World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Design and construction of a radiographic film dryer

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World Journal of Advanced Research and Reviews, 2022, 15(02), 352–361

Publication history: Received on 05 July 2022; revised on 11 August 2022; accepted on 13 August 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.15.2.0798

Abstract

Radiographs are vital in hospital diagnostic processes. After a radiograph is processed from the developer, it must be dried before it can be interpreted by the radiologist. Two methods are basically available for radiograph drying – open sun drying and oven drying. Despite variability in weather conditions which can hamper effective radiograph drying, most diagnostic centers still rely on the open sun drying method due to the unavailability of radiograph dryer. This project presents the design and construction of a radiographic film dryer that is cost effective, user friendly and serviceable using local technology. The dryer is composed of a heater, a blower, an extractor and a drying cabin that is capable of containing 25 detachable film hangers (49.5 cm) placed into two rails (37 cm) at both sides. Good quality of dried radiographs were obtained when chamber heating/air evacuation were done at 5 minutes time interval. 25 radiographs of two major sizes; 18 cm × 24 cm (smallest) and 35 cm × 43 cm (largest) were dried approximately 5 and 10 minutes respectively at maximum temperature of 55 ^{0}C. The drying process was both temperature and time controlled as moisture content was removed from the processed films in real time for quick diagnostic processes.

Keywords: Radiograph; Heater; Blower; Extractor; Moisture Content and Temperature

1 Introduction

A Radiograph is a shadow picture of an object that has been placed in the path of an x-ray or gamma-ray beam, between the tube anode and the film or between the source of gamma radiation and the film. It produces a permanent visible radiographic image that can be kept without deterioration for a number of years. It naturally follows, therefore, that the appearance of an image thus recorded is materially influenced by the relative positions of the object and the film and by the direction of the beam [1].

Radiography has today become one of the most important, and versatile, of all nondestructive test methods used in medicine and by modern industry. Radiography employs highly penetrating x-rays, gamma rays, and other forms of radiation that do not damage the part itself, to provide a permanent visible film record of internal conditions, containing the basic information. In past decades evidence from millions of film records, or radiographs, have enabled industry to assure product reliability; by providing informational means of preventing accidents and saving lives; and has been beneficial for the user [2].

1.1 Radiographic film dryers

There are two major ways employed to drying radiographs which are Automatic Processing and Manual Processing.

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Automatic Processing: It requires an electromechanical device called an automatic film processor, which transports the film from one solution to the next without any manual labor except for placing the film into the device (see Fig.1). This shortens the overall processing time, increases the number of films that can be processed in a given period, and ensures less variability of overall film quality than manually processed films because the processing time, solution temperature, and chemical replenishment are automatically controlled. It operates without human interference right from start to finish; conveys the film through different solutions (sections) by a series of rollers driven by gears, chains & sprockets.

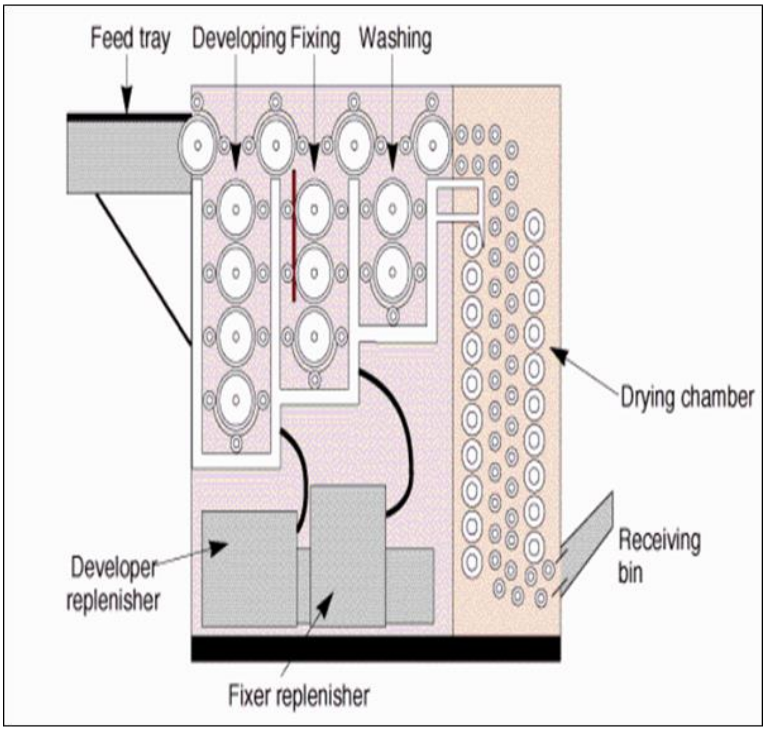


Figure 1 Diagram showing the internal sections of an Automatic Processor

Once the film is fed into the feed tray, it goes into the developer, fixer, washer and dryer spending the required time frame in each section until it is finally ejected through the receiving bin [1].

Manual Processing: In the manual processing method, film is moved from one solution to the next manually until processing is complete. This method requires more labor and time and is more prone to variations than automatic processing. Manual processing is seldom used in diagnostic imaging today and to be processed manually, several steps are required after the films are hung on special hangers. For manual radiographic film processing, several infrastructures are required and are usually located inside the Dark Room as shown in Fig.2 [3].

Processing transforms the latent image into a visible image. The term for the several procedures that collectively produce the visible, permanent image is processing and consists of developing, rinsing, fixing, washing and drying procedures.

- Exposure - Latent image created.
- Development - Converts latent image to black metallic silver.
- Washing [stop bath] – Removal of excess developer.
- Fixing and Hardening - Dissolves out unexposed silver halide crystals.
- Washing - Removes products of processing.
- Drying – Removal of water. [4]

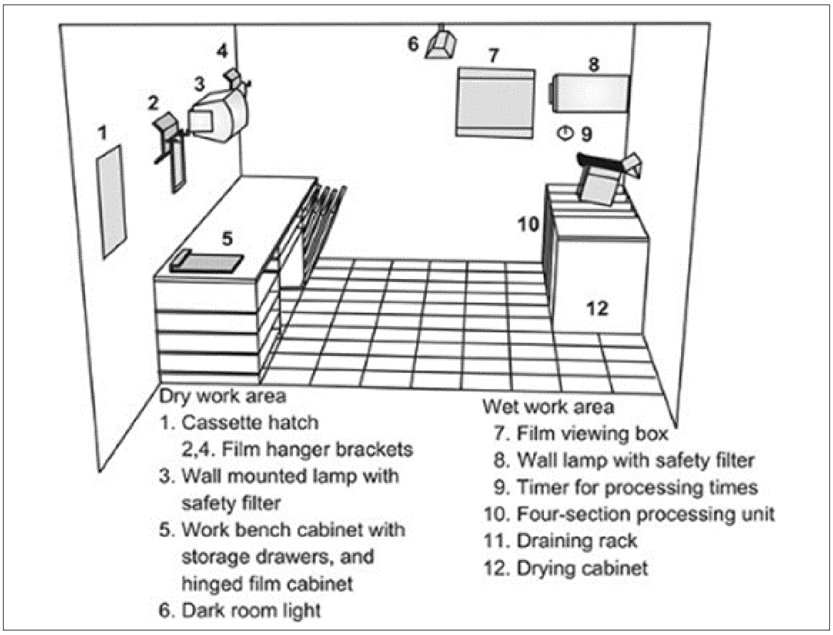


Figure 2 Diagram showing a Darkroom

1.2 Drying process

Drying is the removal of volatile substances (moisture) by heat from a mixture that yields a solid product. The heat supplied during the drying process vaporizes the solvent and the solvent removal must be performed without adversely affecting the formulation or interfering with the physical properties of the material. While drying may involve solvent removal, some chemical reactions can also take place at the same time. It is possible that an outside energy source such as ultra-violet radiation can accelerate solidification during drying which is called curing [5].

Drying high-value products that are likely to be heat-sensitive, such as food, pharmaceuticals and biological products, demands special attention. When some products are dried at higher temperatures, such heat-sensitive products may degrade, change color and appearance and have lower vitamin or nutrient content [6].

It has been observed that most medical institutions (both private and public) in the country still employ the open-air drying method when drying radiographs which takes a long time to achieve simply because automatic processor and dryers are not affordable. This has become a problem because it delays diagnostic processes which can be costly and life-threatening in cases of emergency, in days when so many patients are present and during unfavourable/unpredictable weather. This study is designed to address the long drying time of radiographs by constructing a film dryer that will be temperature/humidity controlled, contaminant free, time/cost/power saving, user's friendly and serviceable using local technology.

2 Material and methods

There are two parts to this study – the dryer cabin and the electronic control module.

2.1 The Dryer Cabin

All forms of oven drying are usually done in a controlled environment, where much of the heat can be harnessed. Thus, the usual practice uses material that permits zero heat exchange between the cabin and the external environment. The cabin used in this project was that of a faulty and abandoned freezer. This choice was made, first not to waste resources and secondly, to put the discarded cabin to profitable use towards waste-to-wealth creation. The size of the cabin is ($57\ cm \times 84.5\ cm \times 55\ cm$). It is well lagged with a gravity supported door.

2.2 The Electronic Control Module

For good drying to occur in any modern oven, various atmospheric parameters such as the temperature, pressure and humidity needs to be monitored and controlled.

The adopted functional block diagram for the electronic control module of the radiographic dryer is shown in Fig.3. The Power Supply Unit (PSU) delivers power directly to the microcontroller, the blower (AC Fan) simultaneously; this is needed for the startup operation of the dryer. The heater dissipates heat into the cabin while the fans spread the heat randomly and equally. The suction fan helps to extract moist air out of the drying chamber. The temperature sensor/Humidity Sensor (DHT-22) helps to monitor both the initial and preset temperature to prevent overheating. It also monitors the level of humidity in the cabin to prevent humid air build up. The information from this sensor is majorly used by the microcontroller to control the operation of the heater.

The Liquid Crystal Display (LCD) is an interface that allows the view of all input commands to the dryer and it also displays information from the dryer. The buzzer sounds an alarm when drying is complete. The microcontroller is the heart of the dryer it coordinates the entire operation of the aforementioned devices.

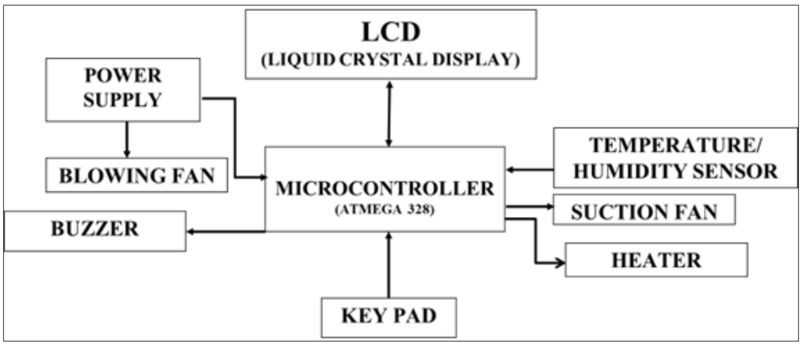


Figure 3 Block Diagram of the Electronic unit

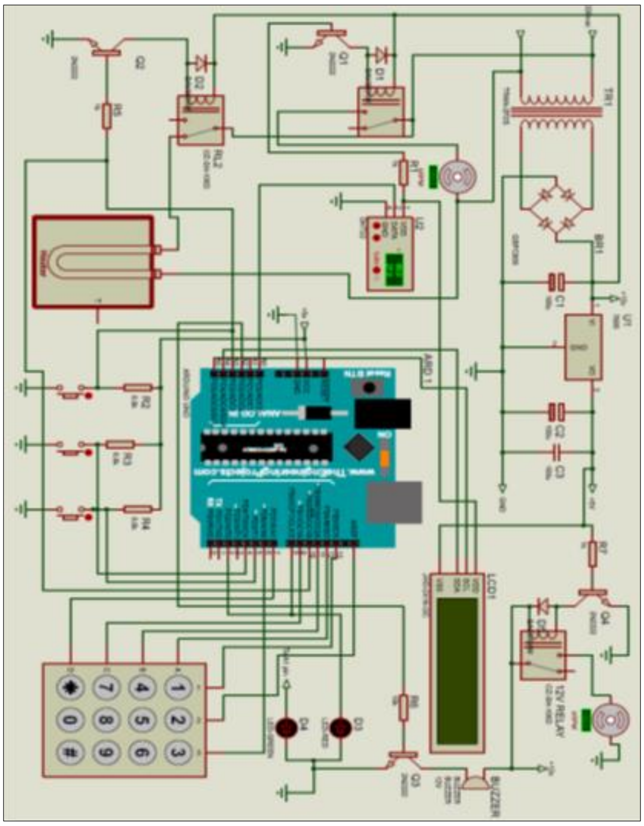
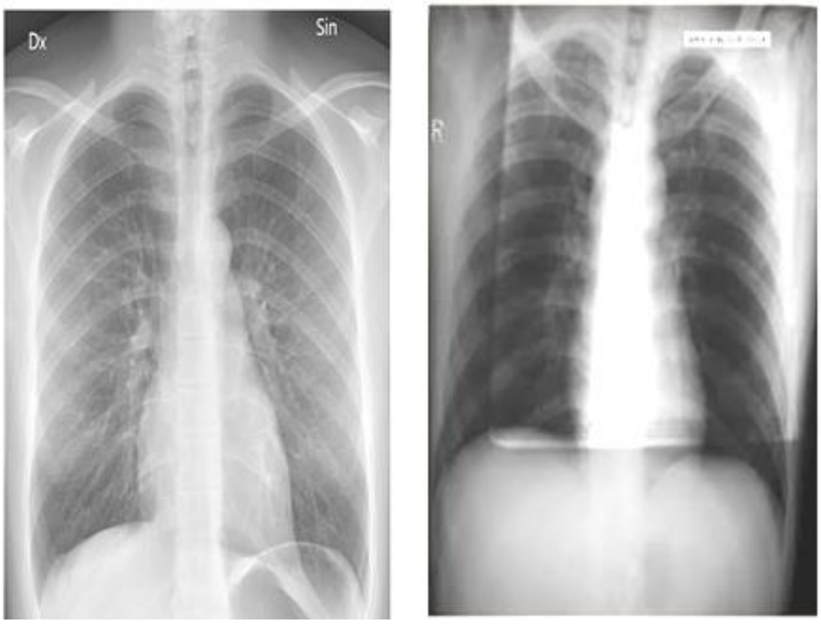


Figure 4 The Complete Circuit diagram of the electronic control unit of the Radiographic film dryer

The complete circuit diagram for the radiographic dryer is given in figure 4. At the beginning of each drying process, the microcontroller initializes the LCD connections, port directions and the A/D converter. The microcontroller reads the cabin temperature and the humidity. The device prompts the user to enter the target temperature. The heater and blowing fan are activated immediately. The microcontroller thereafter checks to see if the current temperature is greater than the initial cabin temperature. It also continuously checks the humidity within the cabin. If the set conditions are not satisfied, the algorithm automatically returns to the appropriate level of the flowchart. As an example, if the initial cabin temperature fails to climb towards the target temperature after 5 cycles, an error message "THE DRYER IS NOT WORKING" is generated. If the required conditions at that level are met, then the heater is turned OFF, the vent is opened and the suction fan is activated. Whenever the humidity is greater than 0, the algorithm will return the dryer to the set mode but if approximately 0, it stops the operation by triggering the buzzer for 120 seconds.

3 Results

The basic tests carried out on the constructed radiographic dryer are discussed here. The constructed radiographic film drying system has the following basic components: a blower, a suction fan/extractor, a 250 W heater, an insulated cabin and the electrical control module. The insulated and well-sealed cabin was needed to minimize heat loss and fast-track drying. After loading the dryer with wet/processed films, and the START button activated, the control module would first record and store the initial cabin temperature and humidity data. It would thereafter put ON the heater and the fan. The cabin humidity and temperature are periodically checked and compared against the initial values. The electronic control algorithm determines the time for the suction fan operation and any possible system malfunctioning. It ensures that overheating does not occur as the set temperature within the cabin is monitored and maintained. Shown in figure 5 are pictorial views of sampled dried radiographs using the constructed dryer. The radiograph in Fig. 5(a), was obtained with the proper functioning of the suction fan while the radiograph in Fig. 5(b) was obtained without the suction fan in place. For dried and qualitative radiographs, it is clear from Fig. 5 that the use of a suction fan is expedient. It ensured adequate air convection and re-circulation within the cabin which invariably led to the quality (contrast and strength) of obtained dried films.



(a) (b)

Figure 5 Dried radiographs obtained when the dryer operated with the suction fan (a), and (b) when it operated without the suction fan

Based on the evidence from Figure 5, time-temperature variation tests were subsequently carried out. The result, which represent the drying time against numbers of radiographs at various temperatures is presented in Table 1. The results showed that the higher the chamber temperature, the lesser the drying times. Also, the more the number of radio-graphs, so also was increase in the drying time (i.e. the more the number of radio-graphs, the longer time it took to dry). This should be expected because the more the number of radiographs to be dried, the more the moisture content and hence, the more the work needed to remove the moisture from the films. It was surprising however that radiograph number increase didn't show a correspondence with drying time. The explanation for this has to do with the Control algorithm whereby the operation of the suction fan per cycle was much more than for lower temperatures.

Table 1 Drying time against number of radiographs at various temperatures

Nos. of Radiographs	**5**	**10**	**15**	**20**	**25**
Temp.	**Drying Time (Minutes)**				
30 °C	12.23	15.16	18.29	20.46	22.03
35 °C	11.35	14.25	16.18	19.48	20.10
40 °C	10.18	11.27	14.39	17.33	19.06
45 °C	08.29	10.37	13.44	15.21	18.12
50 °C	07.09	08.23	09.38	13.42	15.30
55 °C	05.10	06.14	08.26	09.50	10.02

4 Discussion

4.1 Operational cost of the radiographic dryer

Cost savings, particularly in terms of energy usage is expected as part of any equipment design. In this section, we present the operational cost of the radiographic dryer. When the drying chamber is being heated, only the heater and the blower fan are operational while the suction fan is OFF. At the instant the suction fan is ON, the heater would be OFF while the blower fan doesn't stop working in order to aid quick movement of hot air through the vent to the outside of the dryer. Whenever the heater was OFF, some amounts of power were saved.

Power rating of blower fan = 22 W,

Power rating of suction fan = 35 W,

Power rating of the heater = 250 W,

From Table1: It takes 10 minutes to dry maximum 25 radiographs, and at maximum temperature of 55 ^{0}C.

Power = 273.6 W (heater + blower)

Power = 57 W (blower + suction fan)

80 % of 10 mins = 0.13hr

20 % of 10 mins = 0.03hr

$$E = P \times t$$

$$E = P \times t$$

$$= 273.6 \times 0.133$$

$$= 57 \times 0.03$$

$$= 36.40\text{W-h or } 0.04 \text{ kWh}$$

$$= 1.71\text{W-h or } 0.002 \text{ kWh}$$

The Total Energy consumed = 0.042 kWh

$$E = 0.042 \text{ kWh for 10 mins.}$$

According to the Nigerian Electricity Regulatory Commission (NERC, 2020); 1 kWh = N58.75 (20 hours of usage)

So, for 1 hour, 0.252 kWh is consumed to dry 150 radiographs at N14.81

Hypothetically, 1 hour of production is equal to 1 day at N14.81, therefore,

For 1 week (7 days), 1.764 kWh is consumed which costs N103.64

For 1 month (30 days), 7.56 kWh is consumed which costs N444.15

This implies that a very low cost of N444.15 is required monthly on the average to process high volume of radiographs thereby it will not skyrocket electricity billing.

Since drying of radiographs is over time, it is very important to note the energy and power consumed over a particular time frame.

Power consumed during drying: Both fans and the heater are working

Suctioning = 80 % of drying with Heater + blower with 20 % of convective drying (blower + extractor)

Power consumption for 80 % at 30 ^{o}C for 22mins from Table 1

$$P_{blower} + P_{heater} = 22\text{ W} + 251.6\text{ W} = 273.6\text{ W};$$

$$P_{total} = 273.6\text{ W}$$

80 % of 22mins = 17.6mins or 0.293hour

$$\text{Power} = \frac{Energy}{Time} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 1.1$$

From equ. 1.1, Energy = Power × time

= 273.6 × 0.293

= 80.165W$^{\cdot}$h

= 0.08kWh

Energy = 288,000 J or 288 kJ

Power consumption for 20 % of convective drying at 30 ^{o}C for 22mins from Table 1

$$P_{blower} + P_{extractor} = 22\text{ W} + 35\text{ W} = 57\text{ W}; P_{total} = 57\text{ W}$$

20 % of 22min = 4.4mins or 0.073hour

Energy = Power × time

= 57 × 0.073

= 4.161W$^{\cdot}$h

= 4.161×10^{6}kWh

Energy = 14979.6J or 14.98kJ

$$P_{total} = P_{80\%} + P_{20\%} = 273.6 + 57 = 330.6\text{ W}$$

Total Energy dissipated using suction fan:

$$E_{total} = E_{80\%} + E_{20\%}$$

$$= 288kJ + 14.98kJ$$

$$= 303\ kJ$$

Energy consumed during the drying process is 303 kJ

Total Power consumed is $P_{80\%} + P_{20\%} = 330.6$ J

4.1.1 Efficiency

Power Efficiency

$$P_{in} = 330.6\ W,\ Energy = 303{,}000\ J,\ t = 1320\ s$$

$$P_{out} = \frac{E_{in}}{time} = \frac{303000}{1320}$$

$$P_{out} = 250\ W$$

$$Efficiency = \frac{P_{out}}{P_{in}} \times 100 \quad \text{.. 1.2}$$

$$= \frac{250}{330.6} \times 100$$

$$= 76\ \%$$

Energy Efficiency

$$P_{in} = 330.6\ W, \quad t = 1320\ s$$

$$E_{in} = P_{in} \times t = 330.6W \times 1320$$

$$E_{in} = 436{,}392\ J$$

$$E_{out} = E_{in} - E_{heat} \quad \text{.. 1.3}$$

$$= 436{,}392 - 303{,}000$$

$$E_{out} = 133{,}392\ J$$

$$Efficiency = \frac{E_{out}}{E_{in}} \times 100$$

$$= \frac{133{,}392}{436{,}392} \times 100$$

$$= 31\ \%$$

As the energy efficiency of dryer ranges between 20 % - 50 % [7], it can be concluded that the constructed radiographic dryer is functional both in its power and energy efficiency.

Figure 6 The constructed Radiographic Film Dryer

5 Conclusion

Convection can be effectively and efficiently utilized for drying of radiographic film in our medical institutions if proper design is carried out. This was demonstrated and the film dryer designed and constructed exhibited efficient ability to dry without adversely affecting neither the coating formulation nor interference with the physical uniformity of the coating on the film because moistures were eliminated faster, the properties of the radiograph was preserved and qualities enhanced making it suitable for handling thereby increasing the shelf life. Therefore, to shorten drying time and enhance radiograph quality, adequate air convection is expedient.

Power consumption, energy conservation and efficiency are vital factors to be examined in the performance evaluation of a device. From the results, it is observed that the power consumed by the dryer is 330.6 W, making other power consumptions to be negligible. The power consumption during drying with suction fan can be seen to be much less. This has resulted into low cost of operation and with this, the smallest backup power supply generator can be readily useful during power failure; a major challenge in the country. It is also important to note that devices are designed to waste as little energy as possible, this means that as much of the input energy as possible should be transferred into useful energy. At 30 ^{o}C and for the maximum numbers of radiographs (25), energy dissipated was 303 kJ which implies that suctioning consumed less energy and was possible because suctioning allowed the removal of accumulated moist air from the cabin preventing fog or low contrast and enabling temperature control which is not possible in the open air and sun drying methods. In Table 1 above, it can be seen that at 30 ^{o}C, drying lasted for 22minutes. Despite more energy is saved at this level while still able to achieve consistent quality handling of large quantities of radiographs. Efficiency being the measure of how much work or energy is conserved in a process was also considered and calculated. It can be observed that the power efficiency was 76 %, also the energy efficiency of 31 % of energy was transferred usefully during the operation thus making it very effective for this job (doing the right thing), as the energy efficiency of dryer ranges between 20 % and 50 % as stated earlier.

Justifying this study, suctioning process has not only saved power, it has also saved the cost on energy consumption which determines electricity billing. A fast drying time better than the open air drying method, sun drying method and drying without suctioning was achieved due to the manner of operation by distributing heat evenly around the film, removing the blanket of cooler air that surrounds the film when it is first placed in the dryer and allowing the film to dry more evenly in less time because suctioning majorly reduced the thickness of the stationary thermal boundary layer of cooler air around the film, and also moved the cool air away from the film, the layer is thinned and drying occurs faster.

This dryer is weather independent because radiographs can be processed within short time intervals.

Having low power consumption, this dryer can be powered by the smallest generator of 700 W most especially as a power supply back up during power failure.

Waste to wealth creation has also been achieved from the use of an abandoned freezer to refurbished cabin becoming a drying chamber mainly for radiographs.

This study has not only addressed the long drying time of radiographs which is temperature and humidity controlled, contaminant free, user's friendly and serviceable using local technology but as achieved the project's objectives of a simple, efficient, cost and power saving.

Compliance with ethical standards

Acknowledgments

The authors express their appreciation to TETFUND and Federal University of Technology Akure, Nigeria for the approval and provision of funds towards carrying out this study. Your efforts are highly appreciated.

Disclosure of conflict of interest

This is an independently prepared paper. The authors have not declared any conflict of interests either commercially or otherwise in the publication of this paper.

References

[1] Gregory A. Campbell. Film processing: Progress in Polymer Processing. 2nd ed. New York. Hanser Publisher; 2014

[2] Robert Quinn. Radiography in Modern Industry: The radiographic process. 4th ed. Rochester. Eastman Kodak Co; 1980.

[3] Ulio, J.A. Photographic Darkroom Equipment. Processing Equipment PH-406, TM 11 – 405: University of California; 2015.

[4] Neill Serman. Processing the Radiograph: The stages in the production of the Radiograph. Columbia University; 2000.

[5] Abbott S.J. Industrial film drying: The drying curve. Converting Technical Institute. University of Leeds; 2011

[6] Dilip Parikh. Vacuum Drying: Basics and Application. Trade Journal Chemical Engineering. 2015 April; Vol 122, Iss. 4: 48-54

[7] Matuam Balbine et al. Experimental Evaluation of the thermal performance of dryer airflow configuration. International Journal of Energy Engineering, 2015, 5(4): 80-86 DOI 10.5923.