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 Temperature Characteristics Investigation 4 of Chilled Refrigerator with Humidifier I Dewa M. C. Santosa*, IGN Suta Waisnawa, PW Sunu, IBP Sukadana Mechanical Engineering Department, Politeknik Negeri Bali, Jalan Kampus Bukit Jimbaran, Kuta Selatan, Badung-80364, Bali, Indonesia *corresponding email: idmcsantosa@pnb.ac.id Abstract. Post-harvest cold chain of horticulture product in tropical country such as is very urgent to keep the product quality. In this country, the environment temperature and humidity are relatively high, so that the horticultural products are deterioration very fast. On the other hand, this condition can be used naturally for increase the room humidity. This study is aimed to investigate the medium temperature refrigerator performance when apply humidifier to keep the humidity of the system. This research was carried out by experimental investigation. The rig has been built with complete with measurement and instrumentation in order to get a precision control of

temperature and humidity. The results show that the system reach good enough of COP which approximately 3.5. However the humidifier contributed a cooling load that can affect of 1 – 1.5 oC temperature increasing. Further studies will be examined optimisation humidifier system with low electricity consumption and eco operation condition with the best combination temperature and humidity to keep the products still has good quality under long time storage. 1. Introduction Post-harvest storage of vegetable and fruit products are very important because it is related to the rate of damage (deterioration) caused by the biochemical process and microorganisms [1]. Temperature plays important role to reduce the deterioration rate of the product. Horticulture products have specific temperature and humidity in storage, where each product requires different conditions. However, in general for the storage of fresh vegetables and fruits ranging from 0oC to 15 oC with relative humidity ranges from 80 to 95% and post-harvest can maintain for 3 until 6 weeks. While some of Indonesia's original horticultural products such as durian, mangosteen, duku, and chili are required average temperature of 10oC-15oC with the relative humidity 80%-95% for the storage period of 2 weeks to 1 month and certainly can be longer storage if it is set up at more low temperature [2]. Previously, food industry preserve their fresh product in temperatures above 0o C, now it become lowered up to -18oC . This is aimed to reduce damage rate to physical, chemical and microbiology [3]. The quality of postharvest horticultural products is maintained with a temperature reduction system and maintains moisture. It is obtained that with a decrease humidity can increase product durability and can maintain the quality of the product (texture, nutrition, aroma and flavour) and also found that tardiness cooling time post-harvest will reduce quality quickly [4,5] Development of the refrigerators system were focused on the use of environmentally friendly natural working fluid and system efficiency. For example, carbon dioxide is one of excellent alternative refrigerant such as, cheap, negligible Global Warming Potential (GWP), and zero Ozone Depletion Potential (ODP) but it still need more serious solution in terms of problem of safety and low 6 coefficient of performance (COP), when it applies in tropical environment [6,7]. For refrigerator

application, other natural working fluids, such as R600a is widely use with system based on vapour compression system. The R600a has very low GWP comparing with R134a which has relatively high GWP (1,430). In future new concept of refrigerators will be developed according to eco-friendly concept and of course must be has COP [8]. In this research experimental rig also use the R600a to support of green development in Bali. In order to ensure the quality of the products stored in the refrigerator system, it is necessary to control the instrumentation temperature and humidity with precision [9]. Hung et al. [10] conducted research by designing a humidifier that resulted in a very small diameter moisturizing particle. It is intended to get the product kept fresh, and to avoid increased growth of the decay microorganisms resulting from high humidity. With this method will also be possible high humidity can still be maintained while the level of the wet from the product is kept down, so as to control the freshness of the product by lowering the development or activity of microorganisms. In order to energy saving, Chineye et al. [11] create an active evaporative natural which can save energy up to 30% but only works at the temperature of 23oC which used for the storage of temporary horticultural products (pre- cooling) in farming area. Based on the summary review above, as long as the author's knowledge that the studies examined natural humidifier is very limited to be conducted. This is because of this system requires enable humid environment such as in Indonesia. So, this research is aimed to obtain a refrigerator system/cold room for fresh fruits and vegetables that can maintain the humidity of the product with low consumption of electricity. 2. Experimental Set Up The main experimental rig is medium temperature refrigerator prototype using R600a with two kind of humidifier system which was controlled very carefully with high precisely. Data loggers have been set up for temperature, humidity and pressure. Temperature probe were using K type thermocouples, pressure transducers with voltage signal. Environment condition was measured using a specific logger which

covering air temperature, humidity and dew point. Data are logged at every 2 second. The thermocouple has accuracy +/-0.5K, humidity +/-0.5%, and pressure (voltage output) 0.08%. The refrigerator prototype was re-designed to comply the medium temperature condition which was set up at temperature storage of 0oC, 5oC and 8oC, and humidity was controlled at 85%. The experimental rig is shown in Figure 1 as follows. (a) front view (b) side view Figure 1. Experimental rig and measurement set up The position of temperature and pressure measurement in refrigerator cycle are shown Figure 2. The cycles including six stages temperatures and two line pressure condition. There are two extension Temperature and humidity control panel Data logging system Data recording Pressure transducer Humidifier 2 Humidifier 1

doi:10.1088/1742-6596/1569/3/032040 3 coil, first at super-heated area in order to ensure getting excellent superheated condition refrigerant before enter the compressor. Second is after compressor to reduce temperature high pressure superheated (intern cooler) to keep nearly isentropic process. Figure 2. Diagram of refrigeration cycle points 2.1 Experimental procedures Medium temperature prototype of refrigerator has been modified to comply operating temperatures at 0oC, 5oC and 8oC. 4 The humidifiers were designed using automatic control with additional natural humidifier system. Temperature has been set up in refrigeration system (see Figure 2) and also in indoor temperature (air in cabin also measures in every point to get more comprehensive data). High and low pressure line are measured using pressure transduces connecting to the data logger. Data has been logged in very 2 second. The first test group was performed without load testing with temperature set at 0oC, 5oC, and 8 oC with humidity controlled at 85% RH. Second test is testing with load which using real vegetable to see the product quality after keep refrigerated in certain time. 2.2 Data acquisition and data

analysis Data logged in every 2 second and save in the laptop. All of the experimental data are imported to be spread sheet to get easier to calculate and analysis using simple statistical method. Data are combine between the outdoor (environment) condition and the indoor (air condition in cabin). Data are tabulated in table as well as in graphs. 6 Coefficient of performance (COP) of the system is calculating using @Cool pack computer program and analysed depend on each temperature setting and with as well as without load. Effect of natural humidity operational is also investigated in detail. 3. Results and discussion Experimental results have been analysed and shown in table and graphs including with and without load data. Load data including observation of the product quality of the load covering fresh vegetables which was storage in the refrigerator in certain days. However, in this study only 9 focus on the effect of the natural humidity operation to the temperature and operating system. And furthermore for the next studies will concern to the humidifier development to get low energy consumption refrigerator/cold room and best quality of the fresh horticulture products. Condenser K Evaporator 3 1 Expansion Device 6 5 4 Coil extension super heat Filter dryer Coil extension (cooler) 2 High pressure transducer Low pressure transducer

1 International Conference on Science and Technology 2019 Journal of Physics: Conference Series 1569 (2020) 032040 IOP Publishing doi:10.1088/1742-6596/1569/3/032040 4 3.1 Environmental humidity and temperature Environmental data is very important for analysis because it is a fresh water to be conditioned to increase moisture in the cabin. Fresh air is inserted into the cabin periodically with a fan unit system that is controlled with a timer. Data when retrieval of performance data is shown in Figure 3 as follows. Figure 3. 10 Humidity, temperature and dew point of environment data logging From the data Logger environment daily environment is obtained that the environmental temperature is 81.4 F or approximately 27.4 oC and the maximum moisture of 84.8% and a minimum of 62.34% or with an average of 72.23%. Due to the unsatisfactory environmental condition of natural

humidifier, added a mechanical humidifier controlled according to the desired moisture. In this case it is enabled as an additional humidifier to guarantee the humidity above 85% according to the controlled settings. 3.2 Refrigeration operating condition and product quality Two main condition which are with and without load. Data show operational conditions and COP which has been calculating using @Cool Pack based on data from the state of the refrigeration system after modification. Analysis results found that the COP of 3.5 and 3.3 for without and with load, respectively. This COP is a good performance for the general refrigerator system, in a further study will be examined in the improvement of the COP in detail with the optimization of the humidifier system. Visually, Figure 4 show the product that was kept refrigerated for 7 days. The vegetables seems still fresh enough, as good as put for early time. The vegetable condition put in the refrigerator is not the best the condition, because it is taken from traditional market that has undergone a lack of quality of cooling previously. In the advanced study will be tested in the humidity 90% so that the condition optimization is obtained the humidity that best suits the product storage conditions and combined with optimum temperature. Figure 4. Product visually after 7 days keep refrigerated (temperature set at 0oC)

doi:10.1088/1742-6596/1569/3/032040   -20 -10 0 10 20 30 40 50 0 100 200 300 400 500 Temperature (deg C) Point 1 Point 2 Point 3 Point 4 Point 5 Point 6 3.3 Natural humidifier effect to temperature characteristics From the data shown the result of one of the procedures obtained, that with the operation of a natural humidifier occurs the temperature of the system at a rate of approximately 1-1, 5 oC. It is due to the fresh air that is purging into the cooling room become a cooling load both sensible and latent. This condition will be solved by the improvement of natural system by extending evaporator coil used to decrease the resists fresh air flowing ducting designed to clean the moist outside air. The extended evaporator coil is also intended to guarantee the condition of super

heated refrigerant which efficacy compressor. In advanced studies will be analysed the equivalent of energy which becomes a load cooling at the moment of cleaning the fresh air compared to the electricity consumption of mechanical humidifiers that require electricity to increase the relative humidity in every 10% RH. The temperature increase profile is shown in the following Figure 5. Figure 5. Variation of temperature profile as an effect of of the natural humidifier operational (room temperature set at 0oC) 4. Conclusion In this study focused on investigating the operational influence of natural humidifier and mechanics on the refrigeration cycle. The environment condition is the basis of this system because the humid environment can be a source to add moisture to the moist air environments. The moisture distribution of environmental air can increase the humidity in the cabin with significant. But this also leads to the addition of the load on the cooling system, where the overall system is increased by an average of 1oC – 1.5 oC when the humidifier is in operation. In the next research will be focused on improving the natural humidifier design to improve the optimization of the refrigeration system, so it is very reliable applied to the cold room is broken in the villages (farming area) that has a high environment humidity. Thereby, it can guarantee the quality of the product 6 in the form of vegetable and fresh fruit can be maintained well, with low energy consumption. Natural humidifier operating effect

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