

Innovative Laundry Drying System Utilizing Near Infrared Ray Radiation

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ABSTRACT: Conventional laundry drying machines have taken inefficient convective process of air heated by either a boiler-like or an electric heating system. An innovative laundry drying system has been developed, utilizing NIR (Near Infrared Rays) radiation operated by electric power. The new system is simple and solid, composed of rectangular box containing NIR lamps, reflection plates and some fixing devices. It does not require much maintenance expense. If the new drying system is activated, the drum containing the laundry starts rotating. NIR generated by the lamp then travel through the pores in the wall of the drum, and dry the laundry by radiation effectively. The new system turns out to use only 50% of the consuming energy required by conventional driers. It also softens the fabric to prevent static electricity; and sterilizes and disinfects the laundry. Furthermore, it does not cause severe air pollution, noise, and vibrations in the vicinity.

Keywords: NIR (near-infrared rays), radiation, convection, laundry drier, energy efficiency

NOMENCLATURE

NIR: Near Infrared Ray(s)

PCT: Patent Cooperation Treaty

1. INTRODUCTION

Laundry drying machines are an essential home appliance, consuming a considerable amount of energy. Conventional dryers have taken convective process of air to dry laundry. Such driers usually heat air at first, and then facilitate convection of the heated air toward the laundry for drying. They use gas and/or oil, or electric heating system as energy sources to generate heat.

Laundry dryers currently used in large-scale businesses typically have a boiler-like heating structure. Such a convective system has many disadvantages, including low energy efficiency, high initial price and maintenance cost. Moreover, additional measures are required to get other benefits, such as the deodorization, sterilization, and disinfection or the softening of the fabric. The reasons are mainly due to the convective heat transfer, less efficient compared to the direct radiation like the sun-light.

In order to improve such an inefficient convective process, research on direct radiation methods has been conducted. As a

result, an innovative laundry drying system has been developed, utilizing NIR radiation.

This paper discusses the new drying system, including the basic NIR technology, its implementation into practical laundry drying system, and the advantages in terms of energy savings, static electricity, and additional benefits compared with the conventional dryers.

2. NEAR INFRARED TECHNOLOGY

2.1 NIR (Near Infrared Rays)

Infrared rays are found at the very end of a spectrum, outside the red part, that disperses light emitted by the sun or other light-emitting objects, as shown in Figure 1.

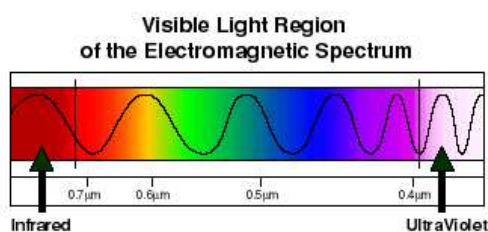


Figure 1: Different Wave Lengths of Spectra of Light [3]

The International Commission on Illumination (CIE) recommended the division of optical infrared radiation into the following three bands: 1) IR-A: 750 nm–1400 nm, 2) IR-B: 1400 nm–3000 nm, and 3) IR-C: 3000 nm–1 mm, as shown in Figure 2. Among them, the rays of light corresponding to the IR-A band are referred as NIR (Near Infrared Rays) [4]. Thus, NIR are infrared rays with the shortest wavelengths.

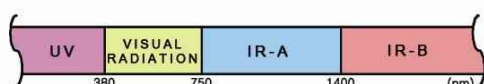


Figure 2: Division of UV (Ultra-Violet), Visual, and Infrared Radiation based on the Wavelength Bands

2.2 NIR Technology

NIR have been commonly used in fiber optic telecommunication because of low attenuation losses in the SiO₂ glass (silica) medium.

Image intensifiers are sensitive to this region of the spectrum. Examples of such applications include night vision devices, like night vision goggles. [4]

NIR are also known to provide heating, photographic effects, photoelectric effects, and fluorescence used for a variety of medical and industrial purposes. Such applications may include sterilization, disinfection, and the treatment of various muscle and joint related conditions.

One of the most excellent applications is the NIR drying technology, applied into drying paints of automobiles, semi-conduct products, and prints. Such drying technology has also been applied into the food products. As an example, apple slices were successfully dried using NIR radiation, with high efficiency. It was stated that the time duration could be shortened by up to 50% with NIR radiation, compared with convection at equivalent parameters [2].

A study of NIR dryer was conducted on textiles with some variable parameters such as types of textiles, distance from the lamp to drying objects, wind velocity, etc. [1] As a result, it turned out that the drying effect was increased up to 32% by decreasing the distance from 0.26m to 0.15m.

However, no attempt has been made yet to implement a NIR radiation system that can be practically used in laundry drying machines. Thus, this research has focussed on applications of NIR into laundry driers.

3. INNOVATIVE DRYING SYSTEM

3.1 NIR Lamp

Near infrared halogen lamps are used to generate NIR. The lamps can be either coated or uncoated. NIR emitted by some sample lamps were tested to assess the spectral irradiance distribution along the

corresponding wave lengths. As a typical example, an uncoated sample lamp was selected, and its NIR was tested. The results are plotted in Figure 3, which shows that the spectral irradiance is well distributed over NIR wavelength regions.

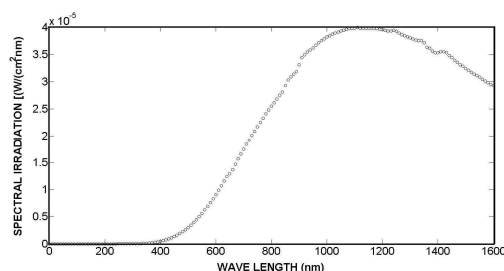


Figure 3: Spectral Irradiance Distributed along the Wavelengths

3.2 NIR Radiation System

In order to implement a NIR drying system, a unit NIR radiation system was developed, as a first step. The unit system is simple and solid, composed of rectangular box containing a NIR lamp, reflection plates and some fixing devices as shown in Figure 4.

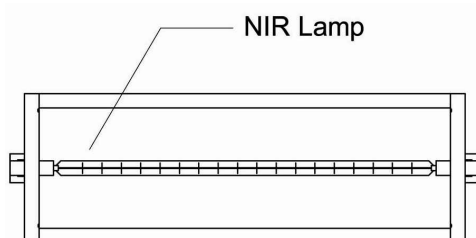


Figure 4: Plan View of the Unit NIR Radiation System

Then, a NIR radiation system was assembled as a modular box by using the unit systems together. The number of unit systems may vary depending upon the capacity of the system, as many as needed. The assembling of the system is relatively easy, inserting the unit systems and fixing them with screws. Thus, the assembled system is strong and secure even under external shock or impact.

Finally, a NIR laundry dryer has been invented by installing the assembled NIR radiation system. The number of NIR systems to be installed can be increased by two or more. Figure 5 shows a skewed view of the laundry drying machine equipped with the NIR radiation system boxes.

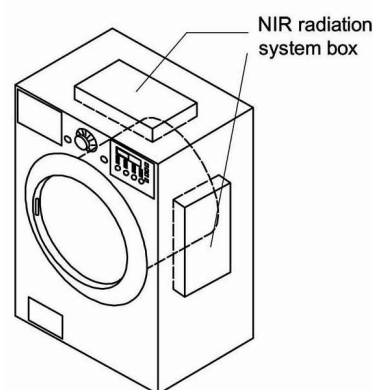


Figure 5: Example of NIR laundry drying machine equipped with NIR radiation system boxes

The NIR dryer shares in common with the conventional laundry drying machine such features as the housing structure with the frontal door; the rotating drum to be placed within the housing; and the control panel installed in the front of the housing.

However, what distinguishes the NIR dryer from the conventional laundry drying machine is the NIR radiation system, inserted near the drum inside the machine so that the NIR will thoroughly dry the laundry.

The NIR radiation systems and the applications of the systems into any laundry drying machines have recently acquired the Korean patent. And the international patent under PCT has already been applied.

3.3 Operation of the System

The laundry, from which excessive amounts of water have been removed, is placed within the drum of the drying machine. With the NIR lamps inside the NIR drying system connected to power, the drying machine is activated and the drum containing the laundry starts rotating. NIR

generated by the lamps then travel through the pores in the wall of the drum and reach the laundry, thereby drying it.

The main advantage of the NIR systems is the drying process by direct radiation that penetrates deeply through the laundry. In doing so, NIR system dries the laundry very effectively and efficiently. On the contrary, the conventional convection method is indirect, less efficient. Figure 6 explains the conceptual differences.

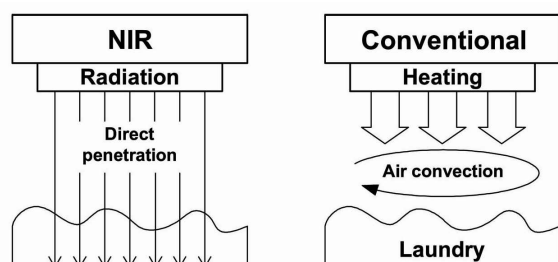


Figure 6: Comparison of Drying Process between NIR Radiation and Conventional Convection Systems

4. ADVANTAGES OF NEW SYSTEM

To compare drying performance, we prepared NIR and conventional dryers with identical capacities as in the drying tests. We used the clothes needed to dry from the same field so that drying characteristics did not change. When the clothes needed to dry were taken into or discharged from the dryer, we took the clothes 20 times on both NIR and convention dryers.

Drying quality was calculated from saving energy and static electricity. Energy consumption was calculated automatically by a balance and the amount of electricity used measured.

A static electricity measuring system includes a probe, a measuring device, and a calibration device. The probe includes a sensor which detects an electric field and outputs signals representing the detected electric field. The measuring device measures static electricity on the basis of the

signals output from the sensor. The calibration device generates a reference electric field. The measuring device is adjusted when the sensor detects the reference electric field produced by the calibration device.

4.1 Energy Savings

The NIR dryer's energy efficiency averaged 17 kW per hour for clothes 50kg, which is 50% better than conventional dryers as shown in Tables 1 and 2. It was the operating data for 8 hours per day and for 30 days.

Table 1: Comparison of Consuming Energy for Different Drying Systems

Items	NIR	Electric Heating	LNG gas
Drying Capacity	50 kg	50 kg	50 kg
Consuming Energy	17 kW	34kw	7 Nm ³ /h

Table 2: Comparison of Consuming Energy for Different Materials

Item	Material	Energy	Time (Min)	Temp (°C)	Ex. Fan Capacity
Steam (Gas)	Cotton	6.06 Nm ³ /h	50	110	1.5 kW
	Wool	2.44 Nm ³ /h	20	70	
	Polyester	1.59 Nm ³ /h	13	75	
	Nylon	1.22 Nm ³ /h	10	60	
NIR	Cotton	14.2kW	50	90	0.75 kW
	Wool	4.2kW	15	60	
	Polyester	2.5kW	9	63	
	Nylon	2.0kW	7	52	

There are several sizes of the NIR dryer and their consuming energy on the followings in Table 3, which are a half of the consuming energy at the conventional

dryers. Thus, it is possible to choose a size as required for each different case.

Table 3: Consuming Energy for Different Sizes of NIR Drying Systems

Model	Size	Max (kg)	Energy (kW)
3D	480x430x115	12	5.1
4D	648x457x115	15	6.8
7D	950x650x115	25-30	11.9
10D	950x774x115	50	17
16D	950x1200x115	70-80	27.2
20D	950x1548x115	100	34

4.2 Static Electricity

Although the peak temperature of NIR is 600°C, the temperature of inside of drum is 77-87°C. That is the reason for drying clothes by a low temperature and medium heat. Therefore the static electricity on the clothes was removed by 99%.

The following tables 4 and 5 showed the results of static electricity and stiffness.

The test was conducted under the conditions of 20±2°C, and 40±2% R.H. 400rpm by Korea Apparel Testing & Research Institute.

According to the test results, the static electricity of the laundry from NIR drying systems is barely noticeable by people. On the contrary, the static electricity from the laundry dried by conventional driers may cause a harmful nuisance to people. This advantage of static electricity is considered to be great for those who enjoy the most advanced technology.

Table 4: Comparison of Static Electricity

Electrostatic Propensity (V)	NIR	Conventional
Cotton cloth	86	290
Wool cloth	860	1900

Table 5: Comparison of Stiffness

Stiffness (mm)	NIR	Conventional
Warp Direction	0.06	0.07
Weft Direction	0.03	0.03

4.3 Additional Advantages

There are several additional advantages found qualitatively from the NIR radiation drying system as follows. Some of them have been in the process of quantitative measurements.

- (1) With good efficiency and less time of drying, infrared rays like sunlight penetrate deeply on the objects. Time for drying and pre-heating is very short. Time needed for maximum output is very short, like a second.
- (2) NIR have shown spontaneously to deodorize, sterilize, and disinfect the laundry. NIR have an intensive anti-bacteria effect, cleansing the air of odours, micro-organisms, and other impurities. The polluted air and odour were removed because of 600°C, the temperature on drying. These ensure the hygiene and safety of the laundry to be used by a greater public at public places and businesses without requiring additional processing or treatment of the laundry.
- (3) It is not necessary to heat directly the air into the inside of dryer.
- (4) The NIR dryer uses radiant heat with short wave permeating the inner part of the object in short time, performing perfect drying with less damage on the laundry.
- (5) The lamp NIR dryer is easy to establish installable to any dryer and has a long life cycle. A NIR Lamp lasts 7,000-12,000 hours. In other words, the NIR drying system does not require much maintenance expenses, except in cases when the NIR lamp has to be replaced after it has been used fully.

- (6) The NIR drying system does not cause environmental problems such as air pollution, noise, and vibrations in the vicinity. However, conventional driers have caused severe environmental problems as mentioned above.

5. CONCLUSION

Conventional laundry drying machines have mainly taken convection of air heated by either a boiler-like or an electric heating system. This convective system has many disadvantages, including low energy efficiency, high initial price and maintenance cost. Moreover, additional measures are required to get other benefits, such as the deodorization, sterilization, and disinfection or the softening of the fabric.

An innovative laundry dryer has been developed, utilizing NIR radiation system operated by electric power.

As a first step, a unit NIR system was invented. It is simple and solid, composed of rectangular box containing a NIR lamp, reflection plates and some fixing devices. Then, a NIR radiation system was assembled as a modular box by using the unit systems together. The assembled system is strong and secure even under external shock or impact. Finally, a NIR laundry dryer has been fabricated by installing the assembled NIR radiation system.

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The new NIR drying system does not require much maintenance expense.

If the new laundry drying system is activated, the drum containing the laundry starts rotating. NIR generated by the lamp then travel through the pores in the wall of the drum, and dry the laundry effectively. The new system turns out to use only 1/2 of

the energy consumption required by conventional driers.

It also softens the fabric to prevent static electricity; and sterilizes and disinfects the laundry. Furthermore, it does not cause severe air pollution, noise, and vibrations in the vicinity.

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