

# Engineering Investigation of Common and Uncommon Perils

Presented to:

Cooper & Scully

26th Annual Insurance Workshop

April 5, 2019

**N E L S O N**  
F O R E N S I C S



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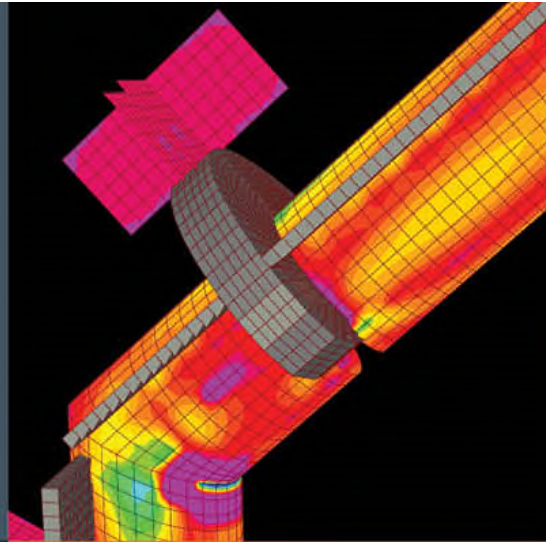
SALT LAKE CITY



⊕ Nelson's professionals deliver exceptional client service; embrace advanced technologies; formulate decisive and independent opinions; and report focused, properly researched, and technically accurate findings.



STRUCTURAL  
ARCHITECTURAL & CIVIL  
ENGINEERING



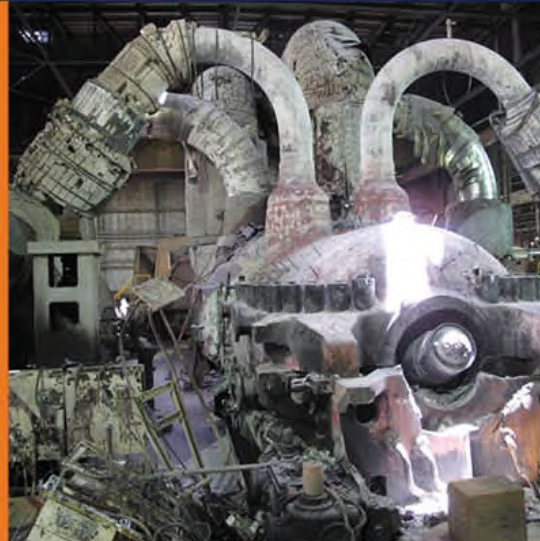
ARCHITECTURE &  
BUILDING ENVELOPE  
ASSESSMENT



ROOFING SYSTEM  
ASSESSMENT



ELECTRICAL  
ENGINEERING &  
FIRE INVESTIGATION



MECHANICAL  
ENGINEERING



COST ESTIMATING  
& APPRAISAL



CHEMISTRY &  
ENVIRONMENTAL  
SCIENCE



CONSTRUCTION  
MATERIALS TESTING  
LABORATORY



MATERIALS  
SCIENCE







⊕ **Nelson Discovery Laboratory specializes in developing customized tests to resolve questions of fact in a dispute or for scientific analysis**

**Roof Sample Testing**

- Roof Core Sampling
- Membrane Delamination
- Membrane Desaturation
- Water Column Testing
- Identification of Coal Tar vs. Asphalt Materials
- Identification of TPO vs. PVC Materials
- ASTM Standard Protocols

**Aerial Drone Reconnaissance and Photography**

- Difficult Access Surveys
- Large and Complex Structures
- Collapse Documentation

**Ground Penetrating Radar**

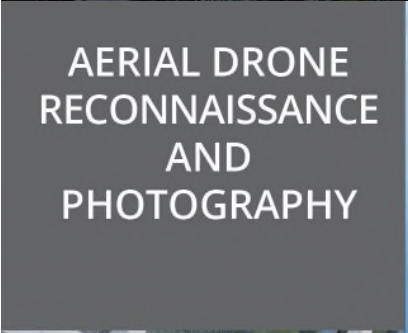
- Concrete Evaluation
- Reinforcement and Void Detection
- 3D Imaging of Concealed Conditions

**Water Infiltration Testing**

- Determining Areas of Water Penetration
- Evaluate As-Built Conditions On-site
- Mock-up Evaluations

**Infrared Imaging**

- Electrical Systems and Building Envelopes
- Anomaly Identification
- Moisture Detection
- Certified Thermographers



(877) 850-8765  
nelsonforensics.com





# About the Presenter

---

Licensed Professional and/or Structural Engineer in 42 states,  
the District of Columbia, and the USVI

M.S. in Civil Engineering – Purdue University

B.S. in Civil Engineering – Purdue University

B.A. in Chemistry – Miami University

CalEMA Safety Assessment Program

Member – ACI, ASCE, ASCE/SEI



Andrew D. Harold, S.E., P.E.  
Executive Director of  
Operations



# Goals

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- Explore methodologies for evaluating damage to buildings which results from any number of perils
- Examine case studies for the investigation of claims related to the following perils:
  - Tornado
  - Hail
  - Fire
  - Hurricane



# What is a Peril?



A source of danger; something that causes loss, injury, or destruction

## Examples of Common Perils (in Texas)?

- Weather (e.g., Hail, Wind, Ice/Snow, Freeze)
- Natural Disaster (e.g., Hurricane, Tornado)
- Foundation Movement
- Collapse
- Fire
- Water Intrusion
- Vehicle Impact
- Mechanical, Electrical, or Plumbing (MEP) Failure
- Design/Construction Defect
- Deterioration

## What about Uncommon Perils (in Texas)?

- Earthquake
  - Tsunami
- 



# Forensic Engineering

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The application of engineering principles and methodologies to answer question of fact that may have legal ramifications.

- Randall Noon

A decorative graphic in the bottom right corner consisting of a grid of thin, light gray lines. The grid is composed of both horizontal and vertical lines, but the vertical lines are curved, creating a wavy, mesh-like appearance that tapers off towards the right edge of the slide.

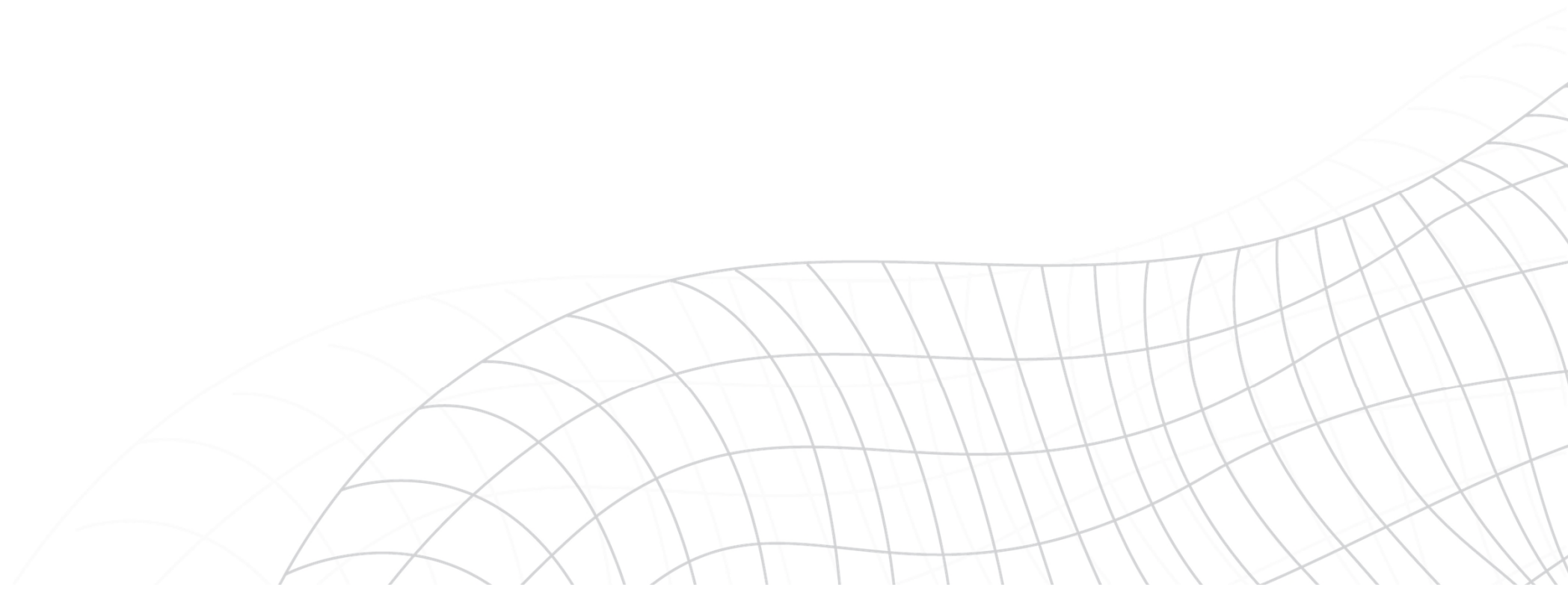


# Forensic Engineering and Technology

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## Why Utilize Technical Investigators?

- Targeted Expertise
- Forensic Discipline
- Industry Knowledge





# Forensic Investigations





# The Scientific Method

Define the Problem

Collect Data

- Document Observed Conditions

  - Photographs

  - Field Sketches/Notes

- Perform Testing

  - Sampling and Measurements

  - Non-destructive (In Situ) Testing

  - Destructive (Intrusive) Testing

  - Laboratory Analysis of Extracted Samples

Conduct Research

- Weather Data

- Reference Material (e.g., codes, design standards, manufacturer's literature)

Perform Analysis

- Explain How/Why the Data Means What It Means

- Provide a Rational Basis for Conclusions

Conclusions

- Grounded in Theory and Practice

Recommendations

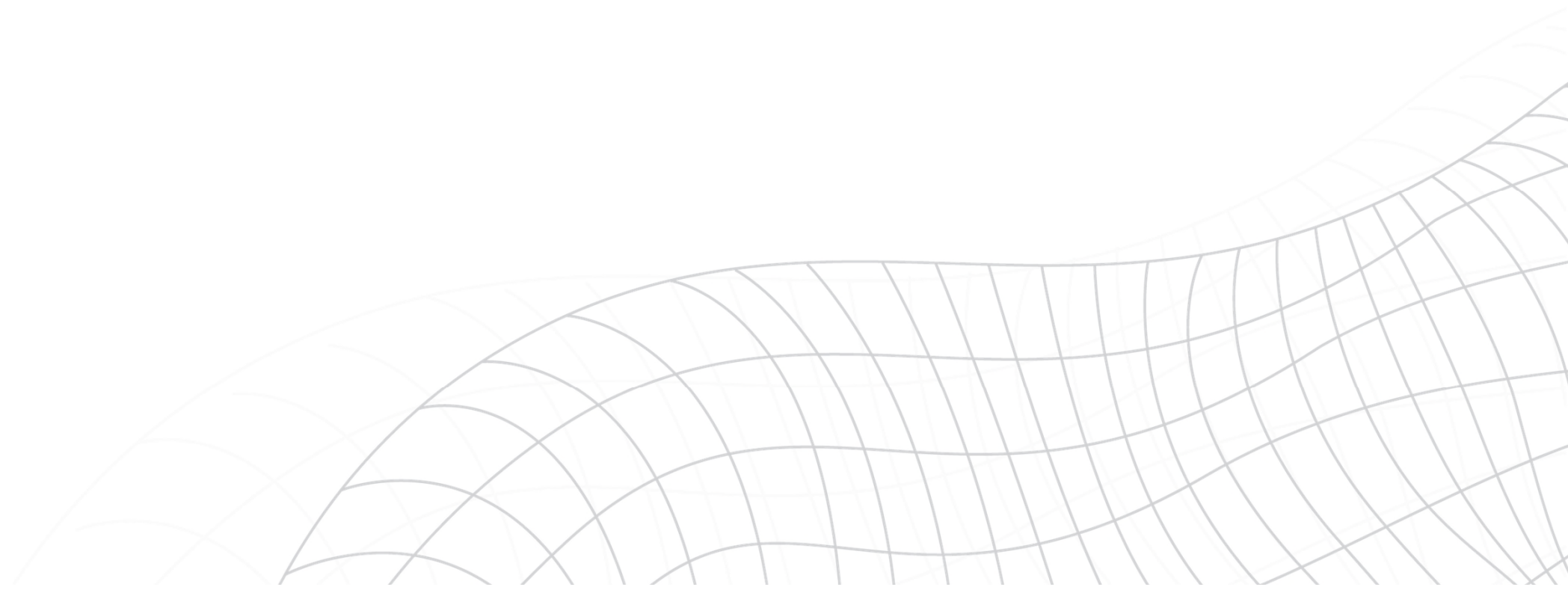


# Types of Forensic Testing

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Non-Destructive


Destructive





# Non-Destructive Testing

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- Visual Observation and Sampling
  - Photographs (Onsite and Aerial)
  - Detailed Distress Survey
  - Elevation or Plumbness Surveys
  - Moisture Testing
  - Infrared (Thermography)
  - Water Spray Testing (Building Envelope)
- 
- A decorative graphic in the bottom right corner consisting of a grid of thin, light gray lines. The grid is composed of both horizontal and vertical lines, but the vertical lines are curved, creating a wavy, grid-like pattern that tapers off towards the right edge of the slide.

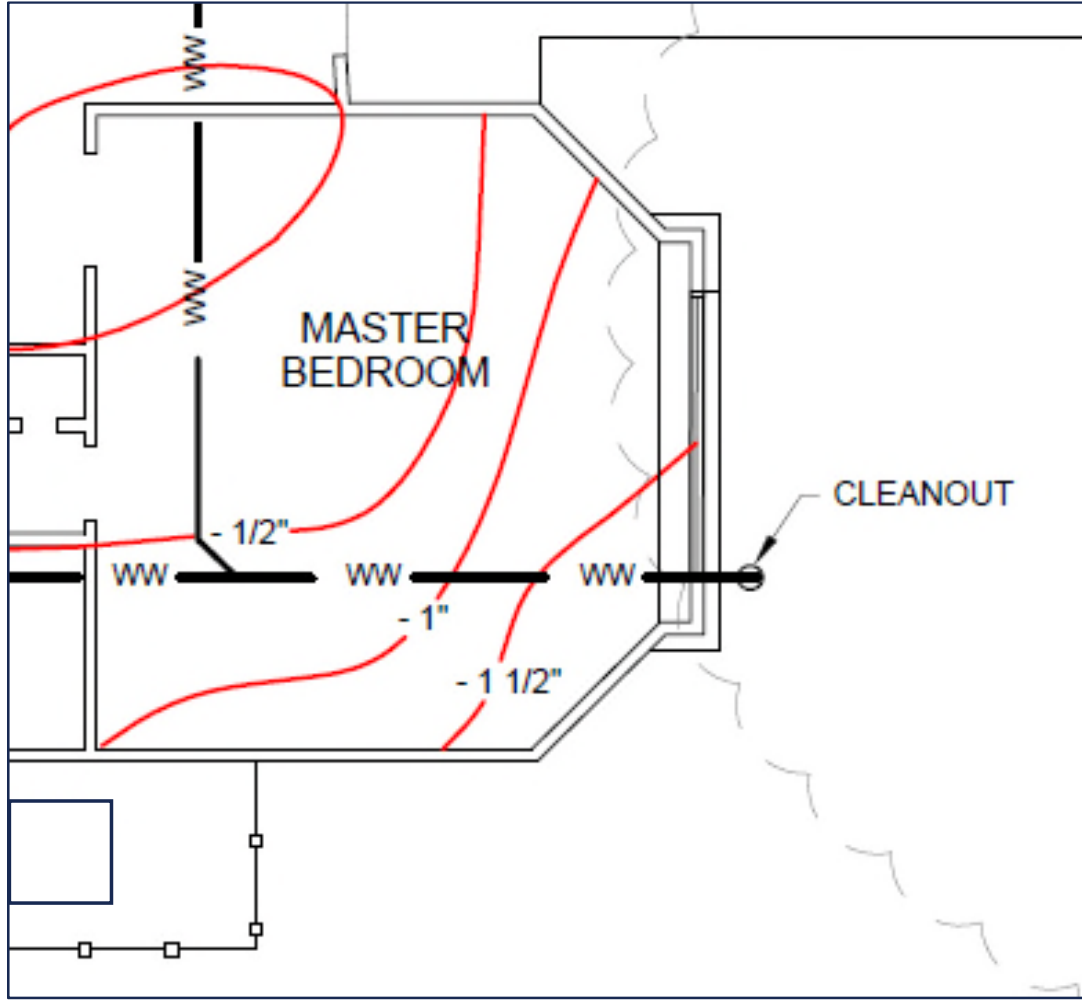
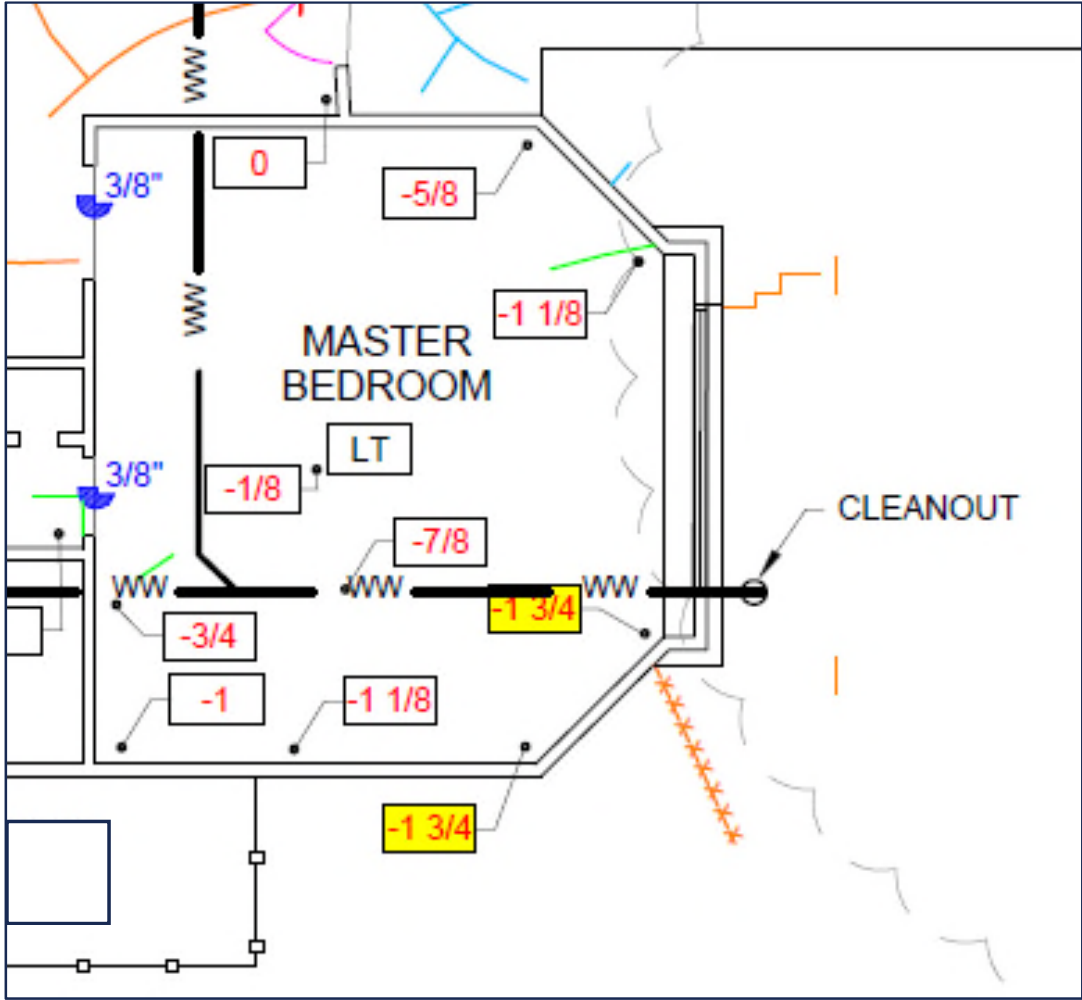
# Non-Destructive Testing



Broom Lines Remaining  
from Crack Mapping  
Survey

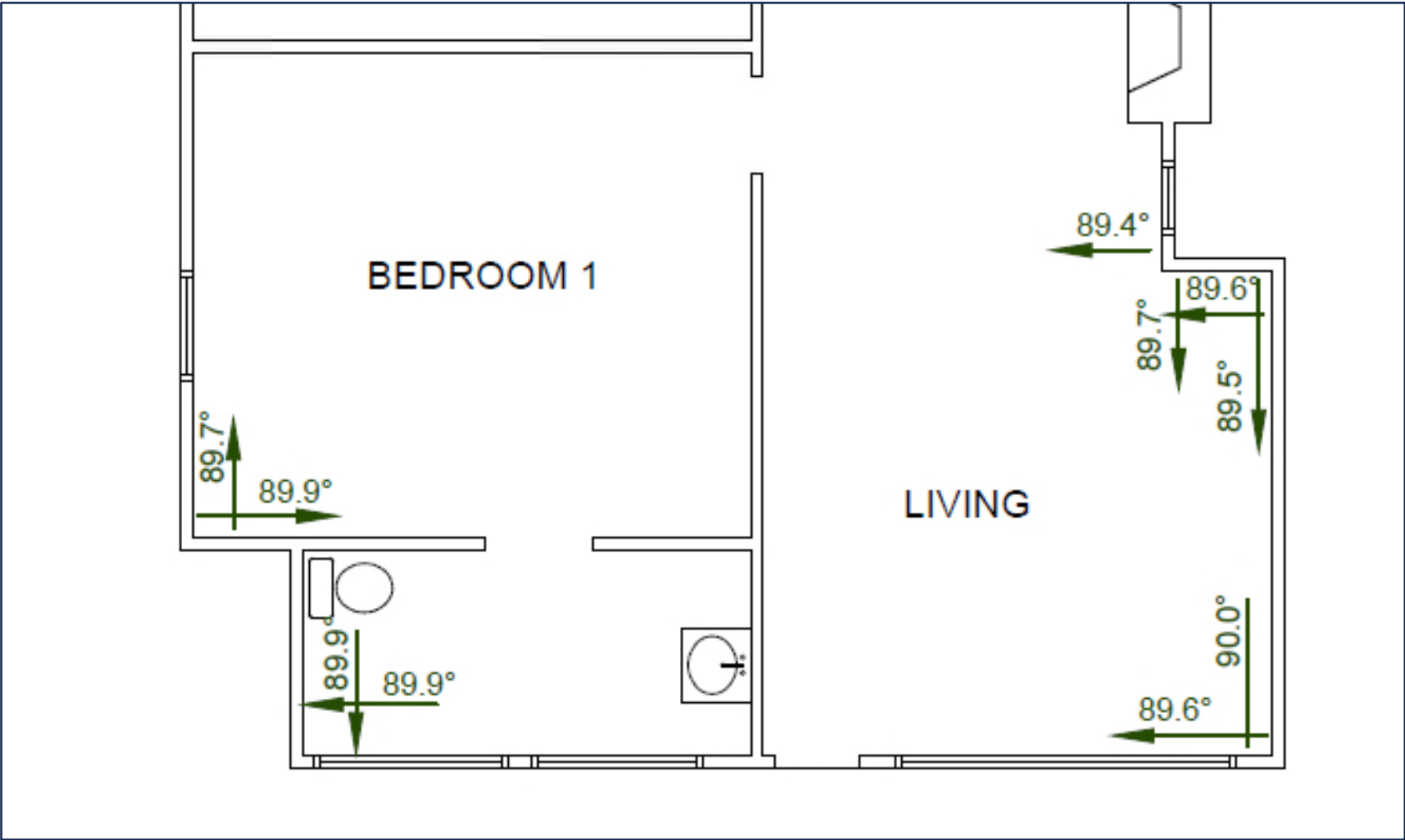


# Non-Destructive Testing



Distress and Elevation Surveys

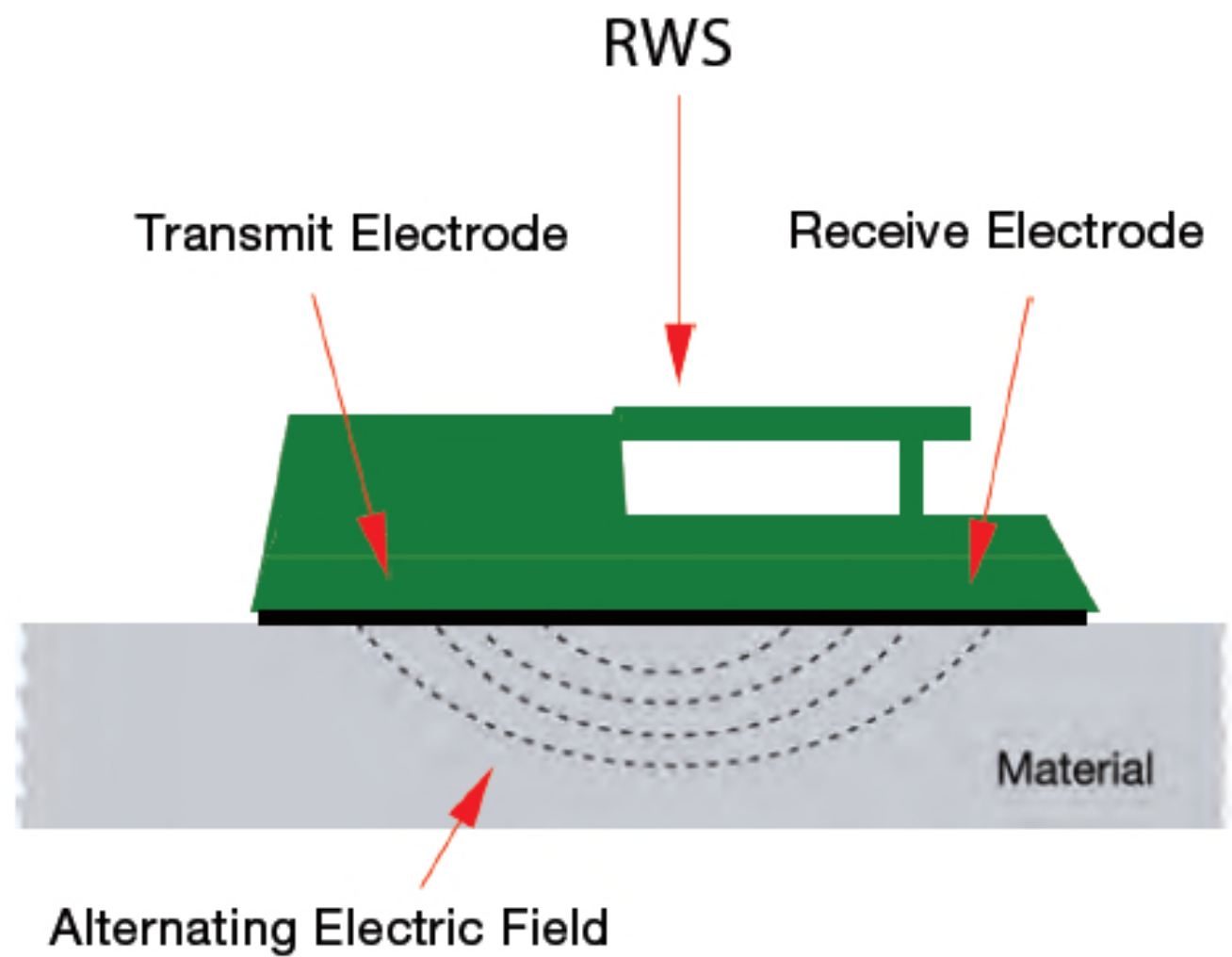
# Non-Destructive Testing



Plumbness  
Survey



# Non-Destructive Testing Tools



Electrical Capacitance (Impedance)  
Testing



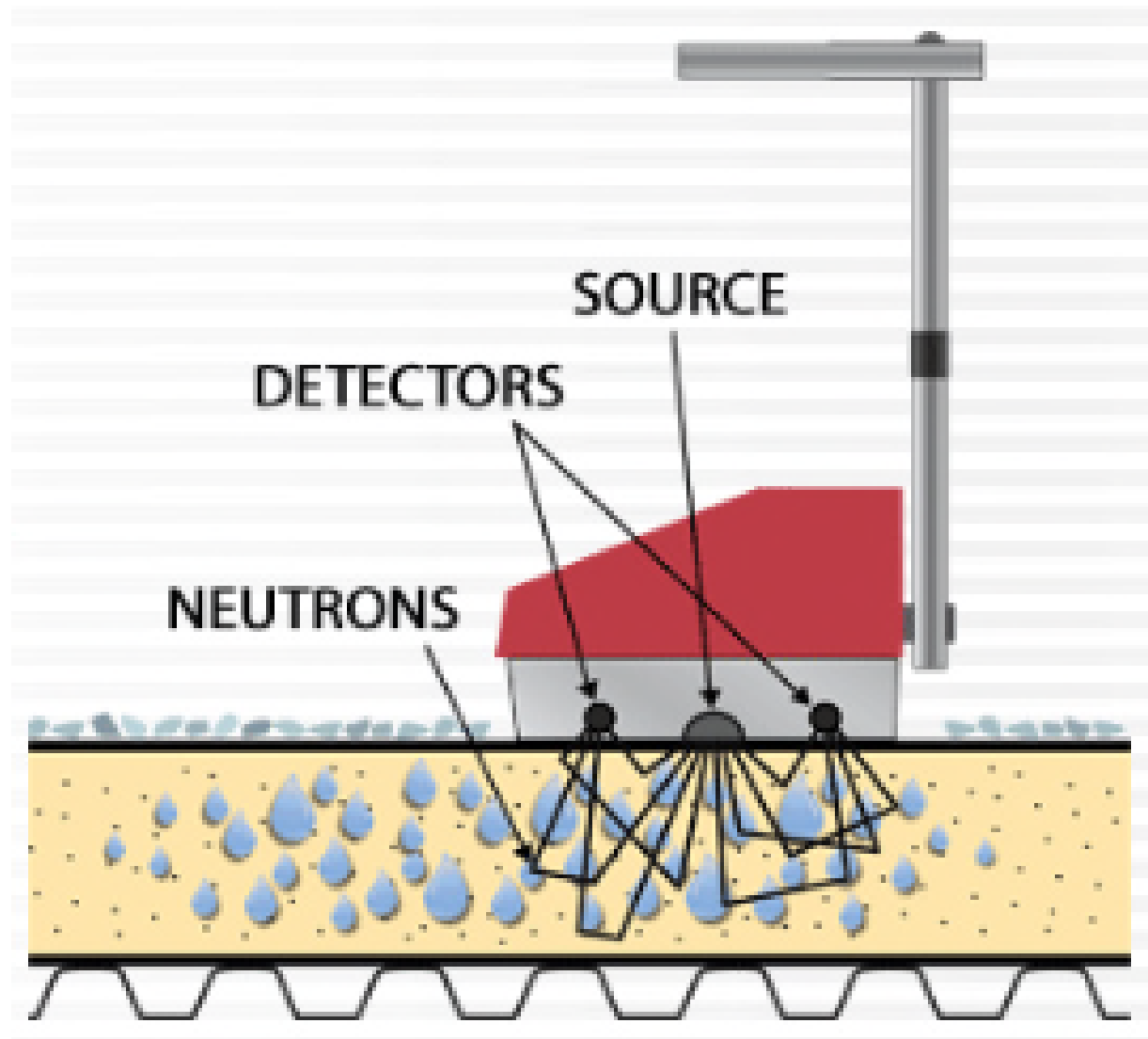
# Non-Destructive Testing Tools



Electrical Capacitance (Impedance)  
Testing



# Non-Destructive Testing Tools



Nuclear Hydrogen  
Detection

# Non-Destructive Testing Tools



Infrared Thermography



# Non-Destructive Testing Tools



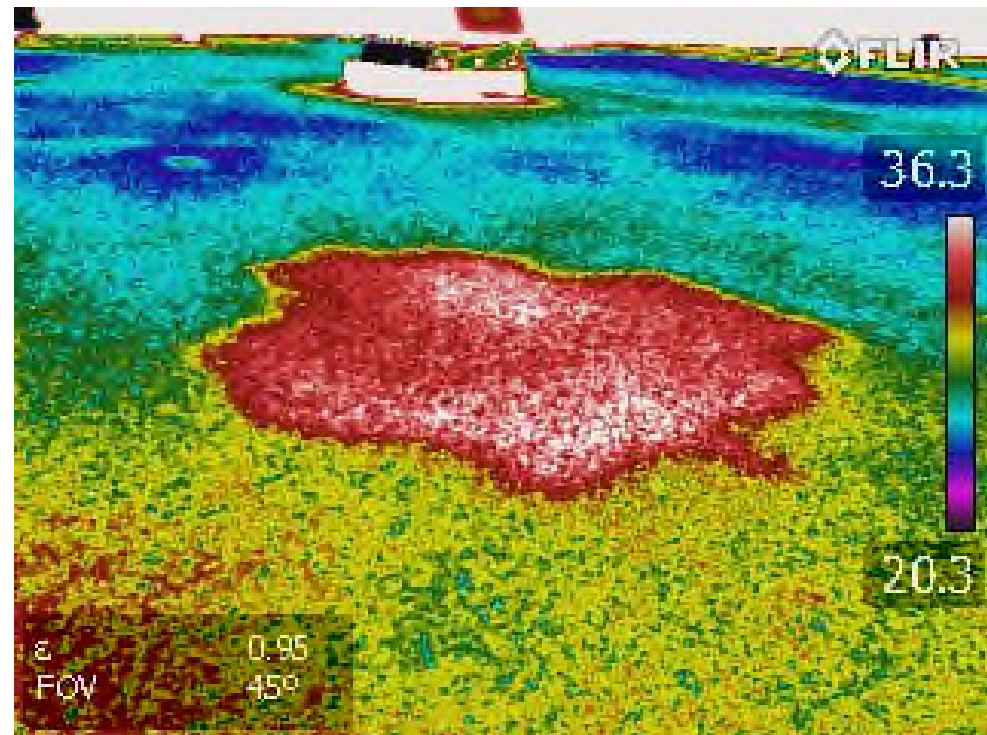
Designation: C1153 – 10

## Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging<sup>1</sup>

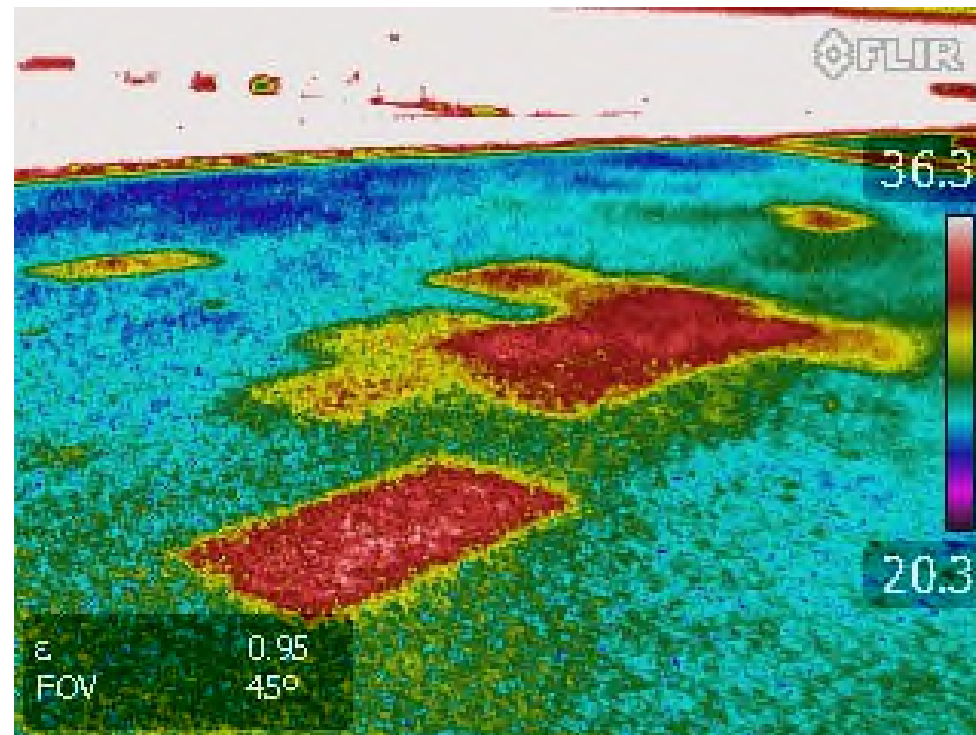
**Table 1 – General Site Conditions for Infrared Roof Survey**

|  |             |
|--|-------------|
| Time of Survey                           | 6:00 PM     |
| Wind Velocity                            | 8 mph       |
| Outside Temperature                      | 51 °F       |
| Weather During Survey                    | Clear       |
| Weather 24 hrs Prior to Survey           | Sunny/Clear |
| Roof Surface Condition at Time of Survey | Dry         |

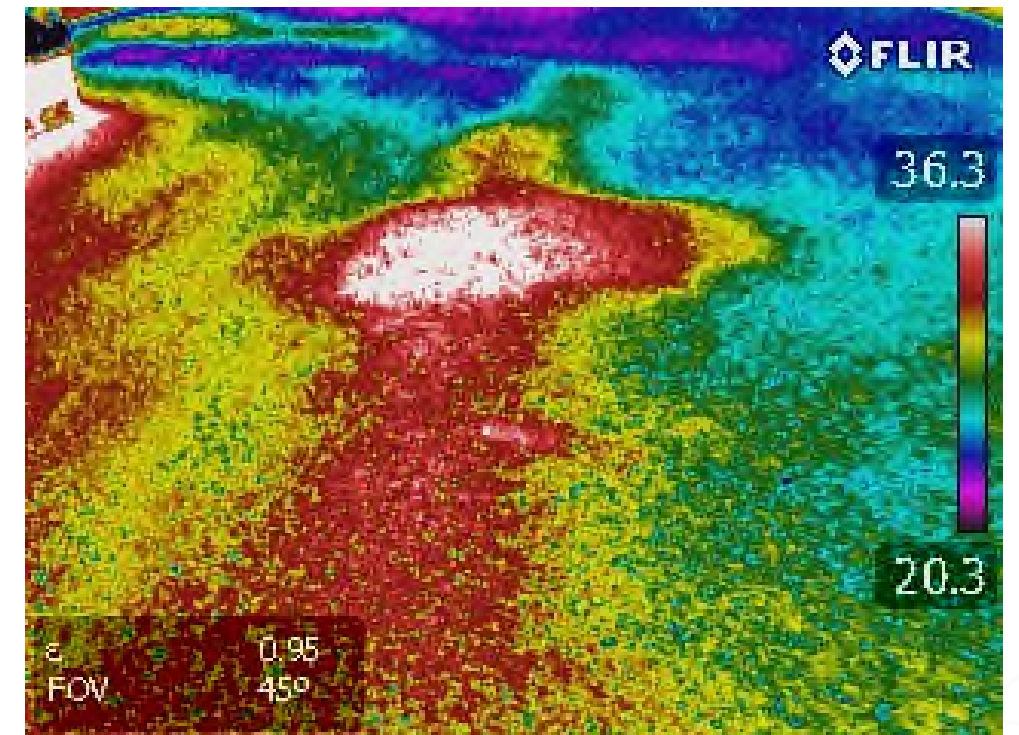
# Non-Destructive Testing Tools



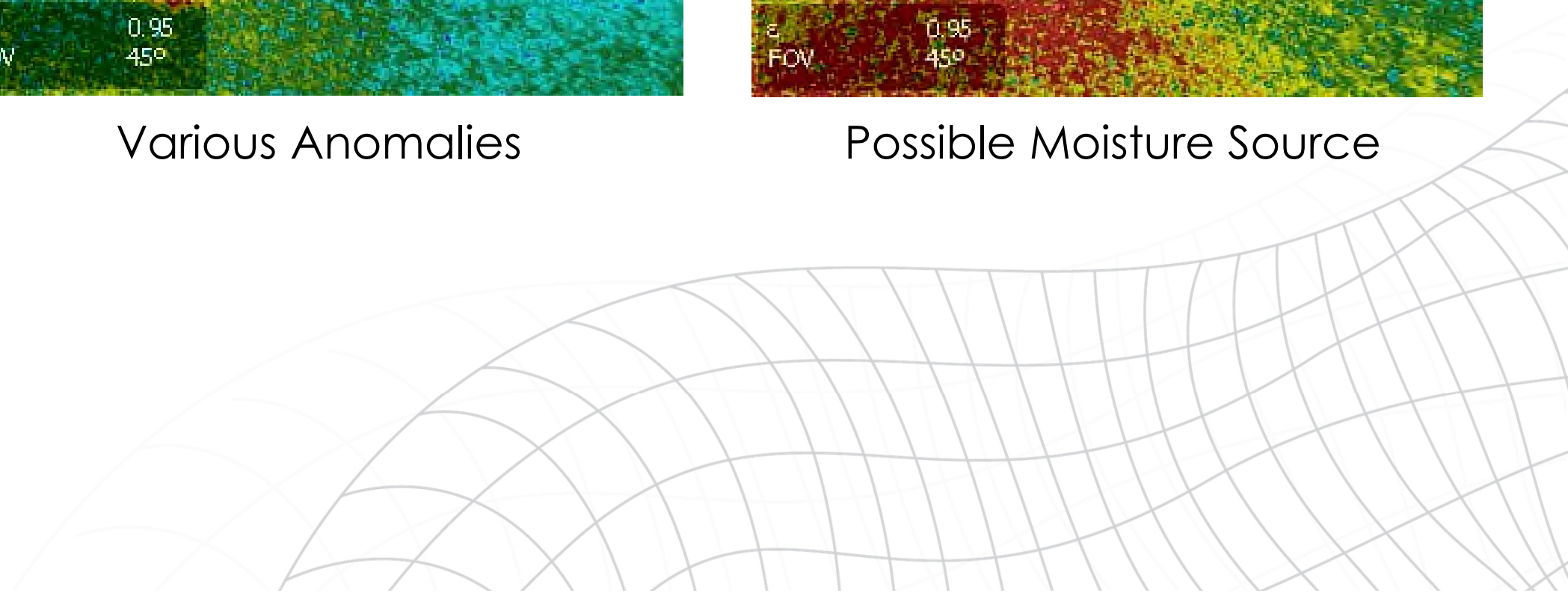
Isolated Anomaly



Various Anomalies

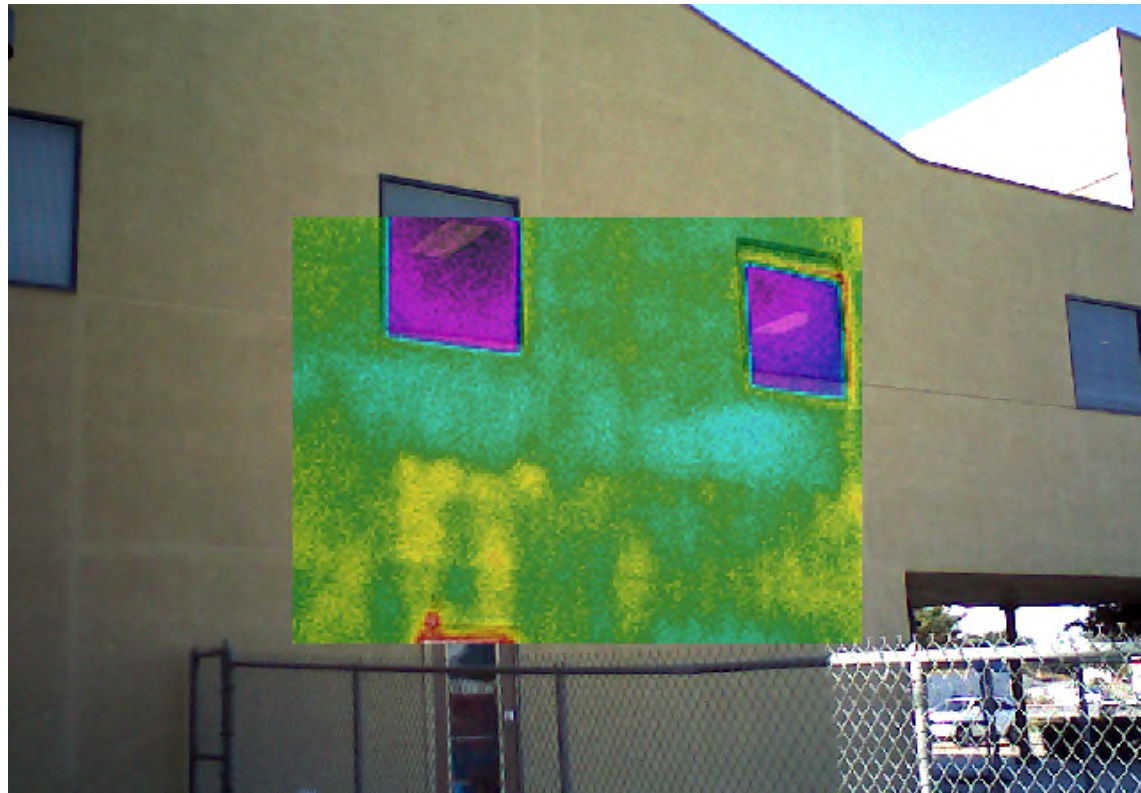


Possible Moisture Source

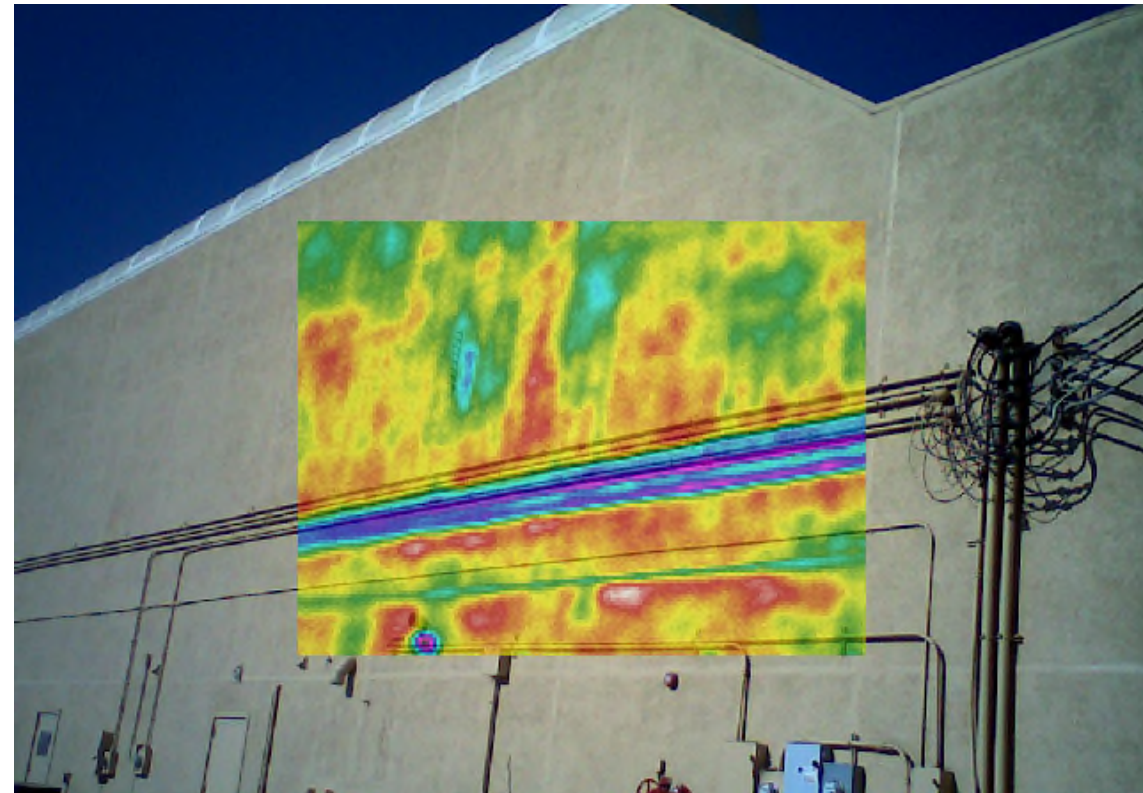




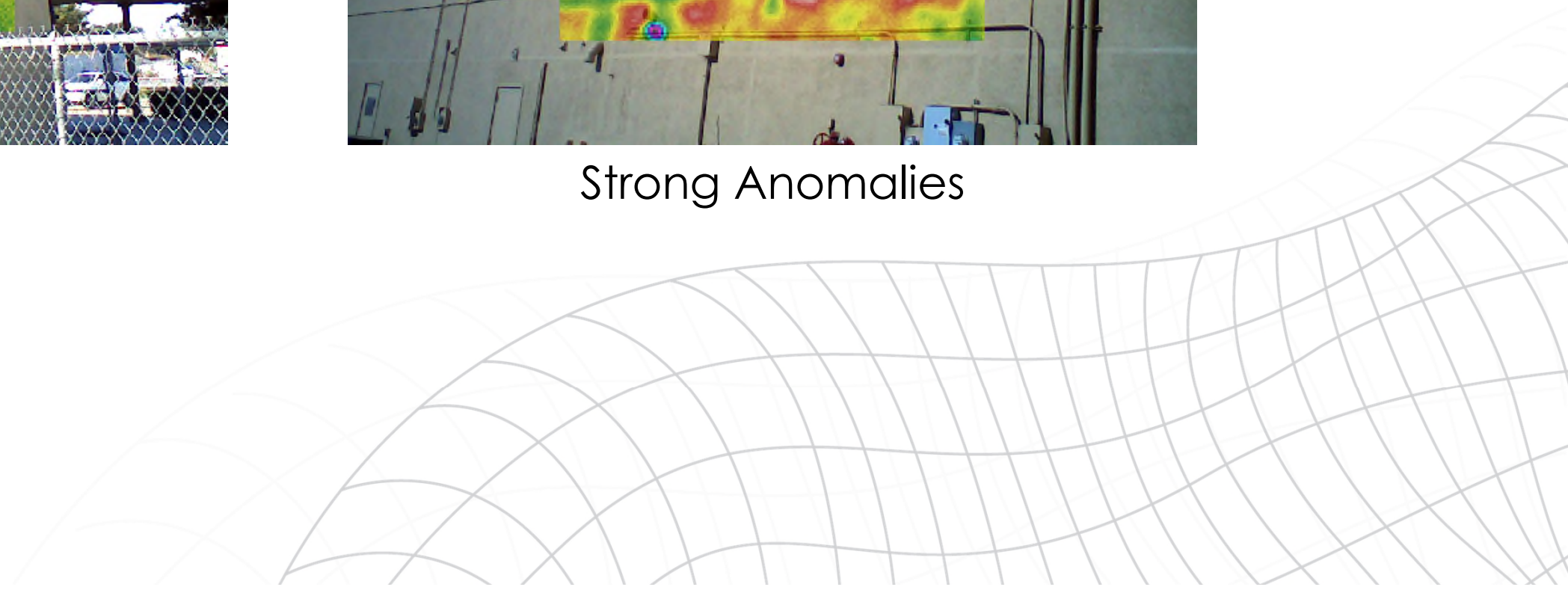
# Non-Destructive Testing Tools



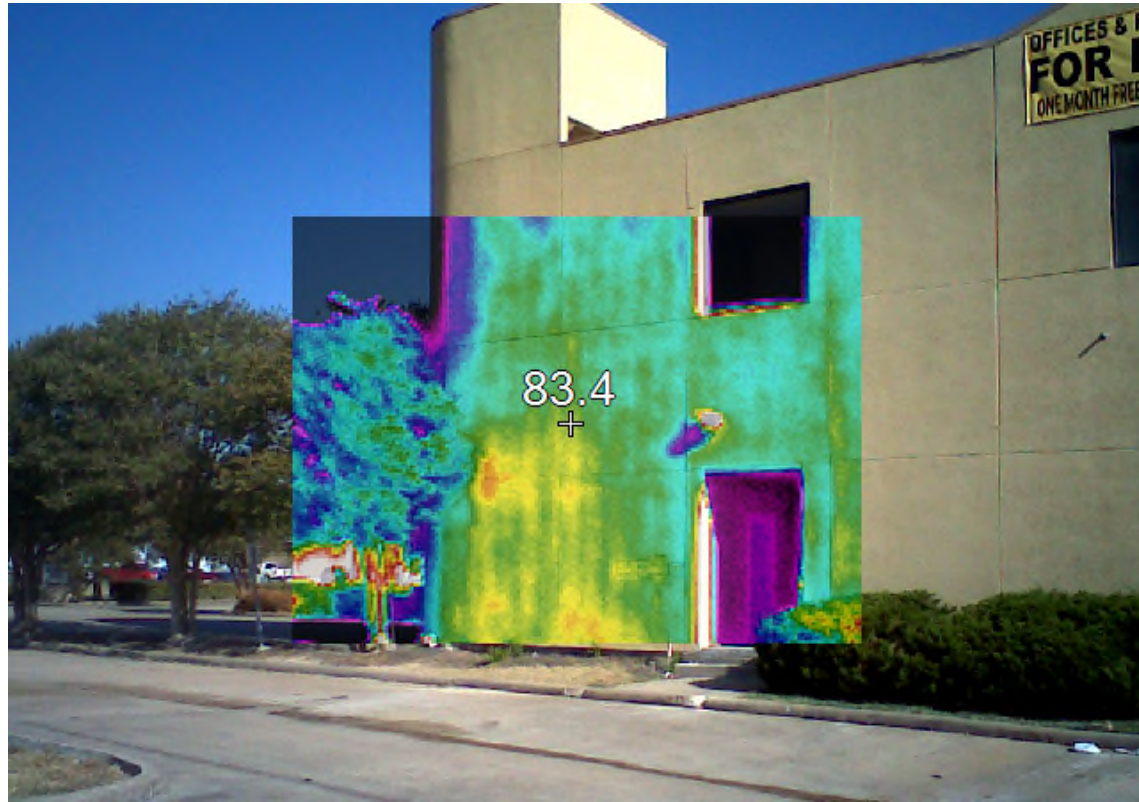
Weak Anomalies



Strong Anomalies



# Non-Destructive Testing Tools



Infrared Image

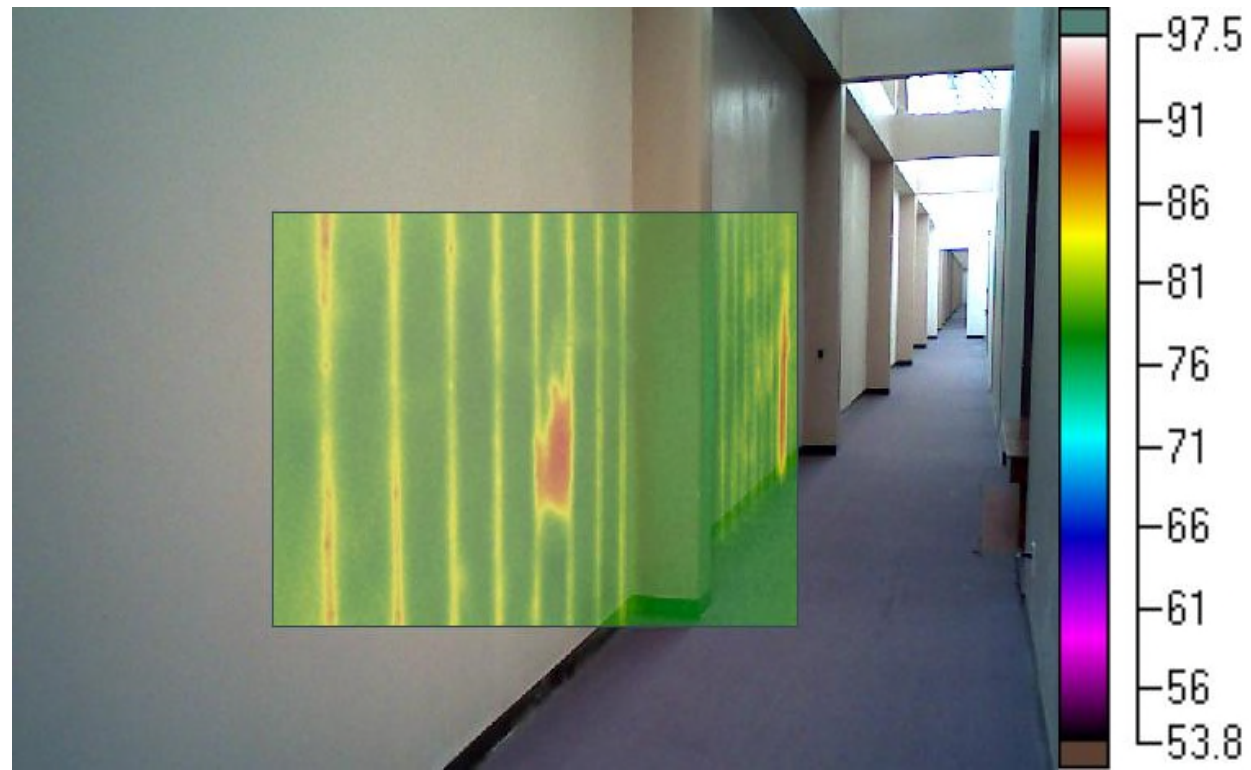


Corresponding Visible Light  
Image





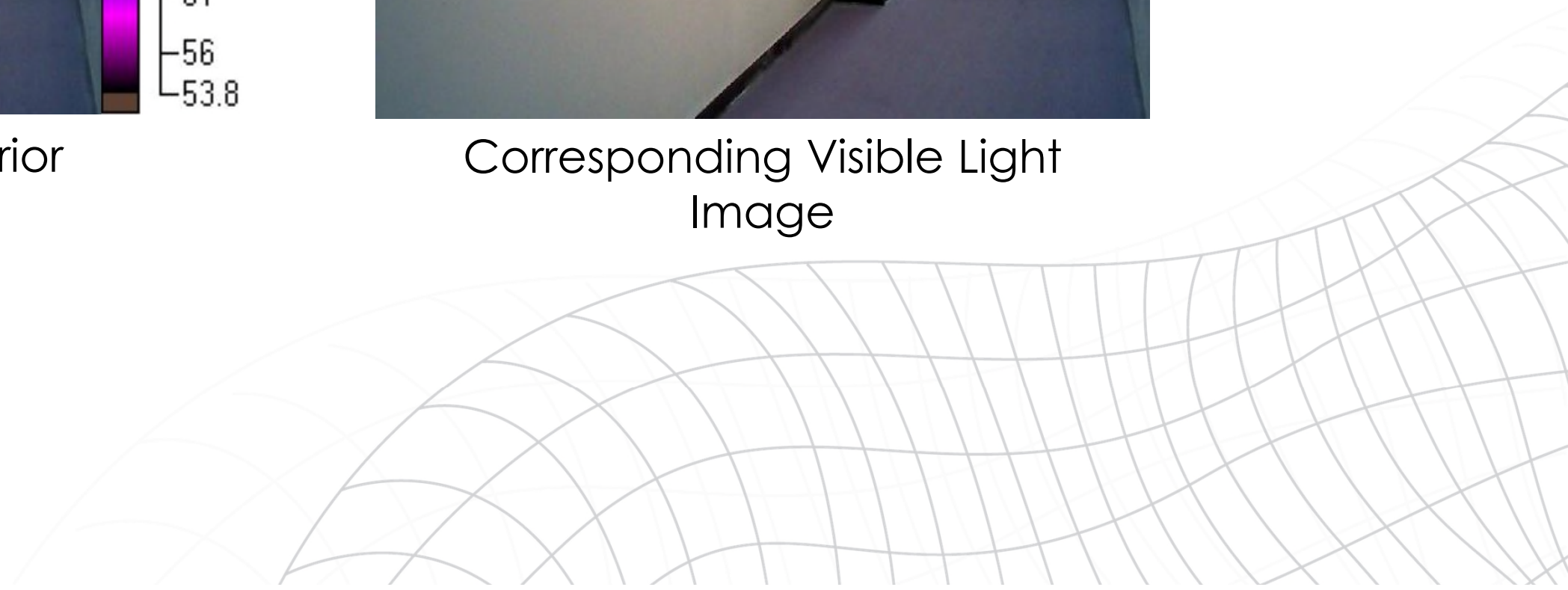
# Non-Destructive Testing Tools



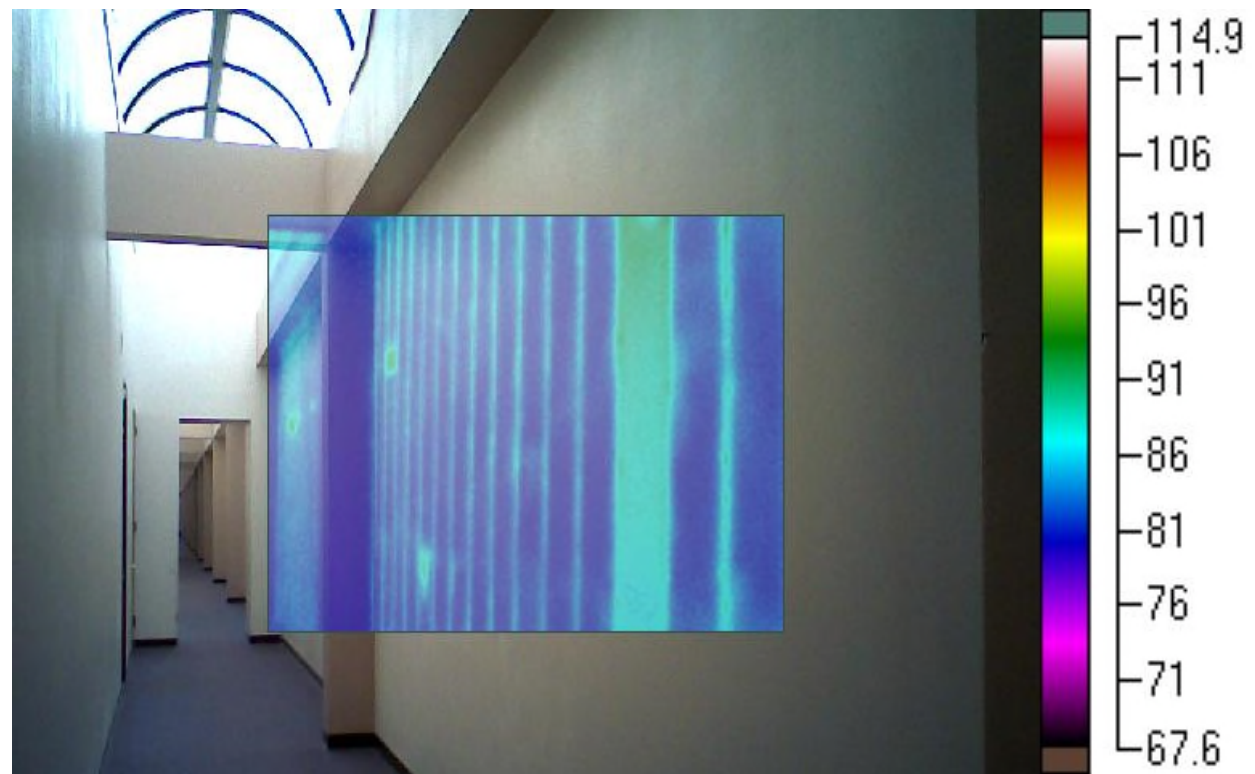
Infrared Image at Exterior  
Wall



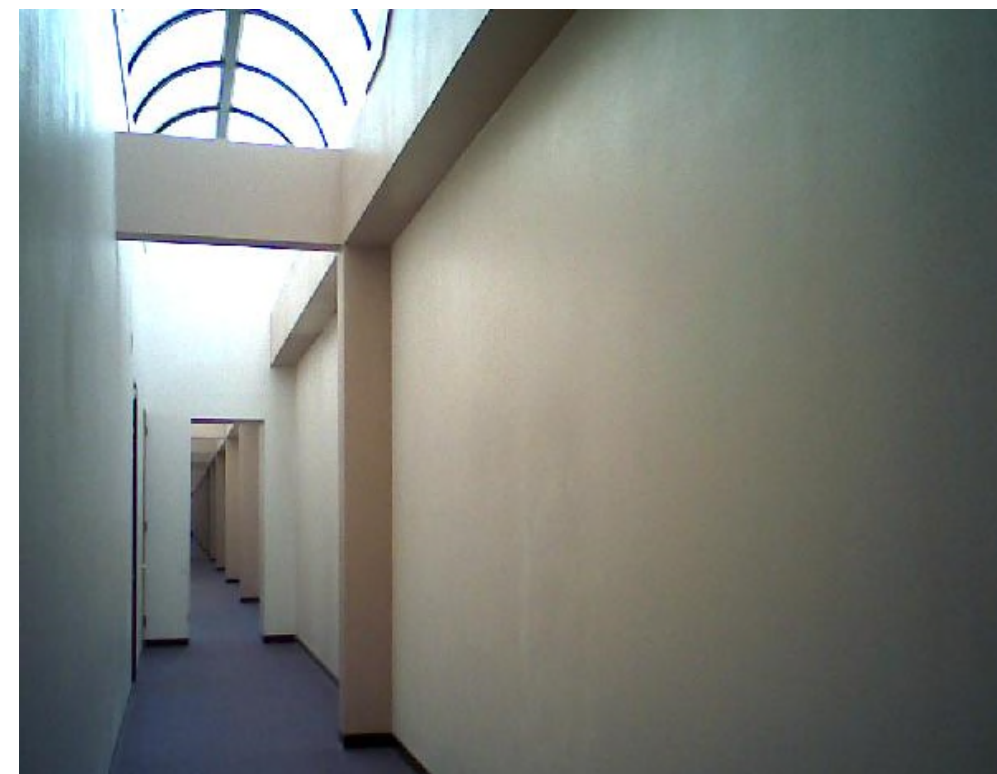
Corresponding Visible Light  
Image



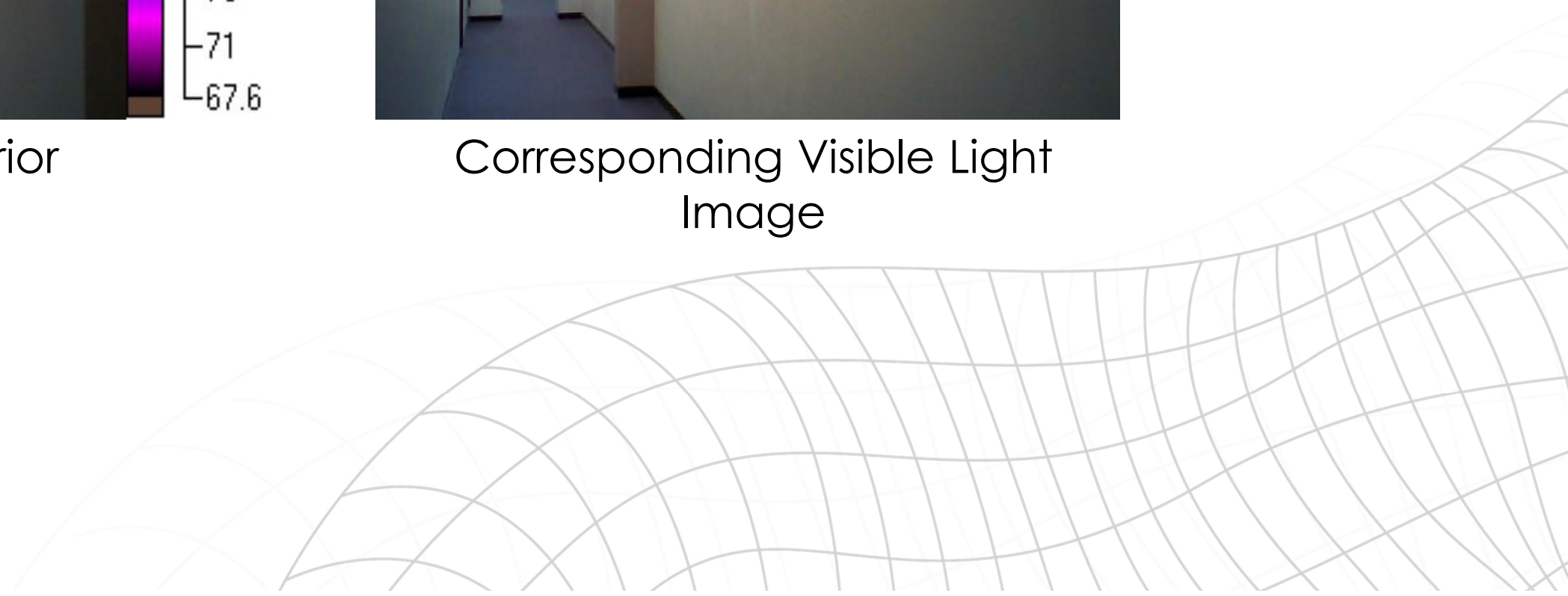
# Non-Destructive Testing Tools



Infrared Image at Interior  
Wall




Corresponding Visible Light  
Image





# Additional Examples of Non-Destructive Testing

---

- Moisture/Vapor Emission
  - Hardness
  - Ultrasonic
  - Structural Analysis
  - Load Testing
  - Ground Penetrating Radar (GPR)
  - Soil Sampling and Testing
  - Water Origin and Quality
  - Mold
  - Asbestos
- 
- A decorative graphic in the bottom right corner consisting of a grid of thin, light gray lines. The grid is composed of both horizontal and vertical lines, but the vertical lines are curved, creating a wavy, grid-like pattern that tapers off towards the right edge of the slide.

# Destructive or Non-Destructive?



Non-Destructive



Destructive

# Examples of Destructive Testing

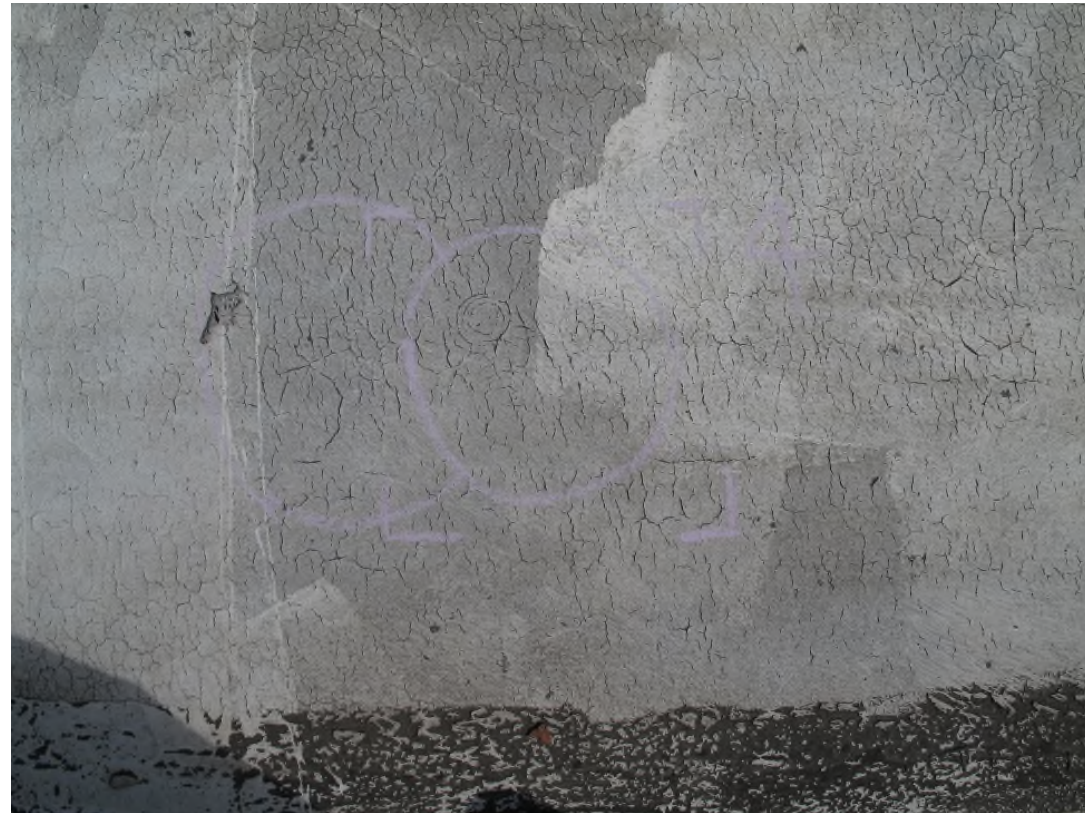
---

- Moisture Probe
- Roof Coring and Sampling
- Wall (Veneer) and Finish Removal
- Concrete/Masonry Probe
- Concrete Coring
- Water Spray Testing
- Load Testing





# Destructive Testing



Roof Coring and Sampling





# Destructive Testing



Exterior Veneer Removal





# Destructive Testing

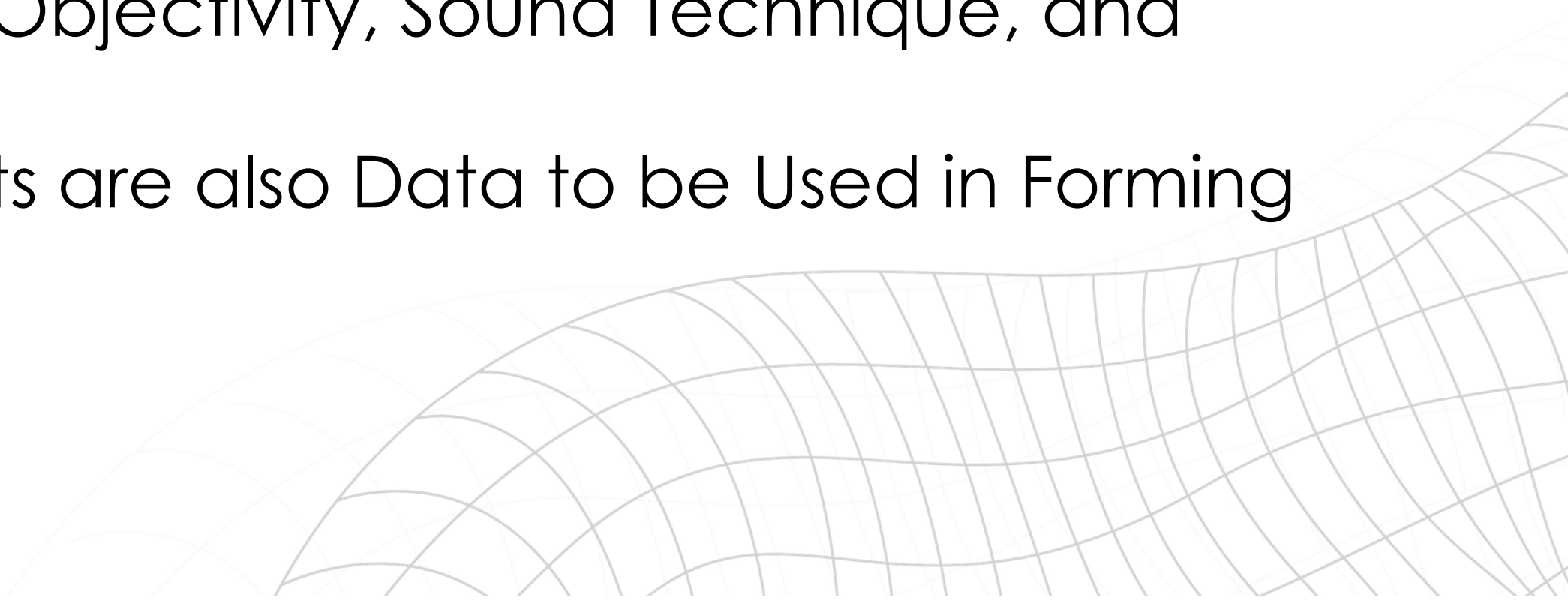


Water Spray Testing



# Testing Summary

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- Gather the Data Necessary to:
    - Test Hypotheses
    - Objectively Support Conclusions
  - Data Collection May Need to be Altered or Augmented Depending Upon Findings
  - Focus Should be on Objectivity, Sound Technique, and Reproducibility
  - Available Documents are also Data to be Used in Forming Conclusions
- 

# Case Study: Hail



Office, Warehouse, & Distribution Facility –  
Englewood, CO

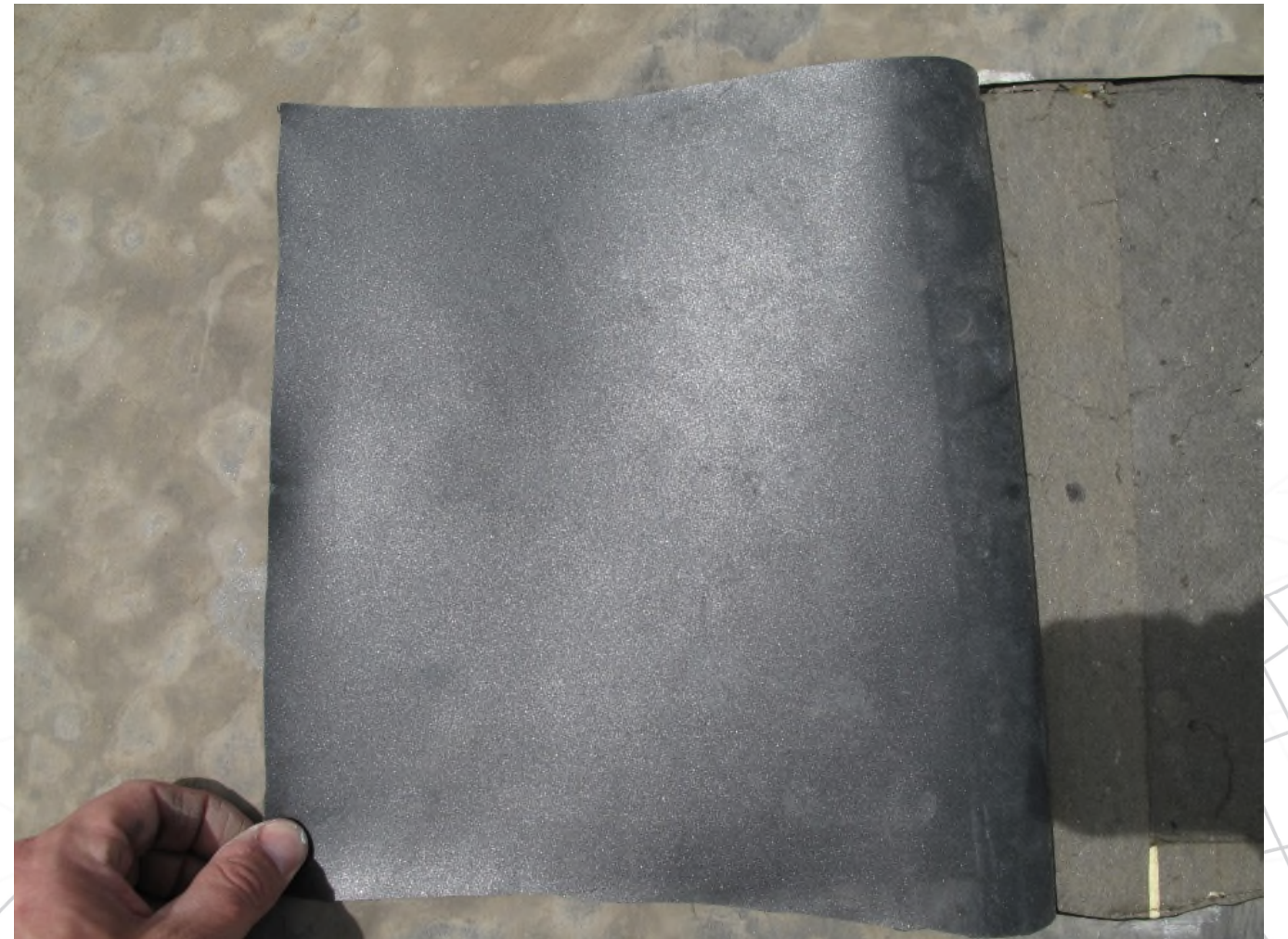


# Case Study: Hail





# Case Study: Hail





# Case Study: Hail





# Case Study: Hail





# Case Study: Hail





# Case Study: Hail



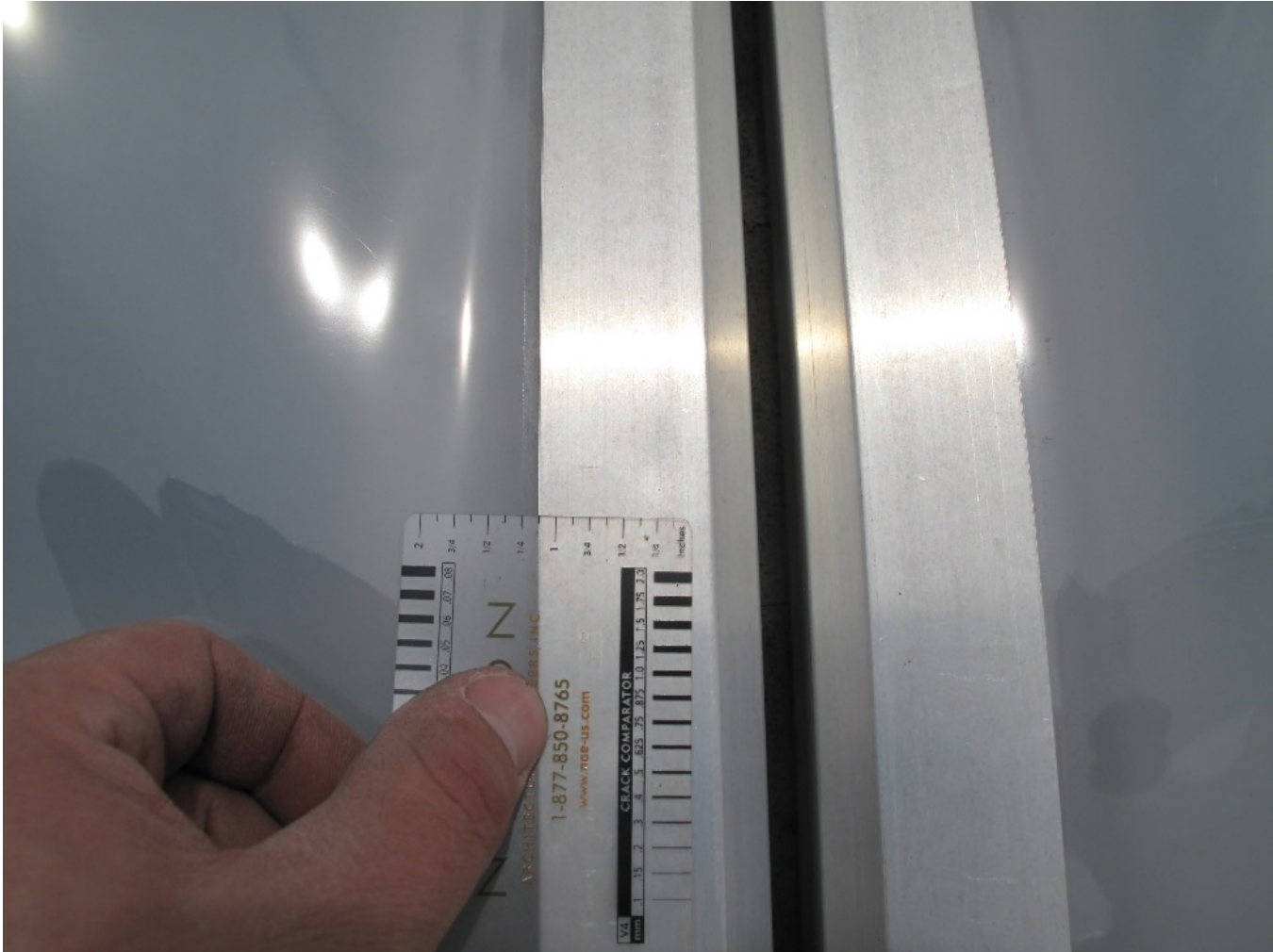


# Case Study: Hail





# Case Study: Hail





# Case Study: Hail





# Case Study: Hail





# Case Study: Hail





# Case Study: Hail





# Case Study: Hail

## Weather Data

- NOAA (NCEI, SPC, NWS)
- Weather Stations
- Purchased Reports
  - CompuWeather
  - CoreLogic
  - Verisk Climate
- News/Media Outlets



Source: Reppenhagen, May 8, 2017



# Case Study: Hail

NOAA's National Weather Service  
**Storm Prediction Center**

Site Map News

Local forecast by "City, St" or "ZIP"  
 City, St   Go

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 SPC on Facebook

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NCEP Quarterly Newsletter

Home (Classic)  
 SPC Products  
 All SPC Forecasts  
 Current Watches  
 Meso. Discussions  
 Conv. Outlooks  
 Tstm. Outlooks  
 Fire Wx Outlooks  
 RSS Feeds  
 E-Mail Alerts  
 Weather Information  
 Storm Reports  
 Storm Reports Dev.  
 NWS Hazards Map  
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 Forecast Tools  
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**Severe Weather Event Summaries**  
 Storm Reports | Monthly/Annual Summaries | Fatal Tornadoes  
 Trend Chart and Data | Radar Coverage Climatology | Online Severe Plot  
 Severe Thunderstorm Events Archive | SVR GIS Page

**NWS Local Storm Reports**

**Note:** On April 17, 2014, an experimental Storm Reports page became available [www.spc.noaa.gov/exper/reports/](http://www.spc.noaa.gov/exper/reports/). For more information, visit the SPC FAQ Section 6.14.

**Note:** On March 8, 2011, the proximity space/time rule is no longer being utilized to de-duplicate events and minimal filtering is now applied to the decoded reports. All comments/remarks in the LSRs are captured on the raw files and the users can decide, for their own purposes, the best way to remove duplicate reports from the LSR's.

**Note:** Starting January 5, 2010, the daily storm report summaries, below, will record **1 inch and greater diameter hail**, as well as severe thunderstorm wind and tornado reports. Please see this [link](#) for more information.

**Note:** These reports are **preliminary** and are plotted and listed "as is" from NWS Local Storm Reports usually sent in realtime. The SPC does **NOT** decode non-thunderstorm related LSRs such as hurricane related wind reports. Please see [SPC FAQ](#) for more details. Consult [NOAA/NWS Storm Data](#) for post-storm summaries and statistics. To obtain official documentation of severe weather, please contact the [National Climatic Data Center \(NCDC\)](#). Click here to search the [NCDC Storm Events database](#).  
 Another good source of Local Storm Reports is Iowa Environmental Mesonet/Iowa State University Department of Agronomy.

Today's Storm Reports (in KML format)  
 (Updated every 10 minutes)  
 (since 6AM CST/7AM CDT)  
 (Reports over the last 3 hours)

Yesterday's Storm Reports (in KML format)  
 (6AM-6AM CST/7AM-7AM CDT)

Past Storm Reports  
 Enter date to retrieve (YYMMDD):

**Monthly and Annual Summaries**

Monthly and annual tornado statistics and severe weather summaries for the U.S. back to 2000.

National Weather Service • Since 1870

NOAA's National Weather Service  
**Storm Prediction Center**

Site Map News

Local forecast by "City, St" or "ZIP"  
 City, St   Go

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 Fire Wx Outlooks  
 RSS Feeds  
 E-Mail Alerts  
 Weather Information  
 Storm Reports  
 Storm Reports Dev.  
 NWS Hazards Map  
 Watch/Warning Map  
 National RADAR  
 Product Archive  
 NOAA Weather Radio  
 Research  
 Non-op. Products  
 Forecast Tools  
 Svr. Tstm. Events  
 SPC Publications  
 SPC-NSSL HWT  
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 About the SPC  
 SPC FAQ  
 About Tornadoes  
 About Derechos  
 WCM Page  
 Enh. Fujita Page  
 Our History  
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 Misc.  
 Staff  
 Contact Us  
 SPC Feedback

**20140929's Storm Reports (1200 UTC - 1159 UTC) (Print Version)**

< 140928 Reports 140930 Reports >  
**Note: All Reports Are Considered Preliminary**

Unfiltered Reports (Google Maps) | Filtered Reports (Google Maps) (More Info)

**SPC Storm Reports for 09/29/14**  
 Map updated at 1212Z on 10/09/14

Legend:  
 ■ High Wind Report (65KT+)  
 ▲ Large Hail Report (2" dia. +)

PRELIMINARY DATA ONLY

**Tornado Reports (CSV) (Raw Tornado CSV)(?)**

| Time | Location    | County     | State | Lat  | Lon   | Comments   |
|------|-------------|------------|-------|------|-------|--|
| 1832 | 18 NW DELTA | DELTA      | CO    | 3888 | 10815 | FUNNEL CLOUD VISIBLE FOR 3 MINUTES TOUCHED THE GROUND FOR ABOUT ONE MINUTE. NO KNOWN DAMAGE. (GJT) |
| 2227 | 8 W CHAVA   | RIO ARRIBA | NM    | 3689 | 10673 | REPORTED TORNADO CAUSED ROOF DAMAGE AND DESTROYED SHED. (ABQ)                                      |

**Hail Reports (CSV) (Raw Hail CSV)(?)**

| Time | Size | Location              | County    | State | Lat  | Lon   | Comments   |
|------|------|-----------------------|-----------|-------|------|-------|--|
| 1900 | 175  | 4 E PAGOSA SPRINGS    | ARCHULETA | CO    | 3727 | 10695 | GOLF BALL SIZE HAIL REPORTED BY AT LEAST SIX PEOPLE. (GJT) |
| 2020 | 100  | 1 SSE HIGHLANDS RANCH | DOUGLAS   | CO    | 3954 | 10496 | (BOU)  |
| 2026 | 100  | HIGHLANDS RANCH       | DOUGLAS   | CO    | 3955 | 10497 | (BOU)  |
| 2033 | 100  | CENTENNIAL            | ARAPAHOE  | CO    | 3960 | 10487 | (BOU)  |
| 2034 | 175  | CENTENNIAL            | ARAPAHOE  | CO    | 3960 | 10487 | (BOU)  |
| 2035 | 125  | CENTENNIAL            | ARAPAHOE  | CO    | 3960 | 10487 | (BOU)  |
| 2042 | 150  | AURORA                | ARAPAHOE  | CO    | 3970 | 10481 | (BOU)  |

National Weather Service • Since 1870

<http://www.spc.noaa.gov/climo/online/>



# Case Study: Hail

The screenshot shows the NOAA National Climatic Data Center (NCDC) Storm Events Database website. The header includes the NOAA logo and the text "NOAA NATIONAL CLIMATIC DATA CENTER NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION". Navigation links for "Home", "Contact Us", "About NCDC", and "Help" are present. The main content area is titled "Storm Events Database" and features a left-hand navigation menu with sections for "Data Access", "Documentation", and "External Resources". The main text includes a notice about a data problem from 1996 to 2006, a description of the database's purpose, and a list of event types. A search section allows users to "Select State or Area" and perform a "Narrative Text Search". A footer contains links for "Privacy Policy", "FOIA", "Information Quality", "Disclaimer", and "Contact Us", along with the "USA.gov Ready" logo.

NOAA NATIONAL CLIMATIC DATA CENTER  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Home Contact Us About NCDC Help

NCDC > Storm Events Database

**Storm Events Database**

**Data Access**  
Search  
Bulk Data Download (CSV)  
Storm Data Publication

**Documentation**  
Database Details  
Version History  
Storm Data FAQ  
NOAA's NWS Documentation  
Tornado EF Scale

**External Resources**  
NOAA's SPC Reports  
NOAA's SPC WCM Page  
NOAA's NWS Damage Assessment Toolkit  
ESRI/FEMA Civil Air Patrol Images  
SHELDUS  
USDA Cause of Loss Data

**Storm Events Database**

**Notice:** A problem with Lat/Lon values from 1996 to 2006 has been detected.

The Storm Events Database contains the records used to create the official [NOAA Storm Data publication](#), documenting:

- The occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce;
- Rare, unusual, weather phenomena that generate media attention, such as snow flurries in South Florida or the San Diego coastal area; and
- Other significant meteorological events, such as record maximum or minimum temperatures or precipitation that occur in connection with another event.

The database currently contains data from **January 1950 to September 2015**, as entered by NOAA's National Weather Service (NWS). Due to changes in the data collection and processing procedures over time, there are unique periods of record available depending on the event type. NCDC has performed data reformatting and standardization of event types but has not changed any data values for locations, fatalities, injuries, damage, narratives and any other event specific information. Please refer to the [Database Details](#) page for more information.

**Select State or Area**  
-- All States and Areas --  
Search

**Narrative Text Search**  
-- or --  
Text Search [\[help and examples\]](#)

The Storm Events Database has changed greatly over time. Please refer to the [version information page](#) for detailed version information and release dates. If you have questions, please [Contact NCDC](#).

Privacy Policy | FOIA | Information Quality | Disclaimer | Contact Us

USA.gov Ready

<http://www.ncdc.noaa.gov/stormevents>

# Case Study: Wind

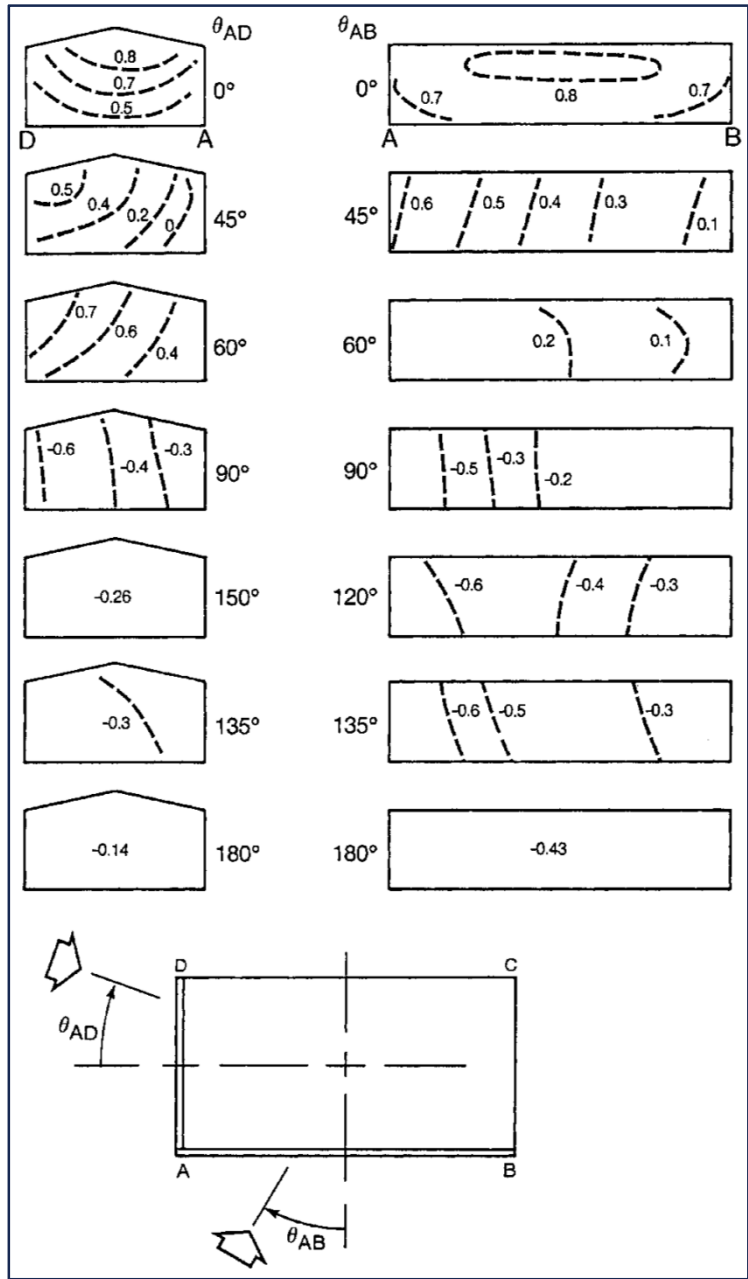


Figure 5 – Local Pressure Coefficients for Walls of Low-Rise Building with Varying Wind Direction (Holmes 1986)

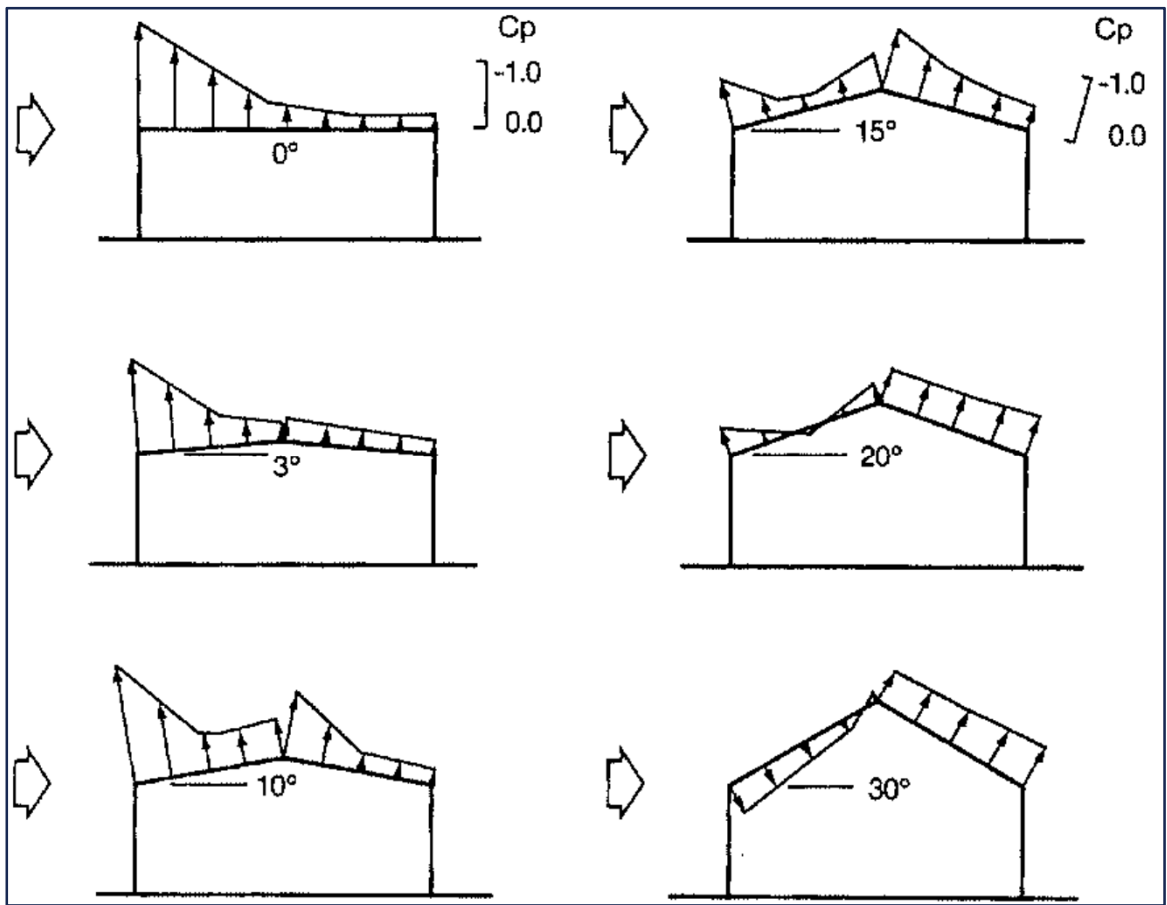


Figure 8 – Local Roof Pressure Coefficients for Roof of Low-Rise Buildings (Holmes 1986)



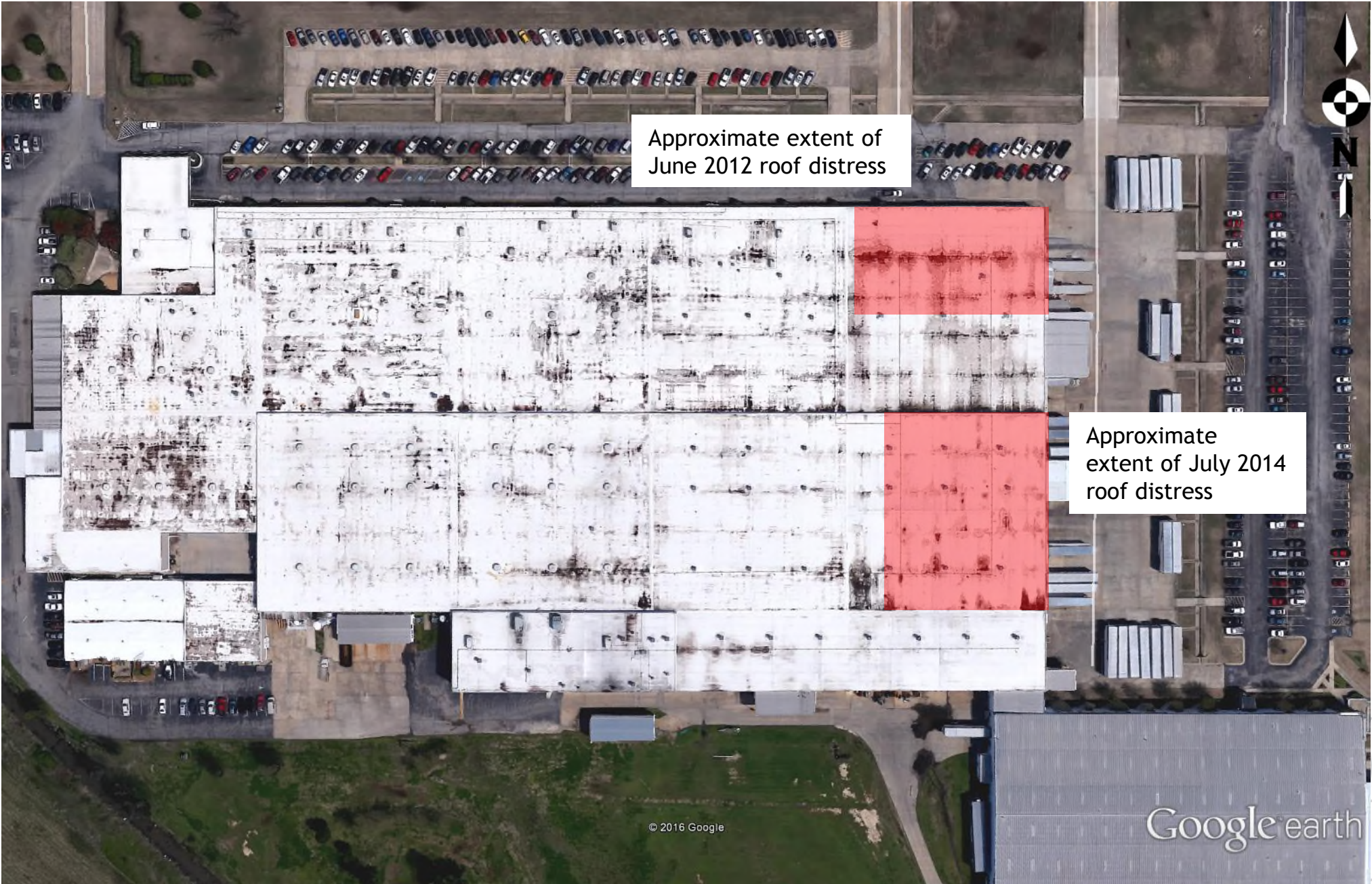
# Case Study: Wind



Office, Manufacturing, Warehouse, & Distribution Facility - Northeast Arkansas

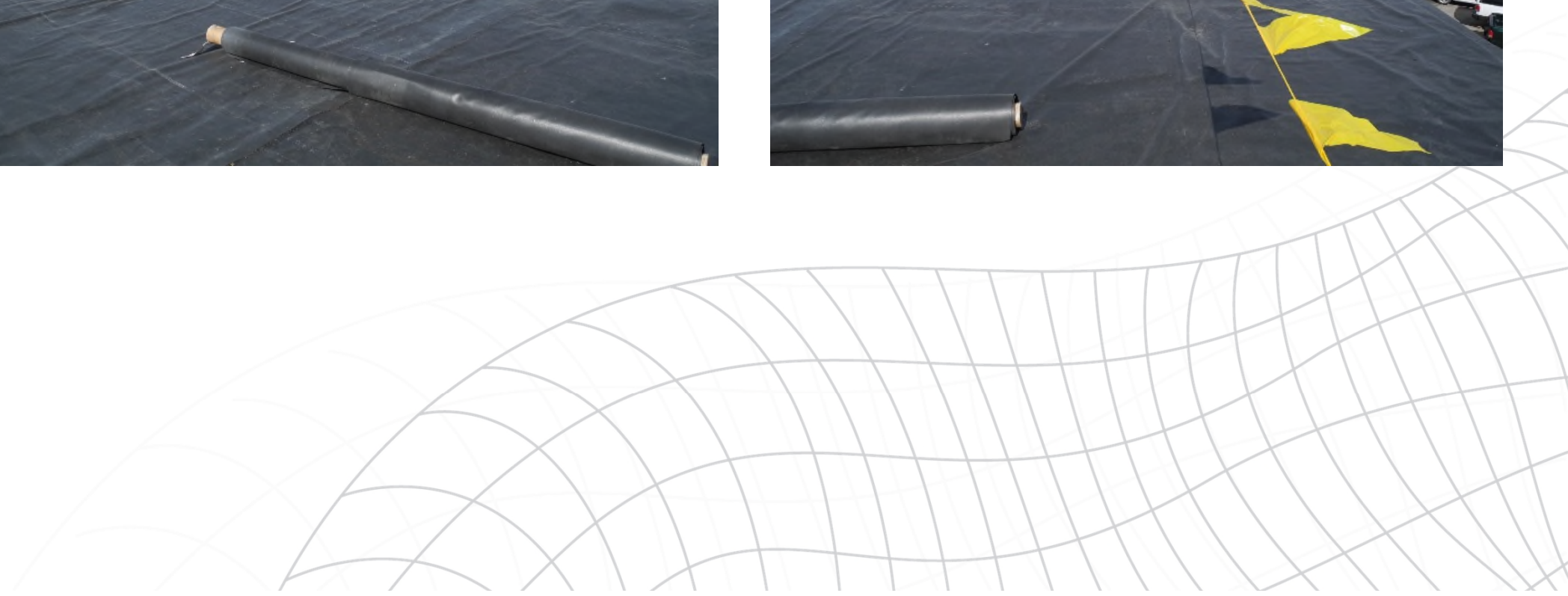


# Case Study: Wind





# Case Study: Wind





# Case Study: Wind





# Case Study: Wind





# Case Study: Wind





# Case Study: Wind



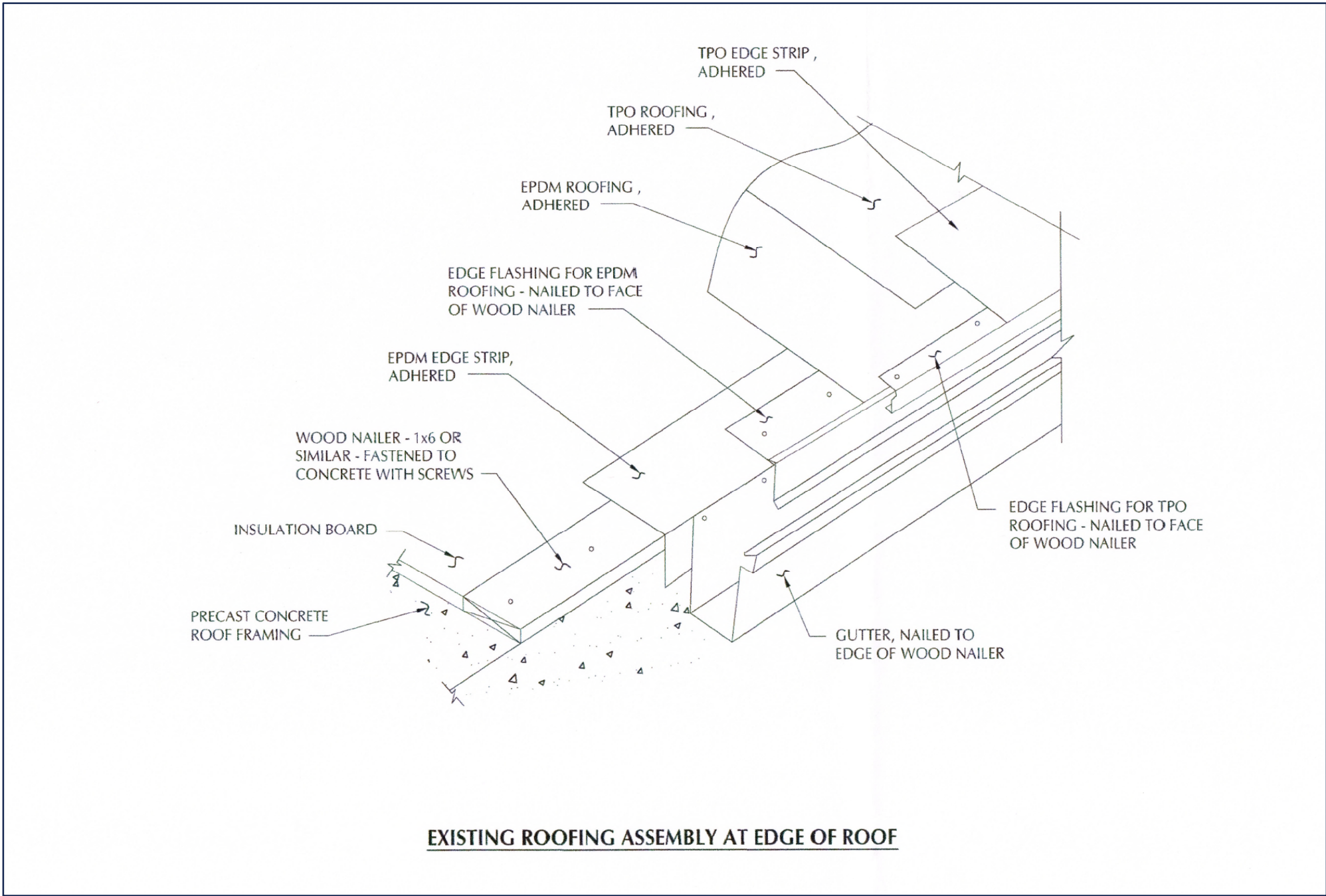


# Case Study: Wind





# Case Study: Wind





# Case Study: Wind



Photographs by Others



# Case Study: Wind





# Case Study: Wind





# Case Study: Snow



Church – Pocatello, ID

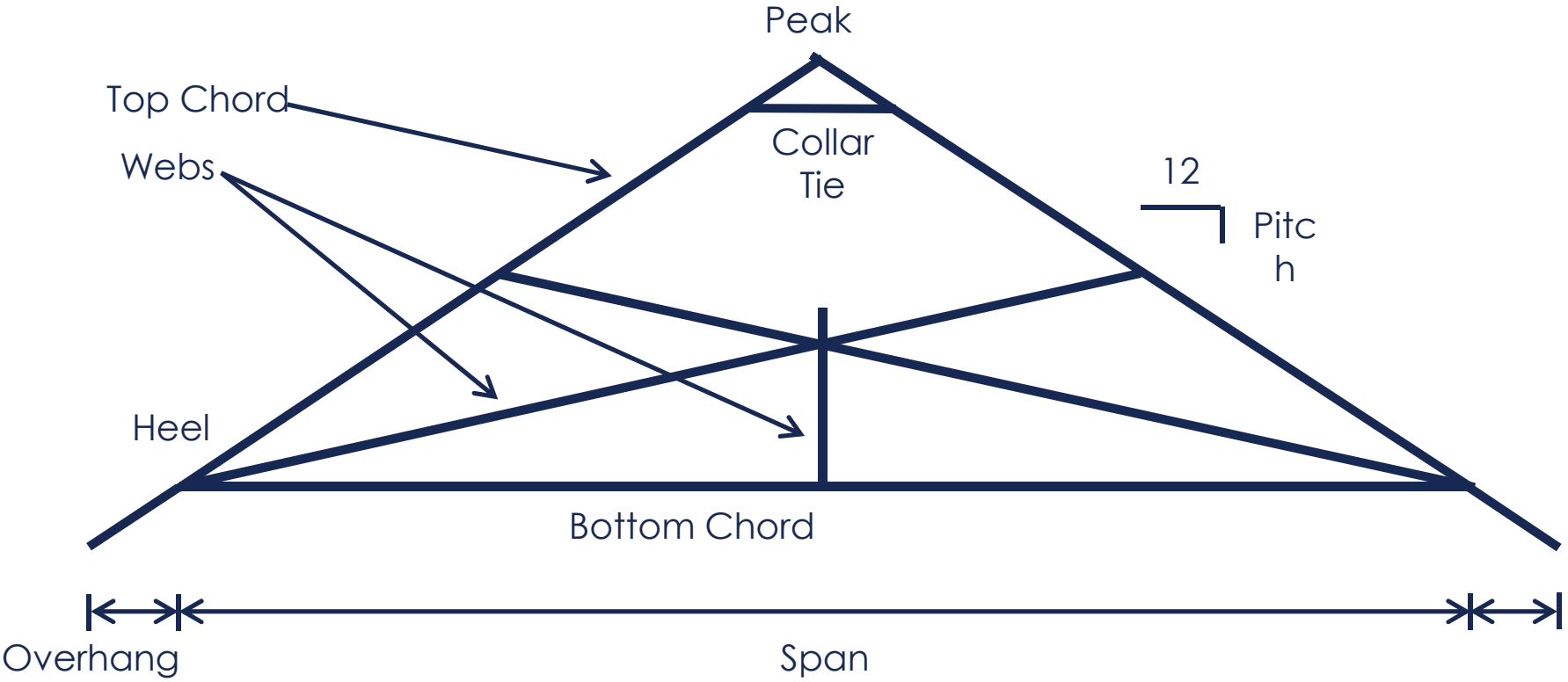


# Case Study: Snow





# Case Study: Snow




Line Diagram of a Typical Roof Truss



# Case Study: Snow

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## Truss Details

- Approximately 36' span w/ 2' overhangs
  - 8:12 pitch (i.e., vertical rise: horizontal run)
  - 24" on center spacing
  - 2x6 chords and webs, 1x8 collar ties
  - 5/8" diameter bolt at visible web-to-chord connections
  - Nailed collar tie connections and splices
- 



# Case Study: Snow





# Case Study: Snow





# Case Study: Snow





# Case Study: Snow

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## Weather Data – NCEI (formerly NCDC)

- Snow data from 1950 – present
- Only events with reported property damage
  - 3" – 5" in October 2007
  - 2" – 4" in November 2011
  - 3" – 7" in November 2014
- Wind data from 1950 – present
  - Multiple events with 58 – 81 mph wind speeds between 1989 - present



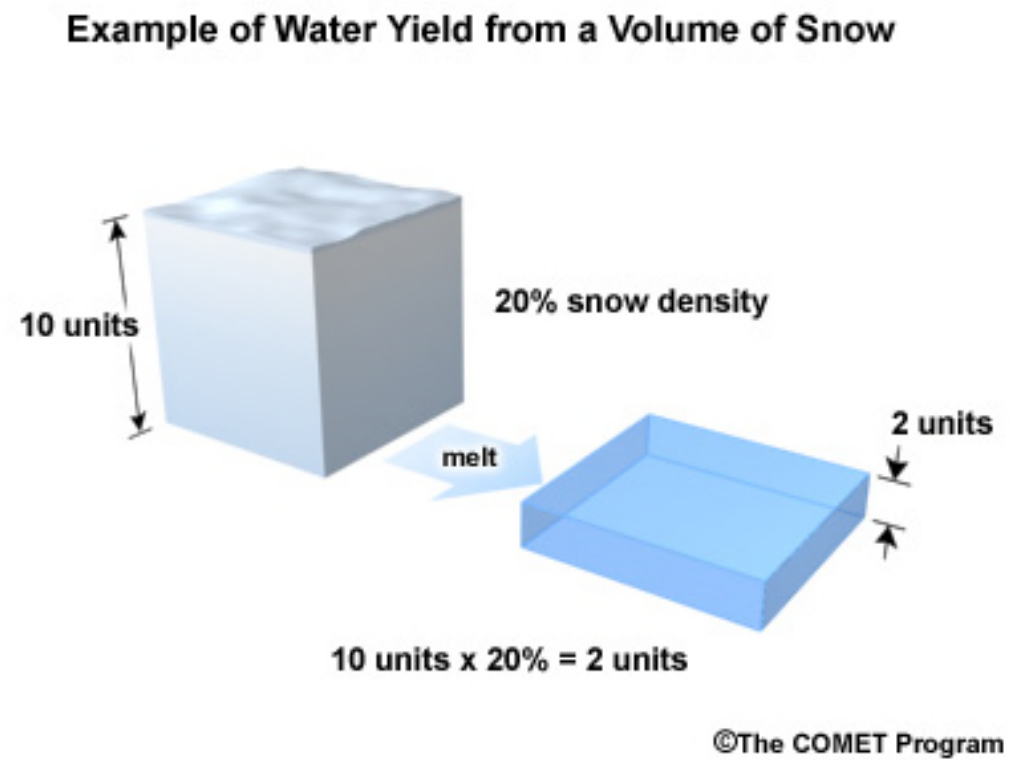
# Case Study: Snow

## Snow:Water Equivalent

- Heavy: 1:1 – 9:1
- Average: 9:1 – 15:1
- Light: > 15:1

(Roebber et al. 2003)

7" of wet snow (5:1) weighs approximately 7 psf.





# Case Study: Fire



Mexican Grocery and Restaurant - Phoenix, AZ (Google Earth Pro 2016)



# Case Study: Fire





# Case Study: Fire





# Case Study: Fire





# Case Study: Fire





# Case Study: Fire





# Case Study: Fire





# Case Study: Fire





# Case Study: Fire



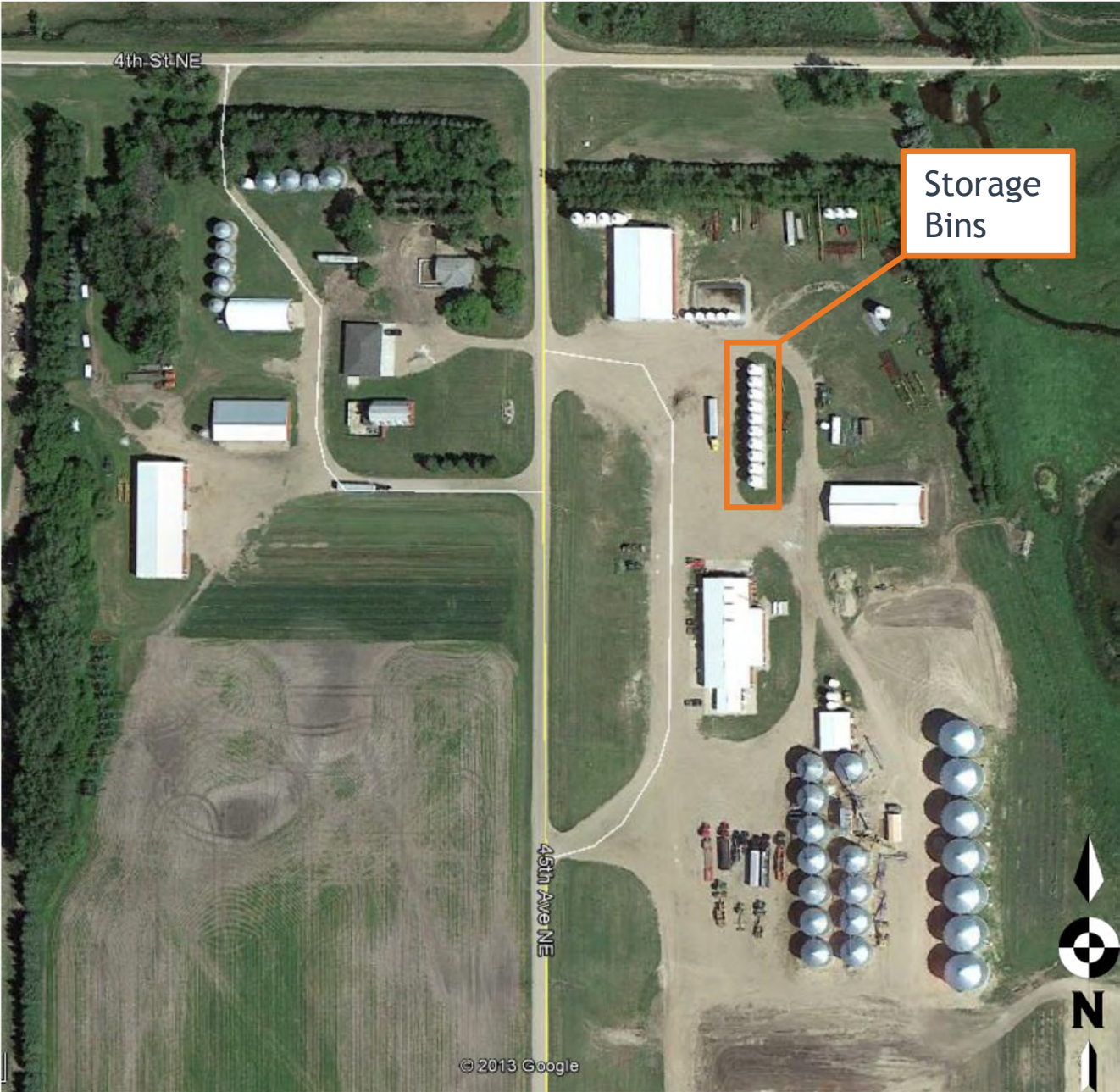


# Case Study: Fire





# Case Study: Collapse



Storage Bin Failure Analysis - North Dakota (Google Earth 2014)



# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse

Figure 2. Typical flow pattern and problem with bulk granular materials such as grains.

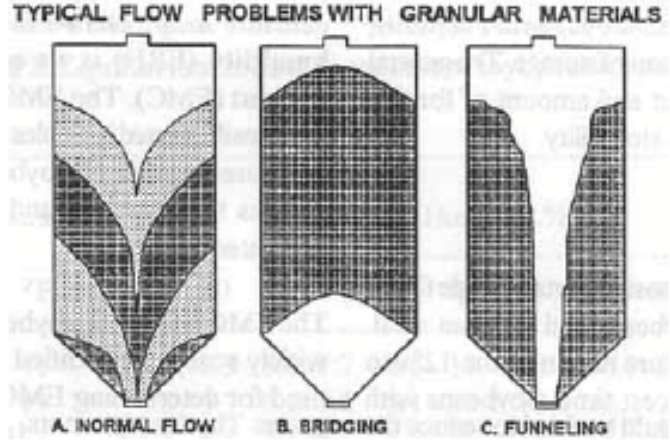
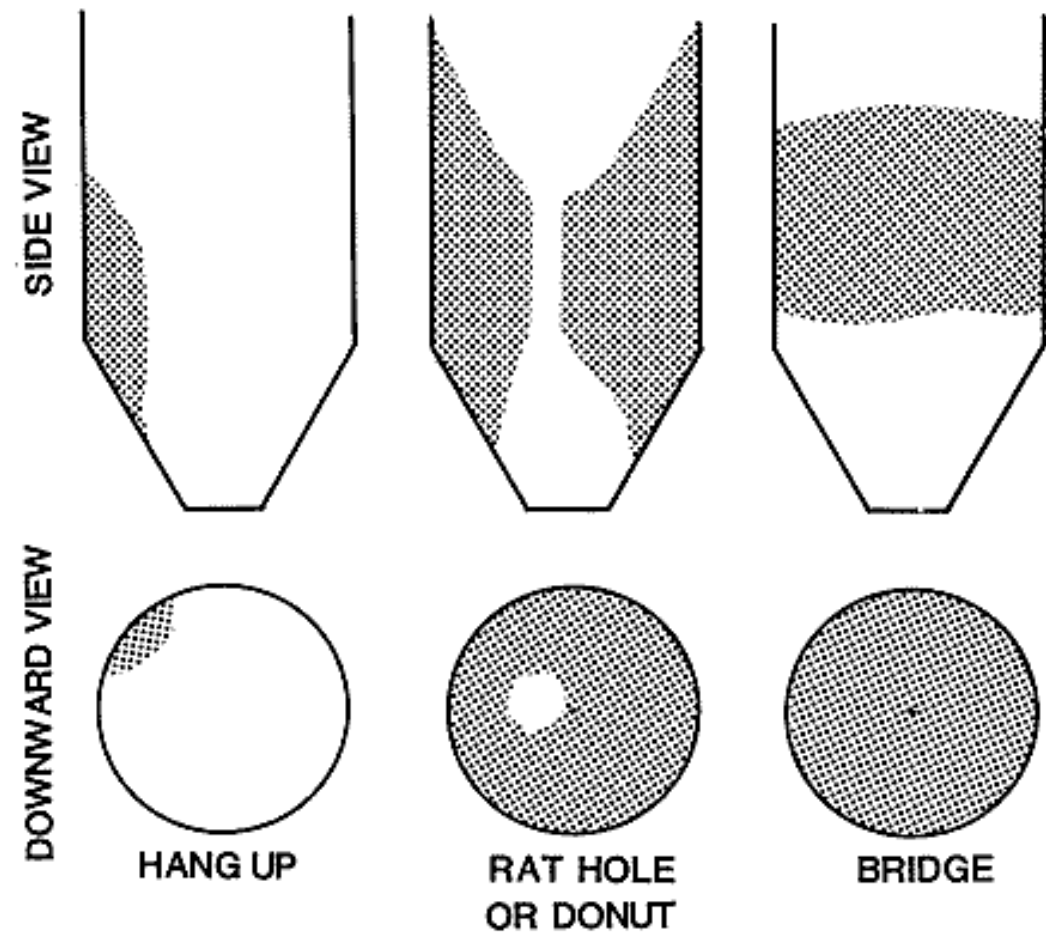
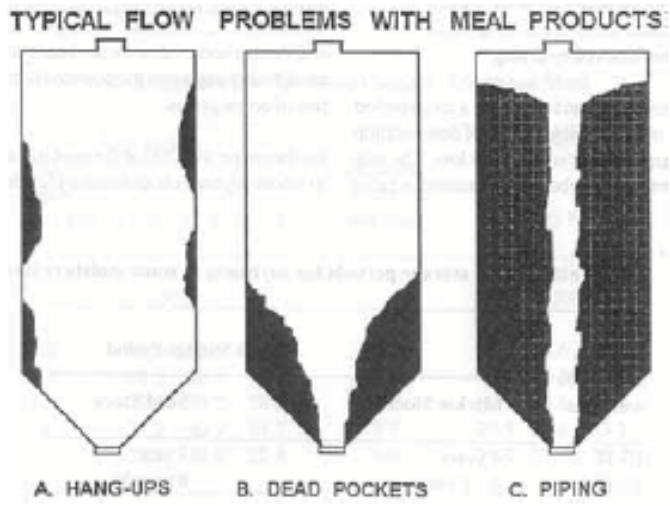


Figure 3. Typical bulk flow problems with meal products during discharge from hopper-bottom silos.





# Case Study: Defect



Making Facility – Northern California



# Case Study: Collapse



Photographs by Others



# Case Study: Collapse



Photographs by Others



# Case Study: Collapse



Photographs by Others



# Case Study: Collapse



Photographs by Others



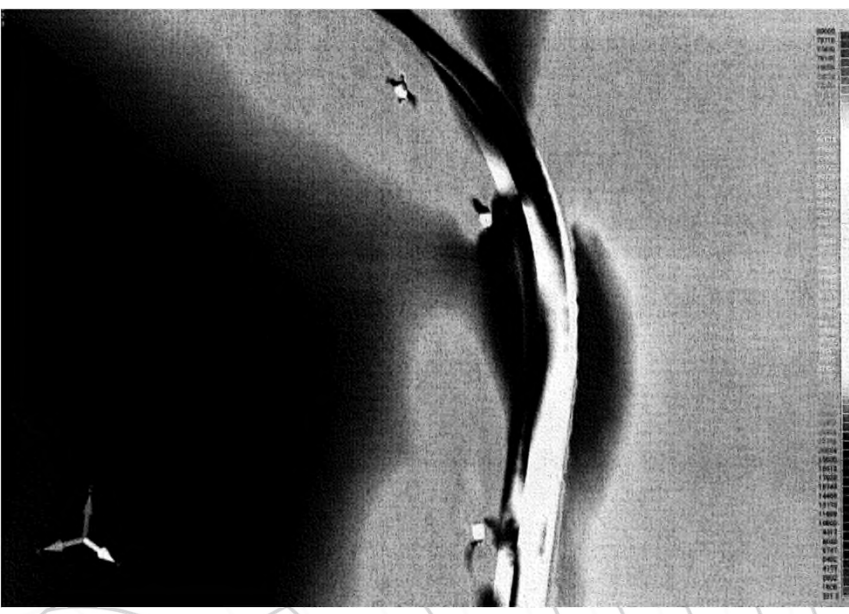
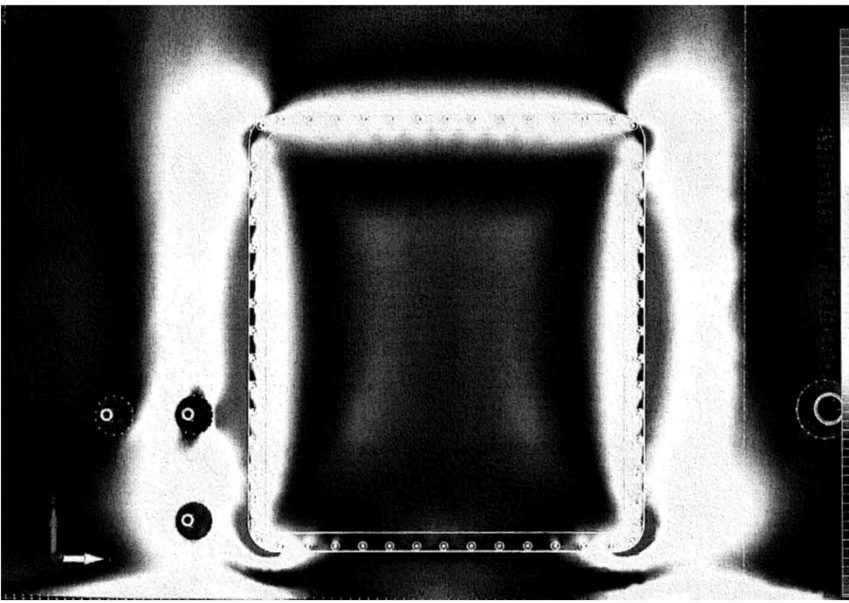
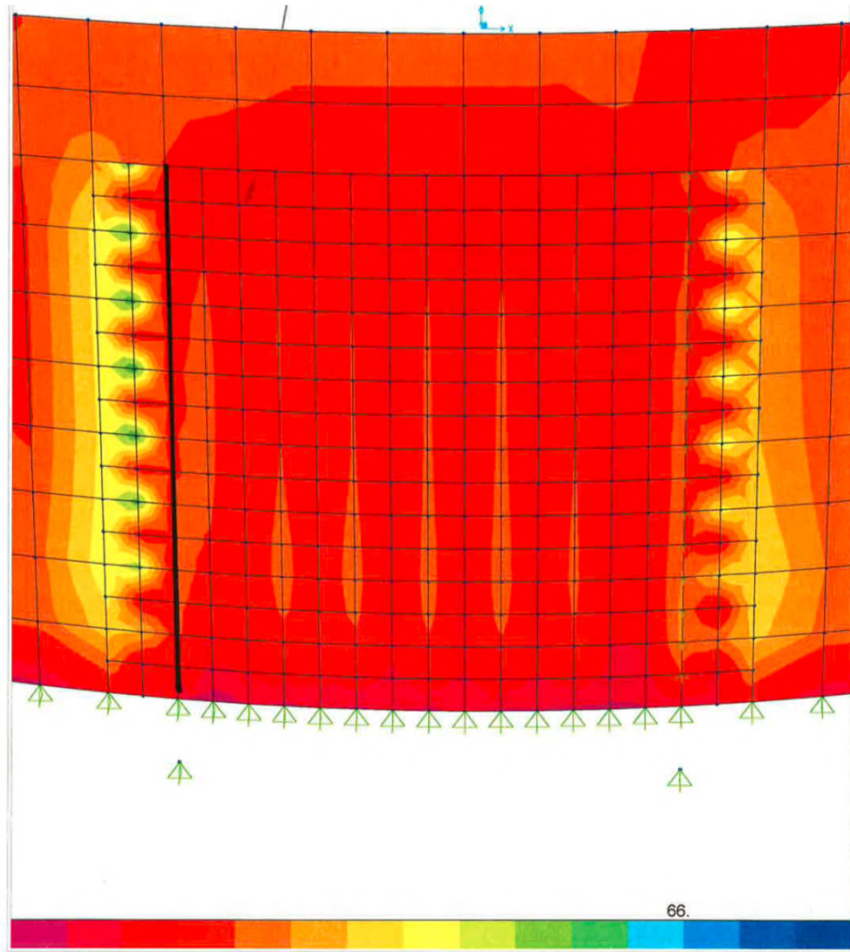
# Case Study: Collapse



Photographs by Others



# Case Study: Collapse



Results of FEA Analysis by Others



# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse





# Case Study: Collapse



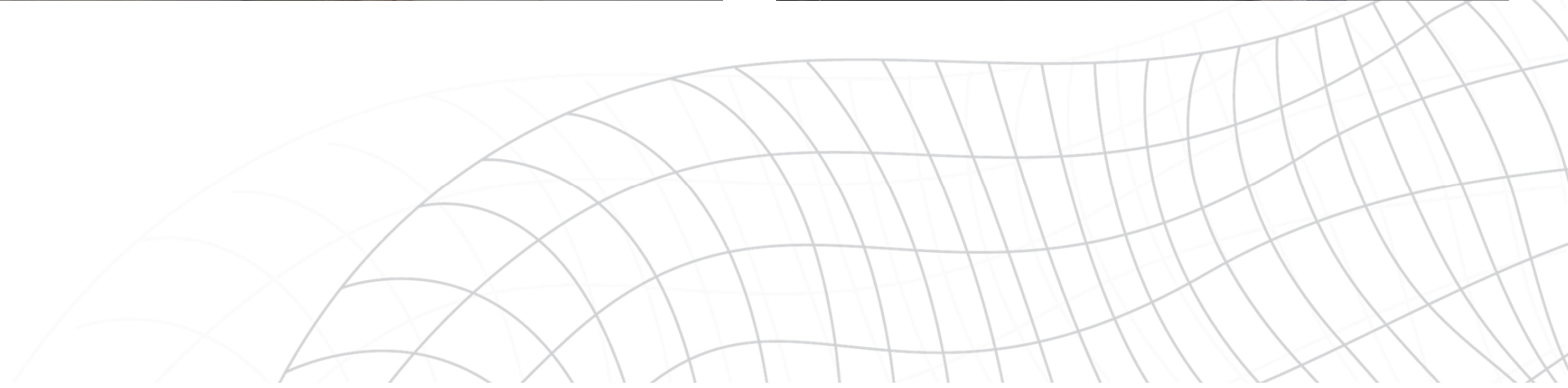


# Case Study: Collapse






# Case Study: Collapse





# Summary

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- Forensic engineering investigations can assist in providing resolution for claims or disputes
  - A typical scope - determine extent, causation, and/or responsibility; provide recommendations for remediation
  - A proper investigation uses the scientific method to *objectively* solve a problem
  - A rational basis should be established for conclusions via a properly substantiated analysis
- 
- A decorative graphic in the bottom right corner consisting of a grid of thin, light gray lines. The grid is composed of both straight and curved lines, creating a complex, wavy pattern that resembles a stylized architectural or engineering drawing.



# Thank you!

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