

AIR HEATING UNITS IN REFINISH SPRAY BOOTHS - STATE OF THE ART AND PROPOSITIONS

Energy efficiency in every part of our live is the one of the main goals of European Union this also applies spray booths. The paper presents an analysis of current state of the art of air heating units used in spray booths for refinish industry. It also presents solutions proposed by the author and the benefits arising from them. The hybrid system with recuperator and heat pump can reduce power consumption of heating unit about ten times. It will minimize six times the total power of the spray booth.

INTRODUCTION

The spray booth the most power consumption unit used in painting process [5]. The most common parts of refinish spray booth which need power supply are fans, lights and air heating units. Table 1 presents power ranges of particular parts. The control circuits and actuators are neglected in case of low power consumption. For central and north part of Europe the power of air heating unit reach upper value of power range equal 300 kW. This value provides possibility of heating the fresh air stream with a volume of 20 000 cubic meters per hour.

Table 1 Power Ranges of particular parts of Refinish Spray Booth

| Unit | Power Range [kW] |
|------------------|------------------|
| Fans | 15 – 22 |
| Lights | 1,5-2,0 |
| Air Heating Unit | 200-300 |

As shown in table 1 a part of the heating unit in total power of spray booth is about 90 percent and more. Then if we talk about the spray booth energy efficiency, mainly heating unit should be taken into consideration. At air heating units can be find different solutions of heat sources also powered by different media.

1. HEAT SOURCES

1.1. Burners

Most often used heat sources are burners. Those are oil or gas burners with heat exchangers.



Fig. 1. Heat exchanger (Cameoline)

The heat exchangers efficiency is usually declared by suppliers on level over 90 percent. Figure 1 presents heat exchanger used by one of spray booth's producer [6].

Can be found gas burners with open flames. One hundred percent of heat is transferred into the air together with combustion products. But water is a main product of gas combustion. It increases humidity of the heated air. In a winter time it is not as harmful as spring or autumn, when the fresh air humidity is high. Increase of air humidity also prolongs the drying time, especially for waterborne paints. Figure 2 shows a gas direct burner with open flames located inside air supply duct.

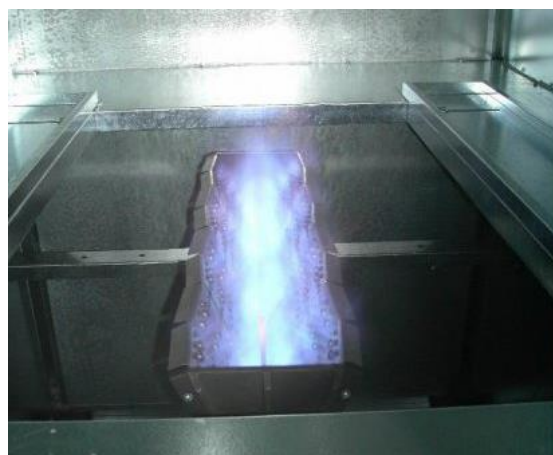


Fig. 2. Direct burner (AIRA-C)

1.2. Radiation Heat Source

The radiation air heating is proposed by Italian company Sy-mach. Electric radiant heaters are located in plenum over ceiling filters. By UV radiation ceiling filters are heated then the air passing through the filter is heated. 100 percent of heat is transferred into the air. On the north part of Europe expected power of heaters is equal 300 kW. It is to high power for electric heaters. In case of emergency stop of fans hot radiant heaters with capacity of 300 kW located close to the filters may cause a fire hazard. Figure 3 shows a solution with radiant heaters.



Clima System Solarys

Fig. 3. Radiant heaters located over the ceiling filters (Symach)

1.3. Alternative Heat Sources

There are another alternative heat sources like renewable energy sources, urban heat or accumulated heat. Figure 4 shows solution proposed by German company Wolf. Proposed installation uses accumulated heat. Heat can be buffered from different sources.

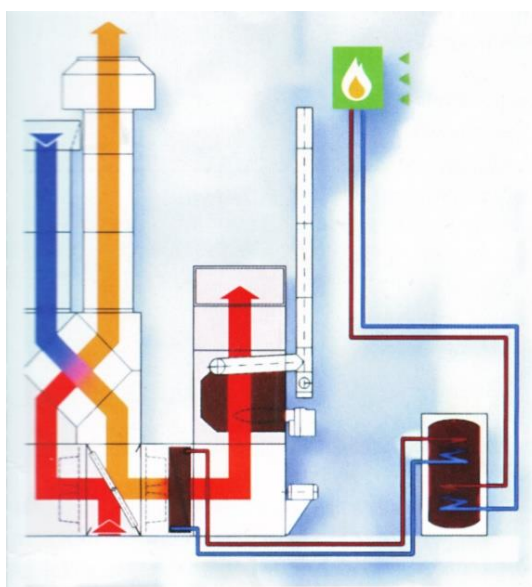


Fig. 4. The use of heat from accumulator (Wolf)

2. HEAT RECOVERY

2.1. Cross Recuperators

In case to increase Energy efficiency of air makeup units, the heat recovery installations are used. Solution shown in figure 4 includes also a heat recovery unit. The most often used in spray booths heat recovery units are cross recuperators. The idea of using cross recuperators comes from building's ventilation systems. The heat recovery efficiency for each recuperator is declared at the level of 45 percent. Figure 5 shows diagram of air circulation inside the spray booth equipped with cross recuperator. Spray booth works in painting mode. Part b of figure 5 presents the physical implementation of heat recovery installation.

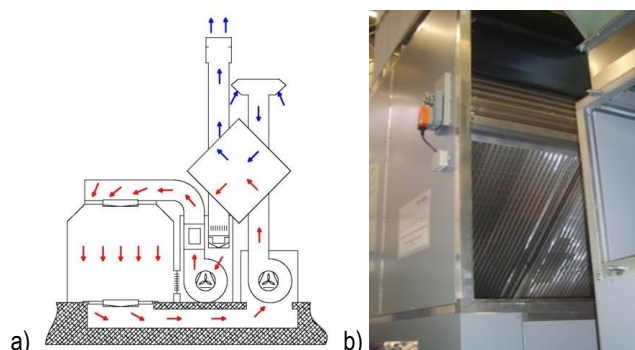


Fig. 5. Heat recovery using cross recuperator a) scheme of air circulation in painting mode b) physical implementation

Real live shows that cross recuperators are sensitive on overspray sediments. The distance between lamellas is in range of 12-15 mm. Is hard to clean up so narrow channels. There are no tools and cleaning methods. Very often the cleaning attempts causes damage of recuperator. Additionally overspray sediments are very good thermal isolators. The average growth rate of overspray sediments is equal 0.5 mm per one thousand hours. The overspray sediments grooving decrease heat recovery efficiency and finally clog recuperators [1], [2]. Figure 6 shows recuperator contaminated by overspray sediments.



Fig. 5. Recuperator contaminated by overspray sediments

2.2. Rotary Recuperators

Rotary recuperators are much easier to clean. The micro channels are washed with high pressure water and dried by air under pressure. Rotary recuperators are used in industrial spray booths. For refinishing spray booth the diameter of rotary unit should be about two meters. This solution is not used for refinishing workshops in case of space requirements for installation with so big diameter. Figure 6 shows construction of rotary recuperator.



Fig. 6. Rotary Recuperator

3. PROPOSED SOLUTIONS OF AIR HEATING UNITS

3.1. Counter Flow Recuperator with Bypass

Generally counter flow recuperators are more effective than cross recuperators. Proposed by author heat recovery unit consist of channels with hot air located inside of fresh air ducting [3]. The efficiency of heat recovery depends on the hot air ducts diameter, quantity and installation high. The bypass is used at the moment when the heat recovery is not expected, for example during post ventilation after drying mode. The hot car body and spray booth construction are cooled, then the heat recovery is not expected. The air circulation with or without heat recovery is realized by closing dampers and opening another ones. During this time the heat can be recovered for heating air inside the workshop. Proposed solution is presented in figure 7.

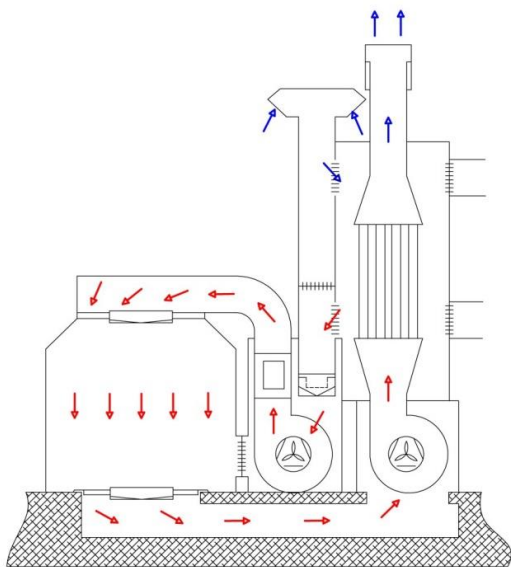


Fig. 7. Counter Flow Recuperator with Bypass

The analysis of heat recovery efficiency for proposed solution were conducted. One of analysis was conducted for diameter of hot air ducts $d_{r1} = 100$ [mm], duct's wall thickness: $\delta = 1$ [mm], total

quantity of ducts $m_r = 78$ pieces. Figure 8 presents heat recovery efficiency as a function of installation height.

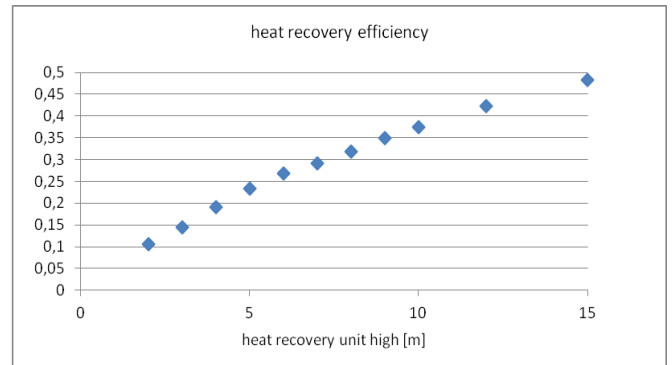


Fig. 8. Heat recovery efficiency as a function of installation height

As shown on figure 8 the heat recovery efficiency similar to cross recuperators can be reached at high about 12 meters. In mechanical strength's point of view it is too high. But efficiency can be increased by the quantity of hot air channels. For double quantity the heat recovery efficiency of 45 percent can be reached at about 6 m high. Modern buildings for works hops are high about 6 meters.

This kind of solution also has another advantage – self cleaning of overspray sediments. The idea is taken from the lottery machines. Flying balls inside the channel hit the walls and clean of overspray sediments. The cleaning process can be conducted when is necessary.

3.2. Hybrid Heat Recovery

In previous solutions of heat recovery the ejected air living recuperator has still positive temperature. Then for the next step of heat recovery a heat pump can be used. Figure 9 shows proposed by the author solution with recuperator and heat pump.

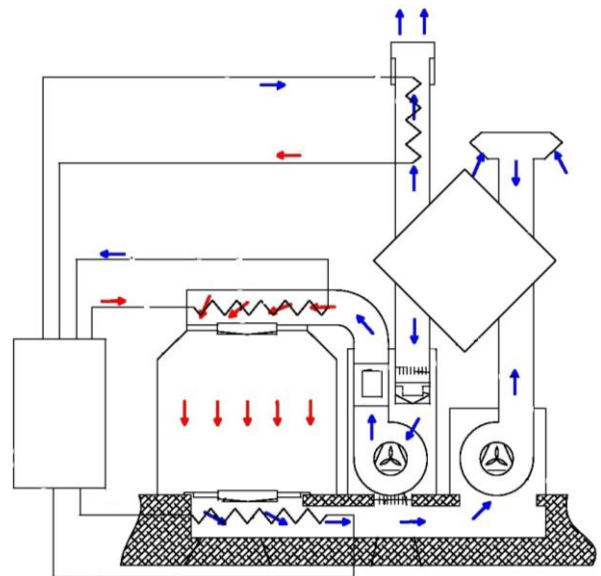


Fig. 9. Hybrid hat recovery with recuperator and heat pump

Heat pumps are characterized by COP parameter (Coefficient of Performance). It describes how many kilowatts of heat can transfer using one kilowatt of electricity. COP depends on temperature difference between liquids inside heat exchangers. Figure 10 shows COP as a function of temperature difference [4].

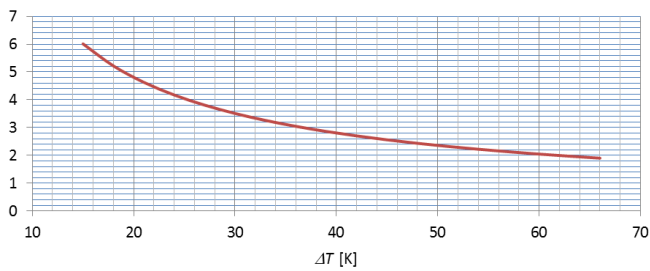


Fig. 10. COP as a function of temperature difference

Fresh air is heated by heat exchanger located over the ceiling filter. Average speed of fresh air flow through the ceiling filter has a value in the range of 0.2 – 0.4 m/s. The surface of the heat exchanger over the entire ceiling filter has a large area. It allows to obtain a high rate of COP by temperature medium in heat exchanger at 35 Celsius degrees. Figure 11 shows results of simulation for following parameters: thermal power of heat pump: 120 [kW], external air temperature: -10 [C].

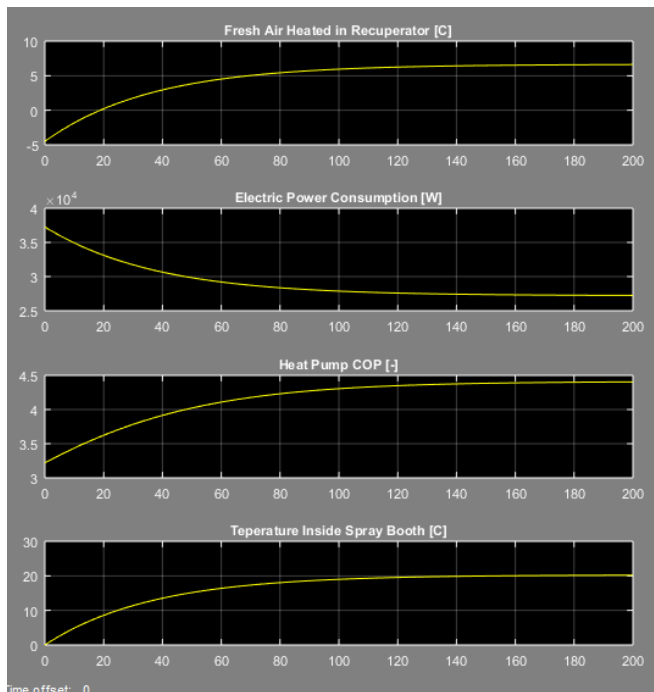


Fig. 9. Simulation results for hybrid heat recovery with recuperator and heat pump

Simulations were conducted at MATLAB/SIMULINK software. Presented graphs show the temperature of fresh air heated in the recuperator, electric power consumption by heat pump, heat pump COP and temperature of air inside the spray booth.

CONCLUSION

Currently on the market the most often are offered air heating units with burners and optional cross recuperators. The hybrid system with recuperator and heat pump can reduce power consumption of heating unit about 10 times. It will minimize six times the total power of the spray booth.

Presented values were obtained on mathematical model simulations. The real savings can be validated on real physical object.

Additionally the use of heat pumps allows for cooling and dehumidifying of the air and gives the possibility of accumulation of heat.

BIBLIOGRAPHY

1. Nikończuk P., Study of Heat Recovery in Spray Booths, Metal Finishing, 2013, Vol. 111. 37-39
2. Nikończuk P., Preliminary analysis of heat recovery efficiency decrease in paint spray booths, Transactions of the Institute of Metal Finishing 2014 VOL 92 NO 5, 235-237
3. Nikończuk P., Zakrzewski B.: Urządzenie do wymiany powietrza z odzyskiem ciepła, zwłaszcza w komorach lakierniczych, patent PL 217481,
4. Zakrzewski B, Złoczowska E., Tuchowski W., Efektywność powietrznych pomp ciepła, Chłodnictwo 2013 No 4
5. Energy Consumption of Painting and Coating Equipment, Project Report, Iowa Waste Reduction Center, June 5, 2002
6. <http://cameoline.pl/>

Ogrzewanie powietrza w renowacyjnych kabinach lakierniczych – stan bieżący i propozycje

Poprawa efektywności energetycznej w każdej części naszego życia jest jednym z głównych tematów Unii europejskiej. Dotyczy to również kabiny lakierniczych. Artykuł przedstawia analizę bieżących rozwiązań ogrzewania powietrza w renowacyjnych kabinach lakierniczych oraz propozycje rozwiązań opracowanych przez autora. Przedstawiono podstawowe korzyści ze stosowania proponowanych rozwiązań. Proponowany hybrydowy system ogrzewania powietrza pozwala na sześciokrotną minimalizację mocy całkowitej kabiny lakierniczej.

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