Challenges with Firestopping and Airflow Containment in Data Centers

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Engineering Director
INTRODUCTION AND TOPICS TO ADDRESS

Firestopping is critical to building design, construction, and operation…

However, beyond Firestopping, what impact does airflow have on…

- data center cooling costs and energy efficiency?
- data hall pressurization for proper operation of suppression systems?
- control of dust & whiskers that could damage server equipment?

Can the firestopping method affect a building’s performance?

What do owners, designers & contractors need to understand when addressing cable pathways in critical facilities?
EXAMPLE OF AIRFLOW & SMOKE PROPAGATION

Real case: fire in a hospital and smoke propagation:

in less than 2 minutes the hallways in this hospital were full of toxic smoke ...
AGENDA

1. What is firestop and why is it necessary

2. Elements of compartmentation

3. Addressing real life applications

4. Critical needs in data centers

5. Best practices to help improve a building’s performance
LET’S START WITH THE BASICS

What is firestop?

- **Firestop systems** (if installed correctly), help restore the rating of a floor or wall as it is penetrated by objects such as cable bundles and resist the spread of smoke and fire.
- **Firestop** is part of the life safety plan in building structures.
- **Life safety** also includes air ducts with dampers, smoke and fire alarms, wired glass, fire rated doors, sprinkler systems etc.

Why is it necessary?

- To give people more time to safely exit a structure, even if they don’t react right away
- Fire and smoke are a major risk to property damage
- Mandated by the Codes: IBC, IFC, NFPA, NEC
MAJORITY OF FIRESTOP APPLICATIONS FALL INTO FOUR CATEGORIES

Through-Penetrations

Interior Joints

Edge of Slab Joints

Membrane Penetrations
WHAT IS THE LEADING KILLER IN FIRES?

Smoke and Toxic Gases

In addition, the biggest threat to damaging communications and server equipment within a building is also smoke and the products of combustion.
FIRE STATISTICS IN THE UNITED STATES

United States 2015 facts
- 1.3 million fires
- 501,500 structure (building) fires
- $10.3B in property damage

A fire department responds to a fire every 23 seconds

More than 8 out of 10 civilian deaths caused by fire were due to structure (building) fires

Source: NFPA Fire Loss Statistics 2015
WHY CONTAIN SMOKE, TOXIC GASES, AND FIRE?

3/4 of all fire deaths are caused by smoke inhalation.
Source: Hall, Jr. John R. NFPA Fire Analysis & Research, Quincy, MA. “Burns, Toxic Gases, and other Hazards”.

Visibility: 47% of survivors caught in a fire could not see more than 12 feet.
Source: NFPA Fire Protection Handbook, 18th Ed. Table 1-1P. Pg.1-15.

Approximately 57% of people killed in fires are not in the room of the fire’s origin.
Source: NFPA Fire Protection Handbook, 18th Ed. Table 8-1P. Pg. 8-17.

Smoke travels 120-420 feet per minute under fire conditions
Source: Estimate based upon ceiling jet velocity calculations for typical ceiling heights and heat release rates.
WE CAN’T RELY ON ANY SINGLE ACTION TO PROTECT LIVES & PROPERTY

The Balanced Approach to Fire Protection
REALITY OF SOME REACTION TO FIRE ALARMS?

Means of egress are designed for occupants to immediately evacuate upon alarm notification.
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THE ELEMENTS OF COMPARTMENTATION

The spread of fire can be restricted by dividing a building into separate compartments with fire-resistive walls and floors increasing the availability of escape routes for occupants.

Compartmentation protects escape routes such as corridors or stairs.
TYPES OF FIRE / SMOKE ASSEMBLIES

- Fire Walls
- Fire Barrier Walls
- Fire Partitions

- Smoke Barriers
- Smoke Partitions

?
COMMON TERM ON PROJECT PLANS: “SMOKE WALL”
COMMON TERM ON PROJECT PLANS: “SMOKE WALL”

Reality: The term “Smoke Wall” does not exist in any building or fire code. Codes recognize: “Smoke Barrier” or “Smoke Partition”

What’s the difference?
WHAT IS A SMOKE BARRIER?

**Definition:** Vertical or horizontal continuous membrane that will restrict movement of smoke

- **Leakage rating** (air leakage) must be less than 5 CFM/SQ.FT. for penetrations or 50 cfm leakage per 100 sq. ft. of wall area
- **Fire rating:** 1-hour

Example: Smoke Barriers divide hospitals into smoke compartments not exceeding 40,000 sq. ft. per IBC 2015.
WHAT IS A SMOKE PARTITION?

- No fire resistance
- Joints and penetrations “shall be filled with an approved material to limit the free passage of smoke”
- Span floor to floor or Floor to ceiling, if ceiling will limit the transfer of smoke
- Sealed windows
- No louvers in doors
- Doors not required to be self-closing
- Most common use: Corridor walls in sprinklered hospitals
EXAMPLE OF AIRFLOW & SMOKE PROPAGATION

Real case: fire in a hospital and smoke propagation:
in less than 2 minutes the hallways in this hospital were full of toxic smoke ...
CRITICAL: CLARIFY THE ASSEMBLY TYPE!

Key Points:

- The term “Smoke Wall” is not referenced in the IBC. Clarify: “Is this a Smoke Barrier or Smoke Partition?”
- “Smoke Barriers” are 1 hour fire-rated assemblies! They require firestop systems and products
- “Smoke Partitions” are non fire-rated and must only resist the passage of smoke.
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HOW TO ADDRESS THIS APPLICATION?

Cable trays through 2 hour fire-rated concrete wall assembly
FIRESTOP REQUIRED BY ALL CURRENT & LEGACY CODES
FIRESTOP REQUIRED BY ALL CURRENT & LEGACY CODES

International Building Code (IBC)
2. Business (see Section 304): Group B.
3. Educational (see Section 305): Group E.
7. Mercantile (see Section 309): Group M.
8. Residential (see Section 310): Groups R-1, R-2, R-3 and R-4.
10. Utility and Miscellaneous (see Section 312): Group U.
IBC: GROUP B (BUSINESS OCCUPANCY)

- Ambulatory care facilities
- Animal hospitals, kennels and pounds
- Banks
- Barber and beauty shops
- Car wash
- Civic administration
- Clinic, outpatient
- Dry cleaning and laundries: pick-up and delivery stations and self-service
- Educational occupancies for students above the 12th grade
- **Electronic data processing**
- Food processing establishments and commercial kitchens not associated with restaurants, cafeterias and similar dining facilities not more than 2,500 square feet (232 m²) in area.
- Laboratories: testing and research
- Motor vehicle showrooms
- Post offices
- Print shops
- Professional services (architects, attorneys, dentists, physicians, engineers, etc.)
- Radio and television stations
- **Telephone exchanges**
Section 714

- Provides all of the nitty-gritty details required for a code-compliant through-penetration firestop

- Some highlights:
  - 714.4.1.2 Through penetrations shall be protected by an approved penetration firestop system installed as tested in accordance with ASTM E814 or UL 1479, with a minimum positive pressure differential of 0.01 inch of water and shall have an F rating of no less than the required fire-resistance rating of the wall penetrated.
IBC: ASSEMBLY TYPES

- “Penetrations through (assembly type) shall comply with Section 714*”
  - 706.9 (Fire Walls)
  - 707.7 (Fire Barriers)
  - 708.7 (Fire Partitions)
  - 709.6 (Smoke Barriers)
  - 712.1.4 (Vertical Openings)
  - 713.8 (Shaft Enclosures)

IBC requires all penetrations through these assemblies to be firestopped with approved methods
IBC: 3RD PARTY FIRESTOP INSPECTION

Special Inspection requirements in accordance with Section 1705.17 for high-rise buildings or in buildings assigned to Risk Category III or IV.

Inspection of installed firestop applications shall be conducted in accordance with:

- **ASTM E 2174**, “Standard Practice for On-Site Inspection of Installed Fire Stops”
- **ASTM E 2393**, “Standard Practice for On-Site Inspection of Installed Fire Resistive Joints and Perimeter Fire Barriers”

- Data center “high risk” code classification currently up to AHJ
- However, precedence has been set as many owners already enforcing internal auditing or 3rd party inspection
AFTER OCCUPANCY: BUILDING OPERATIONS
INTERNATIONAL FIRE CODE (IFC)

SECTION 701.5 MAINTAINING PROTECTION
Materials, systems and devices used to repair or protect breaches and openings in fire-resistance-rated construction and construction installed to resist the passage of smoke shall be maintained in accordance with Sections 703 through 707.

SECTION 701.6 OWNER’S RESPONSIBILITY
The owner shall maintain an inventory of all required fire-resistance-rated construction, construction installed to resist the passage of smoke and the construction included in Sections 703 through 707. Such construction shall be visually inspected by the owner annually and properly repaired, restored or replaced where damaged, altered, breached or penetrated. Records of inspections and repairs shall be maintained.

IFC requires annual inspection of penetrations through fire-rated assemblies
WHY AN EMPHASIS ON FIRESTOP INSPECTION?
WHY AN EMPHASIS ON FIRESTOP INSPECTION?
Codes in most countries require firestopping to be designed and installed per a testing standard.

Firestop systems are tested according to international standards such as:

**USA:** ASTM E 814 / UL 1479  
**Canada:** CAN/ULC S-115  
**Europe:** BS 476, EN 1363, DIN 4102

A successful test yields an approval or firestop listing.
TESTING LABORATORIES & APPROVAL AUTHORITIES

North America: All Test Laboratories are of equal status in regulations (IBC code acceptance)

Rest of World: Accepted approvals vary by country
# FIRESTOP TESTING PARAMETERS

<table>
<thead>
<tr>
<th>Rating</th>
<th>Reference Standards</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>F rating</td>
<td>ASTM E814, UL 1479, CAN/ULC S115</td>
<td>Time period (expressed in hours) that assembly resists the passage of flames</td>
</tr>
<tr>
<td>T rating</td>
<td>ASTM E814, UL 1479</td>
<td>Time by which unexposed (non-fireside) of assembly reaches 325°F (163°C) over ambient temperature</td>
</tr>
<tr>
<td>L rating</td>
<td>UL 1479</td>
<td>Air leakage test run at ambient and 400°F (204°C)</td>
</tr>
<tr>
<td>W rating</td>
<td>UL 1479</td>
<td>Water leakage testing</td>
</tr>
</tbody>
</table>

➢ To achieve successful testing in the U.S. the firestop system must also pass the hose stream test
ASTM FIRE TEST TIME / TEMPERATURE CURVE

Temperature at 10 minutes = 1300 °F

Melting Points (approx.):
- Aluminum – 1220 °F
- PVC plastic pipe – 413 °F
- Fiberglas® insulation – 1100 °F

Sources:
1. NFPA Fire Protection Handbook, 18th Ed. Table 4-16A. Pg 4-183.
2. SFPE Handbook of Fire Protection Engineering, 1st Ed. Table 1-12.1. Pg. 1-166.
3. Owens Corning SSL I or II Fiberglas Insulation specification sheet.
STEPS IN FIRE TEST PROCEDURE

1. Assembly is placed on furnace.
2. Assembly is exposed to fire test.
3. Assembly is subjected to hose stream test.
4. Assembly results after hose stream.
AIR LEAKAGE TESTING

**L-rating (UL)**

- Measures the amount of air leakage through the firestop system in CFM
- Tested at ambient (cold smoke) and at 400°F (hot smoke) temperature.
- Leakage testing is desired in datacenters to protect equipment against smoke damage (fire), zinc whiskers, and for improved energy efficiency
AIR LEAKAGE TESTING

Air Permeability (EN)

• Measures the amount of air leakage through the firestop system in CFM
• Measures air leakage at multiple pressure levels and cable % fill

![Diagrams showing air permeability vs. pressure differential]

Diagram: Joint length-related air permeability

Diagram: Overall area-related air permeability
WHAT IS THE AVERAGE HOURLY RATING OF A TYPICAL FIRESTOP PRODUCT?

ZERO

Only Firestop systems have ratings!
MULTIPLE PARAMETERS OF A FIRESTOP SYSTEM

Firestop system performance can change completely if altering any parameter.
A FIRESTOP SYSTEM IS ISSUED IF ALL ELEMENTS OF THE TEST ARE PASSED
What is percent fill?
WHAT IS PERCENT FILL?

**Definition:** The cross-sectional area of an opening that is occupied by penetrating items, typically cables. Percent fill is specific to each firestop system.

**What is the actual percent fill?**

Visually, the opening appears to be 2/3 full
4” circular opening
85 cables, ¼” diameter

Let’s calculate **actual** percent fill...
WHAT IS PERCENT FILL?

**Definition:** The cross-sectional area of an opening that is occupied by penetrating items, typically cables. Percent fill is specific to each firestop system.

What is the actual percent fill?

**Answer:**

\[
(A_o) = 3.14 \times (2^2) = 12.56 \text{ in}^2 \\
(A_c) = [3.14 \times (0.125^2)] \times 85 = 4.17 \text{ in}^2 \\
(%f) = \frac{4.17}{12.56} \times 100 = 33.2\%
\]

Actual % fill rates are typically half of what they visually appear.
When designing networks, consider a firestop system’s percent fill and plan for future MAC work.

**Consider**
Many firestop solutions limit cable fill to ~ 25% of opening.

**Challenge**
How do you ensure this is not exceeded during actual use?

**Solution**
When designing networks, consider a firestop system’s percent fill and plan for future MAC work.

**Design tip:** Specify firestop pathway solutions allowing up to 100% visual fill.
HOW TO ADDRESS THIS APPLICATION?

Cable trays through 2 hour fire-rated concrete wall assembly
HOW TO ADDRESS THIS APPLICATION?
HOW TO ADDRESS THIS APPLICATION?

- **System Number, Code Standards**
- **F-Rating:** up to 3 hours
- **Concrete Floor or Wall**
- **Allowable cable type, size**
- **Allowable opening size**
- **Allowable percent fill**
- **Preformed, reusable Firestop product**
We learned about firestop systems …
Let’s put our knowledge to the test

How would you address the following application?
HOW WOULD YOU ADDRESS THIS APPLICATION?

Not all firestop applications are tested
ENGINEERING JUDGMENTS

For conditions where a tested system does not exist an Engineering Judgment may be needed

Typical Engineering Judgment conditions:

• Annular space larger/smaller than tested
• Irregular hole shape
• Hole shape different than tested
• More penetrating items in hole than system allows
• Access to one side only
• Structural member penetrations
• Intersections of rated assembly with non-rated assembly

• Engineering Judgments should only be designed by qualified firestop manufacturer’s personnel
• Note: Engineering Judgments can be developed in the design phases of projects
Beyond Firestopping …
Airflow control through most all wall and floor assemblies is becoming increasingly important in data centers as it can significantly impact:

- Data hall / room pressurization
- Dust control
- Cooling costs

Additional concerns with cabling penetrations:
- Noise transmission
- Seismic events

How does firestop system selection impact these design needs?
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DATA CENTER STAKEHOLDERS

What keeps them up at night?

Owner
Facility Manager
Auditor
Contractor
Designer
### DATA CENTER STAKEHOLDER NEEDS & PAIN POINTS

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Key Pain Points</th>
<th>Wall &amp; Floor Penetration Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specifiers</td>
<td>Uptime / reliability</td>
<td>High priority concern</td>
</tr>
<tr>
<td>GC</td>
<td></td>
<td>Limited coverage with traditional technology</td>
</tr>
<tr>
<td>Facility Mgr / Auditor</td>
<td></td>
<td></td>
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</tbody>
</table>

Design & installation considerations should factor firestop airflow control solutions to better impact owner pain points.
DATA CENTER AIRFLOW LEAKAGE RISKS

Mission Critical

<table>
<thead>
<tr>
<th>Data</th>
<th>Power</th>
<th>Cooling</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Cabling</td>
<td>Electric Cabling</td>
<td>Piping/Ducts</td>
<td>Fire, Gas Suppression</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Emergency Lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Access &amp; Security Control Cabling</td>
</tr>
</tbody>
</table>

- Creates largest volume of openings through wall and floor assemblies
- Present unique challenge due to continuous cable re-penetration
SUMMARY: WHY IS AIRFLOW LEAKAGE AN ISSUE?

Powering and cooling costs for telecom and data center facilities come at a tremendous cost. Energy costs for data centers increased 24% from 2010-2014.

Non-water-based suppression systems require rooms to be able to hold pressure levels up to 300+ pa.

Whiskers may physically detach from metal surfaces and cause electronic system failures. Construction dust can cause optical interference or obstruct cooling airflow.

Suppression systems have fast trended to be a key concern of operations due to these systems' high pressure requirement to function properly. Data cables are the significant source of air leakage.
GAS SUPPRESSION SYSTEMS REQUIRE SEALED ROOMS → ESSENTIAL FOR OPENINGS TO HAVE LOW LEAKAGE

Gas suppression systems:
• Rely on lowering the level of oxygen available to fire
• Depend upon a sealed area in order to prevent oxygen from re-supplying the fire

Needs for penetration seals:
✓ Low leakage ratings
✓ Pressure resistance
  • Firestop solutions must remain intact in case of activation of fire suppression systems
  • Standards require yearly review of gas suppression system or yearly documentation that all seals are correctly maintained
SUMMARY: WHY IS AIRFLOW LEAKAGE AN ISSUE?

Powering and cooling costs for telecom and data center facilities come at an enormous price.

Energy costs for data centers increased 24% from 2010-2014.

Non water based suppression systems require rooms to be able to hold pressure levels up to 300+ pa.

Contamination: Whiskers & Dust

Whiskers may physically detach from metal surfaces and cause electronic system failures.

Construction dust can cause optical interference or obstruct cooling airflow.
**Conductive particles:**
- A main cause of conductive dust is zinc whiskers which “grow” on ferrous (steel) surfaces, especially those that have been coated with tin, zinc or cadmium to help protect them from corrosion.

**Risk:**
- Whiskers may physically detach from their surfaces and enter a data center’s airflow causing electronic system failures and short circuits.

**Non-conductive particulates**
- Contamination from construction activities such as cement and drywall dust, or paper and cardboard fibers can cause problems such as optical interference or obstruct cooling airflow, resulting in:

**Risk:**
- lower thermal efficiency and increased cooling costs
- overheating and equipment failure
- shortened equipment life span
- server failures causing enterprise disruption

“Particulate contamination can increase a data center’s power demand by 2% or more”
HEALTH, SAFETY, ENVIRONMENTAL (HSE) COMPLIANCE

Leadership in Energy & Environmental Design (LEED V4)
Cradle to Cradle
Living Building Challenge (LBC) Red List
Environmental Protection Agency (EPA) 40CFR Part 59
National Volatile Organic Compound Emission Standards
South Coast Air Quality Mgmt District (SCAQMD)

HSE regulations are increasing and influencing firestop product selection
**MOVEMENT & SEISMIC CONSIDERATION**

Inquire with consultants regarding relevant movement testing in regards to cable penetrations.

### Influence of seismic actions on mechanical performance, smoke and fire ratings

<table>
<thead>
<tr>
<th>Damage</th>
<th>Smoke</th>
<th>Fire</th>
<th>Overall performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★★</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rating criteria</th>
<th>Damage</th>
<th>Smoke</th>
<th>Fire</th>
<th>Fire ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★</td>
<td>Excellent mechanical performance under seismic conditions</td>
<td>Excellent smoke tightness</td>
<td>Excellent fire performance</td>
<td></td>
</tr>
<tr>
<td>★★</td>
<td>Good mechanical performance under seismic conditions</td>
<td>Good smoke tightness</td>
<td>Good fire tightness</td>
<td></td>
</tr>
<tr>
<td>★</td>
<td>Poor mechanical performance under seismic conditions</td>
<td>Poor smoke tightness</td>
<td>Poor fire tightness</td>
<td></td>
</tr>
<tr>
<td>★★</td>
<td>Very poor mechanical performance under seismic conditions</td>
<td>Very poor smoke tightness</td>
<td>Very poor fire tightness</td>
<td></td>
</tr>
</tbody>
</table>

* for an entire evaluation of post-earthquake risks an additional consideration of inherent product properties and installation reliability factors are necessary and therefore might lead to a degradation or upgrading.

* Federal Emergency Management Agency
  Codes for seismic testing protocol for determining the seismic performance characteristics of structural and non-structural components.

![Test apparatus seismic testing](image1)
![Firestop Sleeve test details](image2)
![Fire test after seismic impact](image3)
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SOLUTIONS: TRADITIONAL FIRESTOP METHODS

Advantages
- Economical
- Versatile, covers multiple applications
- Multiple listings available

Disadvantages
- Non-re penetrable
- Correct installation varies by installer
- Low productivity
- Messy installation
- Wash-off, shrinkage issues
- Inspection concerns

Sprays, Caulks, Sealants

Walls

Floors
SOLUTIONS: “PRE-FORMED” FIRESTOP METHODS

<table>
<thead>
<tr>
<th>Pre-formed Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>• Re-penetrable</td>
</tr>
<tr>
<td>• Reliable, fast installation</td>
</tr>
<tr>
<td>• Enhanced air flow performance vs. traditional methods*</td>
</tr>
<tr>
<td>• Pre-cured, always the right amount of product</td>
</tr>
<tr>
<td>• Easier to design - BIM</td>
</tr>
<tr>
<td>• Inspection advantages – no destructive testing per IBC 2012</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>• Higher product cost but usually lower total installed cost</td>
</tr>
</tbody>
</table>

* Always refer to listed system
INITIAL DESIGN CONSIDERATIONS

Performance Requirements

- Minimum Code compliance for firestop system rating
- Limit airflow leakage
- Room pressurization
- Limit dust spread and whiskers
- Correct installation improvement
- Enhance life safety and property loss prevention
- Ease of inspection
- Re-penetrability (MAC work)
- Labor cost savings

Solution

Traditional Firestop System
(no air leakage performance required)

Pre-formed Firestop System
(with airflow control testing)
AIR LEAKAGE TESTING … IS THERE A DIFFERENCE?

Air Permeability (EN)
- Measures the amount of air leakage through the firestop system in CFM
- Measures air leakage at multiple pressure levels and cable % fill

![Diagram of joint length-related air permeability pressures](image1)
![Diagram of overall area-related air permeability pressures](image2)
COMPARE FIRESTOP & AIRFLOW SOLUTIONS

Firestop pre-formed device pathways: air tightness at 40% cable fill

Testing compared 4" Firestop cable devices with 40% cable fill (57x CAT 6 cables); both devices installed acc. to manufacturer IFU.
Leakage measured @ 21 °C, 52 - 57% RH and tested according to EN 1025.
Airflow in m³/h measured for over- and under-pressure, chart displays average values.
CLEARLY CONVEY DESIGN INTENT

- Detail firestop / airflow resistant cable pathway solutions on Datacom or Telecom plans
- Include in Division 26 & 27 specs
- BIM / Revit design
PROCEDURE / PERMIT PROGRAMS (OPERATIONS)

Implementing a firestop cabling pathway procedure or “permit program” for ongoing operation of each data center facility is critical.

Electronic documentation

Installer training procedures
SUMMARY OF KEY LEARNINGS

• Elements of firestop, compartmentation, and airflow containment
• Code and test standard requirements for barrier management
• Tested systems and engineering judgments
• Impact of firestop systems in building performance … airflow control
• Key owner design considerations
• Best design practices
THANK YOU

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