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A Development of High Frequency Induction Heater for Green House

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***Abstract* – The induction heating system for green house was discussed in this paper. 20kHz oscillator was applied in order to reduce the danger of electromagnetic wave. Out coming wind is controlled by temperature of 50℃ in order to keep the condition of plants in the green house. We developed high frequency induction fan heater which have a power of 10kW and a heat transfer. If we use a diesel heater, it absorb oxygen gas and emits harmful gases in the night. Also emitted CO_2 gas could not helpful for crops in the night. This HF induction fan heater was applied to the strawberry, the hot pepper and mushroom green house in Nonsan area, and got a production increasement and reducement of heating cost.**

***Keywords* – High Frequency, Induction Heating, Green House, CO_2.**

I. INTRODUCTION

In general, a fan heater maintains the fixed temperature in winter by artificially increasing the temperature of air. And the principle is as follows. As heat is conducted to the surrounding air from various types of heat sources, the temperature of air rises. And it becomes possible to be heated by diffusing the air of which the temperature has been increased. The heat sources of this fan heater can be classified into oil, gas, firewood, electric heater, etc. However, in case of fan heater using oil, the oil is expensive. So, the economic burden is heavy. Besides, a place where the oil is purchased is limited to gas station etc. Accordingly, it is very troublesome to purchase the oil. In 2014, FTA between Korea and China gave many farmers an assignment of gaining international competitiveness by technology-intensive agricultural techniques. In particular, except rice, getting agricultural products to have high quality will contribute to the suppression of import of Chinese agricultural products and the increase of farmer's income by export at the same time. On the other hand, a lot of plastic greenhouses are installed all over the country for agricultural production during winter. In addition to that, for heating during winter, various types of heating equipment were installed with the support of government and municipalities. However, heating systems using waste-derived fuel, diesel oil and kerosene cause the accumulation of harmful materials in airtight greenhouses, and deplete oxygen needed for the crops at night. So, this causes many problems in farm that intends to product environmentally-friendly agricultural products. Besides, in case of some installed electric heating systems, air circulation is not smooth. So, a forced heat transfer pipe made of plastic film is installed. However, appropriate temperature cannot be maintained. Accordingly, there are many cases of spoiling agricultural products. Fig. 1 shows an electric heater at a plastic green house in Y city as a model. And Fig.2 shows a multi-purpose carbon dioxide generator installed in a plastic greenhouse. In case of electric heater, if the heated air is in direct contact with the crops, these may be damaged or withering phenomenon accompanied. In case of electric heater installed in Y city, excessive electric bill was charged. So, the heater was replaced with a fan heater using induction heating. In case of N city, it was replaced with fan heater using induction heating in order to reduce the release of harmful materials and the burden of fuel expenses. Therefore, a heating system should satisfy the condition where harmful materials are not emitted, and temperature distribution is uniform by good air circulation, and appropriate temperature is maintained even on a cold night, and maintenance cost is low [1,2,3,4,5,6].

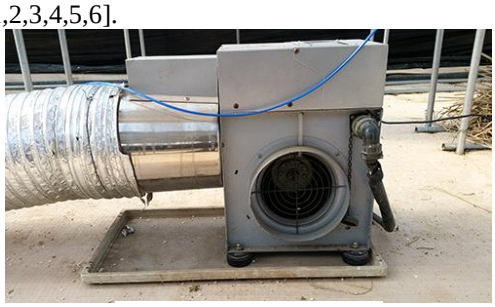

Fig.1. The electric heater

Fig.2. The multipurpose CO_2 generator

II. NECESSITY OF RESEARCH

A. Background Technology

A fan heater is a heating system where a fan that blows air is installed and it is a system that increases indoor temperature by emitting heat to the outside through blowing air. A general operating method of fan heater is as follows. An electric heater or ceramic heater is installed. And if heat is generated by operating the heater, the generated heat is emitted to the outside by operating the fan that blows air. There is a fan heater that uses kerosene or gas. However, there is a weak point of high fuel costs. Besides, an electric fan heater consumes a lot of electric power. So, recently, a high-frequency induction heating system using induced current to consume a small amount of electricity has been started. However, it takes a long

time to increase temperature from initial indoor temperature to the set indoor temperature. Accordingly, there is a problem of deterioration in heating efficiency.

B. Solutions

In order to make up for this weak point, it is possible to increase energy efficiency by transferring heat emitted from a heat exchanging part or circuit board with blowing air besides main air blowing through radiator. To this end, a high-frequency induction heating and air blowing system is composed of radiator part, air blowing device part, induction coil air vent, PCB board vent, etc.

III. System Overview

A. Metal container for induction heating and induction coil

The self inductance of induction coil is calculated as follows.

$$L = N\frac{\varnothing_B}{I} = \mu_0 \frac{N^2}{l} A \quad (1)$$

That is to say, with regard to self inductance of solenoid, if the number of turns is increased, if cross-sectional area is increased, or if length is decreased, capacity increases. Besides, the energy stored in solenoid is proportional to self inductance and to the square of current.

$$U = \frac{1}{2} LI^2 \quad (2)$$

Through this, if induction coil is skillfully designed, current can be properly controlled. In general, the flow of much current is related with safety. And a suitable circuit breaker should be installed. However, if current can be decreased, it is safer. In general, average power supplied by power supply is transformed into internal energy in resistor like a direct current circuit. In an alternating current circuit, there is no power loss relating to pure inductor and pure condenser. Therefore, the proper design of oscillatory circuit and induction coil can effectively control power consumption. This study used a method of installing a coil at a ceramic tube that is heat-resistant and has proper strength. The position at which the coil is installed is not seriously considered because a forced circulation method is used by circulation pump. The induction heating effect is produced as eddy current is generated on the surface of water tank made of steel. And the temperature can be kept at 100℃ or below by water with which the water tank is filled.

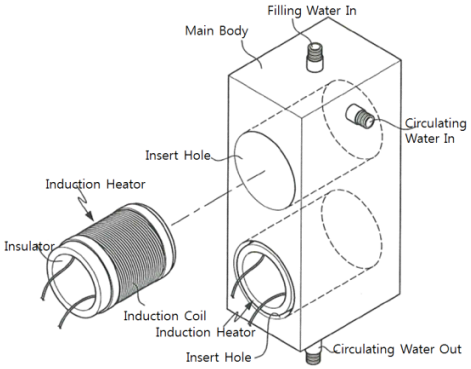

Fig.3. Water heating by HF induction heater

B. 3.2 Heat exchanger

It is effective if the surface area is maximized for the heat release of heat exchanger in case there is a forced convection system such as fan. Surface area can be increased if heat sinks are attached closely to each other. And the shape of radiator in automobile is a good example. In case of natural convection of water, the design of container is a matter of where the heating part is placed. And from the viewpoint of the characteristics of fluid, it is advantageous to place the heating part at a lower position. This is because fluid goes up as density decreases in case of an increase in temperature. If the heating part is placed at the side or upper position, downward water circulation is hampered. So, it is inefficient. However, with regard to an active method, there is a method of circulating water at high rate by using a circulation pump. In this case, the position of the heating part has a less effect. This study selected a forced circulation method utilizing a circulation pump for rapid heat transfer.

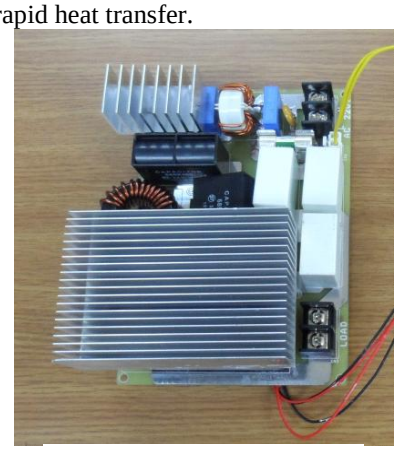

Fig.4. Circuit of HF generator

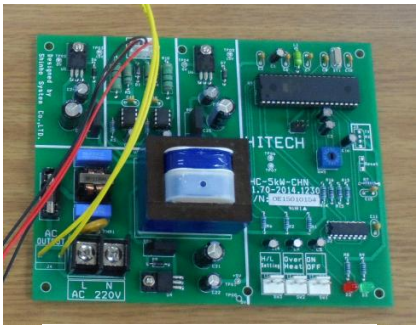

Fig.5. Circuit of auto controller

C. High-frequency oscillation and control

Safety was increased by selecting relatively lower frequency of 20kHz. Fig. 4 shows an oscillatory circuit. And Fig. 5 shows a control circuit. Each module was designed at electric power of 5kW. And in case of 10kW, 2 sets were used.

D. 3.4 Equipment configuration

With regard to the outward shape, a cuboid shape was selected. And as seen from the front, it is composed of induction heating part on the left, heat exchanging and delivery part in the middle, and oscillation and control part on the right. And they are interconnected. When a fan heater is operated, major heat is generated by induction

heating in the water tank. And collaterally, there is heat generated from PCB, heat generated from coil itself, etc. Heat generated from water tank is transferred to radiator by a circulation pump. And heat is given off to the front by main fan. Heat generated from PCB and coil is given off to the outside by 4 small fans. This has an effect of removing a blind spot around the fan heater. Fig. 6 shows the external appearance of fan heater using induction heating. A stopper is put on the make-up water inlet port so as to prevent water from evaporating in the state of stagnant water. With regard to the fan, the wind was made to blow to the opposite direction of radiator in order to reduce noise. Fig. 7 shows a schematic diagram of internal structure.

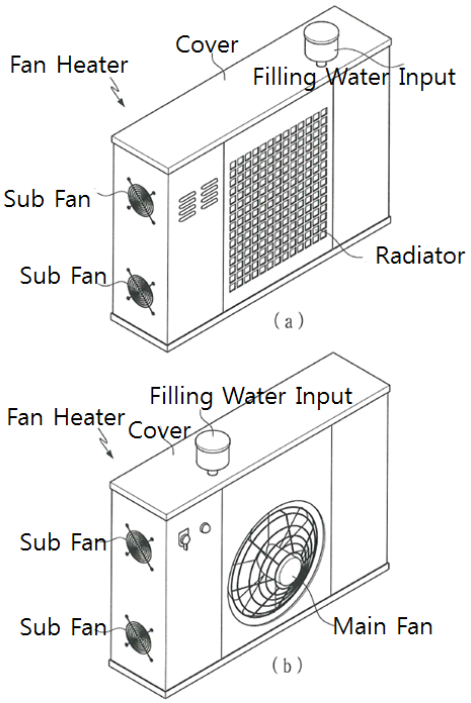

Fig.6. Structure of HF Induction heater
(a: backward, b: forward)

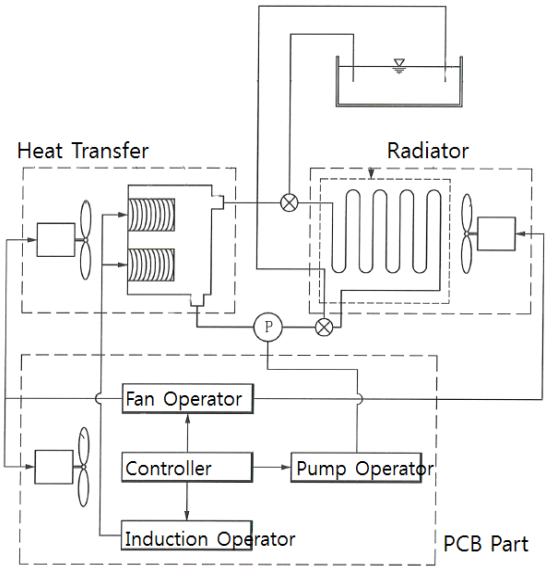

Fig.7. Schematic diagram of HF Induction heater

IV. In-situ Inspection

A. 4.1 Status of cultivation in greenhouse

As of 2013, a survey showed that there are 180,490 farms having a greenhouse for cultivation all over the country, 11,859 farms having an automated greenhouse, 166,256 farms having a general plastic greenhouse, 801 farms having a glass greenhouse, and 3,091 farms cultivating mushrooms, and so on [7].

Some companies developed a storage fan heater using cheap night time electricity in farm village [8], or introduce stand-up high-frequency induction heaters with fan [9] for 33 m^2 or 66 m^2 of heated area. However, these are not suitable for plastic greenhouses on an area of 330 m^2 or above.

B. K Agricultural Research & Extension Services test and analysis [10]

A diesel fan heater and high-frequency induction heater with fan was comparatively tested and analyzed in K Province Agricultural Research & Extension Services located in S city. A test was carried out for approximately 3 months from 13 January 2014. And the main contents of test include the status of crop growth, the present condition of change in temperature, and the comparison of operating costs between diesel fan heater and high-frequency induction heater with fan, and so on. Table 1 is a comparative table of operating costs between diesel fan heater and high-frequency induction heater with fan. The operating costs were calculated on the presumption that the price tax-free diesel fuel is KRW 800/L. It is possible to find that the operating cost of high-frequency induction heater with fan is approximately 1/4 of operating cost of diesel fan heater.

Table 1. Operating Fee

Heating	Fee (KR~~W~~)	Source
Diesel	1,997,518	GARES
Electric	527,328	GARES
E/D	26%	

Fig. 8 shows a change in temperature inside a plastic greenhouse by diesel fan heater and high-frequency induction heater with fan in comparison with open-air temperature. The indoor temperature of greenhouse is affected by open-air temperature. Temperature required according to crop is different. However, in general, it is said that maintaining the minimum temperature of 10℃ is important. The graph shows that the minimum temperature trends of high-frequency induction heater with fan are different before and after February 24. This is because a bias was compensated for after February 24 as the bias of temperature sensor had not catched yet. Therefore, data after February 24 can be regarded as more significant as the minimum temperature of diesel fan heater and high-frequency induction heater with fan was kept at a similar level. As seen here, there is a change according to open-air temperature. However, it was verified that the minimum temperature was kept at 10℃ or above, which was temperature where crops didn't suffer damage from cold weather.

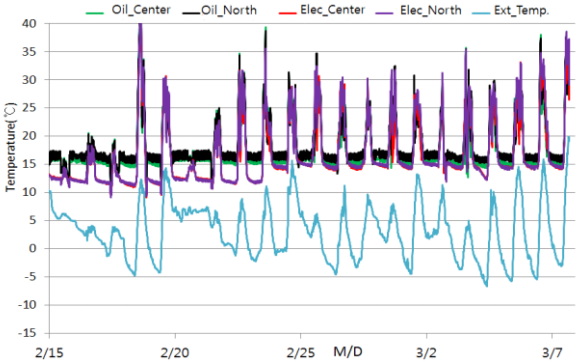

Fig.8. Temperature of green house using oil heater and HF induction heater.

As mentioned above, with regard to growth status, the diesel fan heater emits a large amount of CO_2 at night and depletes oxygen required for plant respiration. So, in the morning, it is possible to verify that many plants have withered. Fig. 9 shows the comparison of tomato development status in greenhouses where a diesel fan heater and high-frequency induction heater with fan is installed.

Fig.9. Tomato growing in the green house(oil heater(up) and HF induction heater (down)).

C. 4.3 Survey after in-situ installation

According to the results of farmers' using high-frequency induction heater with fan after installing this at mango farm in Jeju Island and strawberry farm located in N city, Chungnam Province, it was shown that internal temperature was relatively uniform. And there was no outside moisture inflow. So, no dewdrop was formed on the surface of plastic greenhouse. Therefore, the greenhouse became well-lighted. And mold disappeared. And the yield increased by 30% or above. With regard to fuel cost, the cost was caused to be lower by about 74% than when oil was used. Fig. 10 shows high-frequency induction heaters with fan, which are installed at the greenhouses in strawberry farm and mango farm.

Fig.10. Setting examples(up: strawberry, down: mango)

V. Conclusion

According to the results of applying 10kW high-frequency induction heater with fan after manufacturing this, the yield increased by 30% or above. And heating cost reduction effect was produced by 74% in comparison with the heating cost of kerosene and so on. That is interpreted as an yield-increasing effect produced because plants don't suffer from stress as no CO_2 and harmful gas is emitted at night. Induction heating is thermally efficient as heat is transferred to water inside a metal container after the metal container is directly heated. This is considered to be heating cost reduction effect.

Acknowledgment

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