Reliable fire detection systems for residents with drug and psychiatric disorders

Presentation master project Jishan Mahmud Rumi,
part of Builder research project
Thursday 15th september 2022

Arjen Kraaijeveld associate prof.
Reliable fire detection systems for residents with drug and psychiatric disorders

“A society will be judged by how it treats its weakest members.”

Harry Truman, 1884-1972, American President [1945-1953]
Key figures

17,580 students
2,000 employees
5 campuses
4 faculties

Førde
Sogndal
Bergen
Stord
Haugesund

Associate Professor Fire Safety, HVL
Part time fire fighter since 2003

bachelor- master
fire safety engineer
Part 1 Introduction
Part 2 Background
Part 3 Methodology
Part 4 Results full scale tests
Part 5 Observations / conclusions

Reliable fire detection systems for residents with drug and psychiatric disorders.

Full scale tests carried out in ‘Hall of flame’ HVL
Part 1 Introduction

At-risk groups, challenges
Research project Builder (Building design for At-risk groups) WP-5:

Research Question:

How can innovation within detection- and extinguishing systems increase the protection of at-risk groups?
Part 1 Introduction At-risk groups

› Vulnerable groups (people belonging to at-risk groups) are over-represented in fire fatalities.

› According to the Norwegian Directorate of Civil Protection reports, almost 75% of victims can be described as vulnerable

› Factors:
  - old age,
  - reduced mobility or cognitive abilities,
  - mental health problems,
  - substance abuse

Ref:
1 Kristin Halvorsen, Petter G. Almlov, Gudveig Gjøsund Fire safety for vulnerable groups: The challenges of cross-sector collaboration in Norwegian municipalities
Residents with Drug and Psychiatric Disorders* (ROP) are over-represented in the at-risk groups. Fatal fire statistics Norway:

- 85% of fatal fires in residential buildings
- Almost half of the fatalities aged between 44-78
- Most fatalities had more than one risk factor such as:
  - known substance abuse
  - alcoholic influence
  - smoking
  - mental illness

* Concurrent Substance Abuse and Mental Health Disorders
In Norway, the municipality is responsible for finding housing for residents with drug and psychiatric disorders. It is hard to find suitable housing.

Regarding fire safety: these are ‘worst case’ residents:

› Fire-setting behavior
› At times destructive behavior, access to tools and equipment
› Living independently, no surveillance
› Hoarding disorder, high fire load in the dwelling
› Disassembling safety equipment
› Suspicious, smoke detectors perceived as surveillance
› Removing manual extinguishers
After a fire, during renovation of the dwelling, where should the resident stay? Difficult to find temporary housing.

Water based systems: secondary damage due to vandalism

Extremely difficult to find appropriate technical solutions

Ref 3 Proceedings SUPDET 2019
Arjen Kraaijeveld HVL Fire Protection of at-risk groups by IG-541 and waterbased sprinklers: Full Scale Tests
After a fire, during renovation of the dwelling, where should the resident stay? Difficult to find temporary housing.

Water based systems: secondary damage due to vandalism

Extremely difficult to find appropriate technical solutions

Pre-action sprinkler with institutional sprinkler heads?
Inert gas + CO₂ based extinguishing?

Ref. Proceedings SUPDET 2019
Arjen Kraaijeveld HVL Fire Protection of at-risk groups by IG-541 and waterbased sprinklers: Full Scale Tests

Reliable fire detection systems for residents with drug and psychiatric disorders, SUPDET 2022
The recent national policy is that these residents should be more integrated in society. There is a demand for customized individual housing for persons belonging to these groups.

Robust housing, at the same time providing the residents a decent home.

Is it possible?
Part 2 Background project

Solutions for pilot housing project
On the West coast of Norway three pilot houses for residents with drug and psychiatric disorders will be build. Financed by Karmøy municipality and The Research Council of Norway.

› Innovating solutions must be incorporated into the pilots.

› Architect: Snøhetta
  (National September 11 Memorial Museum & Pavilion at the World Trade Center site)

› Research: Norwegian Research centre (Norce) & Western Norway University of Applied Science (HVL)

Master thesis (2022) Reliable fire detection systems for residents with drug and psychiatric disorders by Jishan Mahmud Rumi

› external tutor Cristina Sanfeliu Meliá
  RISE Fire Research Trondheim Norway (FRIC project 4.3)
Part 2 Background regulations

Norwegian Building Acts and Regulations

› Residents with drug and psychiatric disorders cannot always evacuate unassisted, therefore these buildings must be designed as hazard class 6 buildings (like hotels, prisons, etc.)

› demand for:
  fire detection and alarm system
  fire extinguishing system
  (deviation is possible)

expensive for single houses

Ref. kommunal- og moderniseringsdepartementet, Regulations on technical requirements for construction works (TEK17)
GAP analysis performed by HVL revealed the following:

› A smoke detector must not be sensitive to cigarette smoke and other types of pollution. (narcotic fume/excessive cooking smoke)

› Detectors or alarms shall be least visible and accessible to the user. Due to the obstructive behavior of residents.

› The smoke detectors or alarms must preferably be able to be tested without having to enter the ROP home and have minimal maintenance requirements.

› It is not possible to install manual extinguishing equipment in the dwelling. Due to misuse of equipment.

› Important with automatic early intervention and avoiding secondary damage
Hypothesis: An aspiration system combined with an CO sensor will be able to detect fires, avoid unwanted fire signals and unwanted activations of the automatic extinguishing system.

› Aspiration systems with a CO sensor are currently not on the market, we combined a commercially available aspiration system with a multi-sensor point detector.

› Aspiration system installed in technical room. Suction point in bedroom and combined living room/kitchen. A multi-sensor detector (heat, optical and CO) connected to the exhaust from the aspiration system.

› In addition, multi-sensor detectors in the bedroom and combined living room / kitchen

Objective: mapping the performance of the multi-sensor detectors inside the dwelling vs. aspiration system + multi-sensor detector outside the dwelling (in the technical room)
Part 2 Background concept

Detection system with different alarm stages
› easy to maintain outside the dwelling
› hardly visible inside the dwelling
› difficult to destroy

Extinguishing system
› IG-541 system (INERGEN) with extended discharge
› Activates when fire brigade is on the way
Part 3 Methodology

Full-scale tests in dummy apartment
Part 3 Methodology, apartment

Dummy apartment, built in ‘Hall of flame’

› Dimensions 7.4m × 4.7m × 2.4m (l × w× h), footprint appr. 35 m² (400 ft²)
(25 ft. x 16 ft. x 8 ft)

› Balanced mechanical ventilation system
Part 3 Methodology, equipment

Dummy apartment, built in ‘Hall of flame’

<table>
<thead>
<tr>
<th>Pc.</th>
<th>Manufacturer/brand</th>
<th>Type of equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zettler P405D</td>
<td>Addressable fire alarm control panel</td>
</tr>
<tr>
<td>1</td>
<td>Inergen system HH Fire Eater</td>
<td>Extended discharge system 2+1 cylinders, 80 liter</td>
</tr>
<tr>
<td>2</td>
<td>Zettler 830PC (516.830.054)</td>
<td>Multi-sensor detector: CO, optical and heat</td>
</tr>
<tr>
<td>3</td>
<td>No-flame household smoke detector</td>
<td>Photo electric smoke detector</td>
</tr>
</tbody>
</table>

Reliable fire detection systems for residents with drug and psychiatric disorders, SUPDET 2022
Dummy apartment, built in ‘Hall of flame’

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<td>Multi-sensor detector: CO, optical and heat</td>
</tr>
<tr>
<td>1</td>
<td>Vesda laser compact</td>
<td>Aspiration unit</td>
</tr>
<tr>
<td>1</td>
<td>Zettler P405D</td>
<td>Addressable fire alarm control panel</td>
</tr>
<tr>
<td>1</td>
<td>Inergen system HH Fire Eater</td>
<td>Extended discharge system</td>
</tr>
</tbody>
</table>

- Sensibility 2.6% obs./m optical
- Sensibility 2.6% obs./m optical
- 40 ppm CO
Dummy apartment, built in ‘Hall of flame’

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<th>Manufacturer / brand</th>
<th>Type of equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>K element thermocouples, thermosense UK</td>
<td>Logging temperatures</td>
</tr>
<tr>
<td>3</td>
<td>Dräger X-am 8000 multi-gas instrument</td>
<td>Logging O₂, CO₂ and CO in living room, bedroom and in exhaust aspiration</td>
</tr>
<tr>
<td>3</td>
<td>TRIACLE action camera 1080P SI</td>
<td>Recording experiments /visibility</td>
</tr>
</tbody>
</table>
Dummy apartment, built in ‘Hall of flame’

Aspiration air inlet
Part 3 Methodology, equipment

Dummy apartment, built in ‘Hall of flame’
Balanced ventilation system, very high capacity (6x normal ventilation rate)
› Air inlet 400 m$^3$/h living room. Air inlet bedroom 100 m$^3$/h
› Extraction 400 m$^3$/h kitchen, extraction 100 m$^3$/h bathroom.
Part 3 Methodology, scenarios

- Test carried out following NS-EN 54-7 (Annex G-J)
  Fire detection and fire alarm systems - Part 7:
  Smoke detectors - Point smoke detectors that operate using scattered light, transmitted light or ionization
  Some deviations to make the scenarios more realistic

<table>
<thead>
<tr>
<th>Fire Scenario</th>
<th>Test No</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trial 1: March 2022</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Smoldering (Pyrolysis) Wood Fire (With no ventilation)</td>
<td>101_1 to 101_4</td>
<td>Kitchen</td>
</tr>
<tr>
<td>2 Glowing Smoldering cotton Fire (With no ventilation)</td>
<td>102_1 to 102_4</td>
<td>Living room</td>
</tr>
<tr>
<td>3 Burning Polyurethane (With no ventilation)</td>
<td>103_1 to 103_4</td>
<td>Living room</td>
</tr>
<tr>
<td>4 Burning Heptane (With no ventilation)</td>
<td>104_1 to 104_4</td>
<td>In between Kitchen &amp; living room</td>
</tr>
<tr>
<td><strong>Trial 2: May 2022</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Smoldering Wood Fire (with ventilation System)</td>
<td>201_1 to 201_4</td>
<td>Kitchen</td>
</tr>
<tr>
<td>6 Slow Smoldering Cotton Fire (With ventilation System)</td>
<td>202_1 to 202_4</td>
<td>Living room</td>
</tr>
<tr>
<td>7 Burning Polyurethane (With ventilation system)</td>
<td>203_1 to 203_4</td>
<td>Bedroom</td>
</tr>
<tr>
<td>8 Burning Heptane Fire (With ventilation System and extended spread of Fire)</td>
<td>204_1 to 204_4</td>
<td>In between Kitchen &amp; living room</td>
</tr>
<tr>
<td>9 Smoking Cigar</td>
<td>205</td>
<td>Bedroom &amp; Living Room</td>
</tr>
</tbody>
</table>
Part 3 Methodology, scenarios

Smoldering (Pyrolysis) Wood Fire (With no ventilation) (101_1 to 101_4)

Slow Smoldering Cotton Fire (With ventilation System) (202_1 to 202_4)
Scenario 9:

- extended smoking should not lead to detection
Part 4 results

Full scale tests
pre-test with flaming fire

1. Ignition
2. Pre warning aspiration
3. Aspiration alarm
4. Multi sensor optical
5. Multi sensor heat
10. CO alarm exhaust
14. Optical
15. Activation extinguishing system

CO measurement

Exhaust
Livingroom

Part 4 Results full scale tests

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Part 4 Results full scale tests

No. of detector sensors activated in tests

Not activated during 2 tests with ventilation + sigar smoking
### Timeline of smoke detection & fire extinguishing system activation for scenario 1

- **Smoldering (pyrolysis) wood fire (no ventilation)**

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Pre-Alarm Aspiration</th>
<th>Aspiration Detector</th>
<th>Multi-sensor (Outside) Optical Detection</th>
<th>Multi-sensor (Outside) CO Detection</th>
<th>Multi-sensor (Living Room) Optical Detection</th>
<th>Multi-sensor (Living Room) CO Detection</th>
<th>Photoelectric Detection</th>
<th>Living Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>101_1</td>
<td>0:02:49</td>
<td>0:03:05</td>
<td>0:10:27</td>
<td>0:09:40</td>
<td>0:04:39</td>
<td>0:06:00</td>
<td>0:03:40</td>
<td></td>
</tr>
<tr>
<td>101_2</td>
<td>0:02:45</td>
<td>0:02:54</td>
<td>0:06:16</td>
<td>N/A</td>
<td>0:04:30</td>
<td>0:06:21</td>
<td>0:04:30</td>
<td></td>
</tr>
<tr>
<td>101_3</td>
<td>0:02:55</td>
<td>0:03:03</td>
<td>0:06:48</td>
<td>N/A</td>
<td>0:04:11</td>
<td>0:06:22</td>
<td>0:03:47</td>
<td></td>
</tr>
<tr>
<td>101_4</td>
<td>0:02:26</td>
<td>0:02:32</td>
<td>0:03:59</td>
<td>0:05:45</td>
<td>0:03:04</td>
<td>0:03:59</td>
<td>0:03:15</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0:02:44</td>
<td>0:02:53</td>
<td>0:06:53</td>
<td>0:07:42</td>
<td>0:04:06</td>
<td>0:05:41</td>
<td>0:03:48</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0:00:11</td>
<td>0:00:13</td>
<td>0:02:19</td>
<td>0:01:57</td>
<td>0:00:37</td>
<td>0:00:59</td>
<td>0:00:27</td>
<td></td>
</tr>
<tr>
<td>CV %</td>
<td>6.625</td>
<td>7.543</td>
<td>33.736</td>
<td>25.405</td>
<td>15.120</td>
<td>17.403</td>
<td>11.846</td>
<td></td>
</tr>
</tbody>
</table>
Part 4 Results full scale tests

Timeline of smoke detection & fire extinguishing system activation for scenario 1

- Smoldering (pyrolysis) wood fire (no ventilation)

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Pre-Alarm Aspiration</th>
<th>Aspiration Detector</th>
<th>Multi-sensor (Outside) Optical Detection</th>
<th>Multi-sensor (Outside) CO Detection</th>
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<th>Multi-sensor (Living Room) CO Detection</th>
<th>Photoelectric Detection Living Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>101_1</td>
<td>0:02:49</td>
<td>0:03:05</td>
<td>0:10:27</td>
<td>0:09:40</td>
<td>0:04:39</td>
<td>0:06:00</td>
<td>0:03:40</td>
</tr>
<tr>
<td>101_2</td>
<td>0:02:45</td>
<td>0:02:54</td>
<td>0:06:16</td>
<td>N/A</td>
<td>0:04:30</td>
<td>0:06:21</td>
<td>0:04:30</td>
</tr>
<tr>
<td>101_3</td>
<td>0:02:55</td>
<td>0:03:03</td>
<td>0:06:48</td>
<td>N/A</td>
<td>0:04:11</td>
<td>0:06:22</td>
<td>0:03:47</td>
</tr>
<tr>
<td>101_4</td>
<td>0:02:26</td>
<td>0:02:32</td>
<td>0:03:59</td>
<td>0:05:45</td>
<td>0:03:04</td>
<td>0:03:59</td>
<td>0:03:15</td>
</tr>
<tr>
<td>Mean</td>
<td>0:02:44</td>
<td>0:02:53</td>
<td>0:06:53</td>
<td>0:07:42</td>
<td>0:04:06</td>
<td>0:05:41</td>
<td>0:03:48</td>
</tr>
<tr>
<td>SD</td>
<td>0:00:11</td>
<td>0:00:13</td>
<td>0:02:19</td>
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<td>0:00:37</td>
<td>0:00:59</td>
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<td>25.405</td>
<td>15.120</td>
<td>17.403</td>
<td>11.846</td>
</tr>
</tbody>
</table>

Activation Extinguishing system 0:07:42
### Timeline of smoke detection & fire extinguishing system activation for scenario 5

#### Smoldering (pyrolysis) wood fire (with ventilation)

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Pre-Alarm Aspiration</th>
<th>Aspiration Detector</th>
<th>Multi-sensor (Outside) Optical Detection</th>
<th>Multi-sensor (Living Room) Optical Detection</th>
<th>Multi-sensor (Living Room) CO Detection</th>
<th>Photoelectric Detector (Living Room)</th>
</tr>
</thead>
<tbody>
<tr>
<td>201_1</td>
<td>0:05:02</td>
<td>0:05:40</td>
<td>0:14:38</td>
<td>0:06:01</td>
<td>0:09:07</td>
<td>0:05:10</td>
</tr>
<tr>
<td>201_2</td>
<td>0:05:22</td>
<td>0:07:13</td>
<td></td>
<td>0:09:21</td>
<td></td>
<td>0:05:34</td>
</tr>
<tr>
<td>201_3</td>
<td>0:09:10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0:09:03</td>
</tr>
<tr>
<td>201_4</td>
<td>0:05:50</td>
<td>0:06:21</td>
<td>0:10:05</td>
<td>0:09:09</td>
<td>0:06:15</td>
<td>0:07:36</td>
</tr>
<tr>
<td>Mean</td>
<td>0:06:21</td>
<td>0:06:25</td>
<td>0:10:05</td>
<td>0:11:53</td>
<td>0:07:12</td>
<td>0:08:22</td>
</tr>
<tr>
<td>SD</td>
<td>0:01:39</td>
<td>0:00:38</td>
<td>0:00:00</td>
<td>0:02:45</td>
<td>0:01:31</td>
<td>0:00:46</td>
</tr>
<tr>
<td>CV(%)</td>
<td>26.00</td>
<td>9.89</td>
<td>0.00</td>
<td>23.06</td>
<td>21.09</td>
<td>9.07</td>
</tr>
</tbody>
</table>

Activation: 0:11:53

Extinguishing system: 0:11:53

Reliable fire detection systems for residents with drug and psychiatric disorders, SUPDET 2022

Part 4 Results full scale tests
# Part 4 Results full scale tests

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Aspiration Detection</th>
<th>Multi-sensor Detector</th>
<th>Photoelectric Detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Efficiency</td>
<td>95%</td>
<td>96.87%</td>
<td>100%</td>
</tr>
<tr>
<td>Early Detection Rate</td>
<td>43.87%</td>
<td>28.12%</td>
<td>28.12%</td>
</tr>
<tr>
<td>Co-efficient of variance (CV%) of overall detection time</td>
<td>18.69%</td>
<td>27.69%</td>
<td>22.38%</td>
</tr>
<tr>
<td>Standard Deviation (mm:sec)</td>
<td>00:00:27</td>
<td>00:01:56</td>
<td>00:01:21</td>
</tr>
<tr>
<td>Mean Activation time (Flaming Fire) (mm:sec)</td>
<td>2:19</td>
<td>2:32</td>
<td>2:30</td>
</tr>
<tr>
<td>Mean Activation time (Smoldering) (mm: sec)</td>
<td>24:46</td>
<td>12:18</td>
<td>18:24</td>
</tr>
<tr>
<td>Early activation counts out of eight fire scenario</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>False alarm</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Remote Maintenance</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Low visibility to ROP residents</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Sensible Activation of the Extinguishing system</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Part 5 Observations / conclusions

Full scale testsBoliger til ROP beboere
Aspiration detection unit can detect a broad range of fire and smoke scenarios reliably and efficiently compared to multi-sensor and photoelectric detectors. The aspiration system's detection time is more consistent and has the slightest variation for similar fire scenarios compared to other detectors.

In terms of early detection, the aspiration detection system, in most cases (almost 50%), detected fire earlier than multi-sensor and photoelectric detectors.

Aspiration detection system can be installed with minimum visibility in the dwellings, thus fulfilling the particular need of at-risk group/ROP residents. It requires less maintenance inside the apartment.

Both aspiration detection systems and multi-sensor detectors are less sensitive to cigarette and excessive cooking smoke compared to photoelectric detectors. Therefore, installing them may create fewer false alarms.
Part 5 Observations & conclusions

› The ventilation system significantly affects the aspiration detection system and delays its detection time. But still, it can detect within the tenability limit.

› In the case of a slow smouldering fire, the aspiration detection units’ performance is less satisfactory compared to multi-sensor and photoelectric detectors.

› The pre-alarm feature of the aspiration detection system can initiate precautionary interventions by external resources.

› Combining optical and CO detection within the aspiration system can provide reliable activation of an extinguishing system before the tenability limit exceeds in most flaming and smouldering fire scenarios.
Future work

› The proposed detection and extinguishing solution will probably be used in 2 of the houses for ROP residents in Karmøy municipality. Implementation will require follow-up.

› Several tests with open doors / windows and realistic fire scenarios have been carried out. More tests should be carried out to optimize the sensitivity of the detection system.
thank you for your attention