Cost and Energy Savings for a Factory Building after Modernizing the Heating System

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ABSTRACT

Recently, a thermal investigation of a chemical fiber manufacturing building revealed a large number of energy leaks, both large and small, in the heating system [1]. This led the company to take several steps, like installing better thermal insulation around pipes and within a heating unit to reduce their energy loss. In a subsequent infrared imaging inspection, the improved insulation and heating unit post modernization was investigated. The scan indicated that the changes were largely successful. Comparison of old and new thermal images allowed us to estimate the resulting cost savings as well as times for amortization. However, the thermal inspection also revealed several shortcomings in the repair work, which further emphasized the general need for post action inspections. This paper will report on the modernization actions, the differences between pre and post inspection, energy and cost savings as well as old and new problem areas, which still need to be resolved even after the modernization.

INTRODUCTION

The rising awareness for environmental problems, the most important being the now generally accepted global climate change due to anthropogenic emission of greenhouse gases [2] as well as rising energy costs, have lead to energy saving programs in many factories. Due to economic boundary conditions, it is obvious that any kind of modernization will be critically investigated in regard to time for amortization and effectiveness. In this context, repair work due to thermal insulation problems in heating units of chemical fiber plants have begun. In particular, a comparison of the thermal analyses before [1] and after repair should first investigate whether the modernization was successful and provide enough insight to estimate cost reduction and amortization times.

MODERNIZATION OF A HEATING UNIT

As reported earlier, the production of chemical fibers is an energy-intensive process. The necessary energy in the plant under study was provided by two big identical heating units HU1 and HU2 (Figure 1a), which use gas burners and liquid diphyl as a heat transfer medium [3]. After heat insulation problems were detected [1], it was determined that in the first phase, only heating unit HU1 should be modernized.

Figure 1a. Overview of the two heating units (HU1,2), left unit (HU1) with new thermal insulation

Figure1b. Inner part of the heating unit (HU1), new ceramic insulating plates were attached to the walls

In the inner part of the gas burner (Figure 1b) new ceramic insulating plates were attached to the walls. This thermal insulation material with thickness of 25 mm has a low thermal conductivity of 0.09 W/m·K, at an average operating temperature of the plate of 250°C. The temperature in the inner part of the HU1 is typically around 470 °C. The thermal conductivity of the ceramic plates at this operating temperature is higher than 0.09 W/m·K; the exact value is, however, unknown. The repair work was done while downsetting the unit during the regular annual inspection period of about two weeks. The repair costs amounted to 56,000 €, (approximately $73,000).

COMPARISON OF BOTH HEATING UNITS AFTER REPAIR OF HU1

To make the first qualitative estimate for successful repair work, it is necessary to compare the thermal signatures of two previously identical units. Figure 2 depicts IR-images, recorded with a LW camera (ThermaCam SC2000). While this image was taken, HU1 was operating at a thermal power 3.5 MW_{th} whereas HU2 only at 2.7 MW_{th}. If both units behaved identical, one would obviously expect the HU1 outside walls to be warmer than those of HU2. However, the opposite occurred. Although operating at about 30% more power than HU2, HU1 showed lower thermal losses, i.e. the repair work was indeed very successful.

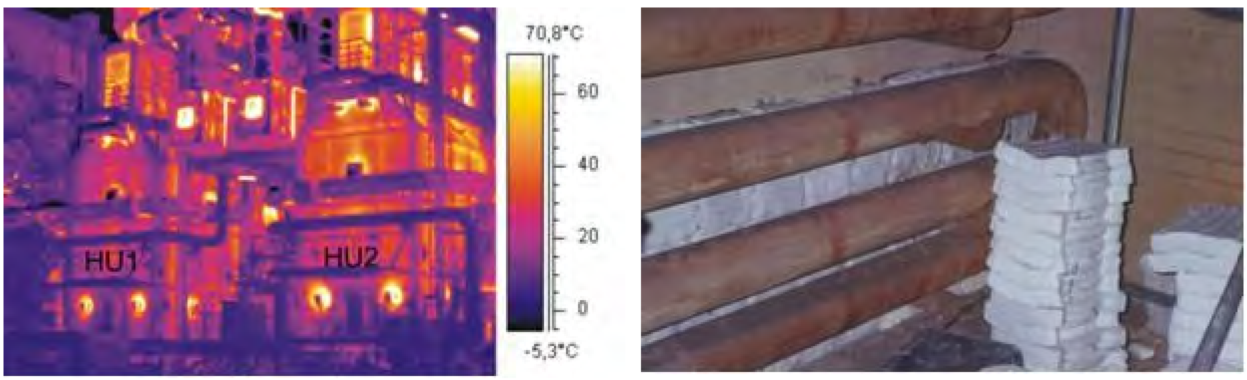

Figure 2. IR-image of both heating units (left: HU1 with new insulating plates inside, right: HU2 not insulated)

A quantitative comparison is shown in Figure 3. Areas AR01 and AR02 were analyzed at about the same observation angles and revealed temperature decreases between 3.7 to 15.5 K. A quantitative analysis of the energy savings proves difficult, however, due to the difference of the two operating thermal powers. For this reason, it proved necessary to make a direct comparison of HU1 before and after repair.

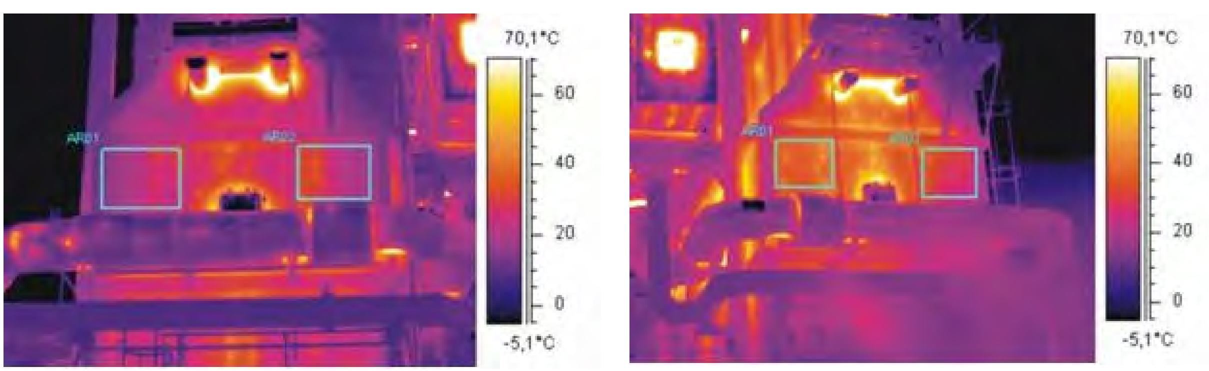

Figure 3. Enlarged sections (AR01, AR02) as indicated in Figure 2 of the front section of HU1 (left) and of the front section of HU2 (right).

COMPARISON OF HU1 BEFORE AND AFTER REPAIR

A detailed quantitative analysis was completed by comparing measurement of HU1 before and after repair (Figure 4). The images were recorded at the end of November 2005 (before) and beginning of December 2006 (after) for comparable operating conditions at P_{th} = 3.5 MW and similar ambient temperature around 5°C (left) and 2°C (right). Figure 4 shows such views of HU1, plotted for the same temperature range. The analysis area AR01 revealed average temperatures of 36°C before and 29°C after repair. This decrease is mostly due to the new thermal insulation and only partly due to the slightly higher ambient temperature after repair.

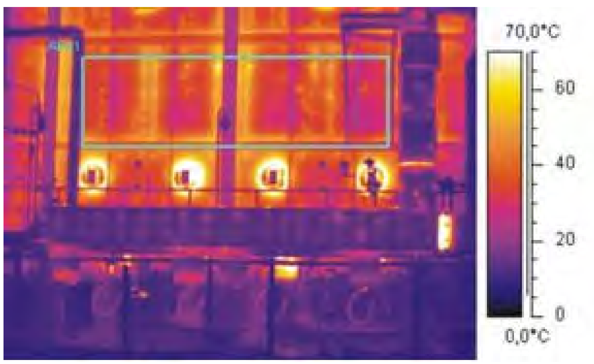

Figure 4. Side view of HU1 before repair work (left) and after repair (right) with the same analysis area AR01. Average temperatures were found to be 36°C (left) and 29°C (right).

A quantitative measurement of the heat flux was made with a heat flux plate [1]. Before repair work, a heat flux of only 250 W/m² was measured. After the repair, a reduction by 80 W/m² led to much lower heat flux of only 170 W/m². Obviously, the exact value depends on the ambient temperature and wind speed [4], and seasonal variations are expected.

The outer surface area of the heating unit amounted to about 240 m². Using an 80 W/m² reduction in heat flux, the reduction in thermal loss power amounts to $P_{reduction\ loss}$= 19.2 kW with an annual cost savings of

$$19.2\ \text{kW} \cdot 8{,}400\ \text{h/a} \cdot 0.035\ \text{€/kWh} \approx 5{,}650\ \text{€/a}.$$

Regarding the costs of 56,000 €, amortization will take 10 years at current gas prices. This period may become smaller if gas prices continue to rise. The repair company predicted 3 years. Presently they plan to modernize heating unit HU2 during the next regular inspection period.

We need to emphasize that a quantitative analysis of energy savings and amortization time is not possible with IR imaging alone. In addition to IR imaging, a quantitative measurement of heat flux is necessary, e.g. with heat flux plates. If only IR imaging is available, a much more sophisticated analysis is needed using the influence of wind speed and its influence on the heat transfer through the walls [4]. Obviously, the seasonal variations of ambient temperatures and wind speed as well as heating power will have an influence on these results.

MODERNIZATION OF A PUMPING STATION IN THE CHEMICAL FIBER PLANT

Besides the heating unit itself, a previous inspection detected heat losses in the pipe system and pumping units [1]. Quantifying these heat losses is usually very difficult [5]. Here, we report results of the thermal analysis after completing repair work on a pumping station.

HEAT LOSSES IN THE OUTER PIPE SYSTEM OF THE PUMPING HOUSE

Figure 5 (left) illustrates appreciable heat leakages in the upper part of the outer pipe system, whereas thermal losses in the lower part of the valve were low. The right visible image of Figure 5 shows the system with new thermal insulation.

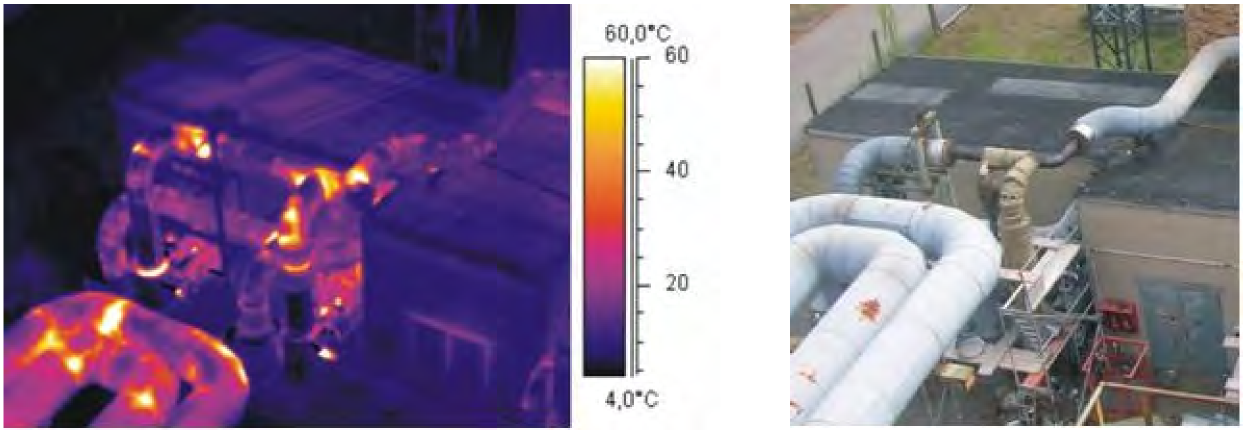

Figure 5. Thermal insulation leak in the pipe system close to the pumping station (left) and visible image of the new insulated pipes after repair work (right).

The new thermal insulation (expanded view Figure 6, right) does not need aluminium lamination like the old insulation (Figure 6, left). A direct comparison of old and new insulation is depicted in Figure 7 (left), in the vicinity of the pumping house. Obviously, the old insulation in Figure 7 (right) was rotten and wet, which led to increased thermal conductivity of the material. Unfortunately, such wet insulation cannot be easily identified with IR-imaging without destroying the system (see wet surfaces [6, 7] since they are covered by the metal hosing of the pipe). The insulation leak detected during inspection may have been caused by a number of different factors, such as shifted insulation mats, wet insulation mats, direct leaks through small holes in the tube, bad construction of the housing with connections of the tube to outer housing, etc. The company estimates that the repair work of the pipe system close to the pumping station leads to a reduction of gas consumption by 2m³/hour. Using a current gas price of about 38.5 ct/m³ (3.5 ct/kWh corresponds to about ~11 kWh/m³), this reduction corresponds to annual cost savings of about 2 m³/h x 8,400 h/a x 0.385 €/m³ ≈ 6,500 €/a.

Figure 6. Old (left) and new (right) thermal insulation of pipe system close to pumping station.

Figure 7. Direct comparison of old and new insulation of pipe system (left) and expanded view of old, wet and rotten insulation mats (right).

HEAT LOSSES INSIDE OF THE PUMPING HOUSE

As previously reported [1], there were also four faulty or even non-insulated pumps in the pumping station (see Figure 8 [1]), with surface temperatures above 340°C! This led to enormous heat losses. As a result of the previous IR analysis, all 4 pumps were getting insulated with thermal insulation mats covered by an aluminum housing (see Figure 9). As a result of the repair work, the room temperature in the pumping house dropped from 30°C to 15°C during winter. The correlated drop on gas consumption was estimated by the company to be around 4 m³/h, leading to annual savings of about 13,000 €. Comparison to the repair costs of about 20,000 € for insulation of the pumps and the tubes outside of the pumping house, the annual total savings of 13,000 € + 6,500 € = 19,500 € corresponds to an amortization time of only about 12 months.

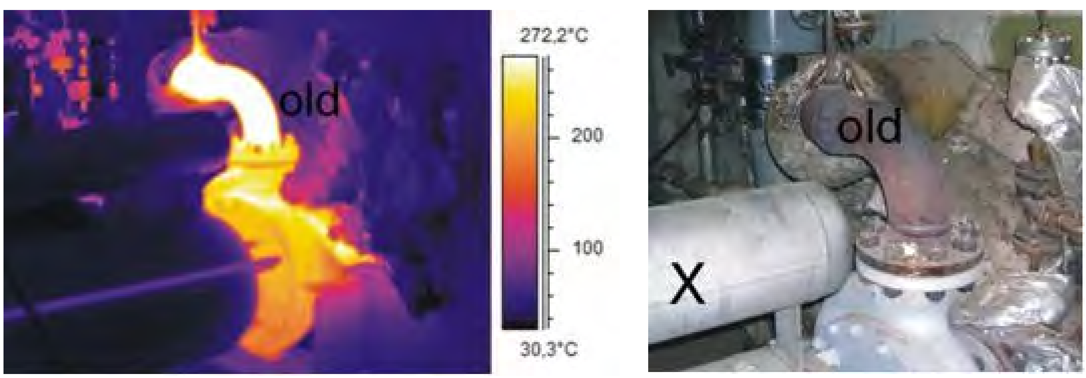

Figure 8. Missing insulation at a pump results in surface temperatures above 340°C [1].

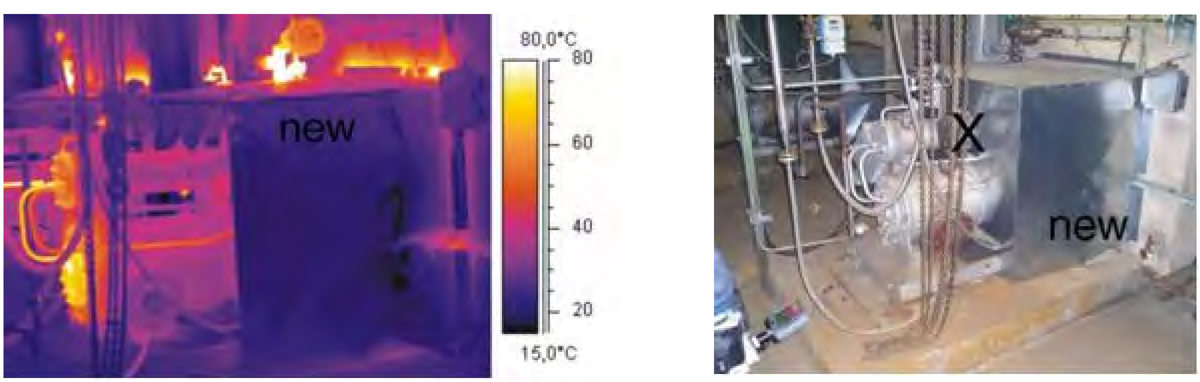

Figure 9. Example of the new insulation of a pump (right). The IR image revealed a strong reduction in heat loss (left). The marked spots in the visible image refer to the same location.

POST REPAIR CONTROL CERTAIN PRODUCTION HALL

The necessity of post-repair thermal imaging analysis is nicely demonstrated by Figure 10. Within the production hall, the tube system close to a steam radiator was covered with new thermal insulation. However, the insulation at an already covered part of a tube was pushed upward for additional work and never was brought back to its original position. Consequently, part of a tube showed surface temperatures above 270°C. The IR analysis quickly helped to identify and solve the problem.

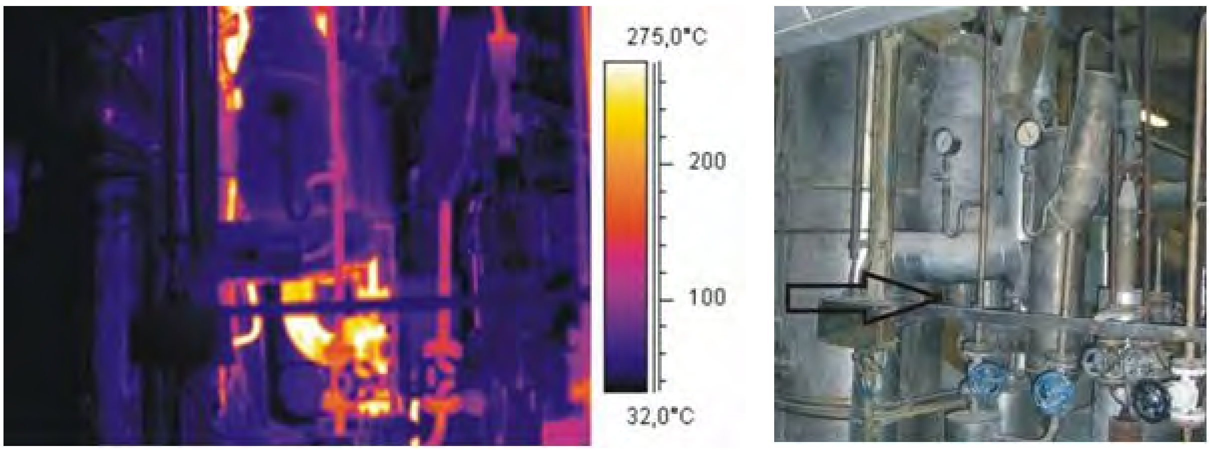

Figure 10. The new thermal insulation on a tube was pushed upward during repair work and forgotten afterwards. Thermography quickly identifies the problem, emphasizing the importance of post repair inspections.

SUMMARY

IR thermal imaging inspections of a chemical fiber plant can help to identify problem areas and suggest repair work. Afterward, post repair inspections revealed the success of the modernization and pointed out problems that still needed to be addressed. In addition, the reduction of gas consumption allowed the company to estimate annual cost reduction and the amortization times for repair costs. In addition, human errors occurring during repair work are more easily identified with post repair inspections, emphasizing the necessity for quality control in repair work.

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ACKNOWLEDGEMENTS

The authors wish to thank the company MÄRKISCHE FASER and F. Zienke for providing the resources to make this work possible.

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