Fluid Heating System using High-Frequency Inverter Based on Electromagnetic Indirect Induction Heating

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ABSTRACT

In this Paper are described the indirect induction heated boiler and induction heated hot air producer using the voltage-fed series resonant high-frequency inverter which can operate in the frequency range from 20 kHz to 50 kHz. A specially designed induction heater, which is composed of laminated stainless assembly with many tiny holes and interconnected spot welding points between stainless plates, is inserted into the ceramic type vessel with external working coil. This working coil is connected to the inverter and turbulence fluid through this induction heater to moving fluid generates in the vessel. The operating performances of this unique appliance in next generation and its effectiveness are evaluated and discussed from a practical point of view.

Key Words: High-Frequency Resonant Inverter Applications, Fluid Heating Appliance, Pipe-line Heating, Electromagnetic Induction-Fluid Heating, Auto-Tuning PID Temperature Control.

1. Introduction

New proposed heat exchange system between the electromagnetic induction heater and fluid is a kind of pipeline system. With this system various kinds of fluid such as vapor, liquid and gases can be precisely heated from low temperature to ultra high temperature. In this process occurs not burning, so that the working environment can be improved. This electromagnetic induction heating technique is used high frequency inverter. By using high frequency inverter high frequency alternative current (HFAC) in the range of kHz to MHz can be made with conventional alternative current.

In this contribution IGBT module is used for high frequency inverter. The total system is composed of phase delayed PWM resonant high frequency inverter, inductor work coil, which produce high frequency flux, and specially designed filled metallic package, which can heat fluid in vessel.

Drift fluid is to be heated abruptly by eddy current losses, which are generated inside of specially designed laminated metallic package. As a load is used a vessel, in which is inserted specially designed laminated package. An auto-turning PID controller controls the temperature at the outlet of the vessel in order to maintain a setting temperature. The converse system from electrical energy to thermal energy has two different types. One of them is DPH (Dual Packs Heater) system. DPH system can heat the fluid from inner to outer through the specially designed laminated package in pipeline. The other is SPH (Single Pack Heater) system. SPH system can directly heat the fluid from induction heated out side of vessel, which is composed of magnetic stainless steel and aluminum.

In this contribution a newly developed DPH and SPH system of a high-frequency resonant inverter controlled electromagnetic induction heating system will be described the performance and its applications.

2. Structure of magnetic induction heating system

Fig. 1 shows the structure of DPH system. Inside of heating vessel in isolated pipeline the specially designed laminated metallic package is inserted, which can be heated by eddy current losses. Working coil, which is wrapped outside of pipeline, makes the eddy current. Electromagnetic induction heater can heat Water or gases in pipeline very rapidly.

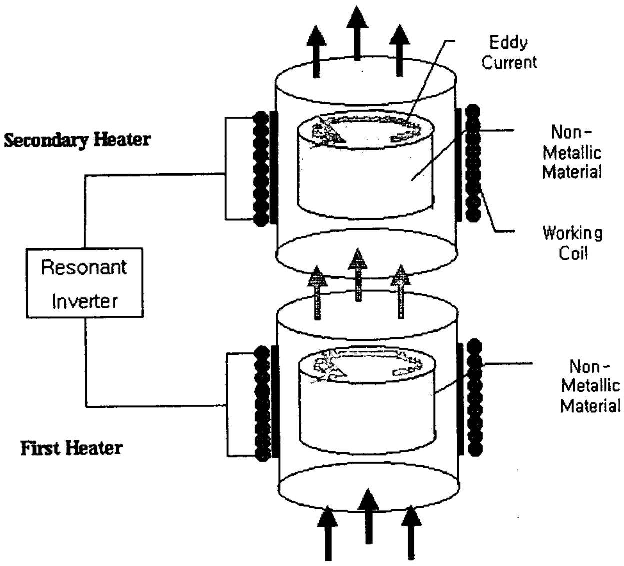

Fig.1 Configuration of the DPH system

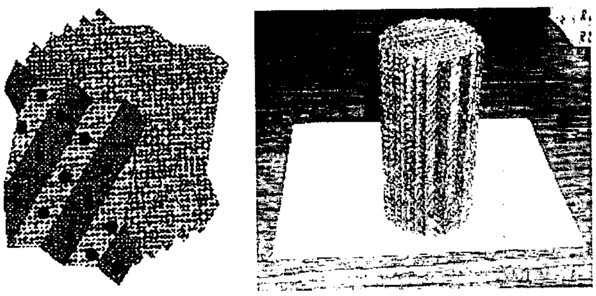

Fig. 2 Induction-heated metallic package

Fig. 2 shows laminated metallic package as heater material. This package is composed of not metallic wire but metallic plates, so that in case of high temperature heating the ability of electrical isolation, opening or shorting is superior. With this package one can obtain good temperature response of the outlet because the heat capability and the fluid resistance are small. So this appliance has many good characteristics.

3. High frequency inverter and its control unit

Fig. 3 shows the voltage-fed full-bridge series loaded resonant inverter. It can be considered as an electrical circuit, which is composed R and L that depends on the depth of isolated pipeline or the material of laminated metallic package. Actually a matching transformer is used between the working coil and the heated material. Capacitor C in fig. 3 compensates inductance L. To choose a working frequency is very important in order to drive for high efficient in series resonant circuit.

By using series compensate capacitor C in R-L circuit we can construct R-L-C series resonant circuit as a load. If the load is not heated to limitation, the circuit constant is scarcely changed, so that we can consider just as R-L circuit. Under the optimal resonant constant to compensate L the series load compensator C can be used. If the turn-on resistance of IGBT is greater than R in R-L load, the series resonant circuit is more effective. In the other case the parallel resonant circuit is more effective.

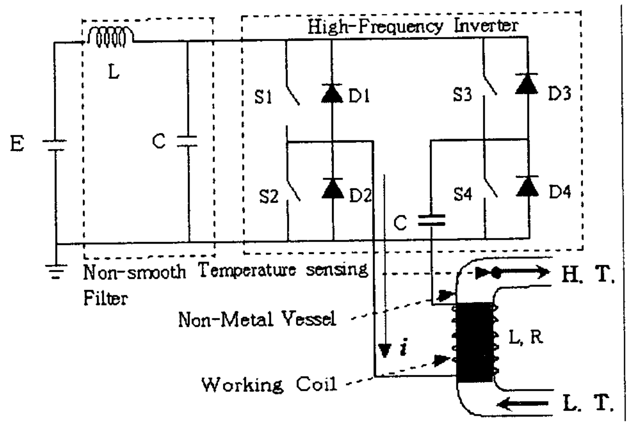

Fig. 3 Voltage-fed full-bridge type series load resonant inverter

Fig. 4 shows voltage-type series resonant switching pattern. One can continuously vary the phase difference ϕ between the phase of driven voltage pulse of S1(S2) and S4(S3) from 0° to 180°, so that the output voltage can be controlled.

Fig. 5 shows the output voltage behavior, when the output frequency is resonant frequency of loaded resonant circuit.

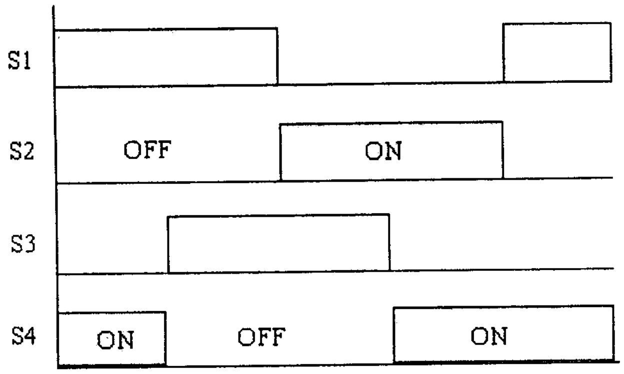

Fig. 4 Voltage-type series resonant switching pattern

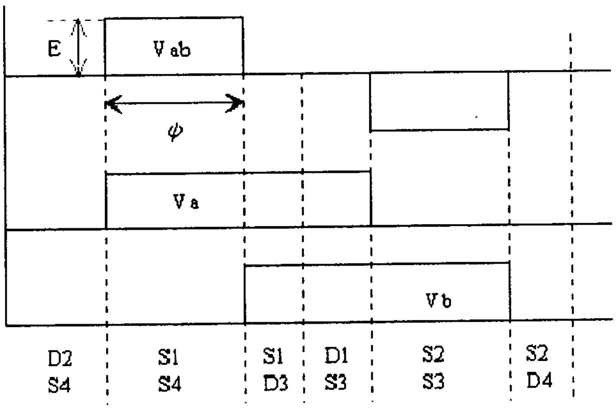

Fig. 5 Steady-state voltage waveform

4. High frequency inverter controlled electromagnetic fluid heating system

Fig. 6 shows the new proposed schematic induction-heated electrical energy conversion system. This system has two major functions. One of them is power transform processing unit, which conventional 60Hz power is transformed to high frequency alternative current (HFAC). The other is control unit, which can control the outlet temperature.

Generally heat exchanger is using the temperature difference between the materials such as fluid or gas without mixing. Here we should heat the inner side of metallic package, so that we need high frequency current in range of several decade kHz. This experimental system is used low voltage drop typed IGBT module (100A/1200V) as switching device for inverter. We used voltage typed current resonant method. IGBT should have low V_{CE}(sat). Of cause also MCT or B-SIT can use instead of IGBT .

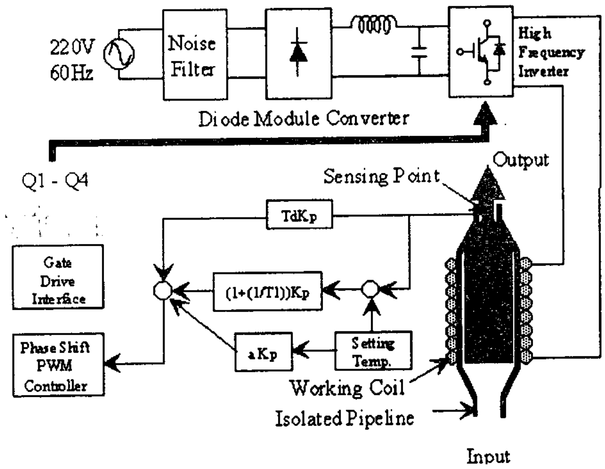

Fig. 6 New proposed schematic induction-heated electrical energy conversion system

A diode rectifier without the smoothing LC filter is used, so that without using a complicated active PWM control sinusoidal wave line current shaping in the utility-AC grid is to be easily performed. To observe in load side, as fig. 6 with simple control system phase-shifted PWM control is performed to switch always near resonant frequency. This satisfies optimal junction condition. By using high frequency inverter DC-HFAC transducer can be made light and small.

Because of using ZCS behavior mode by series resonant circuit, the switching device like IGBT, which is turned on by MOS-gate drive and is turned off by bipolar mode, has tail current occurred little transient loss. Furthermore with only clamp typed lossless snubber circuit, system stability against abruptly voltage surge can attempt. Standard arm of phase-shifted PWM full-bridge inverter is constructed by lossless capacitance snubber as lossless inductance snubber control phase arm. In this view point soft switching can be performed in PWM control process, so that without concerning the PWM control auxiliary resonant commutation arm link typed high frequency PWM inverter can be adopted. Fig. 7 shows used resonant inverter system. The first heater has power of 5kW and the second heater has power of 3kW. DPH load can be controlled by auto-turning PID controller. This can see in fig. 8. Table 1 presents a basic specification of DPH system.

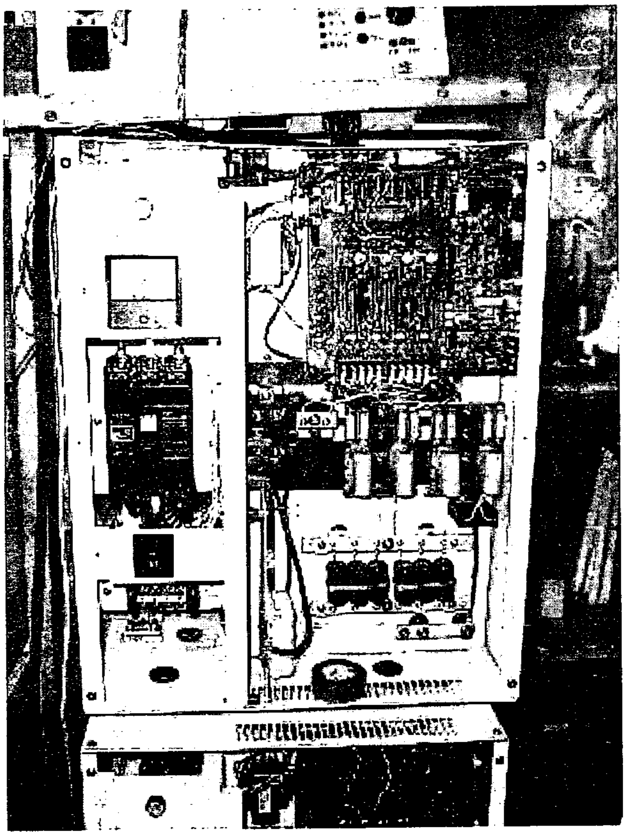

Fig. 7 Experimental set up resonant inverter system

Table 1. Specification of DPH system

Item	Unit	DPH
Capacity of first side	KW	5
Capacity of secondary side	KW	3
Amount of vapor	Kg/h	6.5 ~
Used Pressure		conventional
Temp. control method		PID
Connection Method		direct
Used Line Power		3 Phase 220V
Power	kVA	8.5

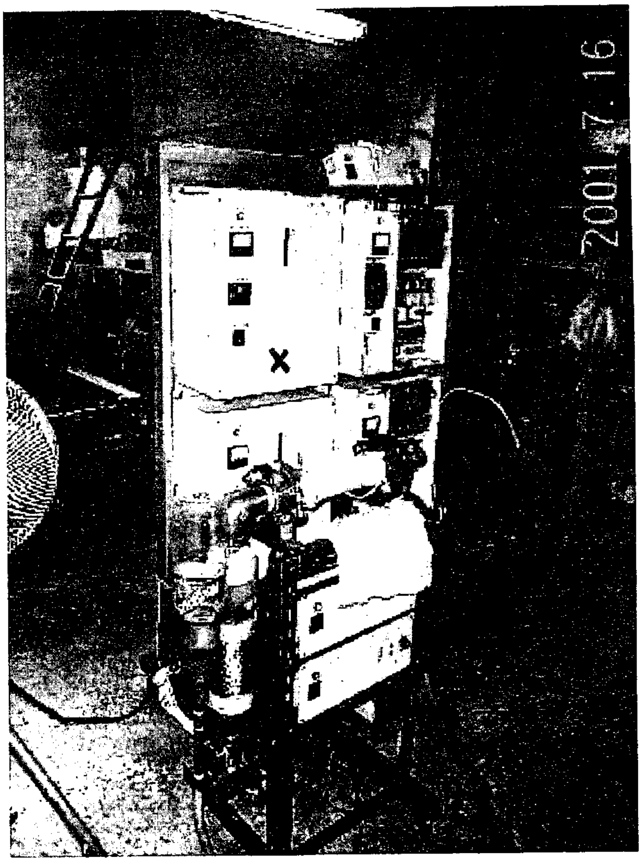

Fig. 8 Total system of the DPH

5. Temperature tracking characteristic

Fig. 9 shows temperature tracking characteristic in care of way air fluid. In isolated pipeline can be filled not only air but also diverse vapor and it can be heated very rapidly. Because the thermal capacity of the heater is small, the responsibility and controllability of the outlet temperature are excellent. The care of open or short of inner heater is not happened. So heat resisting is good and by temperature alterative in low pressure or/and high temperature has good performance.

Fig. 10 shows the temperature response characteristic. As we can see in fig. 10 an occasion of a sudden temperature change the temperature following response is good.

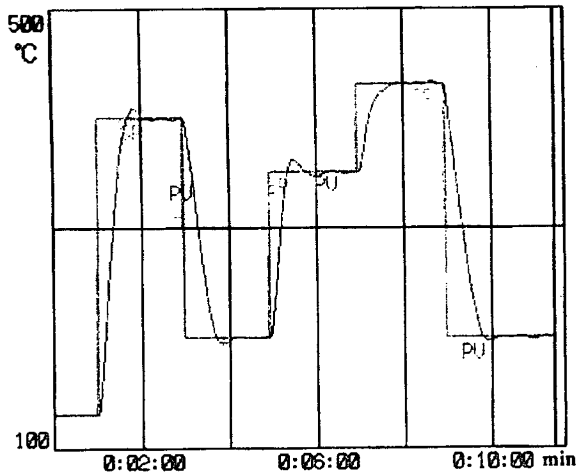

Fig. 9 Temperature tracking characteristics of the proposed electromagnetic induction-heater

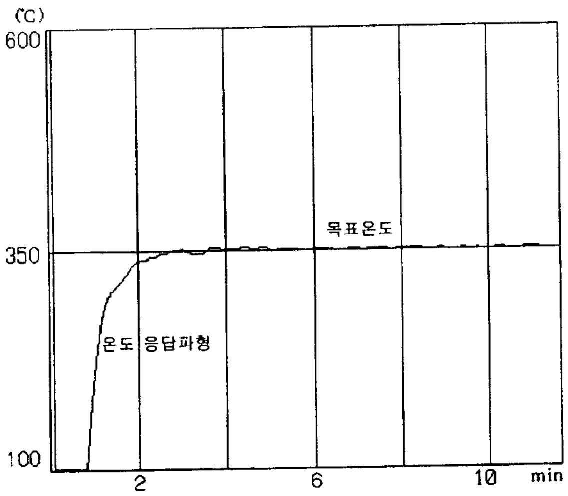

Fig. 10 Temperature response characteristics of the proposed electromagnetic induction-heater

6. Heat radiation vapor generating system

Generally over heated vapor can be made from re-heated saturated steam. In this case need a thermal exchanger. But the proposed system as in fig. 1 needs not a thermal exchanger.

Fig. 11 shows a total system, which consists of saturated steam generator (first heater) by using high frequency resonant inverter control and over heated vapor generator (second heater).

In resonant inverter driven first electromagnetic heater low pressured saturated steam is generated and in second electromagnetic heater low pressured over heated vapor which has 200°~600°C temperature is continuously or instantaneously produced.

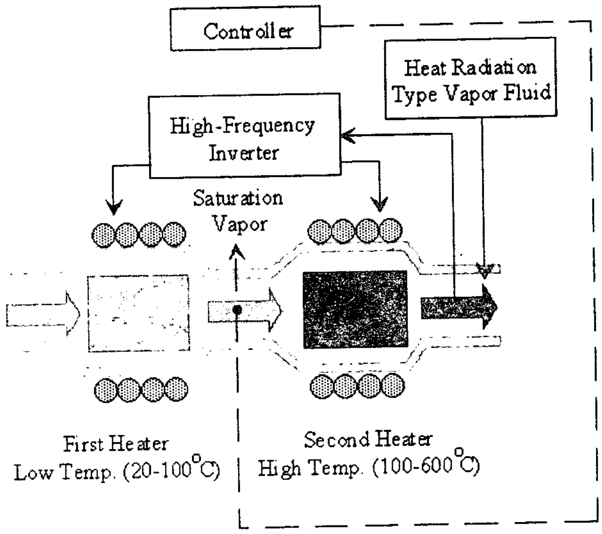

Fig. 11 Generating system of induction-heated saturation vapor & heat-radiation type vapor fluid

Fluid heating system by each electromagnetic heater heats the non-blazable rosin typed insulated vessel which has inside laminated stainless assembly with many tiny holes and interconnected spot welding points between stainless plates. Outside of this vessel wrapped a working coil, which is connected high frequency resonant inverter. The eddy current by working coil produced heat.

If conventional heating system applies to the first heater. Heat emissive vapor is generated by the second heater. Sterilization and dehydration processing can be performed at the same time.

Green cleaning and treatment for metal- or glassware can be done easily and simultaneously. For a measurement the second heater is a little bit modified. First, stainless package for the inner filled heated material is substituted with carbon ceramic.

Second, the reinforced against heat clayish non-blazable rosin pipeline is used. With these alternations the over-heated vapor generator is performed as in fig. 12 shown.

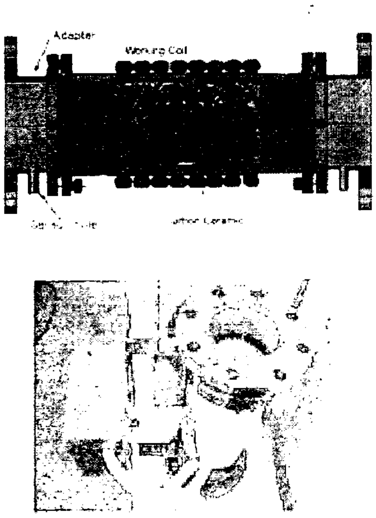

Fig. 12 Part of heat-radiation type vapor fluid system using the carbon ceramic

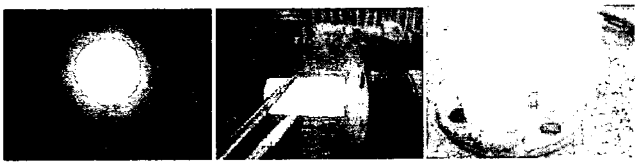

Fig. 13 Heated carbon ceramic Metallic Package

Fig. 13 shows a heated carbon ceramic metallic package, which is heated about 1000° temperature in 3 minutes. The proposed electromagnetic induction heating system has high thermal exchange efficient and can control precisely the temperature. Also instantaneous heating is possible. This DPH is a contactless heating system, so that has high confidence. The deterioration of fluid is not occurred by scale. The whole heating system has compact size.

Now the field of exhaust gas cleaning system and exhaust corpuscle reducing system is researched by using resonant inverter.

7. Conclusion.

This contribution describes a newly developed DPH induction heating system, which is an electromagnetic pipeline type fluid heating appliance.

In table 2 is shown the difference between conventional heater and here proposed DPH heating system. As shown in table 2 it has been practically proved that this DPH heating system becomes more cost-effective, high-efficiency conversion, quick response and precise temperature control realization.

In the future, minimization of switching losses and noise in high-frequency inverter should be more researched

Table 2. Comparison between conventional system and DPH

	Unit	Conv. Heater	DHP
Max. Temp.	°C	260	500~
Heating Method		indirect	direct
Elec. Power	KW	14	14
Energy	Kcal	8170	11000
Motor Power	KW	3.8	-
Cooling Method		Water	-
Weight	Kg	600	20
Settling Time		1 hour	30 ~ 40 sec.
Heating Area	Cm^2	4400	22000

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