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Investigation of Defrost system in Domestic Refrigerator by Using Refrigerant

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ABSTRACT

Efficient energy and its conservation is a great challenge for engineers. All the refrigeration and air conditioning machines consume large amount of electrical energy. To minimize its consumption various technologies are working day and night. As far as government of India is concern, it already started special norms which are standardized by BEE (Bureau of Energy Efficiency). Energy Standards are becoming more stringent and to meet up with them it is necessary to make refrigerators more energy efficient. Energy saving can be done either by optimizing subsystem related to cooling or Defrosting. Commercial refrigerated display and storage cabinets normally use one of five defrost method. Condensing unit off permitting natural defrost along with Hot gas defrost, Electric defrost, Water defrost and other external heat source defrosts. The refrigerators described here are used in supermarkets to display and store perishables products. Focusing here on hot gas defrosts method & its energy benefits over the convention methods like electrical heater method. Main emphasis has been given on defrost cycle of No Frost Refrigerator. It is meaningful to note that the defrost efficiency is compressor discharge temperature by optimize ding discharge temperature.

Keywords: Defrost Methods, Hot Gas Bypass Defrosting, Water Defrost, Electrical Defrost.

I. INTRODUCTION

As far as refrigerator are concerned, defrost is the “inevitable evil”. The frost needs to be melted, or it will severely impact the performance of a refrigerator, and eventually could totally block the air flow. There are quite a lot negative implications associated with hot gas defrost. Additional compressor energy is required to melt the frost or ice layers formed around the evaporator’s fins and tubes. At least, a part of this energy is transferred back to the refrigerated space or heats up the evaporator. It eventually needs to be removed during the cooling process. Also, the Duration (Period) used for defrosting is not used for cooling. This could be a very important aspect in food processing plants, where defrost could significantly limit efficiency levels. In addition, other important but less obvious consequences may undermine integrity such as the Physical / mechanical stress undergone by key components. A lot of lose control found on sealed system valves and controls system used around evaporators it may be characteristic to wrong valve configuration and or settings [2,3].

The main source of mechanical stress is the high pressure coming from the condenser/ heat pipe side also high discharge temperature & pressure differential. While combined, this factor could be quite dangerous and even destructive. Now a day we also see that there is an increased number of companies using CO_2 for low temperature plants, and quite often in combination with hot gas defrost. At the same time, the situation with CO_2 in this case is even more complex than with ammonia, as the pressure level and pressure differentials are much higher. The complexity of hot gas defrost with CO_2 may have caused user to avoid this kind of defrost method and look for other alternatives, such as electrical or brine defrost.

Hot gas defrost is one of the best optimized ways to melt the frost formed on an evaporator. There is a lot of focus on the reduction of energy consumption, by having a quick and efficient defrost. As it is the key to achieving overall energy consumption goals of the refrigeration system. In most cases, it would be also the most cost effective way when compared to e.g. Electrical defrost. This research focuses on valves and controls configurations that could be applied for such systems as well as the ways to optimize the process [1, 5].

II. LITERATURE REVIEW

Here are a few studies aiming the understanding and improvement of hot gas efficiency of refrigeration systems. A number of the significant points could be summarized as follows:

Hot gas defrosts pressure. A popular misunderstanding is that the higher the defrost temperature, the better is the result. In reality, a number of studies shows by Hoffenbecker [1], that a source of lower pressure and temperature gas can obtain good results as well. There is most likely an optimal pressure / temperature that would achieve the highest efficiency. A mathematical model for a frosted coil was developed to determine energy required for defrosting an evaporator.

According to Danfoss [4], hot gas defrost time in the commercial & industrial refrigeration, it is very common to set up defrost based on a fixed time and adjusted during the start-up of the installation. The problem with this concept is that in many cases this time would be on a “safe side” to ensure having a fully clean evaporator. What happens in actual environment is that when defrost is ended earlier the effectiveness of defrost significantly drops.

Another significant inadequacy during the hot gas defrost could be contributed to the vapour passing through the defrost pressure regulator. This vapour requires to be recompressed, and it also increases the necessity for the hot gas feed to the evaporator. The quantity of vapour passing is depending of the type of defrost control in the condensate line. Pressure controlled or liquid level controlled.

As per Julius Rainwater [6] The quantity of energy used for melting down the ice during defrost is more than double as mention by Stoke what is actually needed to melt down the ice. The rest of the energy goes for warming the space, evaporator, tubing and the drip pan.

Also Dong Huang [8] mentioned that the ice is first melted on the coil, and then the ice crashes in to a drain pan and then finally melts completely. What is important here is that the process is sequential; with initially higher demand for defrost in the coil, and only later in the drain pan.

V.Payne & D.LO’ Neal [9] observed that when the hot gas defrosts is begun, the first refrigerant inflow might create a liquid strike, particularly if the evaporator still has some liquid refrigerant that has not been drained. This also occurs if the hot gas supply lines enclose pockets of condensed liquid being thrown by the supplied hot gas pressure, and gas pockets to implode.

III. DEFROST WITH HELP OF REFRIGERANT

Industrial refrigeration systems each accomplish their task with unique designs, nonetheless, all refrigeration plants use similar components and processes. During normal refrigeration operation, sub-cooled liquid refrigerant is routed from a compressor through evaporator coils. As low-pressure refrigerant enters the evaporator, heat is absorbed from the ambient air in the refrigerated space, causing it to evaporate. This causes an evaporative cooling effect. Vapor from this process is recompressed and sent to a condenser to produce more liquid for use in refrigeration in the network of evaporators. This process has a critical inherent flaw. Any moisture content, which has infiltrated the cold space, either from load (fresh produce or other items releasing moisture), or from traffic into and out of the space will tend to freeze to the coldest point in the space. The evaporator coils are the coldest point in refrigeration systems, so they become coated with frost. A critical quantity of frost inhibits effective heat transfer from the cold space. This problem has been recognized as a possible source for energy savings for refrigeration companies. Industrial refrigeration systems address the problem of frost build-up using a frost removal process known as hot gas defrost. In this process, one evaporator in a refrigerated space will be targeted for defrost at a fixed time interval (every 24 hours for example). This evaporator no longer receives liquid refrigerant from the system, and the evaporator is allowed to evacuate. Then high pressure, superheated ammonia vapor refrigerant is forced through the evaporator coils. This process effectively turns the evaporator coils into a condenser.

When the ammonia vapor or “hot gas”, is sent through the evaporator coils it condenses and gives off its latent heat to the frost surrounding the coils and melts the frost. This hot gas is sent through the coils for a preset amount of time, and then the defrost cycle is terminated. Next, the coil pressure is allowed to bleed off, and then the sub-cooled liquid refrigerant is allowed to resume its normal flow.the liquid refrigerant has been evacuated from the evaporator, the flow of hot gas is initiated through the drain pan, which is done to keep any melt water from evaporator coils from freezing when it is collected in the pan. Next, the gas is routed through the evaporator to melt off any frost build up. Then, at the exit of the evaporator a mixture of ammonia gas and liquid is sent to suction for processing or for use in the refrigeration cycle.

IV. EXPERIMENATL INVESTIGATION

The Experimental system consists of a basic refrigeration system along with two stop valve . Thes two stop valve are representing the single solenoid valve in experiment.

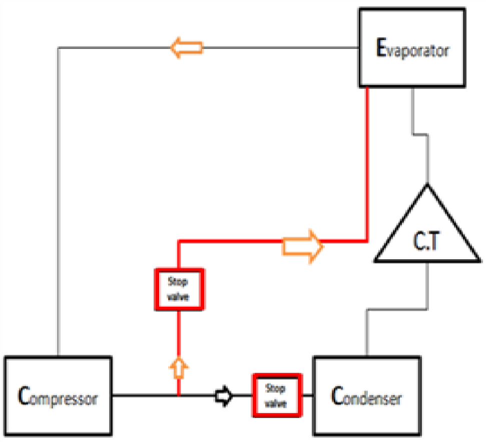

Figure 1: Experimental Set-up

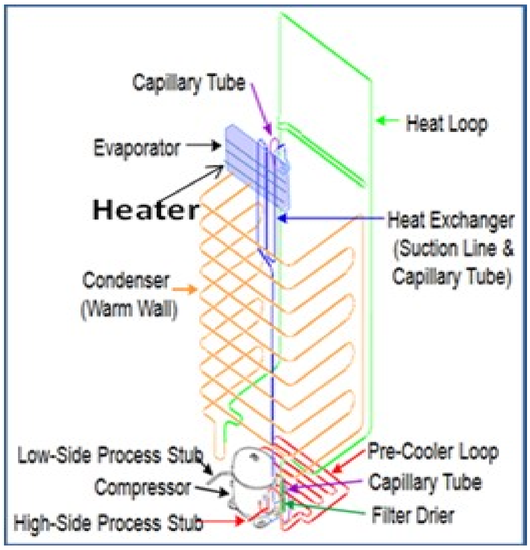

Figure 2: Typical Refrigeration Cycle

A. **Component Description: -**

1) Evaporator: - Refrigerant fluid is transformed from liquid state to gaseous state, absorbing the inside heat of the refrigerator, Evaporator Specification, Tube Outer dia, 8.0mm+/-0.08,Tube thickness, 0.70+/-0.05,fin thickness ,0.15+/-0.025mm,Tube Internal Volume ,0.258L .

2) Compressor: - It pump the refrigerant fluid which on returning from the evaporator in a gaseous state is suctioned & pumped to the condenser, causing low pressure in the evaporator & High pressure in the condenser. Compressor specification, Capacity 166W, Coefficient of performance 1.30W/W, Power consumption 128W.

3) Solenoid valve: - It is electromechanically operating valve, where flow is switched on & Off, valve Specification, Tube Inner dia.1.9mm+/-0.1. Tube Inner dia Output 1: - 2.1mm+/-0.1. Tube Inner dia Output 2: - 0.15mm+/-0.1.

4) Hot gas fluid tube: -Refrigerant fluid is travelled from tube to melt the frost. Tube Specification: - Tube Outer dia.: - 4.5 mm+/-0.0, Thickness of tube: - 0.5mm+/-0.05, Length of tube,4348mm+/-5.

B. **Terminologies with Details**

5) Defrost: - The cycle when the heating cycle get activated in method & ice get melted during this stage from evaporator.

6) Recovery cycle: - It is the phase just after the defrost, it more wattage consuming Phase.

7) Stable cycle:-It is the phase just after recovery cycle; the cycle becomes stable and consumes the less less wattage.

8) Freezer Air: - Average temperature of the freezer air temperature.

9) Refrigerator Air: - Average temperature of the refrigerator air temperature.

10) Over all power consumption wattage: - Power consumption by compressor, Defrost heater, fan & other electronic devices.

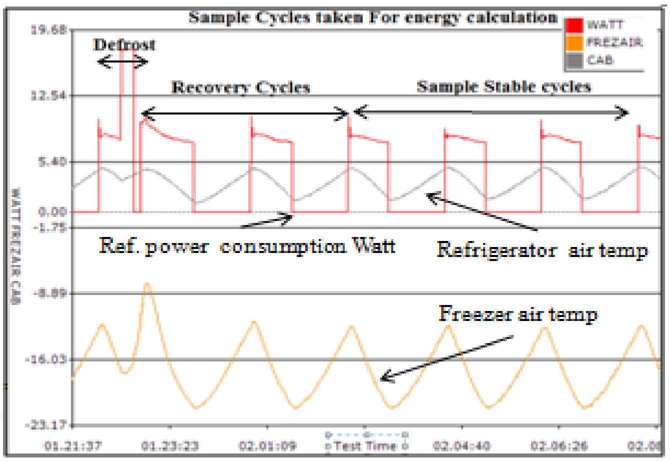

Figure 3: Terminology with details

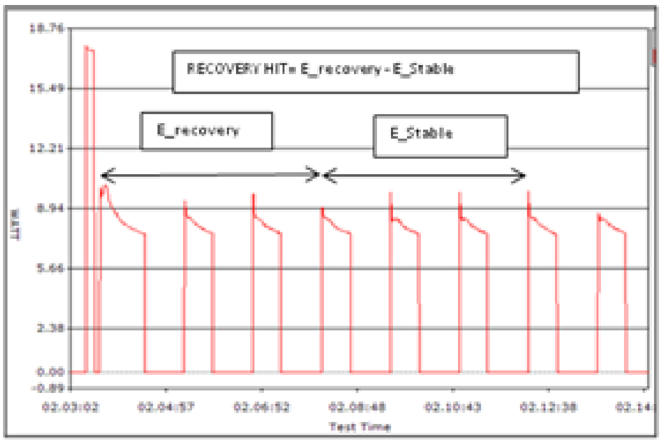

Figure 4: Energy calculation terminology

Recovery_hit = E_recovery - E_stable (1)

Defrost Contribution (%) = (E_defrost + E_recovery_hit) * 100 / Total energy (2)

Max saving (%) = (Total_energy - Stable energy 24hr) *100 / Total energy (3)

Where, E_Defrost = Energy consumed during defrost

E_recovery = Energy Consumed during Recovery cycles(n cycles)

E_Stable = Energy consumed during stable cycles (n cycles)

V. EXPERIMENTAL RESULTS

Table 1 shows the comparison study of electrical heater versus refrigerant defrost where defrost time getting change from 10 mins to 5 mins for warm setting similarly it is changing from 12 min to 8 mins for cold setting. improvement because of this defrost time is 7.75% & 6.25% respectively in energy.

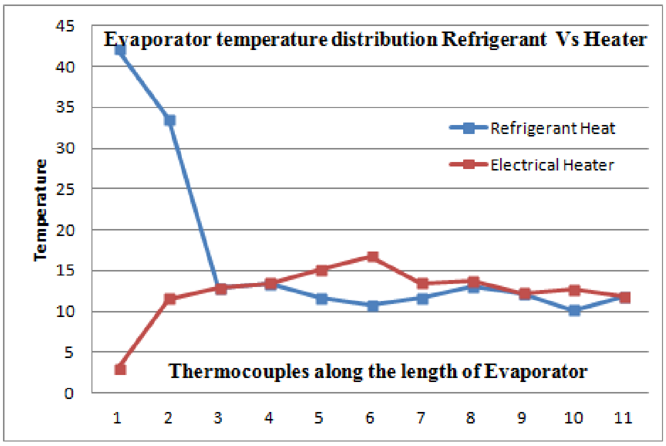

Figure 5: Evaporator temperature distribution graph Refrigerant Heat Vs Electric heater

Figure 5 shows the temperature distribution across the evaporator for refrigerant defrost verses electrical defrost, where we can see the temperature is high at initial stage & getting stabilized after some time in refrigerant heat where as it is consistent in electrical heater.

In Table 2 we are showing the behaviour of the product for different test condition like in no-load pull-down test pressure drop in the system is 0.35 bar same for heavy defrost it will take 5 to 10C temperature for melting the ice from the evaporator. Energy saving because of refrigerant defrost is 6-7%.

Table 2: Different scenario for Refrigerant defrost

Experiment	Objective	Result
Noload pulldown test with Solenoid valve	1.Baseline comparision	No Difference
	2. Pressure drop acros Solenoid valve	0.35 Bar

Defrost with Heavy ice at 32^{o}C	Frost melting Completion	Fail 5^{o}C end temperature, Pass 10^{o}C End temperature
Defrost with heater starting in Off, On	To Check best starting temperature	Negligible Difference
5^{o}C Vs 10^{o}C temperature on bimetal	Check Energy Benefit if any	Nil high heating rate slow bimetal response
Energy HGD best Vs Heater Baseline	Energy Benefit of refrigerant defrost	**6 – 7 %**

VI. CONCLUSION

1. Based on the experimental data it has been observed that there is 6-7% Energy saving by using refrigerant gas defrost in domestic refrigerator.
2. Temperature recovery period is less which can help for better Pull down rate.
3. In comparison with Electrical heater Temperature distribution on evaporator area for refrigerant defrost temperature are not consistent it varies based on time.
4. There are issues related to frost melting in dip tray area in case of heavy frost formation and high humidity condition (90% Relative Humidity)
5. We can see the frost on suction tube at the end of defrost .incase of heavy frost there is a chances of water vapour can enter in compressor.
6. Approximate cost saving because of refrigerant defrost will be 3-2 USD.

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Table 1: Comparison between electrical defrost Vs Refrigerant defrost

Energy Comparing Regular Defrost Vs Hot Gas Defrost				
Product No	143801266			
Temperature Setting	warm	warm	cold	cold
Heater Type	Electrical Heater	Refrigerant Gas defrost	Electrical Heater	Refrigerant Gas Defrost
Avg. temperature FC Compartment ºC	-13.75	-13.76	-17.03	-16.29
Avg. Temperature RC Compartment ºC	4.81	4.91	2.97	1.45
Defrost time (hh:mm:ss)	0:10:03	0:05:40	0:12:57	0:08:18
Defrost energy kWh/24hrs	0.029	0.012	0.040	0.017
No of stable cycle	2	2	2	2
ON Time (hh:mm:ss)	1:08:54	1:03:23	1:28:23	1:39:10
On + OFF (hh:mm:ss)	3:19:48	3:11:54	3:32:13	4:04:45
% Run	34.484	33.029	41.648	40.518
Average Wattage (W)	83.79	85.138	80.65	81.248
Energy Consumption kWh/24hrs	0.0981	0.0918	0.1198	0.1344
Interpolated Energy kWh/24hrs	0.773	0.715	0.864	0.810
Energy Margin	7.75%		6.25%	