# Determining Fire Door Resistance Through Infrared Thermography

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# Determining behaviors of fire doors with thermal camera and traditional methods comparatively

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**Abstract**

In this article, fire resistance test of standard opening single fire door was performed using thermocouple according to the points stated in the regulations. A resistance test was performed with traditional fire mechanism stated in the regulation of TS EN 1634-1 for 136 minutes. At the $32^{nd}$ minute of the experiment, opening was observed at the upper right-hand corner of standard opening single fire door that was tested. Temperatures occurred on the door tested in the experiment were obtained by using Thermocouples as stated in the regulation and temperature values were recorded to Data Logger at 1 minute-intervals. Temperatures occurred on the surface of door were recorded with FLIR T200 thermal camera simultaneously in order to get temperature data at more frequent intervals. During the experiment, temperature values attained from measurement points stated in regulation were determined with 500 thermal images attained from thermal camera. Deformations occurred on the door during fire were examined with the evaluation of temperatures obtained from thermocouples and thermal camera. By determining deficiencies in the door structure depending on the evaluations made, solutions were offered for these. At the same time, it indicates that infrared thermography method as a distant and contactless temperature measurement technique for fire test and thermal cameras can be used

*Keywords*: Fire doors; Standard furnace tests; Infrared thermography; Fire resistance


## 1. Introduction

In buildings, fire doors are utilized commonly. These doors entail specific fire resistance and they act as delimiters or fire enclosures. Nevertheless, the thermal and mechanical properties of materials generally change with high temperatures so sufficient knowledge needs to be known about fire behaviors of construction materials of doors to utilize these doors ideally. It is essential that a fire door functions accurately in buildings especially at fires. Fire doors enable quick evacuation and avoid fire spread. Thus, it is important that they are examined for their fire resistance. For this aim, certain insulation and integrity criteria are evaluated in this study [1].

Inside fire-resistant shafts, buildings services are generally vertical in multi-story commercial construction. In order to accomplish compartmentation at each level, such fire-resistant shafts are needed with building regulations. As the time passes, the buildings become taller and so services such as elevators, stairs, air-conditioning risers and so forth started to be

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located in one part of the building. Thus, this constitutes the “core” of the building. For resistance of gravity loads from the floors, the core generally has an extra structural function and enables sufficient lateral load resistance and stiffness for the building [2].

Structural steel members can be used for the vertical and lateral support in multi-story buildings. These members may be included inside fire-resistant enclosures enabling house elevators, stairs and other services. As for elevator shafts, although structural members are inside fire-resistant enclosures, they are needed to accomplish fire resistance at high levels [3].

With the aim of preventing fires spreading, structural failure and enabling evacuation of occupants and intervention by firemen, necessities for fire resistance are given. These are generally expressed for standard fires. This approach that requires classifying products as their fire behaviors is still used in many countries. As compared to the natural fire, thermal actions from conventional fires are symbolic. However, from conventional fires, more severe thermal actions are needed under some conditions [4].

Materials with various thermal and mechanical properties are used in the construction of fire doors and so these doors have complex structures. They are designed in order to have a great performance for accomplishing fire safety requirements. In the integrity criterion E and the insulation criterion I stated in the European standards EN 1363-1 [5] and EN 1634-1 [6], fire safety necessities of door assemblies are abridged. There are various combinations of door leaves, door frames and supporting walls that need to have many fire resistance tests [7]. Rules related to evacuation of people in the building in the case of fire should be considered in the design of doors placed at exits, walls having fire-separating function, partition walls, ceilings also including suspended ceilings, flooring and installations passing through these construction elements. According to European Norms, TS EN 13501-2 and TS EN 1634-1, fire doors should have the entireness (E), insulation (I), radiation (W), self-closure © and smoke tightness (S) according to the places they are used [8].

Fire resistance classification, class of wall on which door is placed determines also fire resistance of door. According to their resistance to fire conditions, time value is classified. Resistance durations are 90 minutes, 60 minutes, 45 minutes, and 30 minutes and include at most 2 minute-classification needed for any double-acting door. A door having resistance to three-hour fire is generally seen on the walls separating buildings [8].

Within the context of “Construction Materials Regulation (89/106/EEC)” of Official Gazette with the date of 25th July, 2012 and 28364 prepared by Ministry of Environment and Urban Planning, according to declaration related to Reaction Classifications of Construction Materials to fire, Fire Resistance of Construction Elements to Fire, Outside Fire Performance of Roof and roofing’s, classification for fire doors and shutters are given on table 1 [9].

**Table 1. Standard values belonging to Fire Doors and Shutters**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Application areas | Fire doors and shutters (including those involving glass and equipment) and their closing devices | | | | | | | | |
| Standard(s) | TS EN 13501-2; TS EN 1634-1 | | | | | | | | |
| Classification | | | | | | | | | |
| E | 15 | 20 | 30 | 45 | 60 | 90 | 120 | 180 | 240 |
| EI | 15 | 20 | 30 | 45 | 60 | 90 | 120 | 180 | 240 |
| EW | | 20 | 30 | | 60 | | | | |
| Notes | With the addition of “1” or “2” symbols, I classification is completed in order to indicate which insulation is use. The addition of C symbol shows that it enables “self-closure” criterion. (passed/failed test) | | | | | | | | |

Damage in most materials used in constructions is related to temperature behavior of materials. Measurement of materials' temperature is important for understanding the reason of deficiencies that might be exist. For this aim, in order to test materials used in constructions, using non-destructive examining methods enabling us to evaluate behaviors of materials without interruption and destroying them could be useful [10, 11]. IRT technique, one of these methods, is used to determine surface temperatures of substances [12, 13].

This method enables forming of two-dimension image giving temperature distribution of the area according to thermal radiation intensity spreading from the area that will be examined [14, 15]. IRT technique can be commonly used to evaluate the performances of buildings. Especially about energy conservation, it has been commonly used to determine structural deficiencies of buildings such as thermal bridges, air-tightness and humid regions that can exist in buildings [16, 17].

In this study, a fire door was exposed to fire resistance test. In the experimental work carried out, 6 thermocouples were placed on the surface of the door and its data were recorded to data logger and placing 1 thermocouple into fire room near the fire door, its data were recorded. During the experiment, thermal images were recorded with infrared thermography method. At the end of the experiment, comparisons were made examining both thermocouple data and thermal images.

## 2. Material and method

In this study, for fire and smoke control door used as fire door test machinery was prepared according to TS EN 1634-1 rules. At the same time, taking thermal images above the fire door during experiment, their comparisons with thermocouples data used in the experiment mechanism were made. Results were examined and this technique was put forward to be safely used because images taken with infrared thermography technique enabled examining whole surface of door and deficiencies in the area wanted could be followed continuously.

In the study, digital thermometers (thermocouples), thermal camera, fire door, gas concrete wall and inflammable wooden materials are used materials.

Digital thermometer used in the experiment has sensitivity of 1200°C and it was calibrated with the indicators of ELIMKO brand and ENDA brand by Turkish Accreditation Institution according to TS EN ISO/EC 17025, and its Calibration certificate was taken with H12S392. 6 digital thermometers used in the measurements of surface temperature also took Calibration certificates with E12S410 given by the same institution and were used in this experiment.
In the experiment, infrared thermography of Flir brand and T200 model was used. Features belonging to infrared thermography are given on Table 2.

Gas concrete wall and gas concrete roof materials produced and manufactured by Ytong firm as wall materials were used. Technical features belonging to the material are given on Table 3.

As fire door, fire door produced by ME-HA Steel Door Systems in Konya as in the proportions of 1000/2200 mm. Panic Exit Devices used for fire door took certificate of compliance to EN 1125:1997+A1:2001 tests by Warrington Certification Ltd. Special dye prepared for fire resistance and that was produced Boyasan Dye Industry and given certificate approval by Qualicoat (Zurich) on 9$^{th}$ 12, 2011 was used in fire door. All other products used on door were produced by ME-HA Steel Door Systems according to standards related and their certificates were given.

In the experiment, in order to describe conventional fire and maintain it for 120 minutes, calculation of inflammable substances was made and using about 1500 kg wooden materials, the experiment was completed.

**Table 2. Features of thermal camera**

| | |
|---|---|
| IR resolution | 200 × 150 pixels |
| Spectral range | 7.5 - 13 µm |
| Object temperature range | -20°C to +120°C (–4°F to +248°F) - 0°C to +350°C (+32°F to +662°F) |
| Accuracy | ±2°C (±3.6°F) or ±2% of reading |
| Thermal sensitivity/NETD | < 0.1°C @ +30°C (+86°F) / 100 mK |
| Display | Built-in touch screen, 3.5 in. LCD, 320 × 240 pixels |
| Image adjustment | Auto (min span 4°C / 7.2°F) or manual (min span 2°C /3.6°F) |
| Field of view (FOV) / Minimum focus distance | 25˚x19˚/0.4m (1.31ft) |
| Radiometric IR-video streaming | Full dynamic to PC using USB |
| Operating temperature range | –15°C to +50°C (+5°F to +122°F) |

**Table 3. Features of gas concrete**

| | |
|---|---|
| Dimensional Tolerance | ± 1,5 mm |
| Profile Structure | Plane |
| Derz | Adhesive Knit Ytong (1–3 mm kalınlık) |
| Flame / Fire Resistance | Refractory (F180-A) |
| Sound Resistance | 45–65 dB |
| Average Compressive Strength | 50 kgf/cm² |
| Dry Unit Weight | 600 kg/m³ |
| Weight of the Wall Static Account | 700 kg/m³ |
| Thermal Conductivity Coefficient (λh) | 0.19 (W/mK) |

## 3. Experimental study and results

Experimental study was carried out at the laboratory of Construction Department of Selcuk University Higher School of Vocational and Technical Sciences. Experiment mechanism is given on Fig. 1 and images during the experiment are given on Fig. 2.

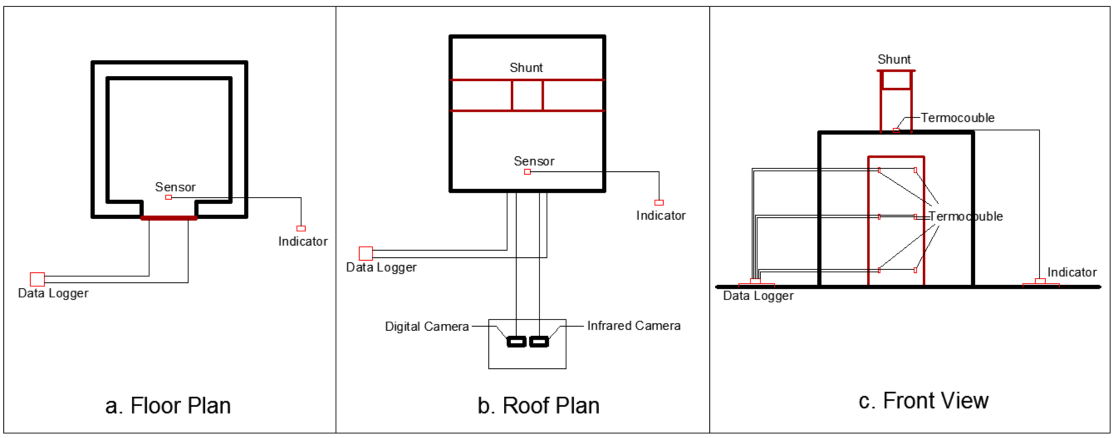



Fig. 1. Experiment mechanism.

Fig. 2. Experiment images of fire door.

After experiment mechanism was prepared, all the indicators and devices were tested to work and first fire was lit. Since the beginning of the fire, all data records were started to be recorded. One of the most elements in fire doors is the place and time when first they have the opening from the corners and start to give smoke. After 32 minutes from the beginning of fire, upper right-hand corner of the door had the opening and fire room temperature read from the indicator at that moment was 654°C, the temperature of upper right-hand corner point on the door surface measured from thermocouple was 59.48°C and temperature where the opening existed and read by thermal camera was 94.7°C. The difference of the temperature taken by thermocouple with the temperature value taken by thermal camera causes from the reason that thermocouple is fixed and thermal camera takes the temperature of the place wanted at that moment. On Fig. 3, the moment when the door had the opening, thermal image taken from ThermaCAM Researcer Pro 2.7 software used by Flir Firm whose producer of thermal cameras with which thermal images are analyzed and temperature values taken above the door during the experiment exist.

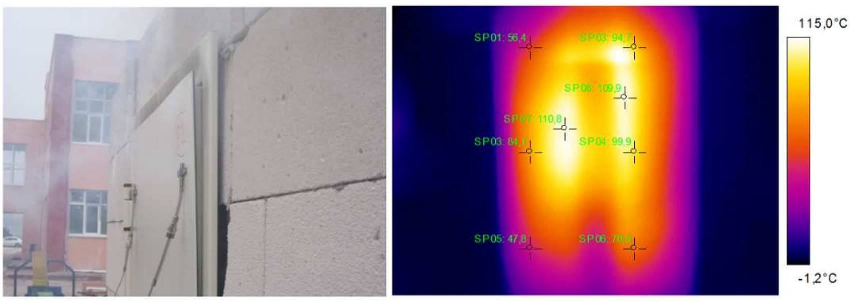



Fig. 3. The moment when the door had the opening and the thermal camera image at that moment.

Experiment time continued for 136 minutes and during this experiment all data were recorded. For each one minute, data were recorded to data logger from 6 thermocouples and at the end of the experiment these data were transferred to computer. At the same time, for each one minutes data were taken from thermocouples that were produced as TC20-1S5Z07-60 model by Elimko firm, placed into the room from the door back surface and had sensitivity of 1200°C and was S type. Then, data were transferred to the computer.

When data obtained are examined, the temperature of fire room reached to 961°C as maximum at the 115$^{th}$ minute of the experiment. As for the temperatures of door surface, upper left-hand corner was observed to reach to maximum temperature, 238.5°C at the 131$^{st}$

minute. The temperature at the upper right-hand corner was determined as 337.59°C at the 114th minute. The temperature at the left middle part of the fire door was measured as 355.77°C at the 134th minute and the temperature at the right middle was measured as 333.73°C as maximum at the 125th minute. Lower left and right parts of the fire door reached the maximum temperature together at the 130th minute. Temperature at the lower left part was measured as 278°C and as 223.96°C for the lower right part. In order not to occupy much space on Table 4, values determined at each four minutes are given. In the Fig. 5, graphic belonging to all values taken at total 136 minutes exist.

**Table 4. Date, time, values of room temperature of the experiment and values obtained and belonging to 6 thermocouples on fire door**

| Read Number (Minute) | Date - Time | In-Room Temp. (ºc) | Top Left (ºc) | Top Right (ºc) | Middle Left (ºc) | Middle Right (ºc) | Bottom Left (ºc) | Bottom Right (ºc) |
|---|---|---|---|---|---|---|---|---|
| 0 | 15:03 | 17 | 3.28 | 3.12 | 4.14 | 3.47 | 3.61 | 3.32 |
| 4 | 15:07 | 20 | 3.24 | 3.11 | 4.31 | 3.49 | 3.64 | 3.38 |
| 8 | 15:11 | 54 | 3.25 | 3.08 | 4.15 | 3.44 | 3.64 | 3.4 |
| 12 | 15:15 | 114 | 3.59 | 3.5 | 4.98 | 3.67 | 3.72 | 3.51 |
| 16 | 15:19 | 195 | 6.37 | 8.03 | 8.77 | 6.55 | 4.09 | 4.51 |
| 20 | 15:23 | 283 | 12.66 | 17.76 | 17.24 | 12.72 | 5.19 | 6.56 |
| 24 | 15:27 | 369 | 24.67 | 31.67 | 29.84 | 23.69 | 7.32 | 10.13 |
| 28 | 15:31 | 529 | 39.19 | 44.82 | 45.04 | 38.17 | 10.55 | 15.29 |
| 32 | 15:35 | 654 | 48.89 | 59.48 | 60.42 | 54.93 | 14.85 | 21.8 |
| 36 | 15:39 | 699 | 62.17 | 79.38 | 86.72 | 79.61 | 19.89 | 28.56 |
| 40 | 15:43 | 714 | 75.16 | 93.09 | 111.58 | 88.14 | 26.8 | 40.9 |
| 44 | 15:47 | 761 | 90.65 | 119.32 | 143.07 | 95.33 | 35.72 | 52.66 |
| 48 | 15:51 | 780 | 107.95 | 142.42 | 172.95 | 114.76 | 49.72 | 67.34 |
| 52 | 15:55 | 792 | 131.33 | 168.28 | 198.23 | 143.72 | 65.79 | 85.13 |
| 56 | 15:59 | 806 | 155.13 | 188.36 | 215.51 | 174.03 | 86.12 | 112.23 |
| 60 | 16:03 | 805 | 170.71 | 199.29 | 225.88 | 198.05 | 107 | 139.08 |
| 64 | 16:07 | 821 | 185.73 | 207.2 | 234.62 | 214.31 | 136.77 | 157.41 |
| 68 | 16:11 | 843 | 195.06 | 210.1 | 241.58 | 222.24 | 152.68 | 166.93 |
| 72 | 16:15 | 854 | 201.13 | 214.63 | 246.69 | 230.95 | 160.77 | 173.7 |
| 76 | 16:19 | 885 | 203.97 | 216.92 | 251.96 | 236.3 | 170.21 | 179.59 |
| 80 | 16:23 | 905 | 212.04 | 220.64 | 263.24 | 240.59 | 179.58 | 184.85 |
| 84 | 16:27 | 910 | 228.61 | 235.19 | 291.92 | 256.75 | 196.63 | 191.12 |
| 88 | 16:31 | 919 | 241.41 | 248.41 | 309.52 | 266.46 | 204.71 | 191.2 |
| 92 | 16:35 | 929 | 249.41 | 266.77 | 320.1 | 275.59 | 211.16 | 190.31 |
| 96 | 16:39 | 943 | 252.68 | 275.49 | 321.57 | 274.82 | 210.25 | 184.48 |
| 100 | 16:43 | 946 | 264.9 | 300.44 | 330.8 | 295.03 | 224.99 | 189.01 |
| 104 | 16:47 | 945 | 274.96 | 317.63 | 334.82 | 305.48 | 245.4 | 191.18 |
| 108 | 16:51 | 952 | 281.49 | 329.96 | 336.85 | 314.31 | 257.89 | 195.93 |
| 112 | 16:55 | 951 | 283.58 | 335.76 | 341.39 | 321.31 | 268.21 | 198.96 |
| 116 | 16:59 | 961 | 280.85 | 328.66 | 344.31 | 316.58 | 271 | 201.51 |
| 120 | 17:03 | 949 | 283.06 | 330.73 | 349.86 | 324.25 | 273.43 | 210.36 |
| 124 | 17:07 | 949 | 287.3 | 337.5 | 356.17 | 333.73 | 277.55 | 221.92 |
| 128 | 17:11 | 936 | 285.1 | 332.83 | 357.47 | 332 | 278.14 | 221.63 |
| 132 | 17:15 | 934 | 283.96 | 324.94 | 356.99 | 323.85 | 275.84 | 221.34 |
| 136 | 17:19 | 931 | 285.2 | 323.25 | 357.09 | 325.34 | 275.69 | 219.9 |

Results of experimental study we conducted for values belonging to F30, F60, F90 and F120 that are fire classes stated in the regulations are given on Table 5.

Images taken with thermal camera and their values about temperatures were examined and every minute of changes of temperatures belonging to fire door could be examined on the images. Also, the material was examined about which sensitivities they showed to heat at which time and it was interpreted. As the heat increased, steel frame and back band began to move heat quickly. When faced to rockwool used in the door, heat continued to move just on

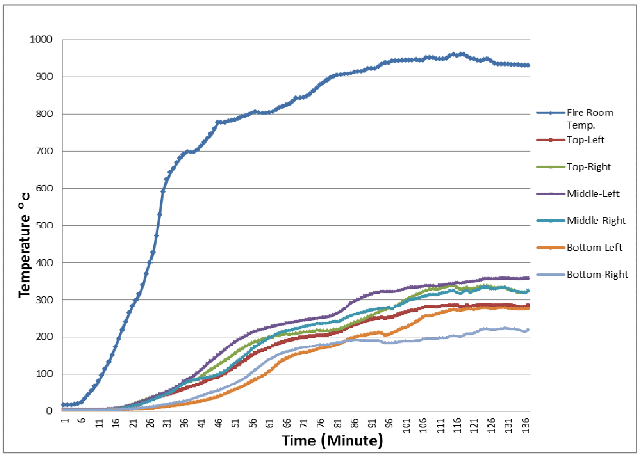



Fig. 4. The graphic of temperature - time belonging to fire door.

**Table 5. Values of F30, F60, F90 and F120 obtained in the experimental study**

| Read Number (Minute) | Date – Time | In-Room Temp. (°c) | Top Left (°c) | Top Right (°c) | Middle Left (°c) | Middle Right (°c) | Bottom Left (°c) | Bottom Right (°c) |
|---|---|---|---|---|---|---|---|---|
| 0 | 15:03 | 17 | 3.28 | 3.12 | 4.14 | 3.47 | 3.61 | 3.32 |
| F30 | 15:32 | 591 | 41.14 | 46.77 | 48 | 41.47 | 11.51 | 16.67 |
| F60 | 16:02 | 803 | 166.74 | 196.47 | 223.14 | 191.79 | 100.6 | 132.49 |
| F90 | 16:32 | 923 | 243.65 | 253.61 | 312.81 | 268.9 | 206.45 | 190.14 |
| F120 | 17:02 | 951 | 282.33 | 329.59 | 349.00 | 319.49 | 274.16 | 208.18 |
| 136 | 17:19 | 931 | 285.20 | 323.25 | 357.09 | 325.34 | 275.69 | 219.90 |

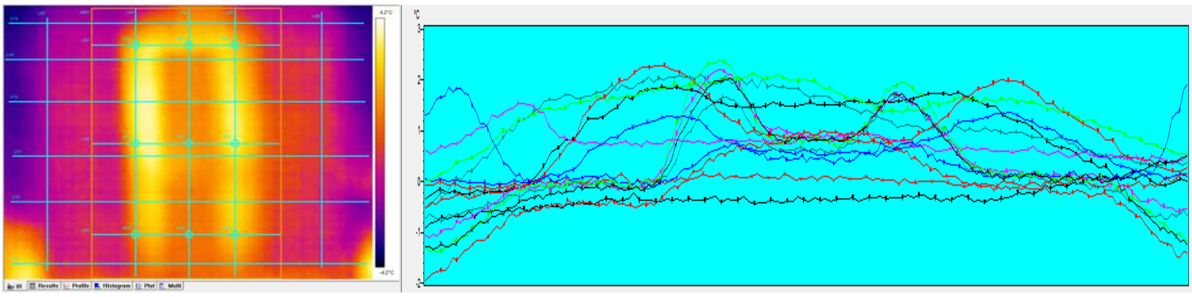
steel frame and back band. While heat increased swiftly inside parts, heat on the parts outside was observed about 25% or 30%. The greatest advantage of thermal camera is found meaningful about the fact that temperature values of area and region wanted can be taken immediately, continuous records of temperature values increasing of the point focused and it shows deficiencies of the product to the producer.

Usage of developed opportunities in thermal camera technology puts forward that both economical and more accurate results can be obtained. On Fig. 5, there is the analyzing phase of images related to fire door and taken by thermal camera and also graphics of temperature changes.

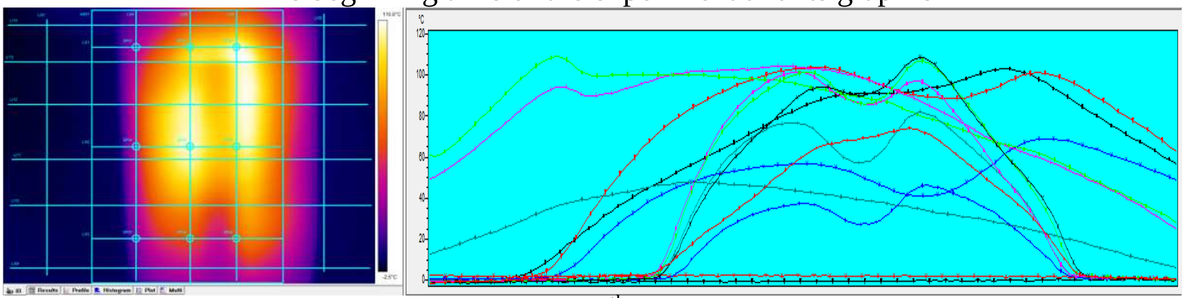
Analyses of temperature changes of thermal changes on the gas concrete wall were also made with thermal camera. After 30$^{th}$ minute of the beginning of experiment, temperature changes on the wall were observed between -1°C and -2°C and at the 60$^{th}$ minute, it was observed as 0°C or 3°C. On Fig. 6, there are thermal analyses and graphics on the gas concrete wall at the 30$^{th}$ and 60$^{th}$ minutes.

## 4. Conclusion and suggestions

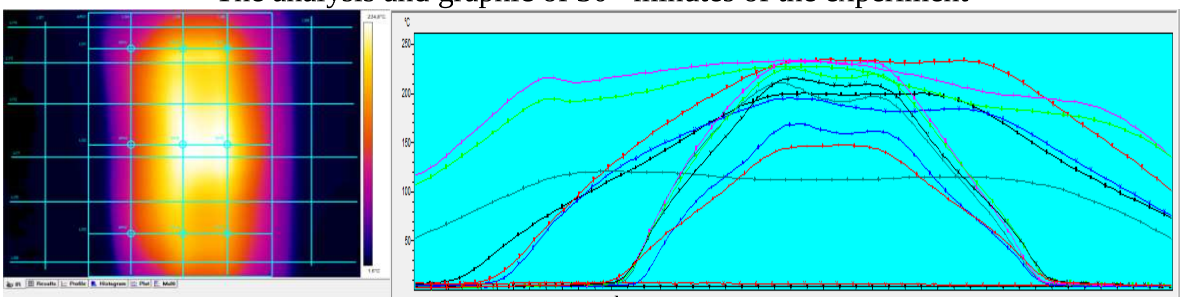
In the experimental study, fire door experiment was performed in the mechanism prepared according to regulations. Fire requires the utmost importance in the matters to be known in



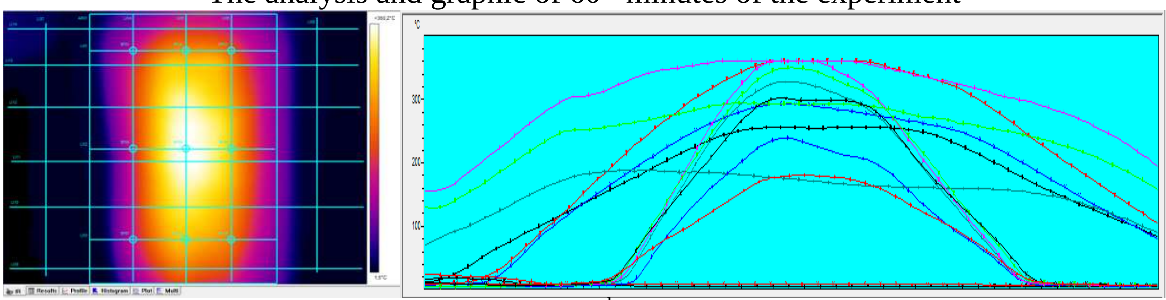
The beginning time of the experiment and its graphic



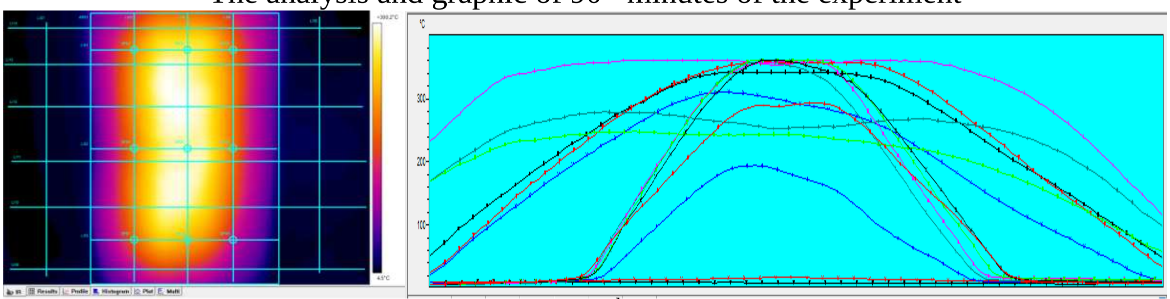
The analysis and graphic of 30th minutes of the experiment



The analysis and graphic of 60th minutes of the experiment

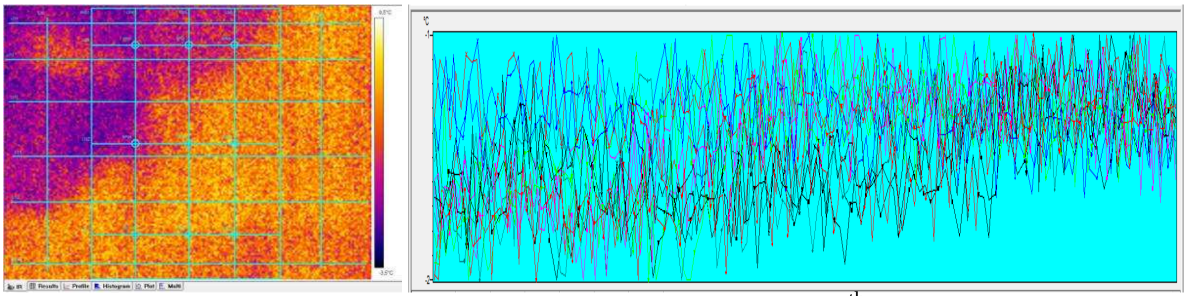


The analysis and graphic of 90th minutes of the experiment

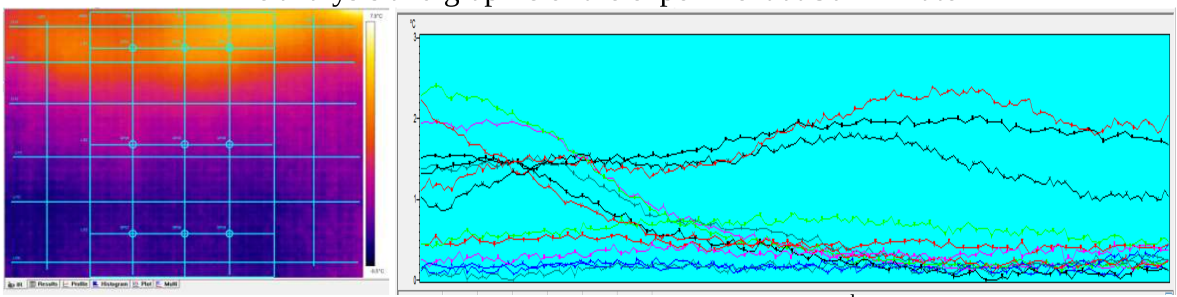


The analysis and graphic of 120th minutes of the experiment

Fig. 5. Thermal image analyses and graphics.



The analysis and graphic of the experiment at 30th minute



The analysis and graphic of the experiment at 60th minute

Fig. 6. Analyses and graphics of thermal images belonging to experiment wall.

order to control the energy coming out and prevent loss of life and properties. Because of not taking necessary precautions and carelessness, fire causes loss of life and properties continuously. Since it is not possible to cease fires completely, escaping them with least loss of life and properties may be possible with the aid of experimental studies that are carried out.

The study conducted tested this fire door we will use about whether it has fire resistance or not in the case of a fire in our daily lives and the fire door was determined to have fire resistance. Method used was prepared in accordance with the regulations. However, because information about deficiencies in the material used cannot be notified to the producer firm, data were gathered with thermal camera and information about how a manufacture can be prepared were given.

In the experimental study, 7 thermocouples were used and evaluation was made according to the data obtained. However, with thermal camera, data can be obtained for each second and evaluated. At the same time, infrared thermography method and thermal cameras are shown to be also used as a contactless and distant measurement technique for fire test. During the experimental study, thermal images above 500 were recorded and evaluated. It was wanted from the producer firm that with regards to fire doors they should use different material which will prevent heat transport at upper right-hand corner, they should enable closing of the door for more at the 32nd minute when the first opening existed and prevent smoke leak. When not to forget that seconds are important during fire, increasing of the time wanted is seen to be essential.

One of the most important subjects in whole experimental study was related to gas concrete wall from which we produce our room. The temperature of surface of gas concrete wall was measured as -1.8°C when we started the experiment and at the end of it, temperature was measured as 4.3°C. The fact that while 961°C was reached in the room related to wall, the temperature of exterior surface of wall was still unnoticeable and increased 6.1°C put forward that gas concrete walls are very good fire insulation materials and can be safely used in both fire insulations and as thermal insulation materials.

Our experimental study was performed at the laboratory of Construction and Construction Insulation Technology Department in Selcuk University Higher School of Vocational and Technical Sciences and at a place where students could watch the experiment. It is meaningful that our students graduated will become conscious about fire danger when they start to work and witness an experimental study about fire insulation.

## Acknowledgement

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