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ROBUST: Renovation of Buildings Using Steel Technologies

WP 2.4 Physical test on roofs and facades before and after upgrading to assess their performance

Individual activity report

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1. BACKGROUNDS OF WORK UNDERTAKEN

With rising energy costs, property managers should consider checking the performance of their buildings. This can be effectively and efficiently done by using a thermographic building survey. Infrared thermography (IR) is a powerful and non-contact diagnostic tool (NDT) that enables the heat differences in equipment and facilities to become noticeable. IR cameras provide complete solutions for the energy conservation, professional infrared inspections of building envelopes and roofing systems. It can detect numerous conditions in which an anomaly can be characterized by an increase or decrease of a surface temperature or retained residual heat.

This NDT method has been proposed for testing the thermal behavior of selected non-residential buildings based on the high resolution camera "Guidir® IR 928+".
The principal approach for IR thermal inspection of the buildings needs the following:

a) prepare or obtain the important documentation of an actual building design structure, technology specification, energy and air supply systems and additional equipments,
b) find the proper weather conditions for the thermal testing (the winter season - the temperature difference between ambient and internal environment building conditions should be sufficient, close to the 15-20 degrees),
c) analyze the thermograms and identify structure or insulation defects, heat leaks and spots using dedicated tool,
d) propose some necessary thermo-modernization works on the facades and roofs,
e) repeat thermal inspection of the building facades and roofs by using IR camera after thermo-modernization,
f) prepare the final report.

2. INVESTIGATION OF THE OBJECTS AND METHODS

Three different form and purposes non-residential buildings have been selected for the IR thermal investigations:

1. the single storey service workshop named *ROBERT* located at the individual house settlement near to Rzeszow town,
2. a steel-construction storehouse located in the city of Lublin,
3. the group of multistoried buildings located in the Rzeszow University campus at the Poznanska street, i.e. laboratories and lecture rooms of the Mechanical Engineering and Aeronautics (ME&A Faculty of RUT – L building),
4. the aircraft production hall in Sokolow Malopolski.

The first object (a workshop house) is a newly designed and currently in usage. The second one and the fourth one – the L building - have been currently put to the thermo-renovation and modernization by means of an insulation improvement of the walls and roofs, over-cladding as well as the replacing of the windows (at the RUT case). These research cases will provide some data on the thermal behavior of buildings before and after the thermo-renovation. The aircraft production hall was investigated only after thermo modernization to expose any defects in improper insulation and to identify areas of relatively high heat losses to ambient air.

An energy benchmarking status of the tested buildings will be based on:

- Specification of buildings construction
  - Structure of walls, ceilings, ground based floors and roofs,
  - Windows and doors type and geometry,
  - Heat transfer coefficient values *U* for all external building parts and baffles,
  - Building energy consumption tool allows to get the energy certificate for whole analyzed object using software AUDYTOR OZC v. 4,5 Pro, Sankom company.

- IR thermography measurements
  - Performing of building thermal images with the aim of high-resolution camera "Guidir® IR 928+,
  - Detailed analysis of IR thermal images for all tested cases by using advanced software tools (Guide IR Analyser V 1.4).

3. THE INFRARED THERMAL TESTS PROCEEDING THERMAL RENOVATION

3.1 Investigations of the single storey service workshop (SWB)

The data collected on the constructional form of the service workshop building (SWB) as well as the obtained IR measurements are presented as follows.

These SWB object named *ROBERT*, designed according to the "*SUNDAY*®" technology, has the steel frame with galvanized thin-walled structural shapes (cold bending process) which are filled by different courses.

Basics data for building:

- *U* coeficient for walls U=0.28 W/m^{2}K,
- *U* coefficient for windows U=1.1 W/m^{2}K,
- Utility area –124.8 m^2,
- Cubature – 732.3 m^3.

Technical specification for *ROBERT* building

- Fundamental bench is made in concrete – steel B15 with d12 mm bars.
- Fundamental walls are made in B15 concrete of 25 cm thickness. Vertical insolation is 4 cm polystyrene.
- External wall is made in *SUNDAY System* including layers:

  - mineral plaster,
  - polistyrene 10 cm,
  - semi concreteboard Cetris 12 cm,
  - Glass fiber (*Unimata Gullfiber* 1129) thickness 8 cm,
  - Vapour preservation foil,
  - Gypsum cardboard 12.5 mm.

Subsequently, a cross-section of the wall–roof connection in the"*SUNDAY*®" technology building has been shown in the fig. 1. The tested object is a service workshop building (a tailor workshop), located at the individual house settlement in the Glogow town.

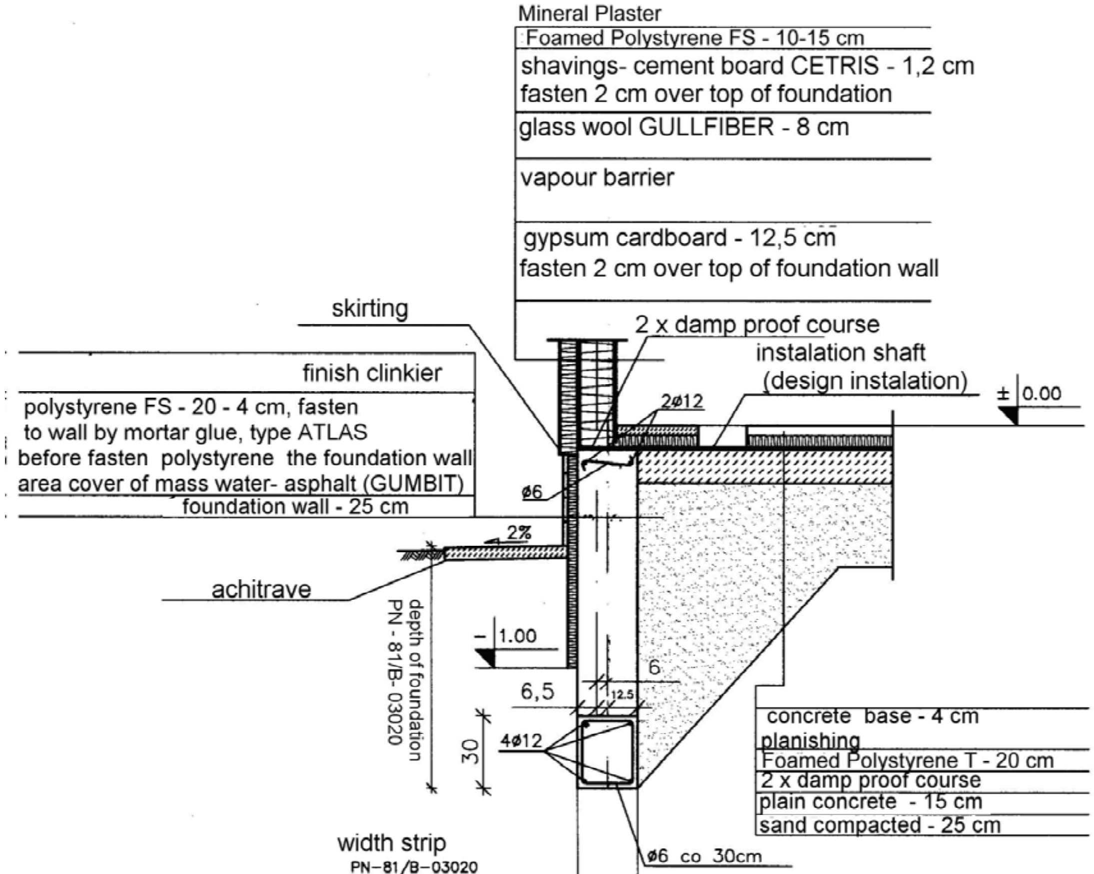
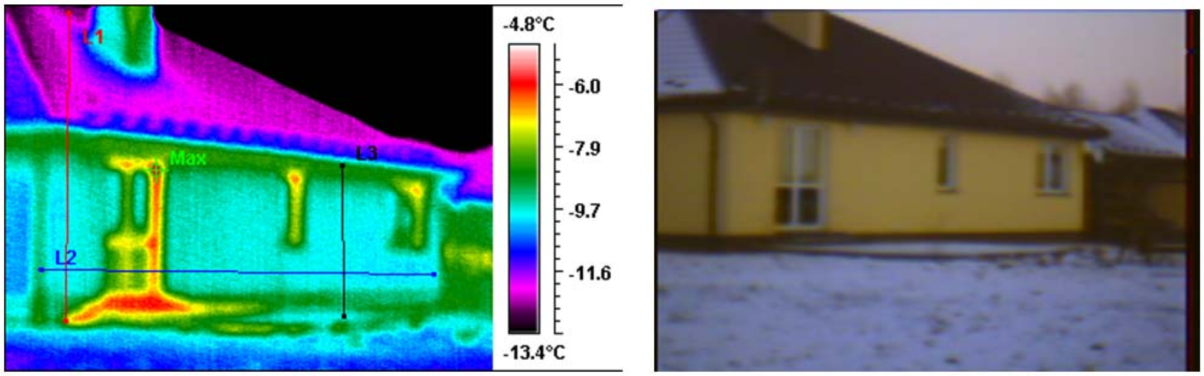


Figure 1. SWB - details of the constructional connections in the "*SUNDAY*®" technology building (fundaments, external walls and floor)

The thermovision image and the real photo of the tested SWB building facade are presented in the fig. 2. The additional input data, including ambient and measurement conditions (time, weather status and temperatures), which have been displayed on the LCD monitor of the *Guidir* IR camera are given as follows, see Table 1.

Table 1. Basic IR measurement conditions (SWB)

FileName	**IMAGE041**
Create Time	January 4-th, 2008; time: 16:45
Emissivity	0.90
Background Temperature	-10.2°C
Distance	20.0 m
Max Temperature	0.0°C
Min Temperature	-13.5°C
Voice Comment	-



a) infrared image b) SWB real photo

Figure 2. Thermal and natural images of the *ROBERT* building

The range of facade walls and roofs temperature variations (Table 2) as well as the thermogram (fig. 2a) present some low heat resistance areas – in the vicinity of balcony doors (especially near the floor, at the bottom part) and on the window frames.

Table 2. IR analysis results (SWB)

Object temperatures	**Value**
Max temperature	-4.4°C
L1: Mean temperature	-13.4°C
L1: Max temperature	-8.0°C
L1: Min. temperature	-13.5°C
L2: Mean temperature	-11.9°C
L2: Max temperature	-6.5°C
L2: Min. temperature	-13.1°C
L3: Mean temperature	-12.3°C
L3: Max temperature	-10.1°C
L3: Min. temperature	-13.0°C

The temperature variation along the selected vertical and horizontal cross-lines L1-L3 are presented in the fig. 3. These histograms provide the percentage of registered temperatures in the analyzed picture and enable the verification of the thermal status of the SWB building. It can be easily noticed that the largest temperature variation goes along the horizontal line L1 (over seven centigrade) and shows the vast heat losses at the balcony frame and windows.

By means of the proper software tools delivered by IR camera's distributor one can follow the complete temperature distribution along the characteristic lines (see fig. 3) and surfaces. Moreover, it enables the identification of some imperfections of the building structure as well as the material defects.

It can be noticed the insingularity of insulation related to its diverse thickness. On the surface of the external layer the temperatures are similar but not identical. In those places where the insulation is mounted properly, the temperature on surface is close to ambient one.

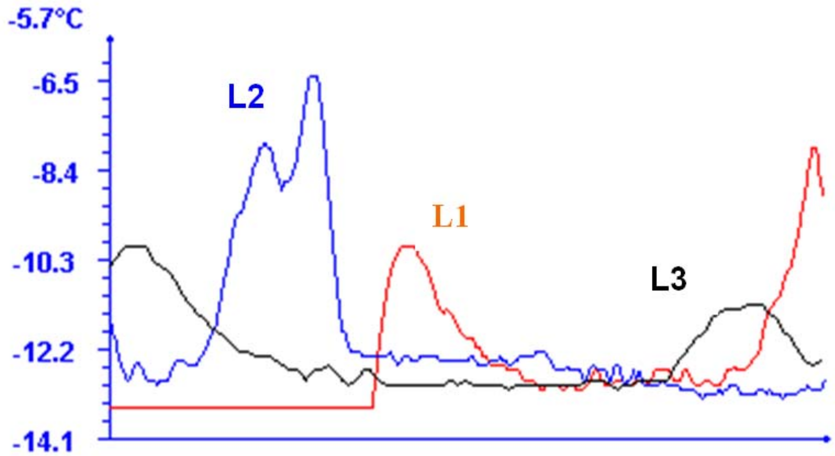


Figure 3. Temperature profiles on the selected lines: L1, L2 and L3 in fig. 2a

The improperly mounted insulation of the balcony window on wall surface leads to increasing heat flow through the wall – line L2. Relatively high heat loses occur in the case of the roof. Insufficient insulation thickness of the ceiling becomes detectible as the temperature increases up to -10,3 ^{o}C – it is about 3K temperature difference in relation to ambient air.

On another picture of *ROBERT* building – the sideways wall – the heat losses reach the high value because of too low heat transfer coefficient for the window – fig. 4.

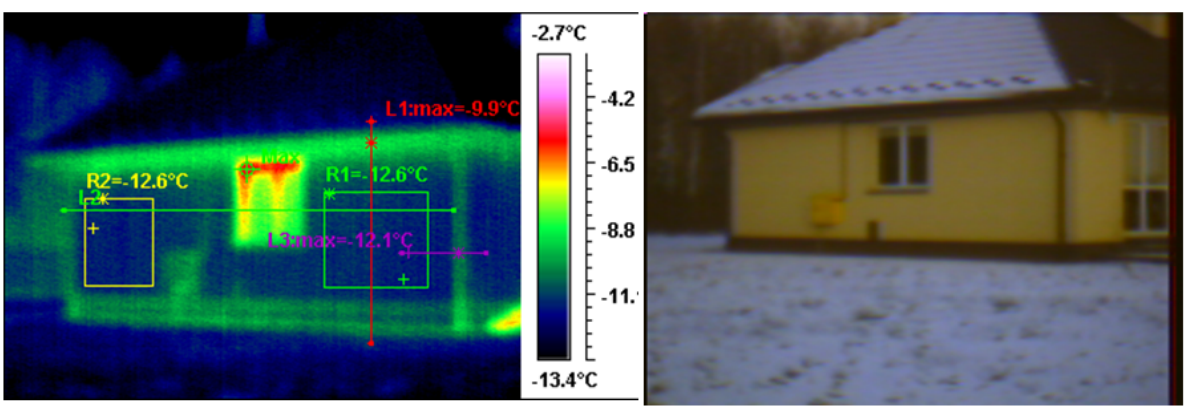
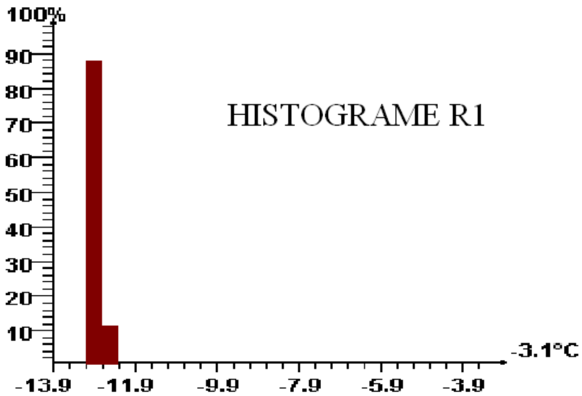


Figure 4. Thermal and natural images of sideways of *ROBERT* building

In the selected areas of thermal image R1 and R2 the temperature distribution was analyzed. Bar chart and histograms in fig. 5 and 6 together with percentage concern of selected range of temperature are presented.

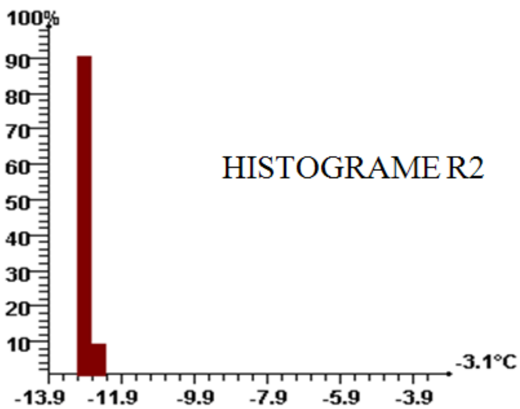
The temperature difference in R1 amounts to 1,2K, but in the area R2 the smaller difference of 0,8K is observed, which means that on that part of the wall the insulation was put carefully and with the same thickness.

It is a steel construction building, what can be observed on infrared images as a linear thermal bridges. The *U* coefficient for the external walls has a proper value according to technical project.



Temperature range [°C]		Concern %
-13.1	-12.7	87.9
-12.7	-12.3	11.8
-12.3	11.9	0.4

Figure 5. Percentage concern of temperature range in R1 area in fig. 4



Temperature range [°C]		Concern %
-13.1	-12.7	90.5
-12.7	-12.3	9.5

Figure 6. Percentage concern of temperature range in R2 area in fig. 4

The building skeleton is visible on the thermal images. Otherwise, the insulation of the main steel figures is not done well or is less than necessary. The temperature of the middle part of the wall is about 2.5 ^{o}C below the temperature on vertical corners of building – what show L1 and L3 line in fig. 7.

On the same wall the vertical temperature distribution was also analyzed (line L1). On the top of the building there is a linear thermal bridge along connection of the wall and the roof. A similar situation occurs on the connection of the bottom part of the wall connected with the fundamental wall.

In the top part of the wall the temperature is higher of about 3.0 ^{o}C than the temperature on the middle part of the same wall. It is the result of defects in building insulation. The maximum temperature on Line L1 in fig. 4 is caused by the leakage of connection.

In the bottom part of the building at a connection of the external wall and the fundament there are thermal bridges with temperature close to vertical steel figures located on the corner of the building. The areas of increasing temperature occurred in the bottom of wall what may result in lower thickness of the insulation of the floor on the ground. Moreover, there is a floor heating systems in a selected part of building

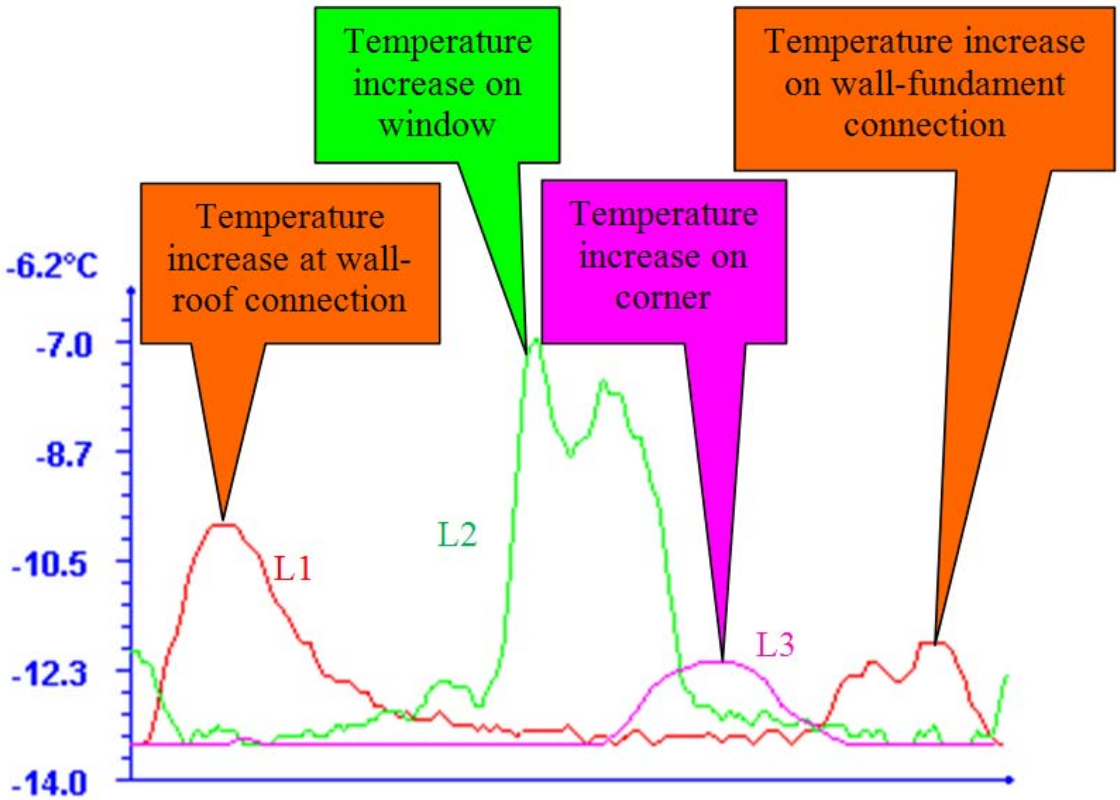


Figure 7. Temperature distribution along line L1, L2 and L3 in fig. 4

3.2 Investigation of a steel-construction storehouse in Lublin

The storehouse complex consists of the store hall, a storage with a bureau and the social rooms and the separated cooling storages. It is a single floor object made in steel technology. Construction of the existing external walls is the following:

- steel brass highest 5 cm, thickness 0.7 mm,
- mineral fiber insulation – thickness 0.10 m,
- internal walls in steel brass highest 2 cm, thickness 0.7 mm.

Investigating the infrared images of the external walls of the hypermarket located in Lublin, the several disadvantages become visible. Mineral fiber insulation slid down and it was a result of insingularity in the technological construction.

On the external wall of building – see fig. 9, numerous colors appear on the infrared images what reflects diverse insulation thickness inside the wall. The histograms of temperature distribution presented in fig. 10, 11 on selected parts of the wall R1 and R2 were prepared.

Figure 8. Typical view of the external wall in Lublin

On figure above, a vast loss of fiber glass insulation in the top part of the external wall at the entrance of the building can be seen. It leads to increasing heat losses up to level as at the wall without thermal insulation.

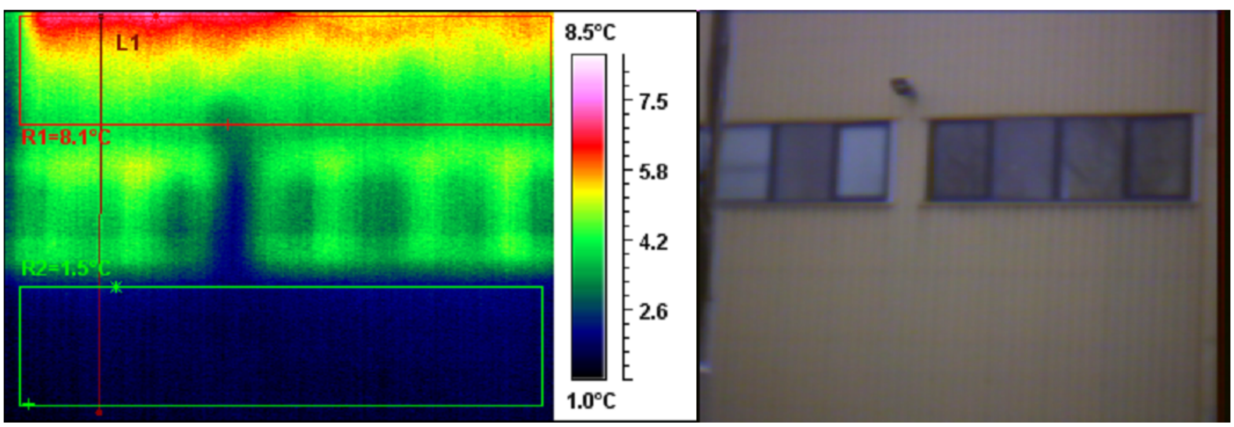


Figure 9. Infrared and normal image of the wall

The image in fig. 9 proves that the insulation in the top part of wall slid down and created the area close to roof with significant loss of thermal properties which directly results in the increase of heat consumption of the building.

The form of the temperature distribution on external surface of the wall is caused by the insingularity of insulation thickness, its various location or its absence – fig. 11 line L1.

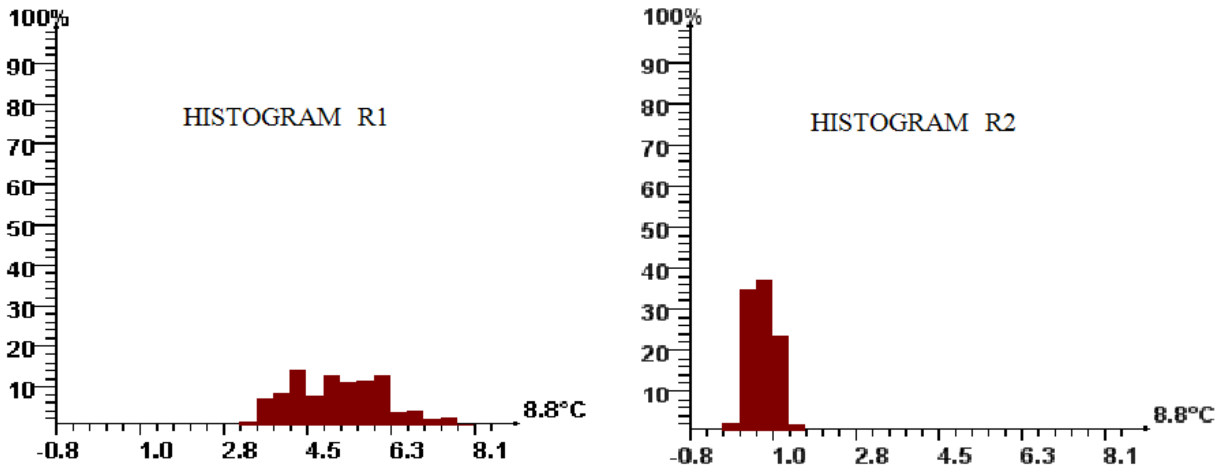


Figure 10. Temperature histogram corresponding in area R1 and R2 in Fig. 9

Line L1 in fig. 11 shows a large disproportion between the bottom and the top of the wall surface temperature. The next thermogram proves that the effect is related to sliding of the insulation. Considering the highest wall temperatures, the difference reaches up to 8K.

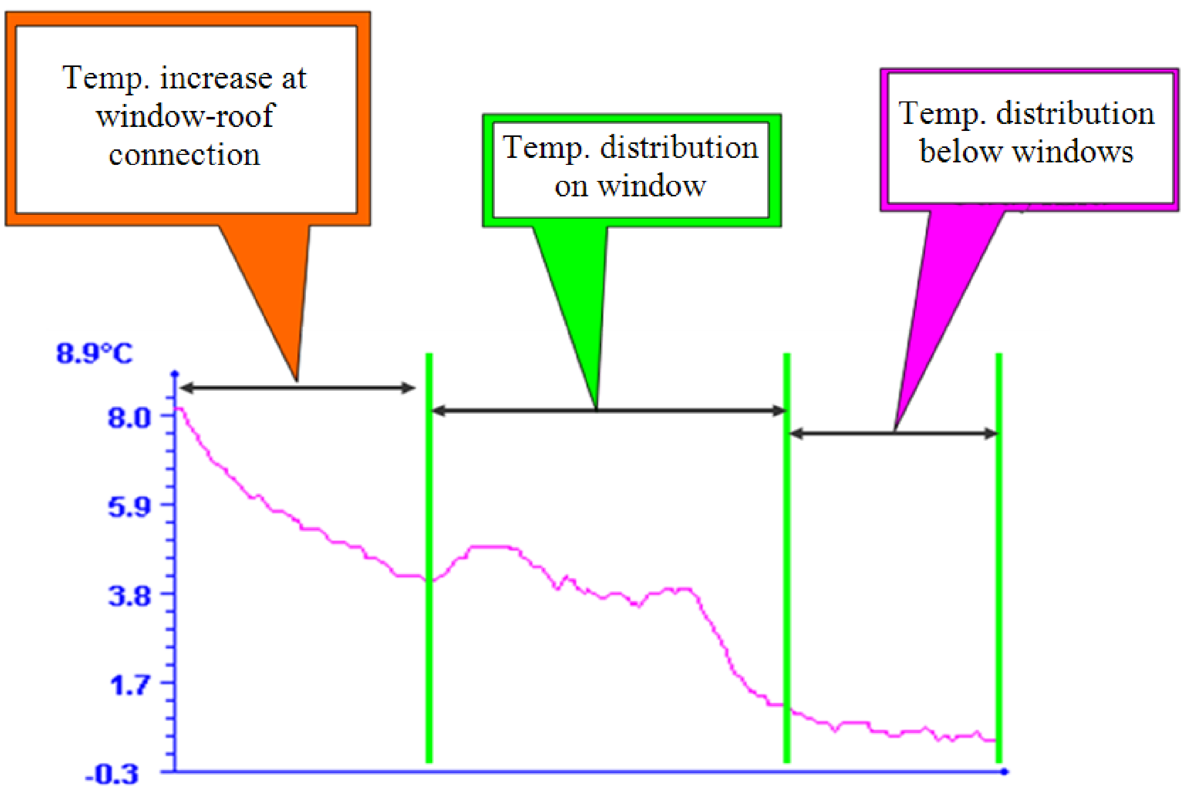
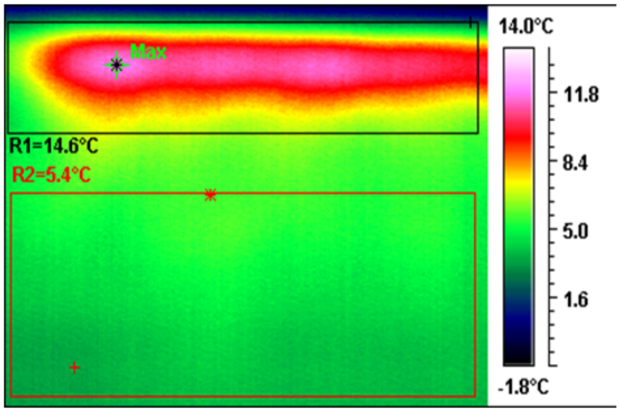


Figure 11. Temperature distribution along line L1 in fig. 9

Relatively high temperatures on surface of the wall (fig. 12) T_{max} = +14.6 ^{o}C (at ambient temperature -1.8 ^{0}C) reflect the technological defects of the wall.



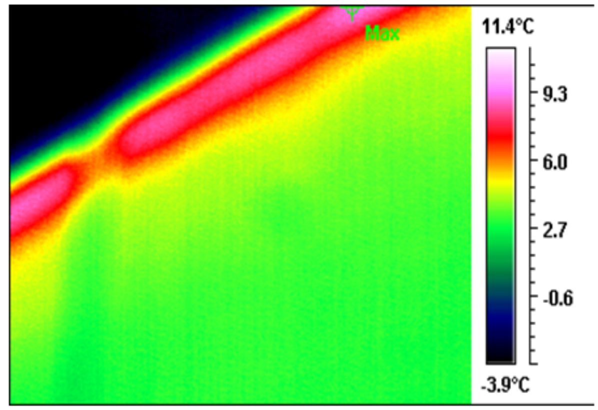


Figure 12. Infrared image of external walls surface of hypermarket

3.3 Investigations of the "L" assembly buildings

The ME&A Faculty (so called "L" assembly), shown in the Figure 13 consists of the five buildings: L27 – L31, connected by four couplers and one separate building L32 (Laboratory of Combustion Engines). Designed over twenty five years ago, the buildings are 3- and 5 – storied and based on the aluminum construction with the glass window facades, see Figure 15. It should be mentioned that such project was originally proposed for the Mediterranean climatic zone design.

After many exploitation problems, especially in the winter season (a very large costs of heating and maintaining the thermal comfort conditions), the University authorities decided for a refurbishment and thermo-renovation of the ME&A buildings. The construction works are in progress and will have been finished by the end of 2010 year.

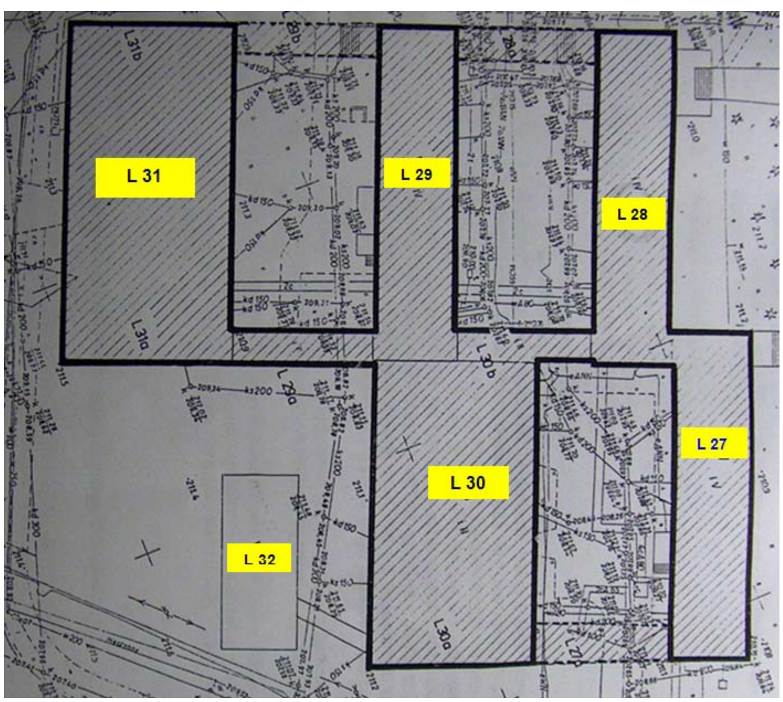


Figure 13. Localization of "L" assembly buildings

A current construction of the external walls (before the thermo modernization) of the first and higher floors in the buildings assembly "L" is presented in the Table 3.

Table 3. Building assembly "L" - External walls construction

Material		Trick-ness	Thermal conduct.	Density	Heat resistance
		d [m]	λ [W/m^{2}K]	ρ [kg/m^3]	R=d/λ [m^{2}K/W]
1/	Gypsum-cardboards	0.010	0.230	1000	0.043
2/	Mineral wool (inside walls)	0.070	0.043	60	1.628
3/	Aluminium	0.005	200.0	2700	~ 0.000

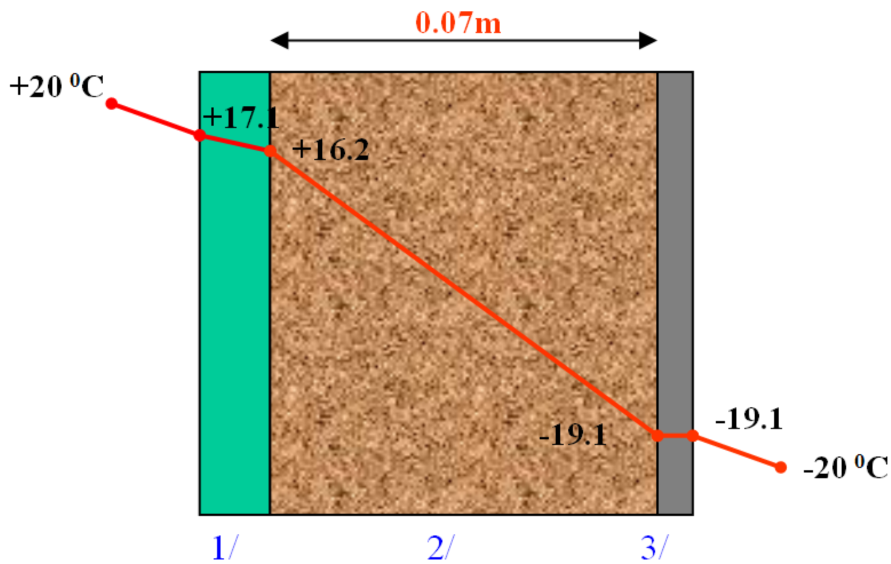
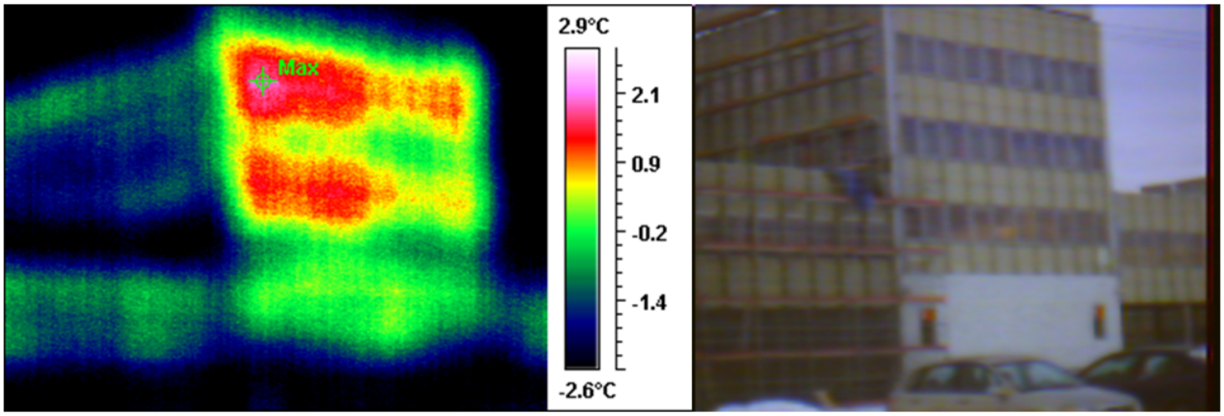


Figure 14. Temperature distribution in an external wall (building „L")

A design heat transfer coefficient for the external walls in "L" assembly buildings was assumed to amount: U = 0.543 [W/m^{2}K]. This value corresponds to the technology level close to the specific energy demands amounting ~ 200 kWh/m^2·a. Relying on the very intensive "cold feeling" during the winter season it was assumed that the insulating-course of mineral wool has slid down inside the frame walls. Apart of many leakages in the large windows area it caused a significant discomfort in the rooms. These problems forced the investment activities and thermo-renovation works.

The thermal investigations of ME&A Faculty buildings have been made during winter (2007/2008). In the Figures 15a, b the image and the photo of the tested walls are presented.

It can be noticed from the Figure 15a, that there is a vast area of the heat losses on the top part of the "L" building facade and in a bottom part (it is partially insulated – see, the white color area) these losses are much lower. The maximum temperature on the wall (directly indicated in the Fig. 15a) amounts 3 ^{0}C.



a) Infrared image b) "L" buildings photo

Figure 15. IR image and photography of tested walls of the "L" buildings

The basic conditions of IR measurements are presented in the Table 4.

Table 4. Basic IR measurement conditions ("L")

File Name	IMAGE014
Create Time	5 November 2007 , time: 15:21:00
Emissivity	0.91
Background Temperature	-6.1°C
Distance	80 m
Max Temperature	0.0°C
Min Temperature	-4.1°C

The infrared image – fig. 15a shows an external wall of L building before the thermal renovation. As one can see the insulation between external and internal wall layers was pulled down and, as the result, the temperature is relatively high on IR image, close to internal one.

3.4 Investigations of the aircraft production hall

The roofs and the facades of production hall of an aircraft company has been thermally investigated. It is an object of the old design and currently in usage. The production hall is a construction made of complex steel and ceramic blocks.

The building is located in Glogow Malopolski several kilometers away from Rzeszow. Because of its complicated shape, the highest roof windows giving natural light, many problems occurred with the proper insulation and prevention from the heat losses.

The roof construction is made of folded steel covered with insulation layer (mineral wool) and felted on the external side. A wide range of temperature distribution in the fragment analyzed on the infrared image R1 is presented. The areas of felt join and all connection fragments are marked as black and the pink areas reveal the best insulation places. The rest of the roof area, because of weak insulation, has the average temperature of 26,7°C on its surface. The external temperature during measurements amounted 9.0 °C.

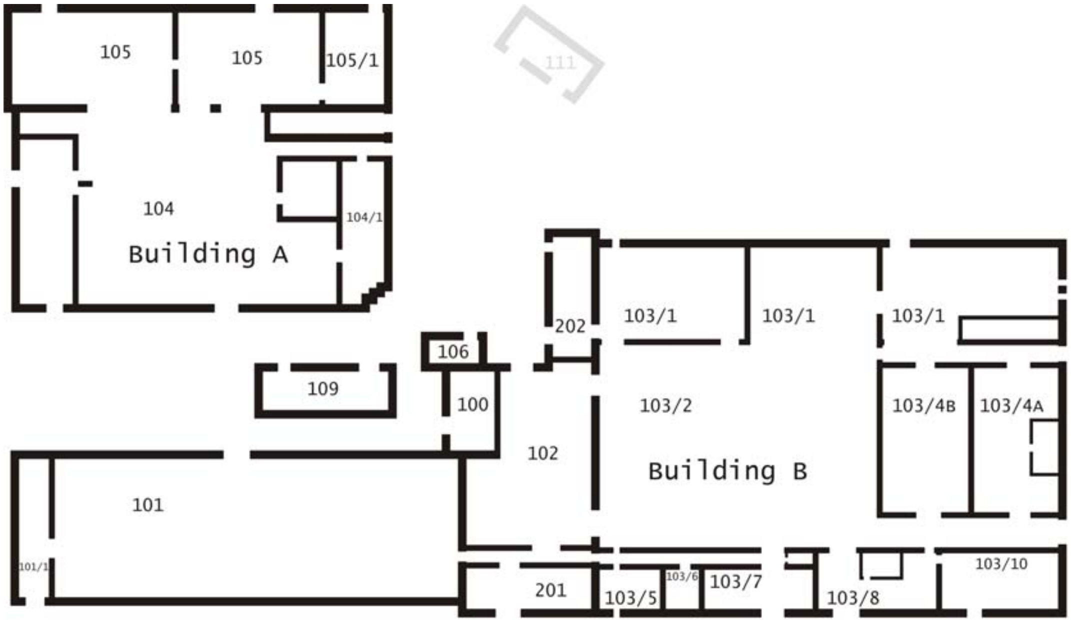


Figure 16. Cross section of aircraft production hall

Considering the IR images taken outside the building, the areas of an improperly insulated roof has appeared – fig. 17.

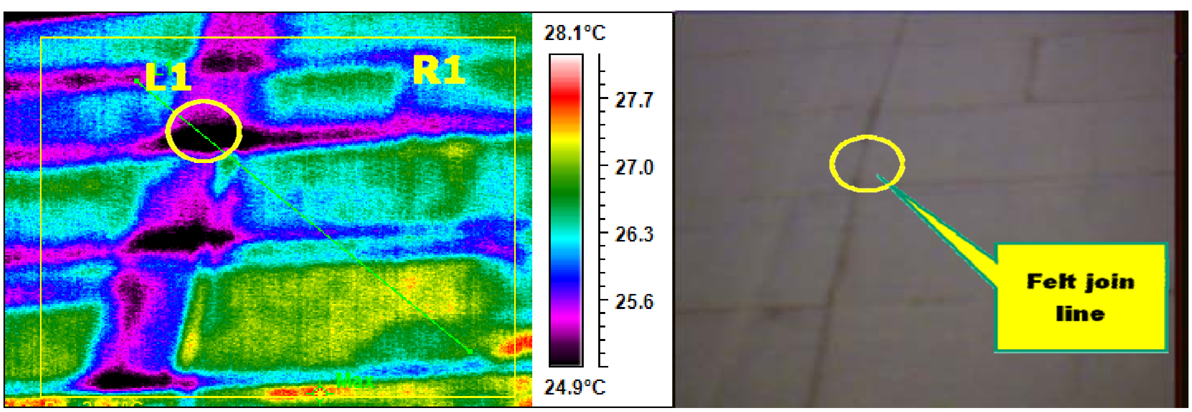


Figure 17. Roof fragment under production hall – building A

On the histogram – fig. 19, the temperature distribution of analyzed area R1 is presented. It reveals highly non homogenous structure of roof. The average temperature of this area amounts 26,1 °C, at external temperature of 9.0 °C taken during measurements. Summarizing, the roof insulation is insufficient which results in a vast heat losses through the boundary.

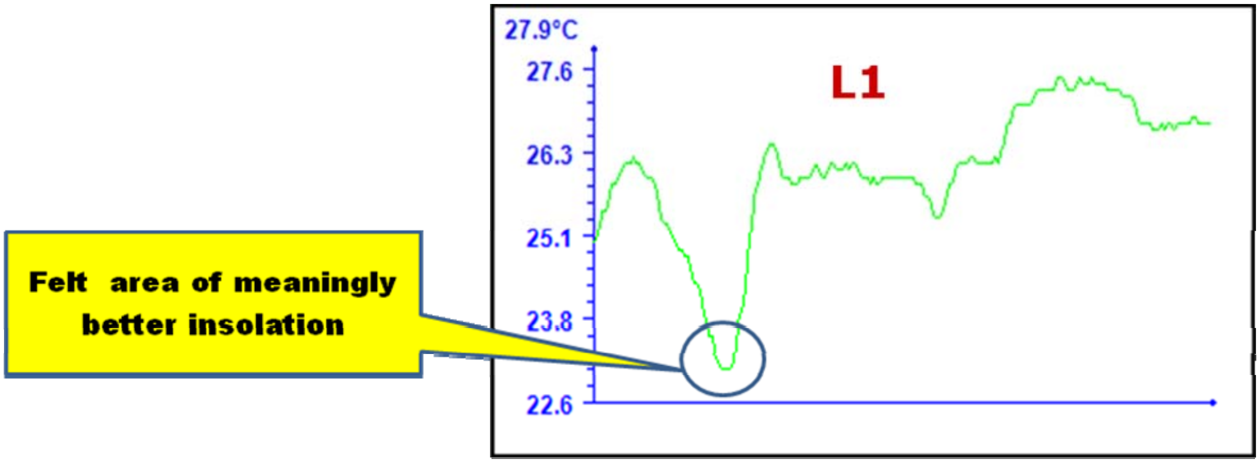


Figure 18. Temperature distribution along L1 line in fig. 17

The minimum of line L1 presented in fig 18 corresponds with the area of best insulation – see black places in fig. 17.

Object parameter	Value
Max temp.	28.1°C
R1: Average temp.	26.1°C
R1: Max. temp.	28.1°C
R1: Min. temp.	23.1°C
L1: Average temp.	26.7°C
L1: Max. temp.	27.5°C
L1: Min. temp.	23.1°C

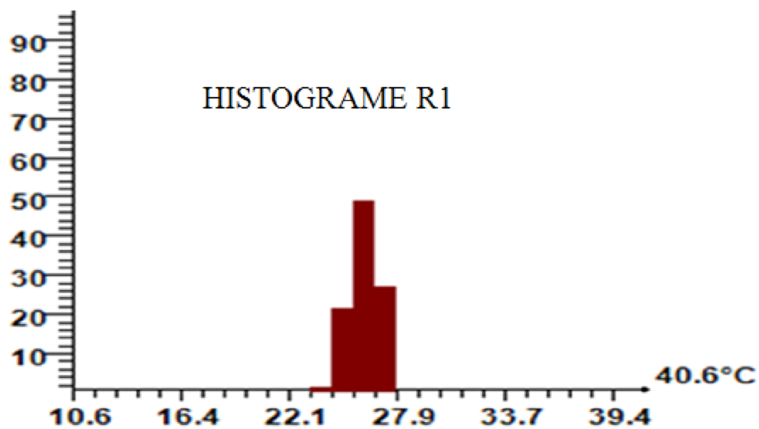


Figure 19. Histogram of R1 area in fig. 17

In the next figures the roof fragment of another building of the same construction as roof presented on slide 17 has been shown, but in this case with poorer insulation – building B in fig. 16. This fragment reveals that the roof is covered with the folded steel without new insulation layer. The R1 area and L1 line was selected to analysis.

Even without temperature analyzing the strong and clear image of the hot area on roof surface can be seen. It means that the heat losses of hall under analyzed roof lead to the increase of power heating consumption. The insulation layer in this case seems to be necessary.

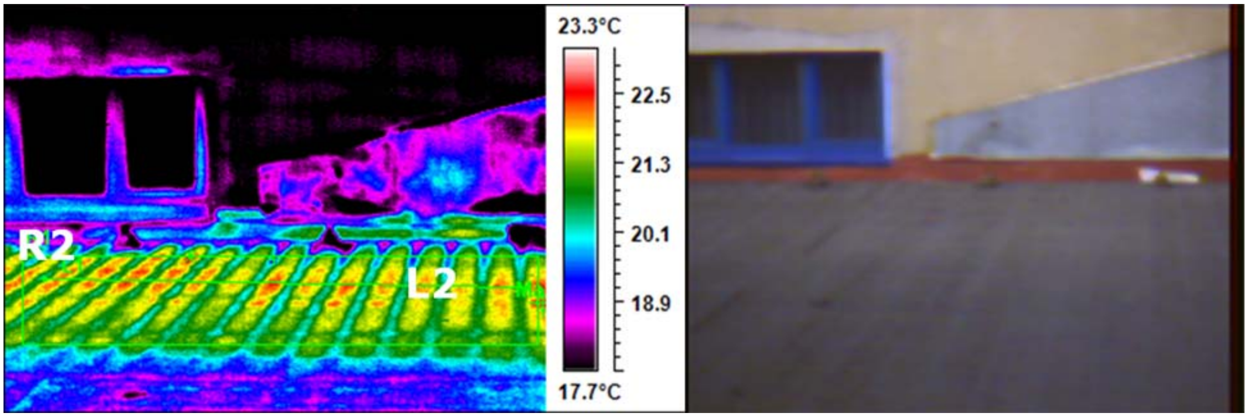


Figure 20. Roof fragment under production hall – building B

The temperature distribution on the felt surface is showed by line L2 in fig. 21. Under the felt there is an old insulation layer and folded steel (folded steel is covered by polystyrene on single side).

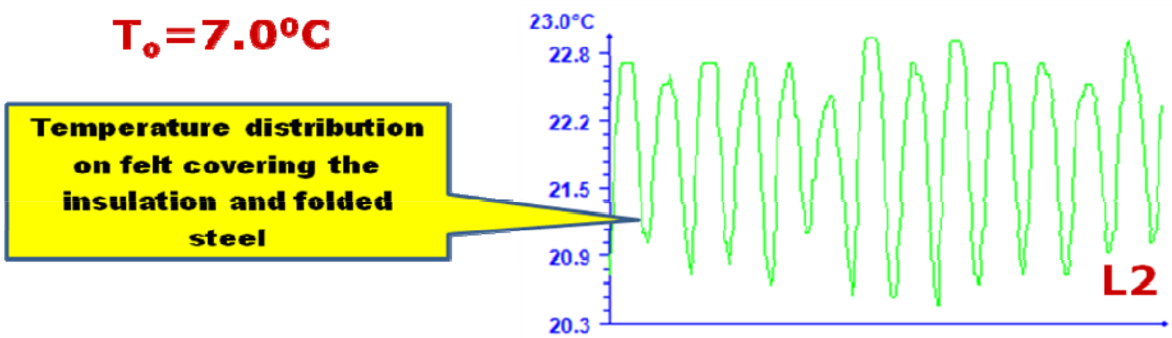


Figure 21. Temperature distribution along L2 line marked in fig. 20

Considering the temperature distribution, one can draw at least 2 conclusions. The insulation layer is very thin or unsuitable. The average temperature of analyzed area R2 is very high - 21,5 ^{o}C, with the external temperature during measurements amounting 7.0 ^{o}C.

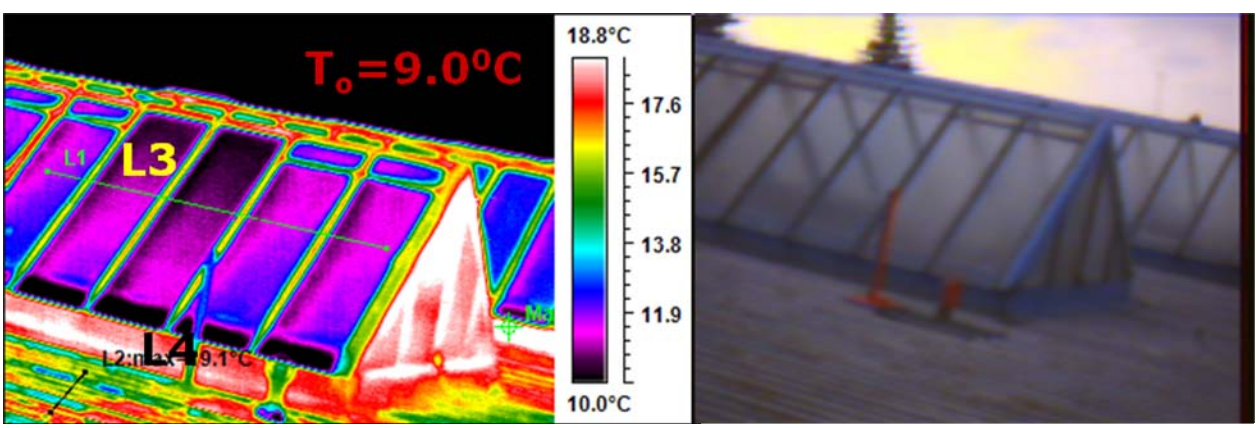


Figure 22 Roof fragment under production hall – building B

In fig. 22 the roof fragment in the same technology as previous one is presented. However there is one difference: folded steel determines the external layer. On the top of the roof there are skylights made from glass and steel. The temperature distribution was analyzed on line L3 and it leads along windows mounted in skylights. The line L4 leads along part of the roof covered by folded steel.

Object parameter	Value
Max temp.	22.5°C
L3: Average temp.	11.0°C
L3 : Max. temp.	18.0°C
L3 : Min. temp.	9.1°C
L4: Average temp.	16.6°C
L4: Max. temp.	19.1°C
L4: Min. temp.	13.5°C

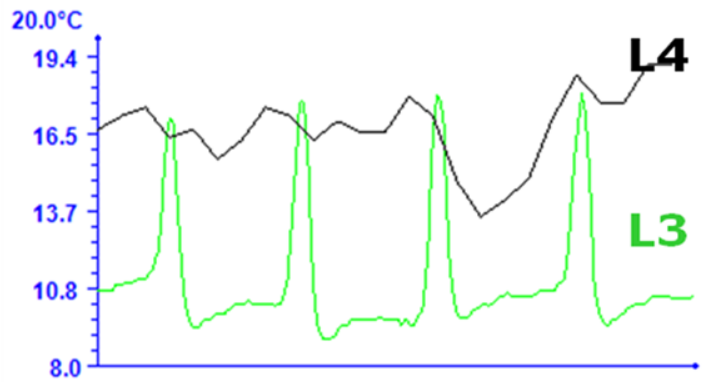


Figure 23. Temperature distribution along line L3 and L4 marked in fig. 22

The windows on the skylights have better U factor than the roof itself, even considering the insulation. These cases are presented on diagrams as line L3 and L4, respectively. It should be mentioned that figure 23 needs to be analyzed more carefully. The real temperature transformation shown by IR camera is achieved by emissivity factor directly corresponding to the material. In the case of the significant difference in emissivity between glass and steel, the two separate IR pictures have been taken at proper emissivity setting for glass and steel. The figure 23 should be considered as a first estimation of the temperature distribution and heat losses through the roof.

In fig. 24 a roof of the production aircraft hall as a R1 area is presented. The significant heat losses through the surface of the roof can be noticed. The average surface roof temperature amounts +17.3°C at ambient temperature +10.3°C.

The second part of the roof marked as R2 area is much better insulated. The average surface temperature amounts +15.3°C at the same ambient temperature that is presented on temperature profile along line L1 and L2 in fig. 25.

The roof insulation leads to decreasing heat flow through the surface analyzed, but there is a non homogeneous structure in insulation showed on the temperature profile along Line L1 in fig. 25. The average temperature difference on roof surface was decreased by 2°C in the same weather conditions.

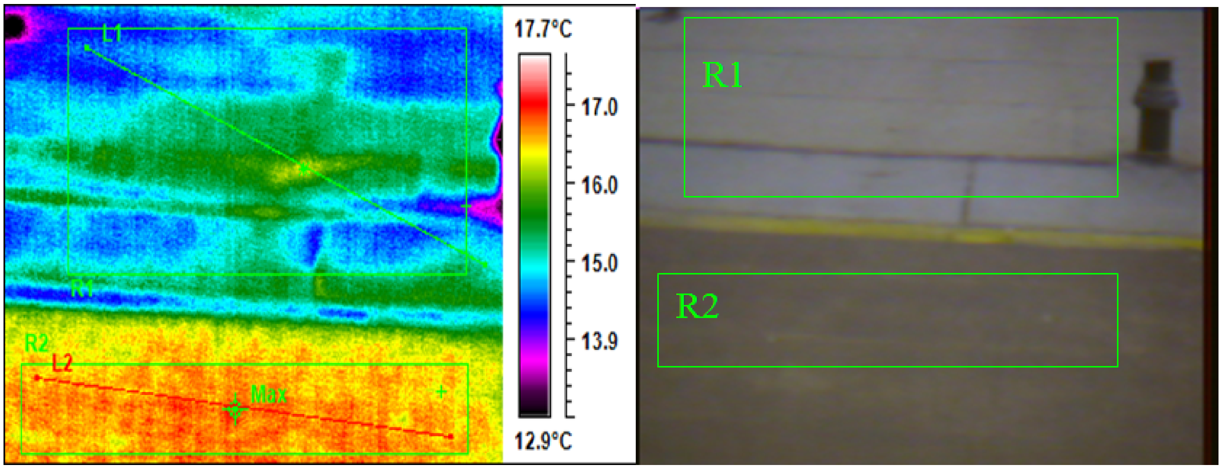


Figure 24. Roof fragment under production hall – building B

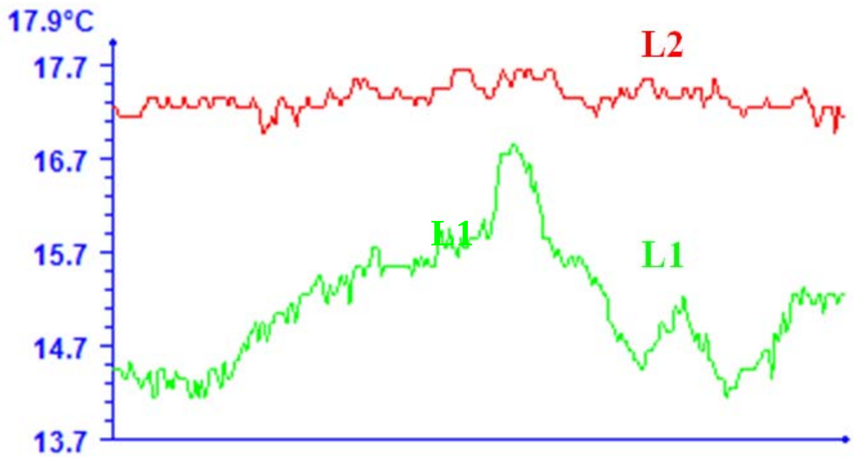


Figure 25. Temperature distribution along line L1 and L2 marked in fig. 24

The percentage concern of temperature in selected areas are collected in diagrams in figure 26.

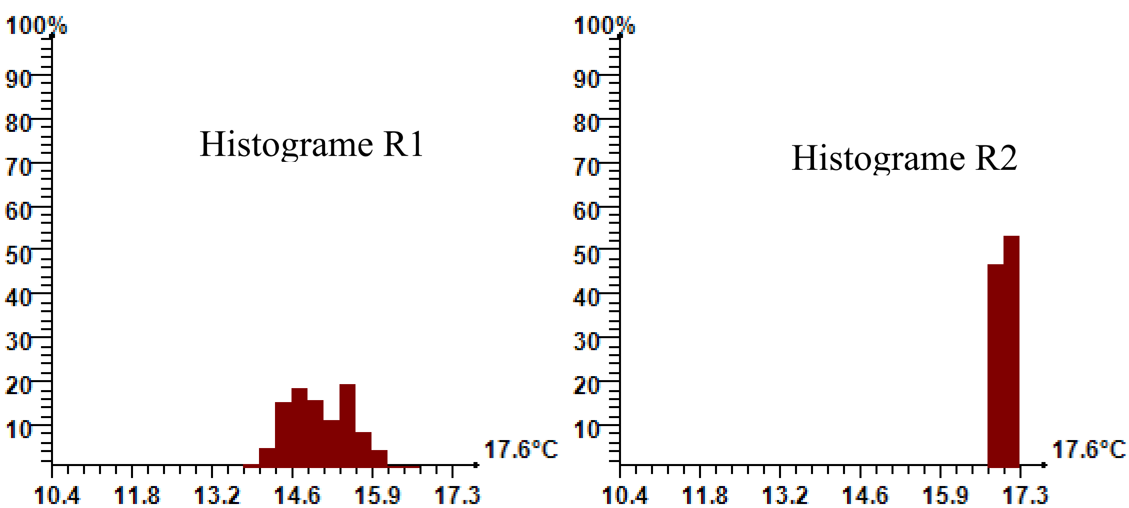


Figure 26. Percentage concern of temperature in areas R1 and R2 marked in fig. 24

In all studied cases there occurs a high level of temperature gradient on the top of the roof at internal side what leads to vast heat losses through boundaries. Those circumstances are a result of a considerable heat gain in hall space from machineries and also from ventilation non insulating ducts, which act as heaters increasing heat gains in hall. All the heated air flows up and collects under the roof, so the IR images improve.

4. THE INFRARED THERMAL TESTS AFTER THE THERMAL RENOVATION

4.1 Investigations of the single storey service workshop (SWB)

After the thermo-investigation is became noticeable that many insulation disadvantages led the investor to take up improvements of the envelope of building by elimination of thermal bridges and heat leakage. As a result of the economical crisis, the investor decide to move the planed activities to the nearest future, so it was impossible to do a new investigation after the thermal renovation.

4.2 Investigations of steel-construction storehouse in Lublin

The investor decided to not improve the insulation and he is aware of increasing heat consumption because of improper work of the insulation of fiber glass and its slides. What is more, in the nearest time there is no possibility to compare the thermal efficiency of building after and before thermal improvements.

4.3 Investigations of the "L" assembly buildings

During refurnishment processes it has been proved that the mineral wool was falling down inside the frame. The new insulation based on mineral wool layer of the thickness d = 0.12 m (previously 0.07 m) has improved thermal performance of the walls up to the value U = 0.333 [W/m^{2}K]. The typical temperature distribution in the external walls after the thermo-renovation is presented in fig. 27.

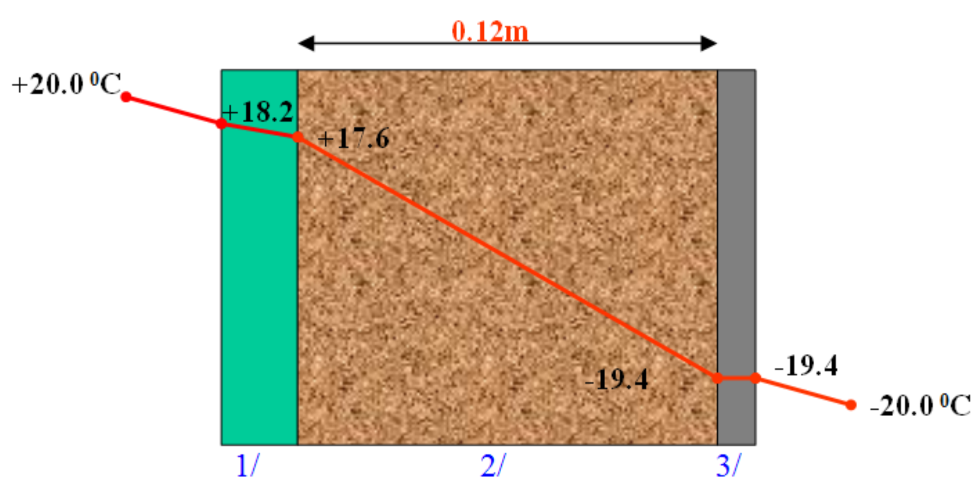
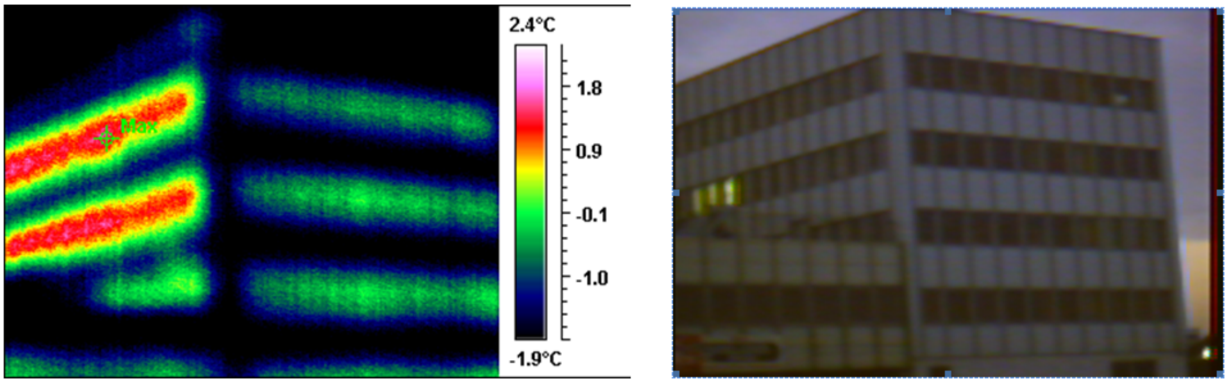


Figure 27. Temperature distribution in an external wall – after the renovation (building „L")

The final effect obtained after the renovation of the external walls and replacement of the old windows is presented in the Figures 28 a, b. Comparing this pictures to the data in the Figure 27, one can see the real improvement of building thermal performance and more uniform distribution of the temperatures on the same right side facade.



a) Infrared image b) "L" buildings photo

Figure 28. IR image and photo of the "L" buildings walls (after renovation)

The basic test conditions of IR measurements are presented in the Table 5.

Table 5. Basic IR measurement conditions ("L" – after the renovation)

File Name	IMAGE053
Create Time	5 January 2008, time: 15:06:00
Emissivity	0.91
Background Temperature	-6.1°C
Distance	80 m
Max Temperature	0.0°C
Min Temperature	-3.7 °C

It should be noticed that the left side of the imaged IR picture, Fig.28a, shows still a very large heat losses through the walls. This part is still improperly insulated and it will be renovated till the end of 2008.

After end of the thermo modernization works the energy certificate have been made to improve the effect overall energy consumption – fig. 29.

The energy certificate for L building also improves the expected effect of the thermal renovation. The primer energy for analyzed building (EP=255 kWh/m^{2}a) is lower then reference value for the modernized building calculated according to technical condition for residential and public building. It means that the thermal renovation was done successfully. Certificate was created with help of computer software tool dedicated to building energy auditing. It is powerful program firm of *SANKOM* company distributed among building and sanitary engineers and designer to perform energy behavior during heating and cooling period. Energy certificate was made in version 4.5 Pro on AUDYTOR OZC.

ŚWIADECTWO CHARAKTERYSTYKI ENERGETYCZNEJ

dla budynku L nr 01/12/2009

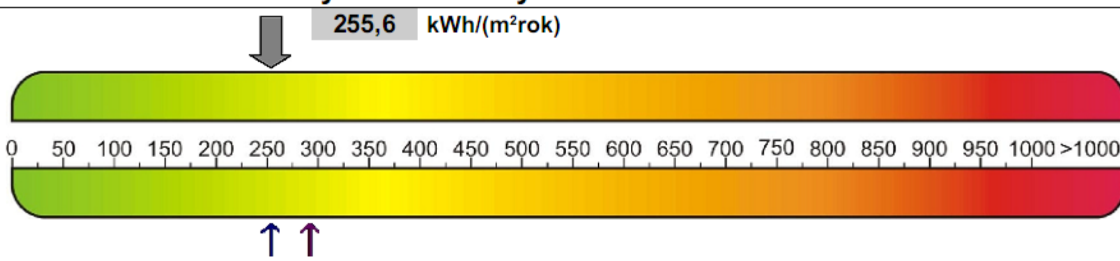
Ważne do: 31-11-2019

Budynek oceniany:

Rodzaj budynku	Budynek sal wykładowych i laboratorium
Adres budynku	ul. Poznańska
Całość/Część budynku	całość budynku
Rok zakończenia budowy/rok oddania do użytkowania	
Rok budowy instalacji	
Liczba lokali użytkowych	350
Powierzchnia użytkowa (A_f, m^2)	22532
Cel wykonania świadectwa	☐ budynek nowy ■ budynek istniejący ☐ ogłoszenie[4)] ☐ najem/sprzedaż ☐ rozbudowa ☐ inny

Obliczeniowe zapotrzebowanie na nieodnawialną energię pierwotną

EP - budynek oceniany



Wg wymagan WT2008[2)] budynek nowy

Wg wymagań WT2008[2)] budynek przebudowany

[1)]Charakterystyka energetyczna budynku określana jest na podstawie porównania jednostkowej ilości nieodnawialnej energii pierwotnej EP niezbędnej do zaspokojenia potrzeb energetycznych budynku w zakresie ogrzewania, chłodzenia, wentylacji i ciepłej wody użytkowej (efektywność całkowita) z odpowiednią wartością referencyjną.

[2)]Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. Nr 75, poz. 690, z późn. zm.), spełnienie warunków jest wymagane tylko dla budynku nowego lub przebudowanego.

3)Bez chłodzenia i oświetlenia

[4)]W przypadku budynków użyteczności publicznej - tablica w widocznym miejscu

Uwaga: charakterystyka energetyczna określana jest dla warunków klimatycznych odniesienia - stacja : Rzeszów

oraz dla normalnych warunków eksploatacji budynku podanych na str 2.

Sporządzający świadectwo:

Imię i nazwisko:

Nr uprawnień budowlanych albo nr wpisu do rejestru:

Data wystawienia: 31.11.2009

Data: 31.11.2009

Pieczątka i podpis

Figure 29. Energy certificate to "L" buildings (after renovation – 1st page)

4.4 Investigations of the aircraft production hall

In the fig. 30 there was presented the roof of an aircraft production hall after the thermo modernization – building B. The proper result obtained is a result of proper insulation thickness selection as well as it took part in building's art of state. At the average ambient temperature +10°C, the temperature on the roof surface is in the range between +9,7 to +10.4 on 97.5% roof surface – fig. 31.

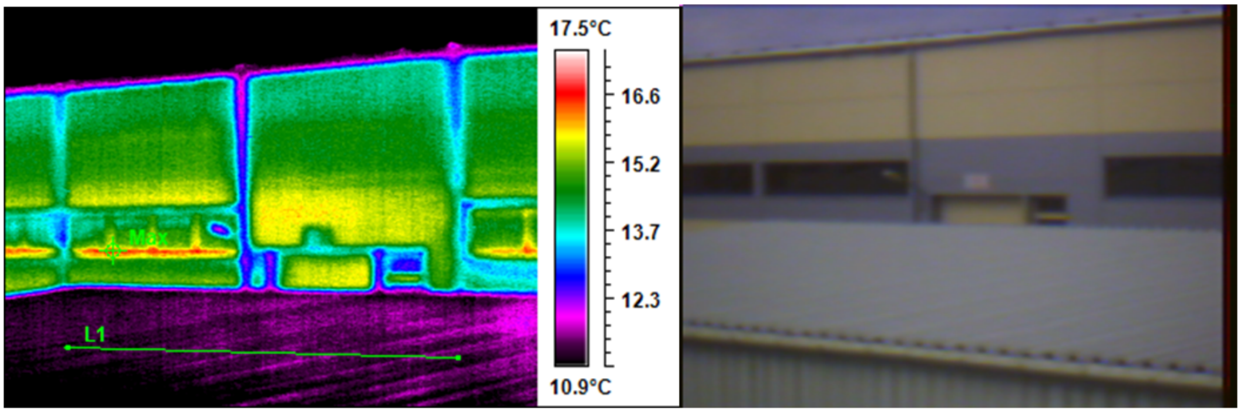


Figure 30. IR image and photo of the production hall walls (after renovation)

The maximum temperature is still a proof of an improperly mounted insulation. In the area close to the bottom part of the window the temperature reaches its maximum +17.5°C and it means that the modernization was done carelessly.

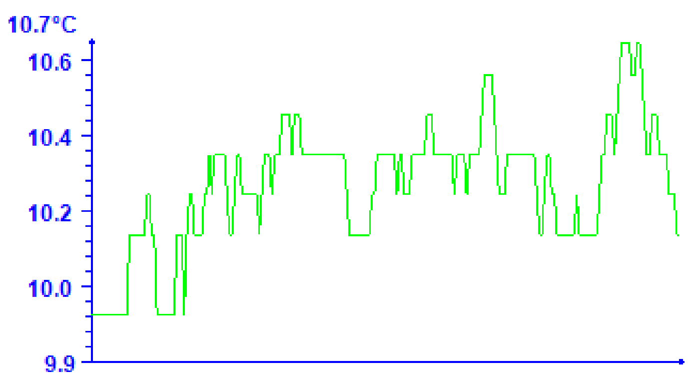
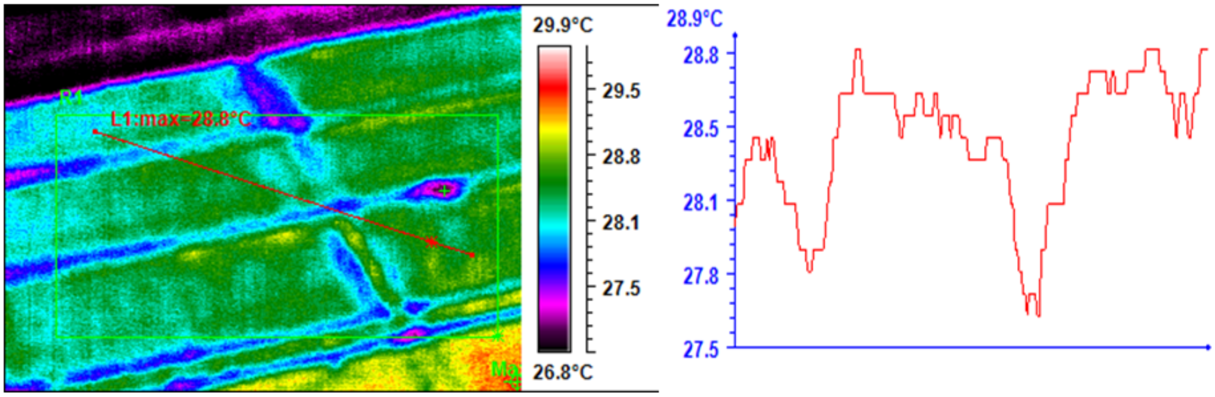


Figure 31. Temperature distribution along line L1 marked in fig. 30

A similar effect of thermo renovation can be seen in fig. 32. A part of the roof after the additional insulation and a new layer of felt put on does not give results expected. There are visible temperature differences along roof surface because of the various thickness of the insulation.



a) IR image b) temperature profile

Figure 32. IR image and photo of the production hall roof (after renovation)

In a table 6 the IR conditions during measurement of the roof at the aircraft production hall after the thermo modernization are presented.

Table 6. Basic IR measurement conditions

Object parameter	Value
Max temperature	28.1°C
R1:Averange Temp.	26.1°C
R1:Max Temp.	28.1°C
R1:Min Temp.	23.1°C
L1: Averange Temp.	26.1°C
L1:Max Temp.	27.5°C
L1:Min Temp.	23.1°C

In fig. 33 result of thermal investigation for case of summer period and cooling system inside the building is presented.

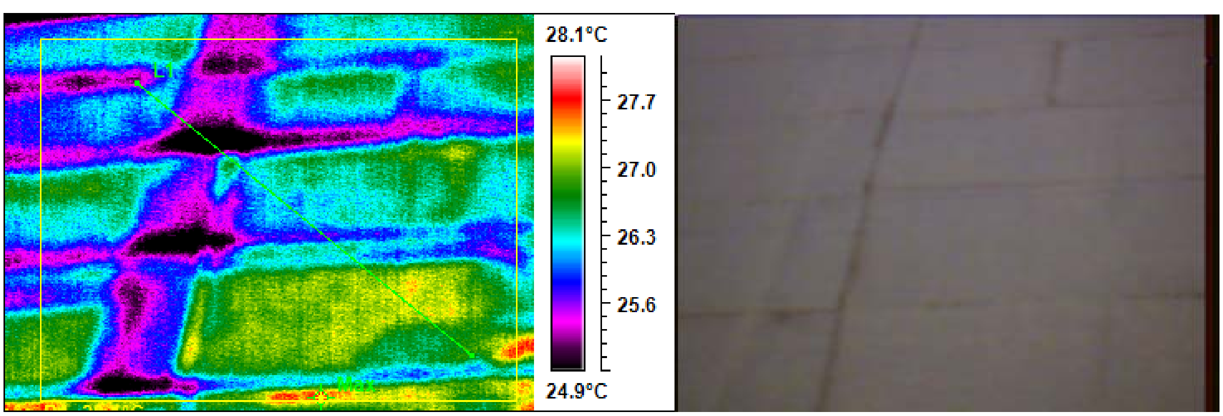


Figure 33. IR image and photo of the production hall roof (in the case of cooling system inside the building – after renovation)

The non homogeneous temperature distribution on the surface of the roof reflects improperly selected insulation thickness. There is a working air-conditioned system inside the hall and cool air is accumulated under the ceiling what leads to uncontrolled cool losses. The air inside the building in that case should be mixed to prevent temperature stratification and decrease temperature difference between ambient air and cooling room.

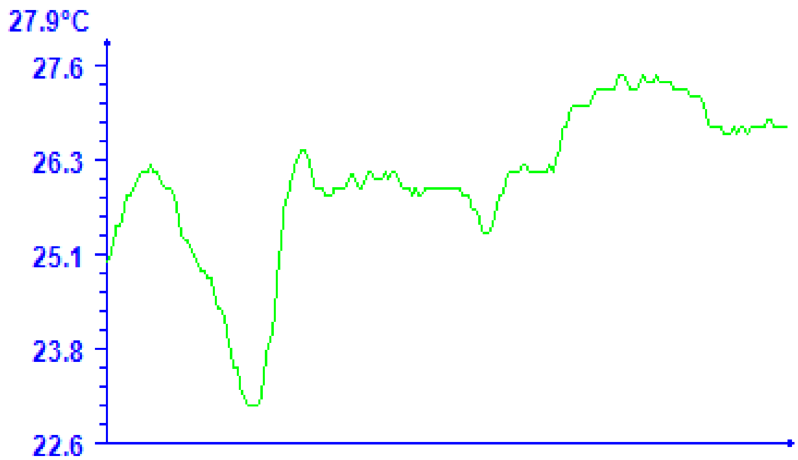


Figure 34. Temperature profile along L1 line in fig. 33

In those places where the mounted insulation sticks to each other, there is sudden decrease of the temperature close to temperature in cooling room and it equals 23.0 ^{o}C at ambient temperature as 28.5 ^{o}C. Such a difference may lead to the large amount of cooling energy flow out of the building.

5. PROBLEMS ENCOUNTERED

Frequently encountered problems are caused by some restricted needs of IR camera operation (measurement distance and the weather conditions). The optimal weather conditions for IR testing should be as follows:

- Steady and not to high ambient temperature (< 5 ^{o}C),
- No windy whether (wind speed < 2-4 m/sec),
- No rainy or snowing days,
- Almost clear sky (without the fog but not very sunny day)
- Optimum distance less than 25 m (IR Guidir 928+).

Considering the recent winter time in Poland (Rzeszów, Nov. 2007 – Dec. 2009 year), it should be mentioned that till now there were only few days with the sufficient climatic conditions for proper IR testing.

6. CONCLUSION

Based on thermal images made for selected objects some conclusion has drown:

ROBERT building:

1. There are many insulation failures in building thermal cover, typical for that type of buildings, described on previously pages.
2. Indicated disadvantages (mainly linear thermal bridges) after certain period of time will lead to negative humidity effects, damage the building construction and make worse indoor microclimate.
3. Insulation defects can influence on level of energy consumption as it ware.
4. With such a construction of the building, in the case of intightness of external building boundaries (not careful mounted insulation), there is the vertical convection moves of air, which perturb horizontal heat flow through external walls. (It can be prove by infrared images from outside and inside the building).

After thermal investigation for building in SUNDAY Systems technology a couple recommendation are made:

1. Increase tightness of insulation, especially at connection walls with roof.
2. Increase thickness of insulation on ceiling round (width about 0,8 m) at roof connection.
3. Increase thickness of insulation on floor round (width about 0,8 m) at walls connection.
4. In the case of floor heating system, the special attention has been taken during montage work.
5. Possibility of building corners insulation together with architects should be taken under consideration to solve problems with thermal bridges.

Hypermarket in Lublin:

There are typical defects occurring, as in the other analyzed buildings. The major are as follows:

- Slid down of mineral fiber in the bottom of external walls.
- Technological inthightness at connection external walls with roof.
- Non homogeneous of building boundaries cased by various insulation thickness.
- Insingularity in insulation inside boundaries.

In many cases considered, the external walls surface histograms show homogeneous construction and insulation thickness but the temperature on their surface allows to assume that the U factor was selected too large. One of possibilities is to mount the insulation of the right thickness but of other type then it was suggested in the technical project.

L – complex at ROT

It was one of two buildings which have been taken to thermal renovation. In the case of L-building it should be noticed that some part of the building (south oriented wall) reveal vast heat losses through surroundings. This wall is still improperly insulated and it should be renovated as soon as possible.

Aircraft production hall

There are typical defects occurring also in other buildings analyzed. The characteristic figure for this building is the heat loss through the roof. The roof is insulated but it has several imperfections in the insulation connections as well as in the selection of the thickness of it. Because of the above-mentioned, the additional layer of insulation is needed as well as the another layer of water proof material. Inside of hall, a huge amount of technological heat gain can be used to hall heating by mechanical ventilation systems or others, eliminating heat losses through the roof.

7. PUBLICATIONS AND PATENTS

There are two publications up to now that presented results obtained on the conferences:

1. Thermovision analysis of the building in aspect of the thermal insulation,
2. Thermovision research of steel construction buildings

The next publication described whole process of thermal building examination is being prepared.