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"WALCZAK'S PIPES" IN THE GREENHOUSE HEATING SYSTEM

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Abstract

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Diversified heating circuits inertia is particularly important by high variability of external conditions were the greenhouse is often overheated or large heat losses are noted. To meet these needs a new generation of heating pipes were used. They are hexagram-shaped pipes called "Walczak's pipe". Tubes of such shape have several times smaller volume in comparison with traditional heating pipes of the same outer diameter and higher stiffness. The preliminary assessment of the "Walczak's pipe" installed in the greenhouse is highly positive. Compared with the traditional system it enables better heat management. In the first research stage, the thermal efficiency was defined in different ambient conditions at selected flow parameters and various water temperatures. With regard to the accepted flow values, it is notable that "Walczak's pipe" has greater thermal efficiency per unit of power comparing with traditional tube. During the study, there was also a thermographic analysis of pipes' surface performed and the heat flow distribution was determined. Analyzing the temperature distribution on the "Walczak's pipe" remarkable are the areas with higher values comparing with standard tube. It can be concluded that in the heating system with "Walczak's pipe" energy transferred by radiation increases. This is particularly advantageous solution to use in greenhouses. It allows to obtain a higher leafs temperature with respect to the ambient temperature (vegetation heating). This parameter has a beneficial effect on the vegetative growth of cultivated plants.

Keywords: Walczak's pipe, heating pipes, greenhouse, heating system

INTRODUCTION

The wide knowledge of new harvest technologies and plants requirements in under cover production make demands to producers regarding construction and equipment of greenhouse. Achieving high and qualified crops is possible when optimal conditions of growth are guaranteed (Beck *et al*., 1990; Gaziński, 2005). Modern greenhouses should fulfill those conditions, hence their constructions and equipment changes radically (Bredenbeck, 1989; Bakker, 1995; Dabbene i in., 2003; Kurpaska i in., 2004; Kurpaska, 2007). In order to gain well light access the height of greenhouses rises together with reduction of heat loses (Kurpaska, 2008; Grabarczyk, 2008). The constructors of greenhouses try to fulfill horticulture producers needs nevertheless our research shows that there are significant possibilities to improve growing microclimate and reduce heat loses.

The power need in heating system of greenhouse has a great diversity of heat. These differences range from a few to several times, both during the day and depending on the changes in climatic conditions. Research shows that greenhouses use on average 15–25% of peak power. Any change in the intensity of solar radiation (what is common during autumn and spring) results in immediate heating power demand (Zabeltitz, 1991; Rutkowski, 2006; Rutkowski, 2008a, 2008b, 2009a, 2009b, 2009c).

In connection with high amount of heating water inside installation (ca. 20m³·ha⁻¹), the heating system requires a heat source with optimal heating power and volume of warm water. Above mentioned factors force the use of such solutions that provide heat demand as well as the efficient use of energy.

Modern heating system in the greenhouse should not only ensure proper temperature but also it aligns the air movement in the vegetation zone and responds for quick system reaction to change external conditions (Henten, 1994; Kurpaska, 1995; Wysocka-Owczarek, 2001). To meet these requirements the independent control of heating circuits with varied thermal inertia shall be done. Diversified heating circuits inertia is particularly important by high variability of external conditions were the greenhouse is often overheated or large heat losses are noted. To meet these needs a new generation of heating pipes were used. They are hexagram-shaped pipes called "Walczak's pipe". Tubes of such shape have several times smaller volume in comparison with traditional heating pipes of the same outer diameter and higher stiffness. Low capacity of heating system enables its' quick response to variable external conditions. The preliminary assessment of the "Walczak's pipe" installed in the greenhouse is highly positive. Compared with the traditional system it enables better heat management. Heating has a significant impact on plant growth and health condition. The aim of the heating system is to maintain the proper temperature, depending on the plants growth stage.

Among many heating systems the most common in Poland are heating elements with the tubes form arranged in a different configuration in use. Among the new trends, there are good sleeves located under the gutters for growing plants. This system allows also the waste heat utilization (Rutkowski, 2011). The basis for an efficient heating system are pipes installed with the adequate capacity, properly arranged to the plants and the appropriate control system, matched to the heating system and certain climatic conditions.

It is also important that applied systems should guarantee plant leaf temperature above ambient temperature. Independently controlled heating circuits should have proper temperature and efficiency to meet all the growing requirements and provide smooth air movement in the vegetation zone. That contributes to the heat savings and also reduces losses of supplied CO_2 (Libik, 1994).

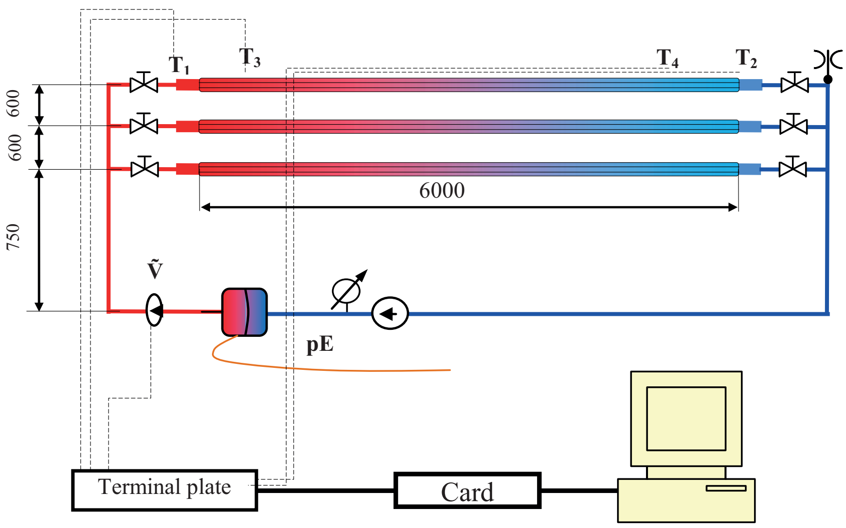
MATERIAL AND METHODS

The evaluation of heating pipes with a cross section of a six-star (Walczak's pipes) are conducted. Analyzed pipes are produced from thin-walled round steel pipes with diameters of 38 and 55 mm. They have more than 2.5 times smaller capacity in comparison with standard pipes. It enables fast change of heating system parameters at rapid changes of external conditions. The study was carried out in accordance with the standard guidelines of the thermal devices measurement.

The lab station is located at the Faculty of Production and Power Engineering of University of Agriculture in Krakow.

At the Fig. 1 the key system elements are presented i.e. a set of tubes and measuring system. The basic system elements are three heating pipes with a length of 6000 mm installed as shown in the Fig. 1, arranged horizontally and connected to the system powered by heat flux generated by heating elements placed in the heat storage tank of 10 dm³.

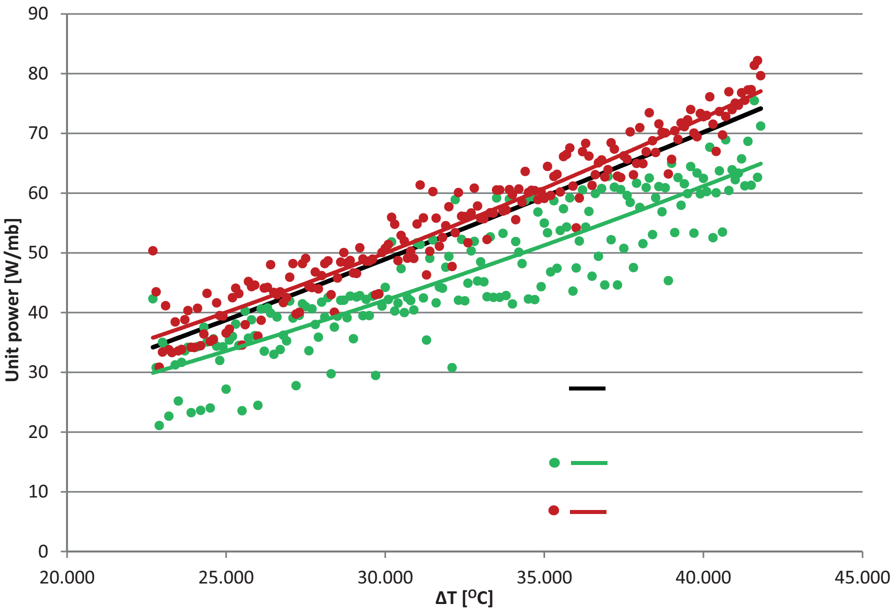
An essential component of the measuring system was DT9818 USB card with sixteen analog voltage inputs. Measured values were recorded directly to a PC using an DasyLab 11.0 application which managed the card operation. The measured values were recorded at a sampling rate of 1.0 Hz. Temperature measurements at the heating pipe input and output and its environment were



1: *The scheme of research system of heating pipes*

I: *Measuring elements of test stand*

Symbol	Measured value	Device
T_1, T_2	Input and output temperature	Temperature sensor PT 100, Range 0–60 (°C), Precision; 0.01 (°C)
T_3, T_4	Ambient temperature	Temperature sensor PT 100, Range 0–60 (°C), Precision; 0.01 (°C)
4	Air humidity	Humidity transmitter PWW, Range; 0–100 (%) RH, Precision; ±2 (%)
5	Flow rate of medium	Flowmeter MTWH, QNOM= 2.0 ($m^3 \cdot h^{-1}$), 1.0 (dm^3/impuls)



2: *The unit power efficiency of pipes according to temperature differences at two flow rates*

made by paired sensors (T_1, T_2, T_3, T_4 – Fig. 1). Such arrangement of sensors allowed to complete balancing of the heat flux in the heating system. Also the flow rate of the working medium in the hydraulic system was measured with MTWH flowmeter.

In the research also relative humidity was monitored, inside and outside the room where the system was installed. The specification of all the measurement elements are shown in the Tab. I.

Electricity is necessary to power the heaters providing heat flux to the pipes using a circulation pump supplied with constant voltage (DC). The circulation pump allows to adjust abruptly the medium flow in terms of five values of the flow rate.

RESULTS AND DISCUSSION

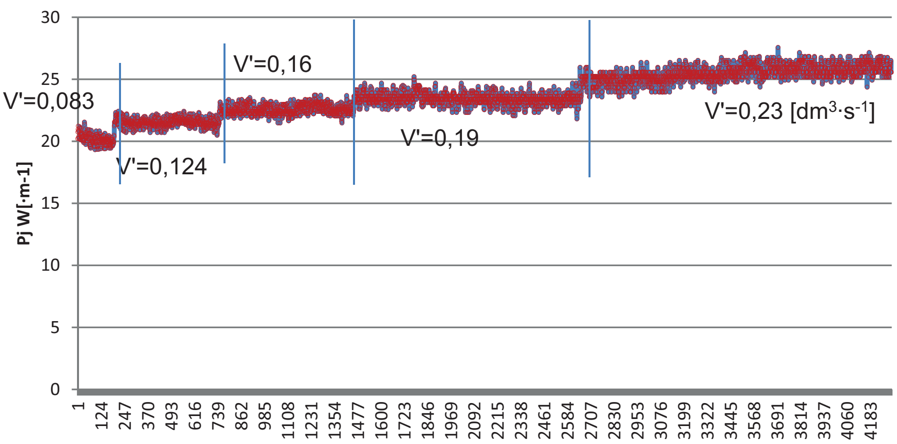
In the first research stage the thermal efficiency was defined by ambient temperature of 6–8 °C. The heating medium which is a heat carrier was water at a temperature of 60 °C.

Test results for the analyzed and standard pipe with a 51 mm diameter are shown on the Fig. 2.

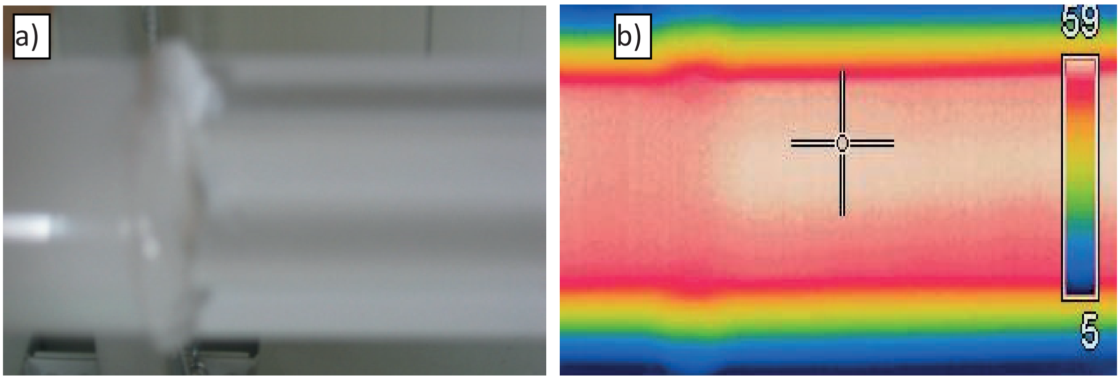
The trend line of a unit heating capacity of Walczak's pipes and standard pipe has been determined for different ΔT values (difference between the temperatures of the heating element and the environment). With the increase of temperature difference (ΔT) at a flow rate of 8.5 $dm^3 \cdot min^{-1}$ (corresponds to 0.24 $m \cdot s^{-1}$ speed) trend line is growing (green line, Fig. 2). For example by temperature differences of 22–24 °C the unit efficiency of 1 meter pipe rises of 33 W.

It is also observed that with rising of the flow rate of the heating medium to 12 $dm^3 \cdot min^{-1}$ (equivalent to 0.35 m/s) markedly increases the heat efficiency of pipe in the range of whole analyzed temperature difference.

Comparing the trend line of pipe by flow of 12 $dm^3 \cdot min^{-1}$ with trend line of 8.5 we have noticed much more dynamics of the unit heat efficiency. Referring the gained results to the exploitation values by Tantau (1982) it can be concluded that the analyzed pipes by higher flow rates have a higher



3: *The unit heat power of star-shape heat pipe (rolled with diameter of 51 mm) by Δ T = 16 (⁰C) depending on medium flow*



4: *The connection of Walczak's pipe with rounded pipe: a) real view b) thermography*

unit power efficiency. Rising of power efficiency is particularly visible by highest temperature difference. Having into account remark of significant power change of heat pipe the detailed research by constant temperature difference between ambient and heating medium. During this test only medium flow was changed and results from 5 repeats are showed on the Fig. 3.

The effect of the constant difference between temperatures of ambient and medium inside the pipe was achieved thanks to electric heater supplied with constant power which has delivered proper heat flow to the medium.

By constant temperature difference of ΔT = 16 (°C) for star-shape heating pipe a significant rise of power unit from 20 to 26 $W{\cdot}m^{-1}$ is observed, that is 30% by flow rate from V' = 0.083 to 0.23 $dm^3{\cdot}s^{-1}$.

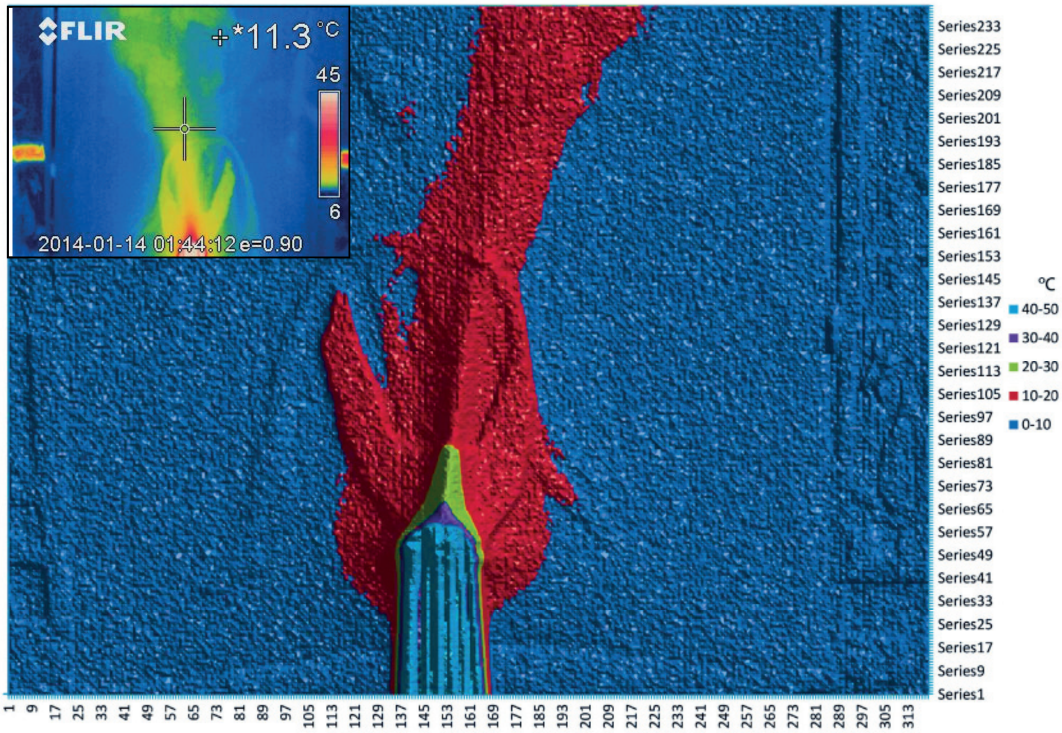
Such a large increase (30%) in the unit power of Walczak's tube, by a constant temperature difference between the outside and the factor inside the heating system made by only three times increase of medium, offers new possibilities to control the microclimate inside the greenhouse. The second stage of research on heating pipes was the analysis of temperature distribution on the pipe surface and around it, with use of thermovision camera.

The heating pipes have differential temperature on its surface (Fig. 4b) in comparison with heating pipes with round profile. The lowest temperature on the protrude star elements (perimeter) allows using heating medium with higher temperature without plants burns. The highest temperature at the beginning of the star's vertices allows bigger heat transfer by radiation (Fig. 4).

Analyzing the spatial distribution of temperature around the heating elements there is remarkably much better heated air flow around the heating element of Walczak's pipe.

This flow is remarkable wider at the basis with wide range. The standard pipes have much worse temperature distribution in the ambient. The heated air stream is narrow at the basis and much more shorter.

Heating elements – Walczak's pipe, beside presented positive heat values connected with new pipe construction, have also better exploitation values connected with movable vegetation heating system due to the smaller water capacity and limitation of the weight of the movable heating elements. These pipes are easy to install (Fig. 6).



5: *Spatial temperature distribution around the Walczak’s pipe, thermography and raster*

6: *Heating elements of movable vegetation system (Walczak’s pipe – primary diameter of 51 mm)*

CONCLUSION

Analyzing the research results and the production in the objects where the Walczak’s pipe where installed it can be stated that using starshape heat elements is reasoned.. Analyzed elements have a small water capacity (heat) and thin wall material and they meet the literature requirements for movable vegetation heating system (Fig. 5).

Differentiation of the temperature in the heating circuit about 2–6 °C (depending on medium temperature) influences on the form of heat transfer to the plants. It can be stated, based on the preliminary observations in the production objects, that the health of cultivated plants (tomatoes) is higher in comparison with those with traditional heating system. Detailed research on the ambient temperatures and the heat loses thru covers with use of Walczak's pipe will be the goal of coming analysis.

Based on current results it can be concluded that Walczak's pipes are suitable both for the movable vegetation system as well for the others heating system requiring larger pipe cross sections. Simultaneously it was found that, the pipes connections on the curves (especially by long pipes connections) should be with beadings with lower flow resistance and facilitate system venting.

These remarks were undertaken by the pipe producer.

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