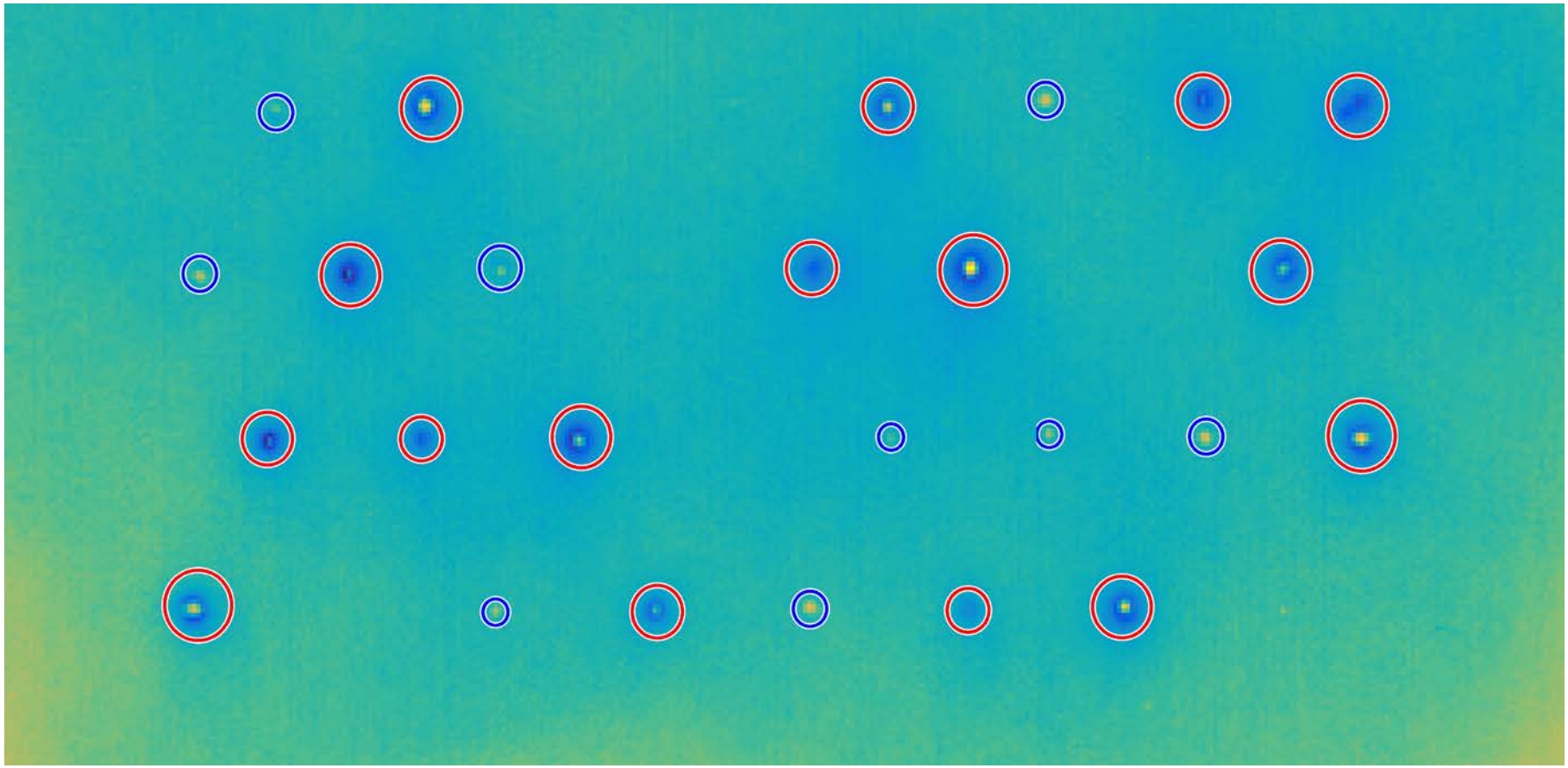
Novel Infiltration Diagnostics based on Laser-line Scanning and Infrared Temperature Field Imaging

(New Project)

2017 Building Technologies Office Peer Review



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: October 01, 2016

Planned end date: September 30, 2018

Key Milestones

1. Milestone 1.1: Accomplishment of system design for laser-spot size variation. (Dec 31, 2016)
2. Milestone 1.2: Demonstration of the infiltration location scanning system. (Mar 31, 2017)

Budget:

Total Project $ to Date:

- DOE: $231,201
- Cost Share: $51,456

Total Project $:

- DOE: $500,000
- Cost Share: $104,232

Key Partners:

Xinwei Wang	Kejin Wang
Mahdi Ramezani	Xiaohui Zhou

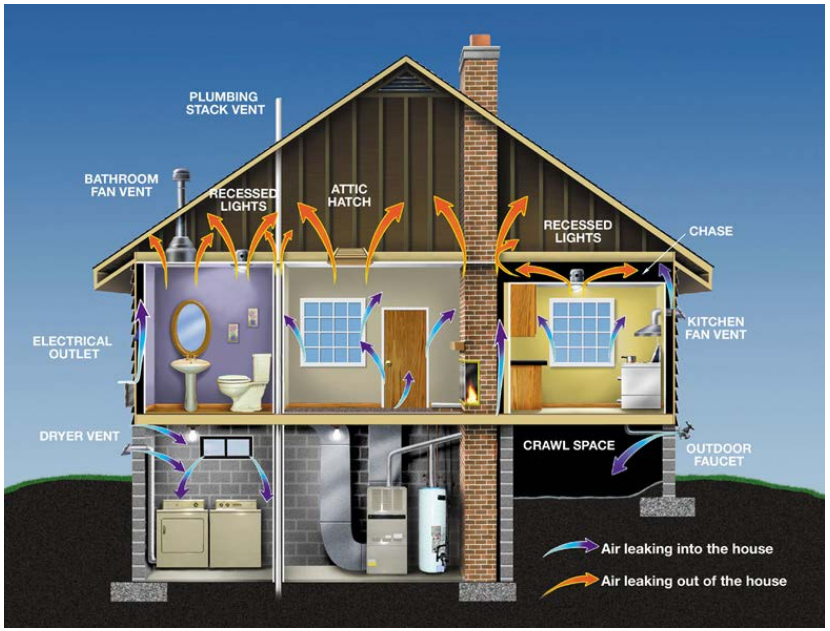
Project Outcome:

The focus of this project is on development of novel infiltration diagnostics methods based on infrared temperature field imaging. A laboratory scale setup capable of maintaining a desired pressure difference was designed and various mock walls were used for data collection. Video and image processing was performed using scanning laser spot heating and liquid spray cooling and criteria for recognition of through hole on the test materials as well as determining infiltration occurrence were developed.

Building air infiltration

Building Technologies Office (BTO)'s Multi-Year Program Plan (MYPP) program of Emerging Technologies (ET)

1. Typical building energy use reduction of 30% by 2020 comparing to 2010.
2. 2025 goal of 35% energy use intensity (EUI) reduction in existing residential buildings.
3. 2025 goal of 30% energy use intensity (EUI) reduction in existing commercial buildings



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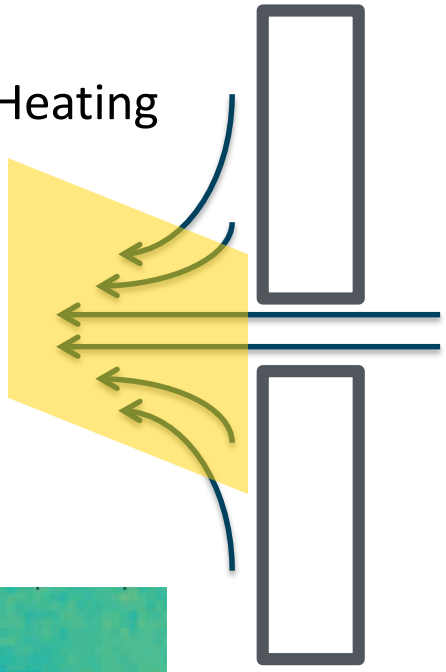
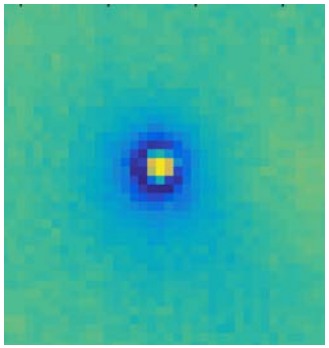
BTO's MYPP (2016-2020)

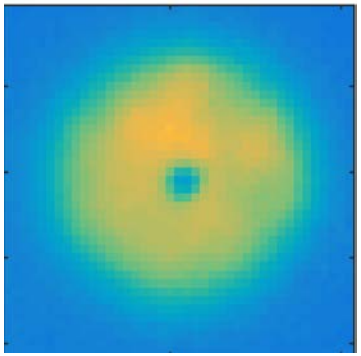
Thermal effects of infiltration/exfiltration

Laser Spot Heating





Liquid spray cooling



Approach

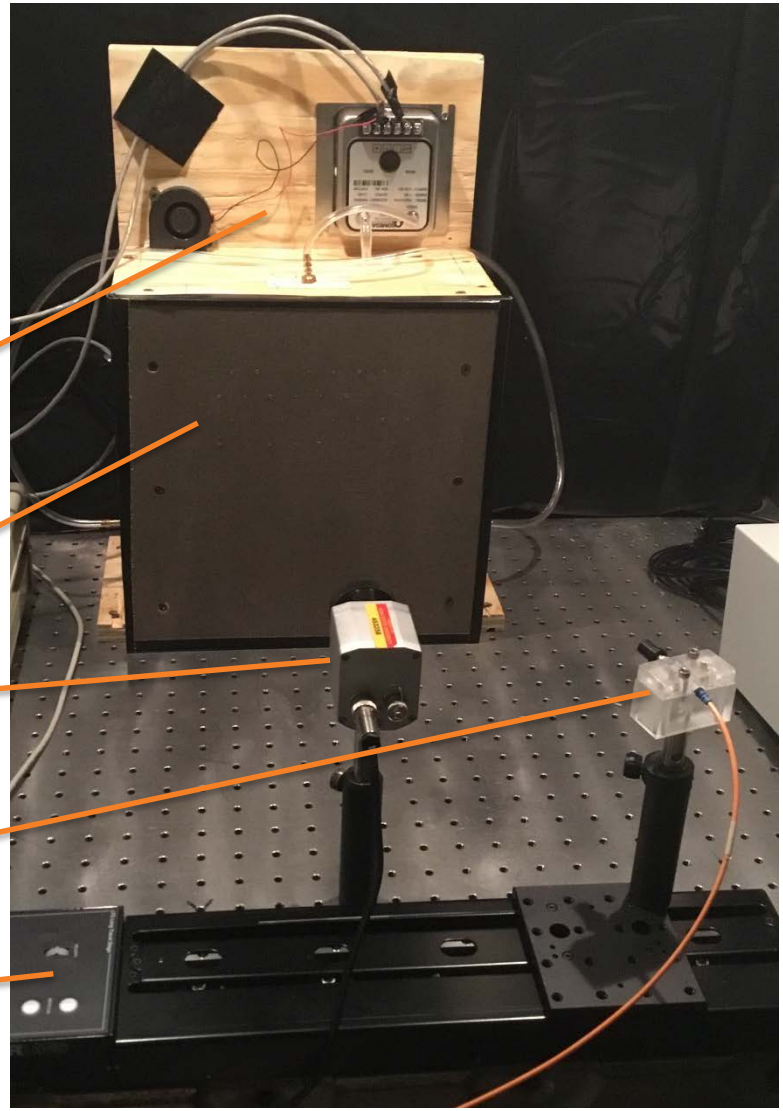
Approach: Our approach is based on videography using infrared camera and analysis of the resulting temperature field for calculation of the local relative heat transfer. Heating with a scanning laser for finding the potential areas and cooling with liquid spray for confirming infiltration zones are used.

Key Issues: As different materials are being tested, an ongoing issue with this method would be to ensure the reliability and robustness of the developed criteria for determining infiltration area.

Distinctive Characteristics: This approach is unique in the sense that it needs minimal setup and tear-down and is not disruptive to occupants due to being applicable from outside the building. Another important aspect of this method is that it does not require an entire building inspection and is applicable to only sections.

Infrared Temperature field videography

A novel infiltration diagnostics method based on infrared temperature field videography, using scanning laser heating and liquid spray cooling.

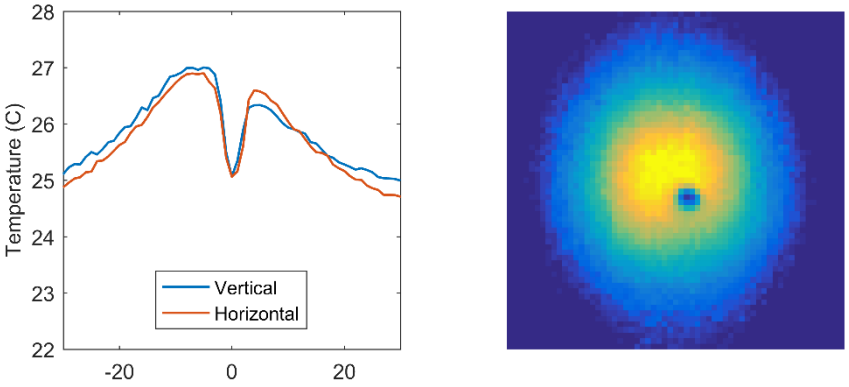


Effective parameters study

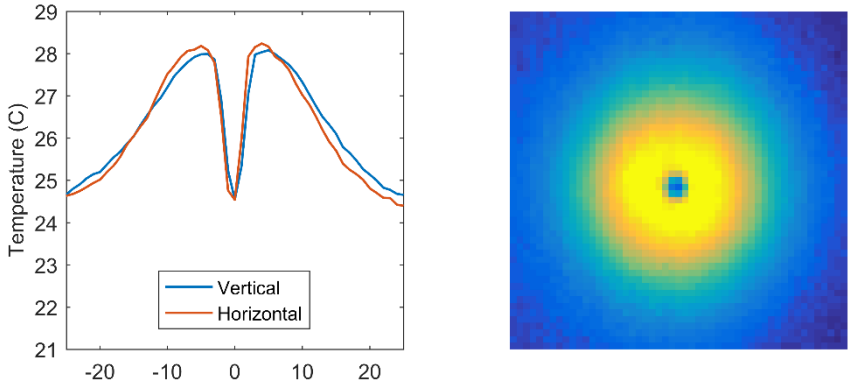
1. **Laser power and spot size** determines the maximum temperature range and heated area size
2. **Camera distance** from the wall affects the resolution of the image (Number of pixels per hole diameter) changed from 3-30 cm
3. **Mock wall materials** of plywood (1/4” thickness) and drywall (5/8” thickness)
4. **Hole size and types** of 0.5, 1.0, 1.5, and 2.0 mm both through and half depth
5. **Pressure difference** was set at 0, 15, and 50 Pa

Laser spot heating temperature field photography

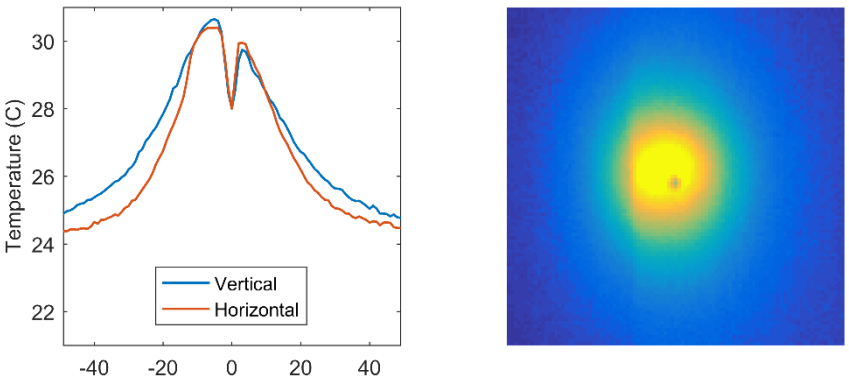
Through hole, Δp = 50 Pa, d = 0.5 mm, l = 6 cm.



Through hole, Δp = 50 Pa, d = 1.5 mm, l = 25 cm.



Half hole, Δp = 50 Pa, d = 0.5 mm, l = 6 cm.



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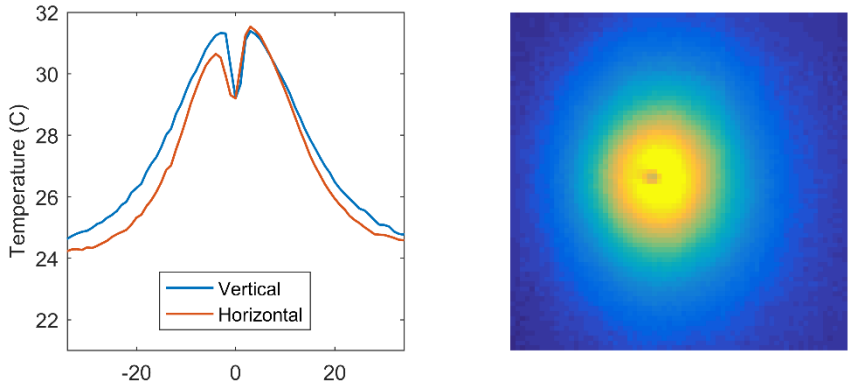
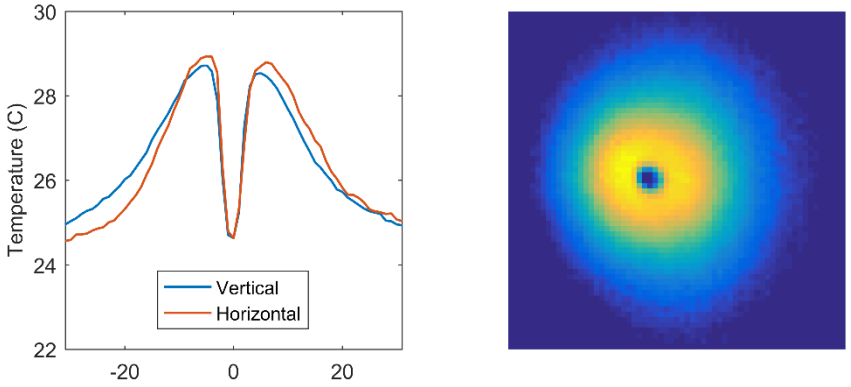
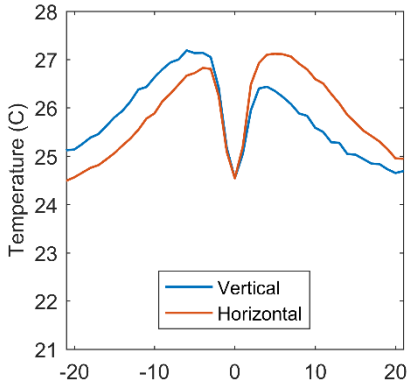


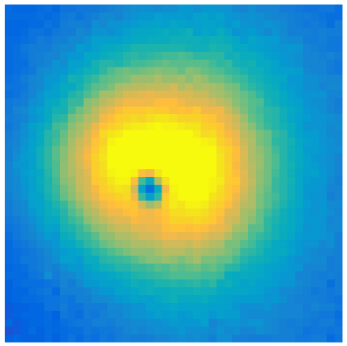
Laser spot heating temperature field photography

Through hole, Δp = 50 Pa, d = 2.0 mm, l = 25 cm.



Through hole, Δp = 50 Pa, d = 2.0 mm, l = 35 cm.





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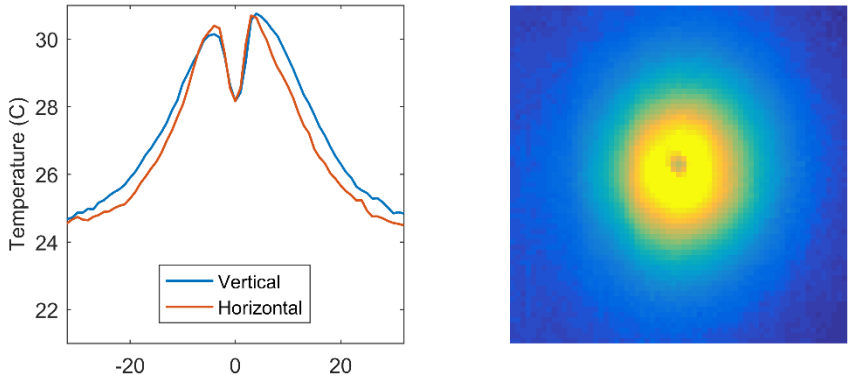

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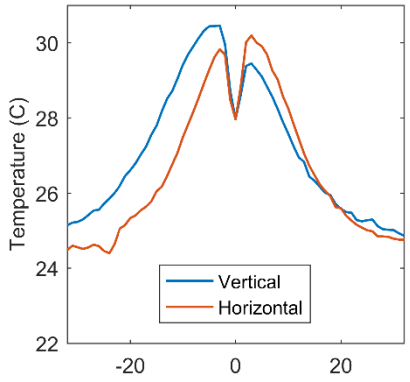
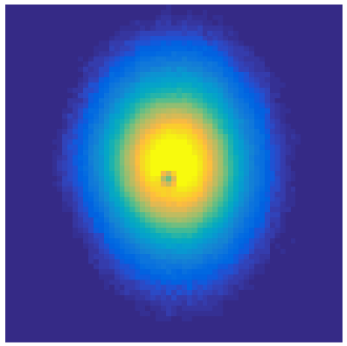
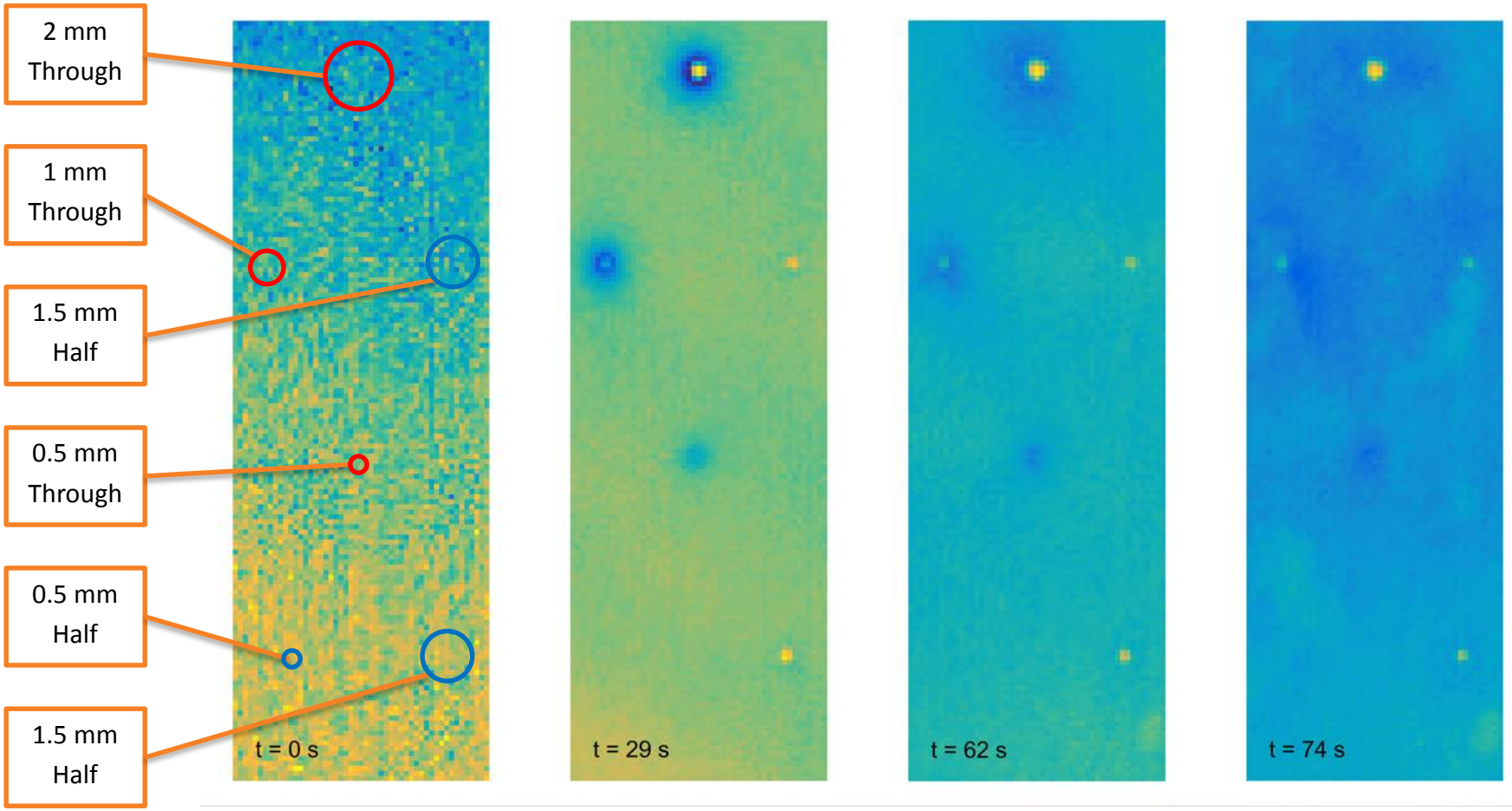




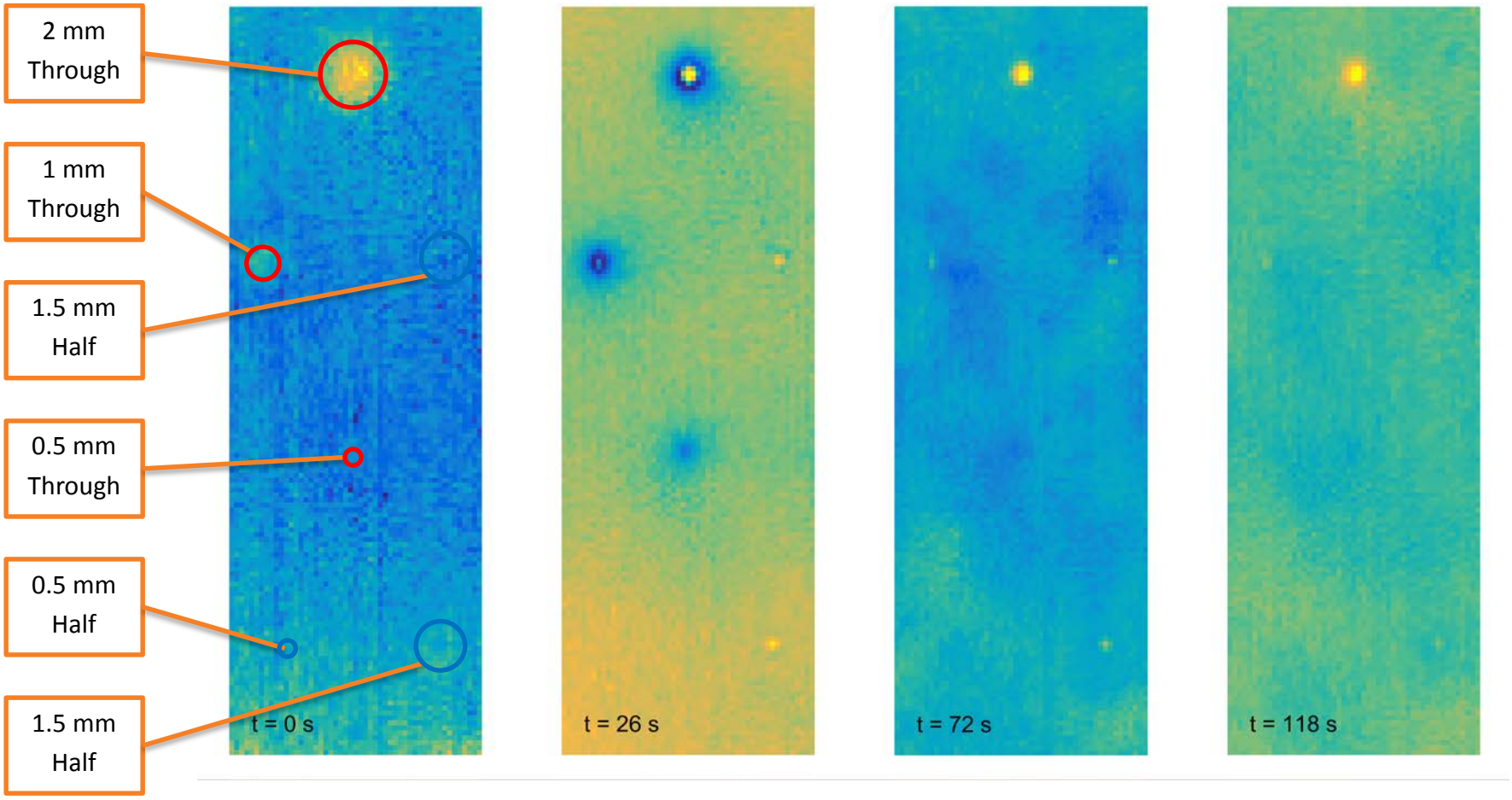
Spray cooling temperature field videography

Drywall, Δp = 15 Pa, Ethanol.



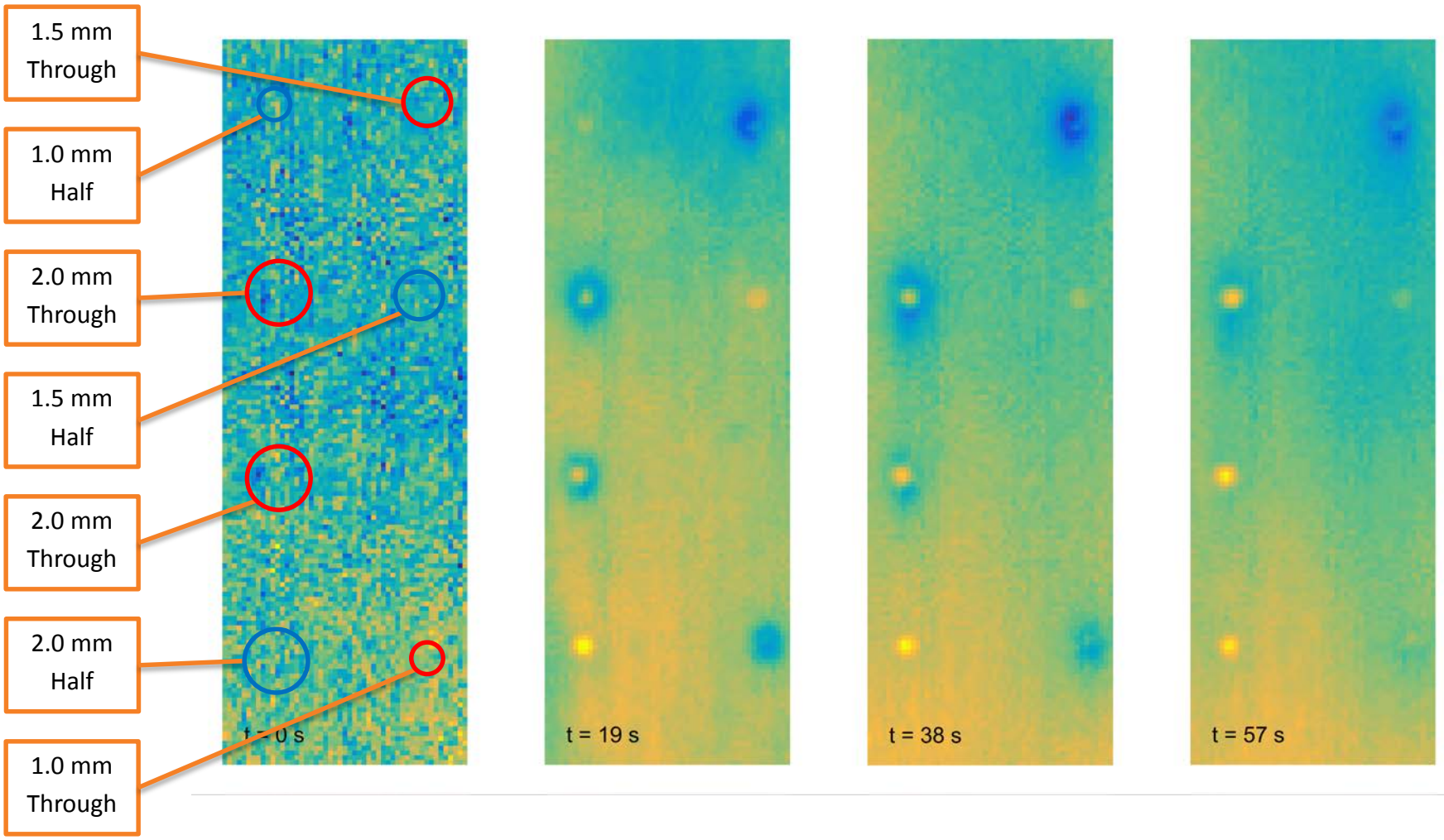
Spray cooling temperature field videography

Drywall, Δp = 50 Pa, Ethanol.



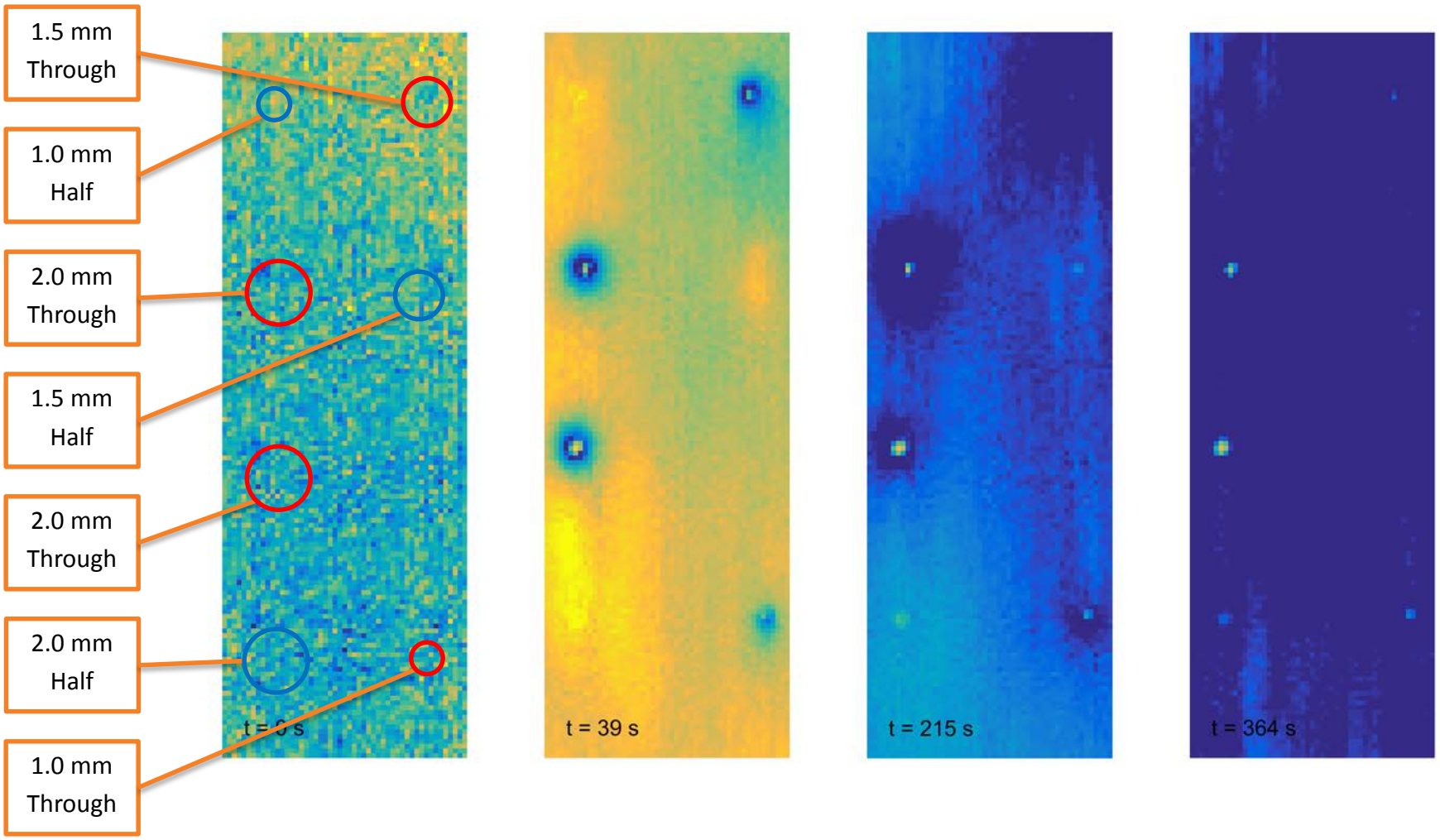
Spray cooling temperature field videography

Plywood, Δp = 15 Pa, Ethanol.

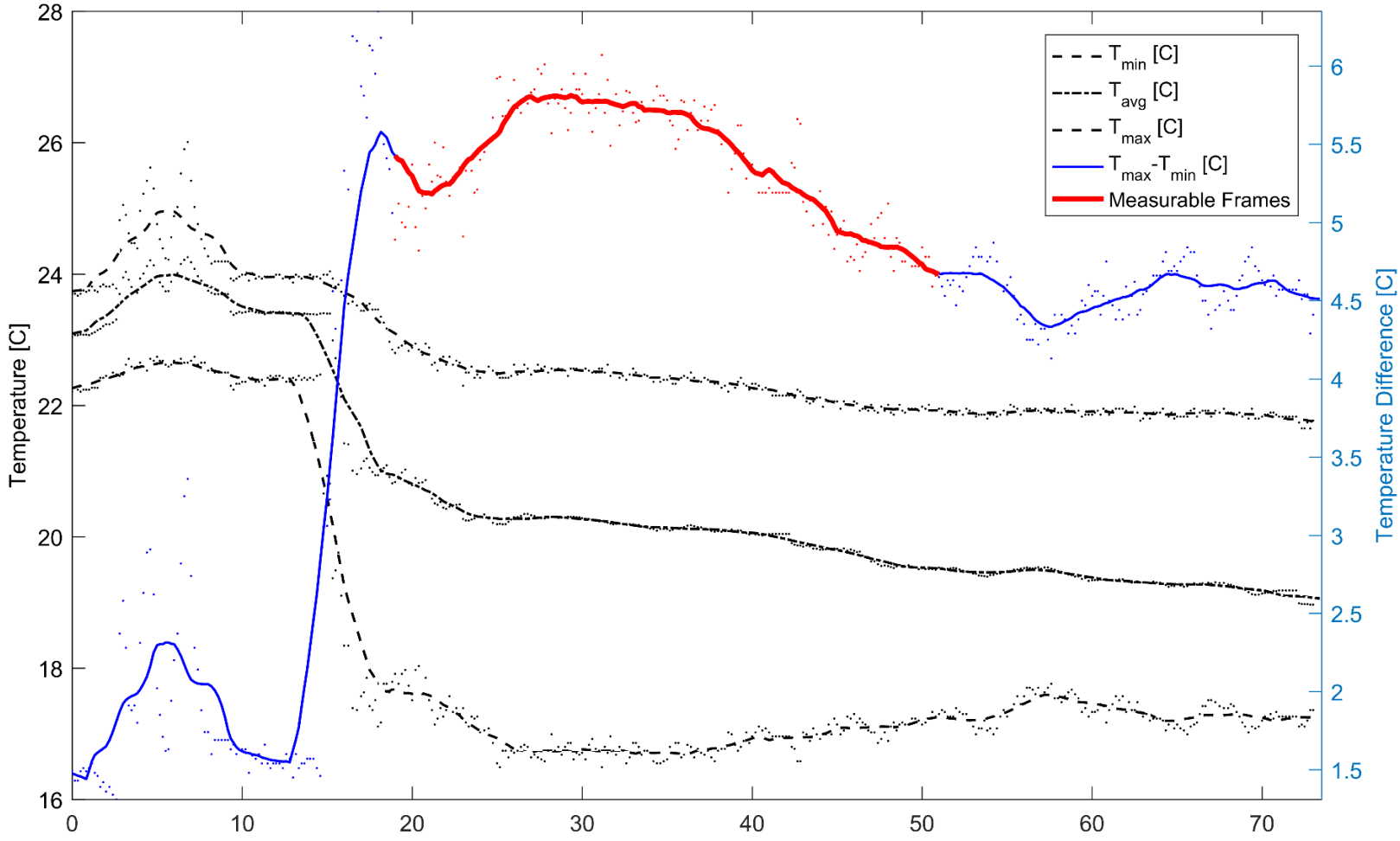


Spray cooling temperature field videography

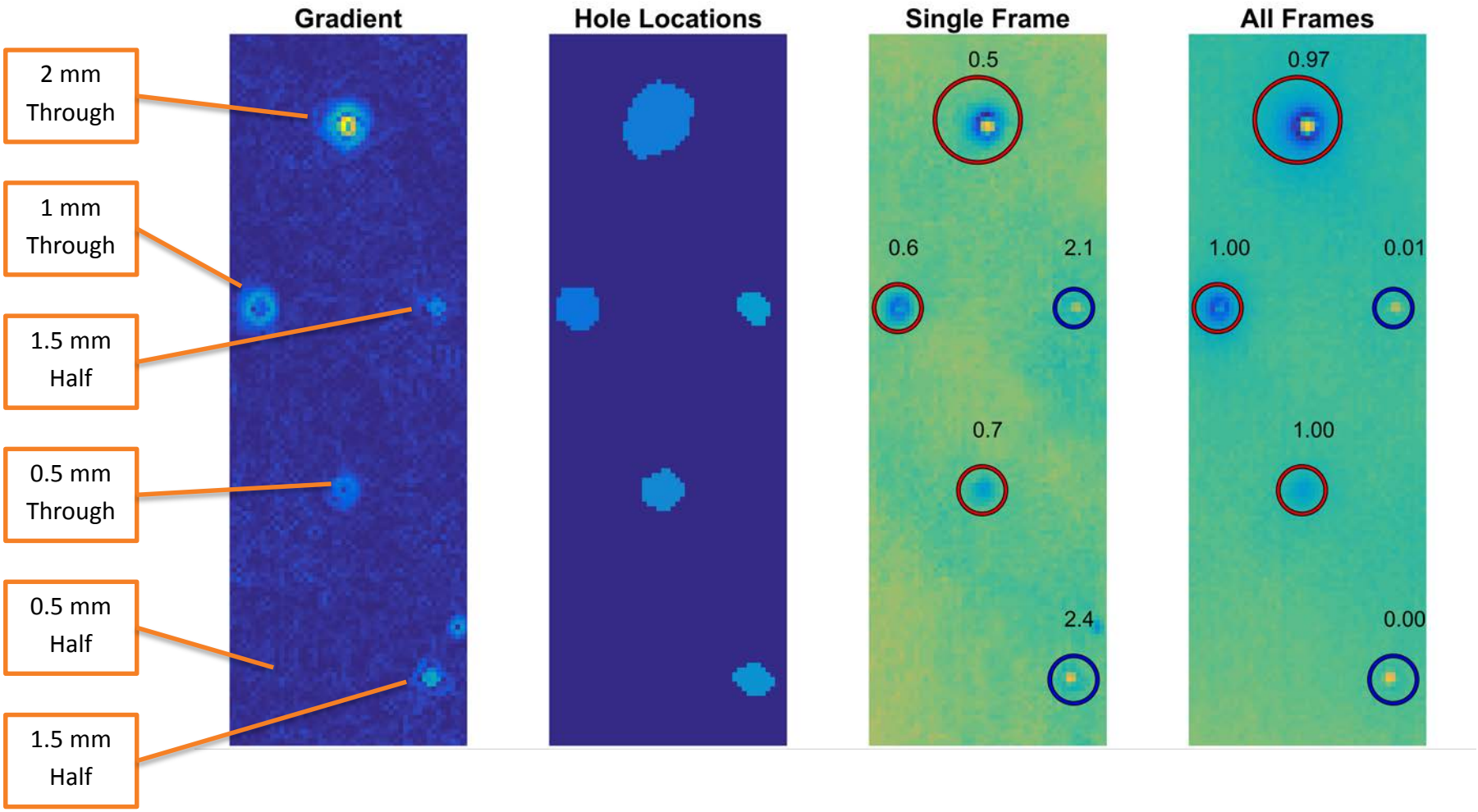
Plywood, Δp = 15 Pa, Water.



Temperature field frame processing



Finding infiltration areas



Progress and Accomplishments

Accomplishments: The experimental setup was designed and set up for testing with various mock walls. Holes of 0.5-2 mm diameter on two different wall materials were tested.

Market Impact: We are still in the very early stages of this project and no market impact is expected at this point.

Awards/Recognition: We are still in the very early stages of this project and no awards or recognitions are yet received.

Lessons Learned: Applicability of this method is found to be highly reliant on the resolution of the infrared camera as the recorded images need a minimum number of pixels per hole area to allow a reliable processing of the images. It was also found out that even though the laser warming can reliably find out suspicious infiltration areas, it is virtually difficult to determine whether there is infiltration in that area of small infiltration site.

Project Integration, Collaboration, and Future Plans

Project Integration: We are still in the very early stages of this project and no major attempt for integration of the project is carried out.

Partners, Subcontractors, and Collaborators: Xinwei Wang/PI. Prof. Kejin Wang and Dr. Xiaohui Zhou/co-PIs. Mahdi Ramezani/post-doctoral fellow

Communications: We are still in the very early stages of this project and no major communications have been disseminated so far.

Next Steps and Future Plans:

We are currently undertaking the following two major tasks:

1- Laser heating scanning of different wall samples
2- Spray cooling imaging of different wall samples
3- Pattern recognition analysis for hole recognition

The following tasks are planned to follow:

1- Integration of computer controlled automation of equipment
2- Pattern recognition analysis for differentiation of crack from aggregate
3- Study and comparison of infiltration versus exfiltration

REFERENCE SLIDES

Project Budget

Variances: N/A.
Cost to Date: $231,201 / $500,000 from DOE
$51,456 / $104,232 from Cost Share
Additional Funding: N/A.

Budget History					
FY 2016 (past)		FY 2017 (current)		FY 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$		$231201	$51456	$268799	$52776

Project Plan and Schedule