a typical office building. Because radiant energy decreases as the square of the distance from the source, the thermal impacts of the fire are much less significant for beams at the proposed height.

- **Open Office Layout**
  Traditional office buildings typically include enclosed office rooms connected by corridors. In these types of buildings, flashover – the sudden involvement of all combustible materials in a room – is a concern since the energy of the fire is being radiated back to the contents of the room. Flashover occurs in smaller spaces because the heat is rising so rapidly that the ignition temperatures of all materials is reached around the same time. In the proposed open office layout, however, heat will disperse across the floorplate, decreasing the effects of thermal radiation on combustibles in the vicinity of the source fire.

As part of the rational analysis, a PyroSim computer simulation will be developed to determine the surface temperature on the structural elements during a worst-case fire. PyroSim was developed by Thunderhead Engineering Consultants, Inc., and utilizes Fire Dynamic Simulator (FDS) software from the National Institute of Standards and Technology (NIST) to model smoke generation, fire development, and air movement. See Section 2 for further discussion regarding the fire model.

2 DESIGN FIRES

The fire performance assessment of the structure requires identification of design fires and the quantification of these fires. The criteria for design fire scenarios are based on occupancy-specific design scenarios representative of a worst-case fire for the building structure. In the process of selecting a design fire, several factors are considered, including the source of ignition, arrangement and quantity of combustible materials, fire development, spread, and the duration. The scenarios developed and used in this analysis are the worst-case design fire scenarios.

Two distinct scenarios have been identified as the worst-case design fire scenarios for the project. The first scenario is a focused study on the column and the second scenario is focused on the beams. The scenarios are discussed below.

- **Fuel Array**
  The worst-case design fire for both scenarios was determined to be an elongated padded sofa in two different orientations, described in Section 2.1 and 2.2. Ignition is anticipated in one initial unit, which then ignites the next unit, and continues until the fuel is completely consumed. Conservatively, each unit ignited reaches peak heat release rate (HRR) and then decays but continues to smolder for the rest of the duration of the simulation. The CFD computer software models chain ignition and decay for the entire length of the sofa.

- **Location**
  Both design fires will originate on Office Level 02, since this floor has the smallest floor to ceiling height (15'-4") and floor to beam structure height (~12'-0").

- **Bay Size**
  In both scenarios, the fire originates at upholstered sofas located in a representative building area 60-ft x 60-ft in size. This is derived from a 30-ft x 30-ft structural grid that is typical throughout Building X. Building X includes open office areas significantly larger than the representative bay size, but as a conservative measure, the design fire will be modeled as an enclosed space with walls on all four sides. A small 1 ft x 1 ft opening will be included along the lower portion of one wall to prevent an artificial pressure build up, which would cause errors in the simulation data results.

Other layouts were also considered for the fire simulation, but the proposed layouts were determined to be the worst-case scenarios. For example, the kitchen areas may be enclosed with wood partitions with exposed wood stud framing. These studs will not have a concentration of the fuel array as other scenarios. With the limited amount of combustible materials, compared to the large mass of upholstered sofa, the potential for flashover is greatly reduced.

Section 2.1 and 2.2 of this report describe the location of the fire and fuel package in the grid. General model parameters that apply to the building environment in all scenarios are described in Appendix A. See Appendix B and C for detailed simulation input parameters for each fuel package and further description of growth rate.

2.1 Scenario 1: Worst-Case Fire for Columns

Fuel Package: Sofa A (Appendix B)

The building is proposed to have all exposed steel structures consisting of beams and columns with no fire-proofing or other protective covering. The largest fire load expected would be in the waiting/circulation areas, where a six-seat padded polyurethane sofa may be placed adjacent to a load-bearing column. Fire at one of the sofas has the potential to spread across to other sofas within the vicinity, exposing the column to high temperature anticipated to impact the load-bearing strength.

For the modeling analysis purposes, upholstered sofas will be considered to wrap around the columns. This approach is a conservative model that simulates the furniture layout for a worst-case design fire. The columns are spaced 30 feet apart; the floor to floor height on Office Level 02 is 16'-0", and the floor to ceiling height is ~15'-4". As depicted in Figure 1, the portion of the sofa in red indicates the upholstered furniture where the fire originates. The fire then spreads to adjacent sofas and burns sequentially. This also heats the column located directly adjacent to the point of fire origin.

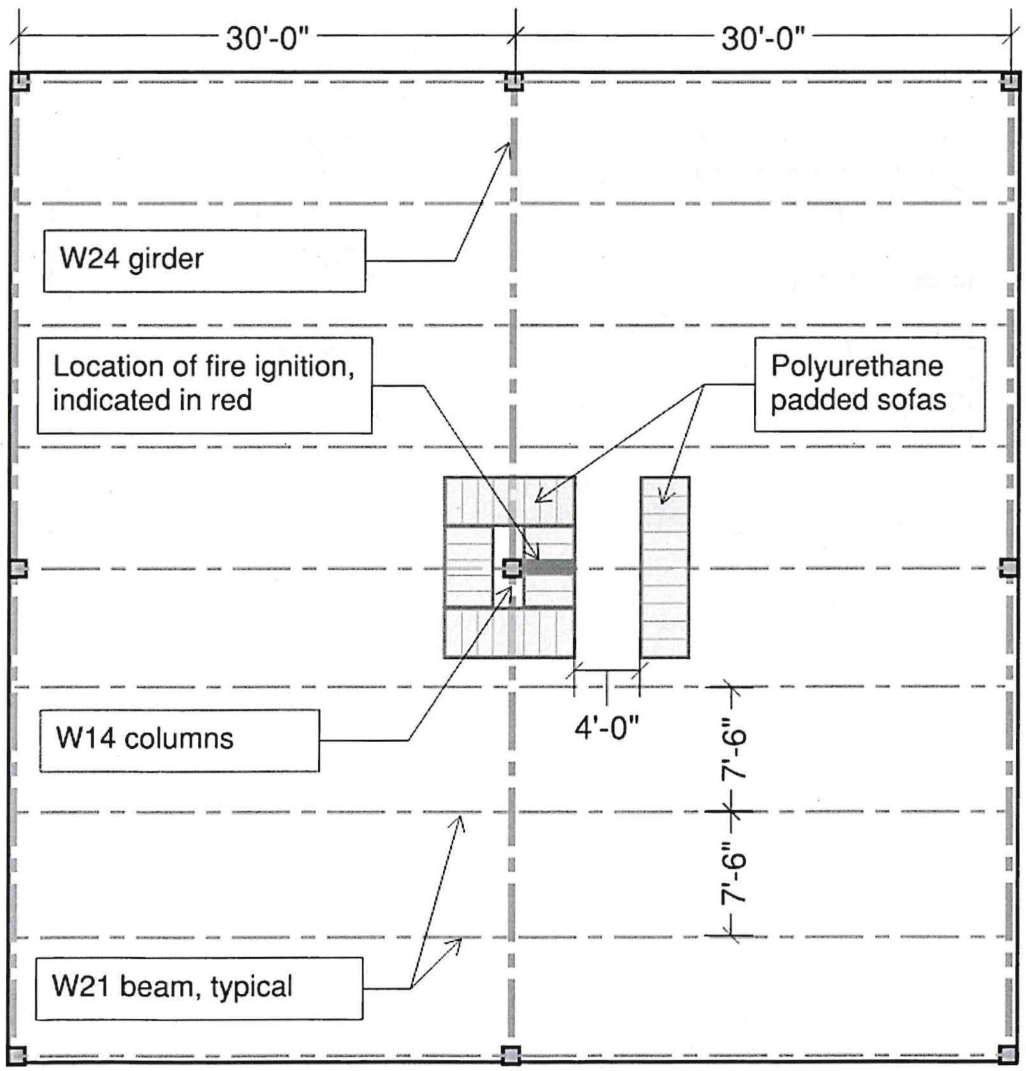


Figure 1. *Location of fire adjacent to the column.*

2.2 Scenario 2: Worst-Case Fire for Beams

Fuel Package: Sofa B (Appendix B and C)

This is similar to Scenario 1, except that multiple sections of upholstered sofas are located within the area of four columns, forming an elongated U-shaped layout. This layout simulates a furniture condition with combustible wood elements that extend approximately 8 feet above the floor. This model will facilitate a conservative analysis of the beam structure by exposing combustible elements within a closer proximity to the structural frame. The large area of the sofa is located directly below the exposed beams without any fire protection covering. Fire at one section of the sofa spreads across to other sections and propagates to the plywood wall covering, impacting the exposed beams and steel floor assembly above. The ignition of the sofa will occur 2/3rds along the length of one side. This is a conservative point of ignition that accounts for the air flow due to the natural fluid dynamics in this setup. This will allow for the maximum spread of fire and heat.

The upholstered sofa sections are located directly below the beams. The beams are spaced 7 feet 6 inches apart, represented in a typical 30-ft by 30-ft grid in Figure 2 below. The floor to floor height on Office Level 02 is ~16 feet, and the distance between the floor and the lowest exposed beam is ~12 feet. The wall with plywood covering runs the length of the sofa section. The fire originates in the middle indicated by red and spreads to adjacent sofa and burns sequentially.

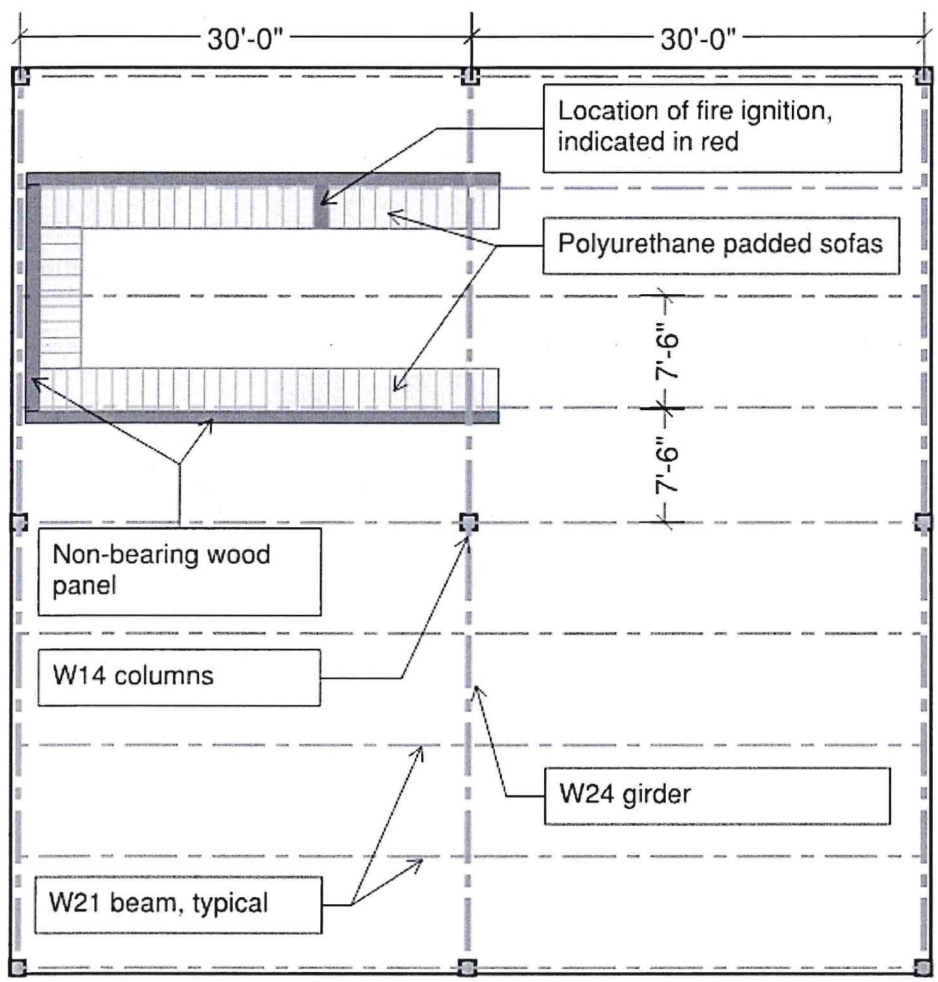


Figure 2. *Location of fire below the beam.*

3 STRUCTURAL CRITERIA

Basis of Structural Fire Engineering

Structural fire engineering will be performed according to ASCE 7-16 Appendix E, the 2016 Edition of American Institute of Steel Construction 360 (AISC 360-16) Appendix 4, and the Structural Fire Engineering Manual of Practice (ASCE/SEI-138). MKA will conduct a structural analysis of the steel portion of the structure to validate that mandatory structural performance objectives are satisfied.

Mandatory Structural Performance Objectives

The structural components, members, and system will be designed to maintain their load bearing capacity for a duration of one hour. This exceeds the time required for safe and complete evacuation of the building occupants, which is the criteria recommended criteria by ASCE for Performance-Based Structural Fire Design.

Discretionary Structural Performance Objectives

Additional performance objectives relating to the serviceability or expected repairs/downtime after a significant fire event were discussed with the building owner and it was determined that none are needed.

4 PROCESS FOR ANALYZING STRUCTURAL CRITERIA

MKA will use the surface temperatures provided by Code Unlimited, together with structural material and geometry information, to perform heat transfer analysis. This will determine the internal temperatures of the structural system at multiple timesteps throughout the design fire duration. Due to the relative simplicity of the geometric conditions and lack of insulating materials on the steel, a lumped mass model is anticipated to be used for heat transfer calculations.

Once the structural internal temperatures are determined for each timestep, structural analysis will be completed using the procedure outlined in AISC 360-16 Appendix 4. Initial design checks will be made using the simplified procedures of Section 4d. Where required, additional design checks will be made using the advanced provisions of Section 4c. Considered effects will include loss of strength and stiffness at elevated temperatures, change in length due to thermal expansion, and restraint effects due to adjacent structure. The elastic and inelastic response of the structure due to these effects will be determined during both the heat-up and cool-down phases of the design fire.

At all times, the structure will be required to resist the design load combination during fire exposure (0.9 or 1.2)D + AT + 0.5L + 0.2S per section 4.1.1:

- D = nominal dead load
- A_T = nominal forces and deformations due to design basis fire
- L = nominal occupancy live load
- S = nominal snow load

5 STRUCTURAL RESULTS

The results of the structural analysis of fire effects will be presented to the City of Redmond in the permit calculations. Member design capacity ratios under design basis fire effects and design load will be shown on framing plans. A calculations package will be compiled for City of Redmond review.

6 FINAL STRUCTURAL FIRE ENGINEERING REPORT

The final structural fire engineering report will document the results of the surface temperature analysis described above. This is anticipated to include images of the model, as well as maximum temperature ranges for the steel members and at the underside of the concrete slab. In addition, the report will also reference:

- Design Fire Scenarios and CFD Analysis – Report by Code Unlimited
- Structural Performance and Analysis – Report by MKA

The final report will provide the rationale and justification for "Alternative Materials, Design and Methods of Construction and Equipment" as permitted by §104.11 of the IBC. The final submission to the City of Redmond will be stamped by a Fire Protection Engineer and a Structural Engineer, both licensed in the State of Washington.

APPENDIX A: BUILDING INPUT PARAMETERS

The following simulation input parameters are related to general building and environment conditions that remain constant in every design fire scenario. The structural fire engineering fire model will not include the activation of smoke detectors or sprinkler activation, nor the effects of a smoke control system. The table below describes the input parameters that will be used in the FDS simulation, along with the resource used to determine each parameter.

INPUT PARAMETERS TABLE - BUILDING			
	PARAMETER	***DESIGN FIRE***	***SOURCE***
1.	*Mesh size*	*1 ft x 1 ft x 1 ft*	*Preliminary mesh size; to be based on FDS simulation.*
2.	*Duration Factor*	*1 hour*	*Based on Type II-A construction, which requires the primary structural frame to maintain its integrity when exposed to a design fire for the duration of one hour.* *(No credit will be taken for occupants exiting the building in less than one hour).*
3.	*Visibility Factor*	*8*	*Based on illuminated exit signs. Klote, J. (2016). "Smoke Control." SFPE Handbook of Fire Protection, Fifth Edition, 1818.*
4.	*Interior Air Temperature*	*72 °F*	*ASHRAE Standard 55-2013, Thermal Environmental Conditions for Human Occupancy*
5.	*Exterior Air Temperature*	*N/A*	*The focus of this study is on interior structural elements. Effects of exterior air temperature are negligible for this analysis.*
6.	*Wind Direction & Speed (July)*	*N/A*	*The focus of this study is on interior structural elements. Effects of wind are negligible for this analysis.*

APPENDIX B: SOFA FIRE INPUT PARAMETERS

BASIS OF PARAMETERS:

The following input parameters are for design fires that designate a sofa as the fuel package. The sofa fire will be modeled based off data from a full-scale fire test conducted under a furniture calorimeter as reported by the National Bureau of Standards.

FIRE GROWTH:

The full-scale test, conducted as a non-sprinkler-controlled fire, produced a fast growth rate fire with a peak Heat Release Rate (HRR) of 3,200 kW with a published growth curve (see Figure 1).

The sofa in the proposed design fires are significantly larger than the three-cushioned test sofa. Therefore, the model will incorporate a sequential burn of the sofa based on the approximate HRR Per Unit Area (HRRPUA) rather than instantaneous ignition over the entire surface area of the furniture. The simulation will model realistic combustion of the sofa by modeling sequential ignition in increments. As a conservative measure, the point of ignition will be located at the center of the sofa to allow for fire spread in two directions, unless otherwise stated in the description of the design fire.

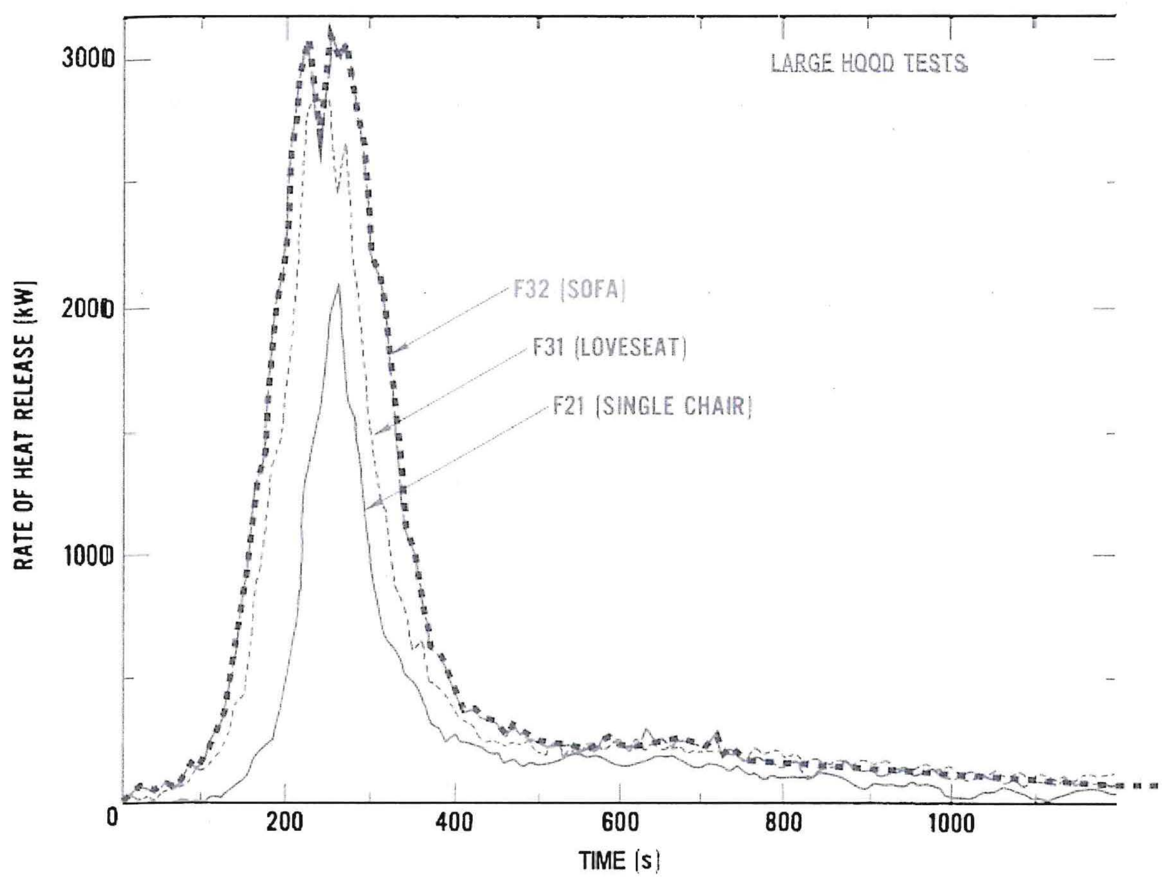


Figure 1: *The HRR curve of a three-seated sofa from a full-scale fire test performed by the National Bureau of Standards was used a basis for determining the fire parameters of a fire propagating along a large sofa.*

SPRINKLER ACTIVATION:

The Structural Fire Engineering models will not incorporate the effects of sprinkler activation in order to study the effectiveness of the structural system without considering active protection systems. This is a conservative analysis; in reality, sprinklers would activate, cooling the surrounding area, wetting adjacent surfaces, and taming the fire to a controlled burn, resulting in significantly less severe thermal loading on the structural system.

INPUT PARAMETERS TABLE – SOFA FIRE			
	PARAMETER	***DESIGN FIRE***	***SOURCE***
1.	*Design Fire Size*	*HRRPUA* *Sofa: 1,750 kW/m²*	*Established based on NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, Table 2A, pg 30 (1982)*
2.	*Fire area*	*Sofa A: 60 ft² (5.57 m²)* *Sofa B: 117 ft² (10.87 m²)* *Composed of 3 ft x 1 ft slices to simulate sequential burn*	*Approximate dimensions of the worst-case large sofa, based on furniture in existing office buildings owned by the same tenant.*
3.	*Auto-ignition*	*0.4 kW/m2² radiant heat flux (input into device for heat flux)*	*Based on FDS comparison testing to the full-scale fire test described in NBSIR 82-2604.* *This is significantly more conservative than other referenced standards: the SFPE 2016 indicates a heat flux of 30 kW/m² for sofas and the NFPA 92 indicates a heat flux of 10 kW/m² for sofas.* *SFPE. 2016. "Handbook of Fire Protection Engineering," Fifth Edition, pg. 586.* *NFPA 92 §5.2.5.7 Standard for Smoke Control Systems*
4.	*Design fire location*	*Locations specified in Section 3.1.*	*Analysis performed by Code Unlimited.*

INPUT PARAMETERS TABLE – SOFA FIRE			
	PARAMETER	DESIGN FIRE	SOURCE
5.	Fire growth rate	Follows NIST test curve until sprinklers activate (based on temperature at ceiling from model) then decreases linearly over next 30 seconds to 30 kW HRR. The fire is then held at 30 kW HRR for the remainder of model run after decrease.	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, pg 23 (1982)
6.	Peak HRR	To be determined.	To be based on FDS simulation.
7.	Reaction	Polyurethane	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2A, pg 32 (1982)
8.	Soot yield	0.024	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 9, pg 37 (1982)
9.	CO yield	0.0012	NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2B, pg 31 (1982)
10.	Radiative Fraction	0.35	NFPA. 2008. "NFPA Fire Protection Handbook", Twentieth Edition, pg 3-156
11.	Critical Flame Temperature	1327 °C	NIST Special Publication 1019, "Fire Dynamics Simulator User's Guide", Sixth Edition. Table 17.23, p. 243
12.	Surface Temperature	TMPA (Ambient Temperature)	Based on FDS comparison testing to the full-scale fire test described in NBSIR 82-2604.

APPENDIX C: WOOD PANEL FIRE INPUT PARAMETERS

BASIS OF PARAMETERS:

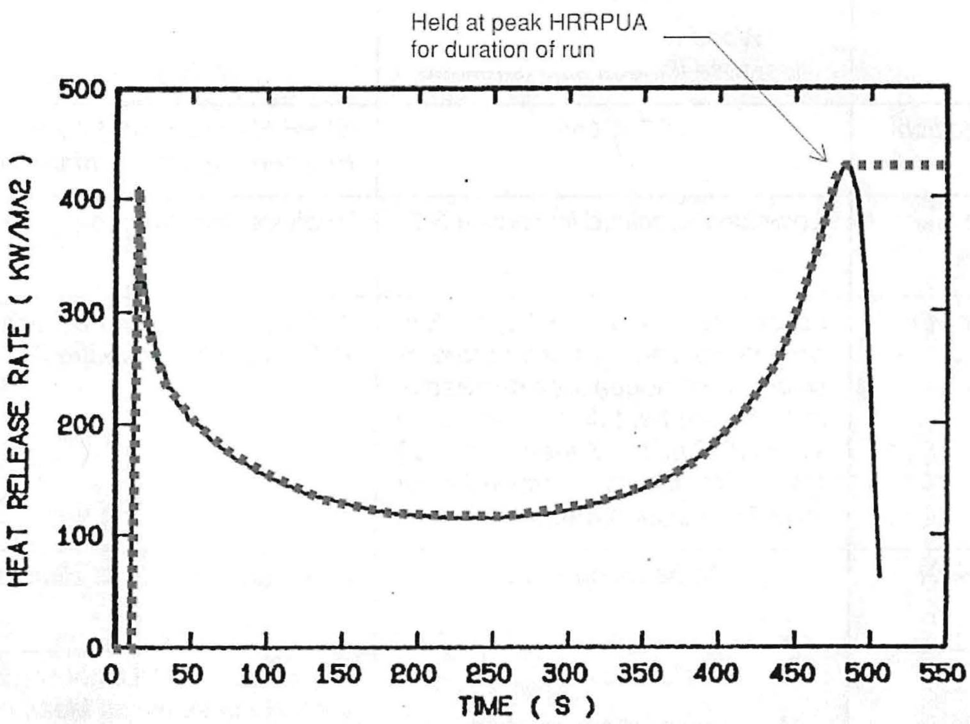
The following input parameters are for design fires that designate a wood panel backing Sofa B as the fuel package. The wood panels will be based off a fire test of a Douglas Fir particle board specimen conducted by the National Bureau of Standards.

FIRE GROWTH:

The full-scale test, conducted as a non-sprinkler-controlled fire, produced a peak HRRPUA of 380 kW/m2 and the study includes a published growth curve (see Figure 1).

Sofa B will include a plywood backing that contributes to the overall fuel array in that design fire scenario. Due to the size of the panel backing, the simulation will model a sequential burn based on the auto-ignition temperature of a similar species of wood, rather than instantaneous ignition over the entire surface of the panel.

The wood panel could be placed against a wall or other insulating surface that would disrupt the HRR decay of the panel board. Therefore, as a conservative measure in the model, wood species will be held at the peak HRRPUA for the duration of the model run (see Figure 1).



22. Calculated Heat Release Rate for Dry 12.7 mm Specimen of Douglas Fir Particle Board Exposed at an External Radiant Flux of 100 kW/m²

Figure 1: *The HRRPUA curve of a Douglas Fir particle board specimen performed by the National Bureau of Standards was used a basis for determining the fire parameters of a fire propagating along the wood panel.*

SPRINKLER ACTIVATION:

The Structural Fire Engineering Parameters memo will not incorporate the effects of sprinkler activation in order to isolate the effectiveness of the structural system without considering active protection systems. This is a conservative measure; in reality, sprinklers would activate, cooling the surrounding area, wetting adjacent surfaces, and taming the fire to a controlled burn.

The table below shows the input parameters that will be used in the FDS simulation along with the resource used to determine each parameter.

INPUT PARAMETERS TABLE – WOOD PANEL FIRE			
	PARAMETER	***DESIGN FIRE***	***SOURCE***
1.	*Design Fire Size*	*HRRPUA* *Wood: 430 kW/m²*	*NBSIR 85-3163 'Douglas Fir Particle Board' William J. Parker, Figure 22, pg. 86 (1985)*
2.	*Fire area*	*Wood Panel*: 6.97m² (75 ft²)* *Composed of 1.0 ft-wide slices to simulate sequential burn* **Wood width and area will decrease if mesh size is refined*	*Approximate dimensions panel backing, expanded due to mesh size.*
3.	*Auto-ignition*	*17 kW/m²*	*SFPE Handbook of Fire Protection Engineering, 2nd Edition, Figure 2-14.4*
4.	*Design fire location*	*Locations specified in Section 3.1.*	*Analysis performed by Code Unlimited.*
5.	*Fire growth rate*	*Follows test curve until sprinklers activate (based on temperature at ceiling from model) then decreases linearly over next 30 seconds to 30 kW HRR. The fire is then held at 30 kW HRR for the remainder of model run after decrease.*	*N85-3163 'Douglas Fir Particle Board' William J. Parker, figure 21, pg. 85 (1985)*
6.	*Peak HRR*	*To be determined.*	*To be based on FDS simulation.*
7.	*Reaction*	*Polyurethane* *Most conservative reaction in a simulation fire with both sofa and wood elements.*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2A, pg 32 (1982)*

INPUT PARAMETERS TABLE - WOOD PANEL FIRE			
	PARAMETER	***DESIGN FIRE***	***SOURCE***
8.	*Soot yield*	*0.024* *Most conservative soot yield in a simulation fire with both sofa and wood elements.*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 9, pg 37 (1982)*
9.	*CO yield*	*0.0012* *Most conservative CO yield in a simulation fire with both sofa and wood elements.*	*NBSIR 82-2604 'Upholstered Furniture Heat Release Rates Measured with A Furniture Calorimeter', Vytenis Babrauskas, J. Randall Lawson W. D. Walton, William H. Twilley, table 2B, pg 31 (1982)*
10.	*Radiative Fraction*	*0.35* *Most conservative radiative fraction in a simulation fire with both sofa and wood elements.*	*NFPA. 2008. "NFPA Fire Protection Handbook", Twentieth Edition, pg 3-156*
11.	*Critical Flame Temperature*	*1327 °C*	*NIST Special Publication 1019, "Fire Dynamics Simulator User's Guide", Sixth Edition. Table 17.23, p. 243*
12.	*Surface Temperature*	*300 °C*	*Conservative default parameter established by Pyrosim in edition 2018.3.1210.*