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ENERGY SAVING BY USING HOT GAS DEFROST IN VAPOUR COMPRESSION SYSTEM

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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 optimizeding discharge temperature.

KEYWORDS: Defrost Methods, Hot Gas Bypass Defrosting.

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 an 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 defrost 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.

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 factors could be quite dangerous and even destructive. Now a days 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.[5,1]

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

1) Hot gas defrost pressure. A popular misunderstanding is that the higher the defrost temperature, the better is the result. In reality a number of studies shows (Stoecker, 1983) that a source of lower pressure and temperature gas can obtain good results as well. There is most likely an optimal pressure / temperature (Hoffenbecker, 2005) that would achieve the highest efficiency.

2) 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 the defrost is ended earlier the effectiveness of defrost significantly drops.

3) 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.

4) The quantity of energy used for melt down the ice during the defrost is more than double (Stoeker,1983,Hoffenbecker,2005) of 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.

5) Finally, it should be 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.

6) 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. [1,6]

Let's consider those issues in relation to the valves and controls used to control a hot gas defrost process.

1.1 Hot Gas Defrost Controls Group

Fig. 1 presents a typical industrial refrigeration evaporator with hot gas defrost. Control valves for the evaporator could be divided in the 4 main groups:

Pumped liquid feed to the evaporator. This valve train typically includes stop valves, filter, a solenoid valve, a regulating valve, a check valve and a final stop valve.

1. Hot gas feed line. Usually it has a stop valve, a filter, another solenoid valve and a stop valve .
2. Condensate line. Here we can see one or the other pressure controlled valve or a float Proposition to drain the liquid. Both significantly different defrost principle.
3. Wet return line. This line needs to have an automatic shut off valve and a stop valve.

The defrost process could be divided into 4 main sections.

First, the liquid source to the evaporator is turn off. Evaporator fans should still run for sometime, suction valve remains open in order to make sure that remaining liquid refrigerant will boil out. Second, the suction valve will be closed, evaporator fans will be stopped, the hot gas solenoid valve will be opened and the feed of the evaporator with the hot gas starts. Thirdly, when the defrost is ended , the hot gas solenoid valve will be shut down, the suction valve will be free. Finally, the liquid feed is opened again, water droplets on the evaporator fins are allowed to freeze, and only then the evaporator fans will be started again.

Crucial considerations in the hot gas defrost process are avoiding pressure/temperature stresses and system ineffectiveness by managing a slow pressure built up in the refrigerator at the start of defrost and at the same time a slow pressure release from the refrigerator after the process. Both hot gas solenoid and main suction valve selection are critical when goal for a safe and efficient defrost process.

Considering the efficiency considerations determined above, let's review the established valves configurations. It should also be considered, that the defrost with CO2 is a more rough one, and a conventional approach for CO2 evaporators with hot gas defrost should be chosen.

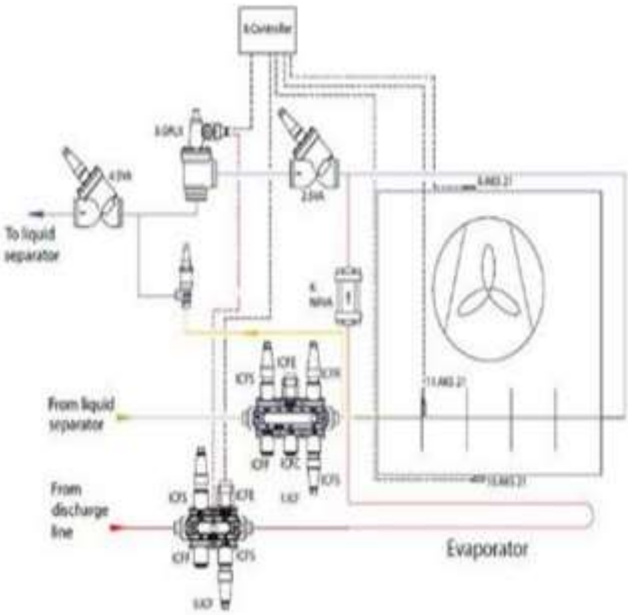

Fig.1Typical configuration for an industrial refrigeration evaporator with hot gas defrost

1.2 Hot Gas Defrost Controls Group – Liquid Feed Line

Liquid feed line has the minute influence on the hot gas defrost method. What could be significant to consider here, is the quantity of liquid that is fed to the evaporator. In case PWM (pulse width modulation) method is used, the amount of liquid refrigerant in the evaporator will be lower. That should reduce the time needed to get rid of the liquid refrigerant. It could also be expected that the amount of ice is lower as well, as the temperature deviation on the surface in on/off periods is lower (figure 2). This liquid feed method has been positively used in a number of CO2 systems with forced rerotation. In ammonia systems, this control method has not been widely applied yet.[10]

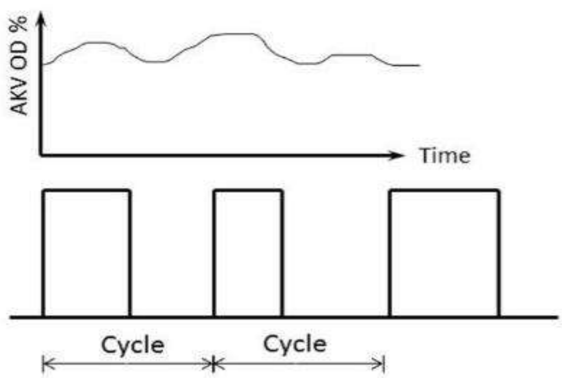

Fig.2 Pulse width modulation liquid feed

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1.3 HOT GAS DEFROST CONTROLS GROUP – HOT GAS LINE

The most common way to feed hot gas in an evaporator is with a conventional solenoid valve. Motorized valves and motorized ball valves have also been used for the purpose, especially for CO2 systems. With higher pressures, and higher pressure differentials, the risk of liquid hammer in CO2 hot gas defrosts systems is higher than with ammonia. Clearly, the weakness of the solution with motorized valves is that they are more complicated to set up, and valve trains with motorized valves are pricier than traditional ones.

Another point, which is especially critical for the ball valves, is that the opening speed must be adjusted to a relatively low level. A solution with 2 solenoid valves, the first area for the required hot gas defrost quantity, and the second for 10-20% of the flow and installed in parallel to the first one (Figure 3) could be more cost Productive and proficient. The shorter solenoid switch on first and feeds the evaporator with hot gas for the first few minutes, increasing the pressure in the evaporator and supply lines in a controlled way. After that the second solenoid opens and the main defrost starts. This valve train composition has already been used in a number of installations and in general confirmed to be successful.

The advantage of the motorized valves in hot gas defrost lines is that they make it feasible to have an intelligent hot gas control. That may include not only slow opening, but slow closing as well. That could be relevant in those cases, when the defrost is not done based on timing, but rather on other factors, such as surface temperature control.

Finally, in order to limit the hot gas pressure / defrost temperature and maximize the defrost efficiency; a subsequent regulator could be installed. It is only essential to install one such regulator for a group of evaporators attached to the same hot gas line. The arrangement of the valve should be such that it can provide enough hot gas for all evaporators that might be defrosted at the same time.[15,13]

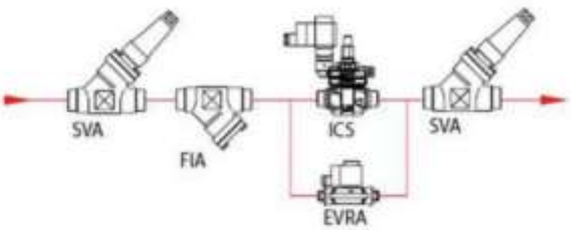

Fig. 3 Hot gas feed line with double solenoid valve

1.4 HOT GAS DEFROST CONTROLS GROUP CONNDENSATE LINE

There is a large variation in the code devices, used in condensate lines of evaporators with hot gas defrost. Differential pressure regulators are normally common, but upstream pressure regulators and float valves are applied as well. As discussed, the float valves are likely to be the most efficient controls for the hot gas defrost. A permutation of float valve in condensate lines with subsequent pressure regulators in hot gas lines would be a preferable one, in order to make sure that the defrost pressure is kept on the finest level.

There are weaknesses of the solution with float valves as well. First, the priced could be comparatively high. The cost might be partly reduced by installing a float regulator in a common evaporator condense line for several evaporators. Secondly, for high pressure refrigerants, such as carbon dioxide (CO2), float regulators are hard to find. In this case replacement must be discovered. One of them is steam traps, which are coming from other industries, and can manage high pressures. Even though steam traps are acquiring popularity, those devices are not very common in the refrigeration industry yet. all considerations valid to float valves used in condensate lines, should also be relevant to steam traps.

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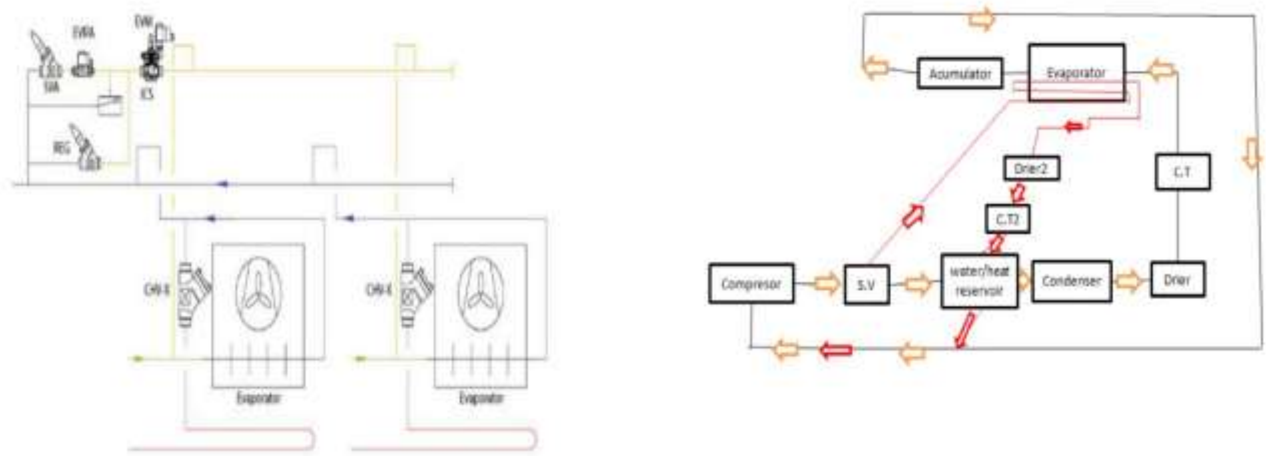


Fig.4 Float valves in condensing lines with multiple evaporators. Only valves in the condensing lines are indicated.

1.5 HOT GAS DEFROST CONTROLS GROUP – WET RETURN LINE

Control valves used in wet return lines are solenoid valves & gas powered solenoid valves (both of them need to have a bypass valves to avoid liquid throwing after defrost), 2 step gas powered solenoid valves, motorized valves and motorized ball valves. Preferred options are either 2 step gas powered solenoid valves or motorized valves. On one way they help avoiding liquid throwing, either because of the 2 step function because of the slow opening speed. On another way, they give minimal pressure drop during the cooling cycle, which is especially critical at low temperatures.

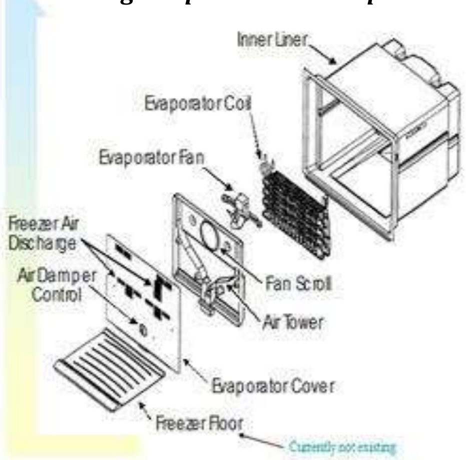
An advantage of the 2 step gas powered valves is that they don't required any additional changes in settings. The second phase opens autogeneticlly when the pressure difference over the valve drops below certain value. Motorized valves require speed adjustment,
but have no need for an additional hot gas line

to power them. Motorized valves are especially popular for carbon dioxide (CO2) systems, as they are easier to get for higher pressures. Ball valves with a bypass solenoid valves are frequently used as well. The benefit of the solution is the low pressure drop during the cooling cycle. However the leak possibility over the stem is a cause for concerns.[4,9]

II. AN OVERVIEW OF HOT GAS DEFROST MECHANISM

The experimental system consist of basic refrigeration system along with two stop valve . this two stop valve are representing the single solenoid valve in experiment.

Fig.5 ***Experimental Setup***



ISSN: 2277-9655
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Fig. 6 Typical Evaporator design

Terminology with detail

1. Defrost: the cycle when the heating cycle get activated & ice get melted from evaporator.
2. Recovery cycle : It is the phase after defrost which take more compressor on time to compensate the required cooling set by user on display
3. Stable Cycle : It is the phase after recovery cycle in which compressor becomes stable & consume same wattage in every cycle.
4. Freezer Air : Avg. temperature of freezer air.
5. Refrigerator Air temperature : Average temperature of refrigerator air
6. Wattage : Sum of power consume by compressor, heater, fan motor & other electronic devices.
7.

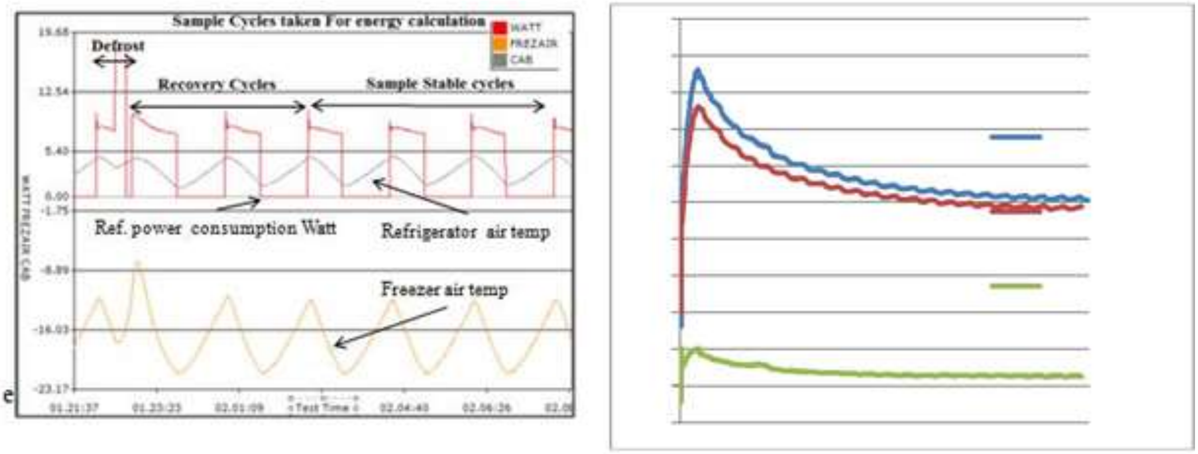

Fig. 7 Real time trend of refrigerator cycling & defrost

Calculation Formula

E_Defrost = Energy consumed during defrost.

E_recovery = Energy Consumed during

Recovery cycles(n cycles)

E_Stable = Energy consumed during stable cycles(n cycles)

Recovery_hit= E_recovery - E_stable

$$Defrost\_Contribution = \frac{(E\_defrost + E\_recovery\_hit)*100}{Total\_Energy}$$

$$Max\ Saving(\%) = \frac{(Total\_energy - Stable\_energy24hrs)*100}{Total\_Energy}$$

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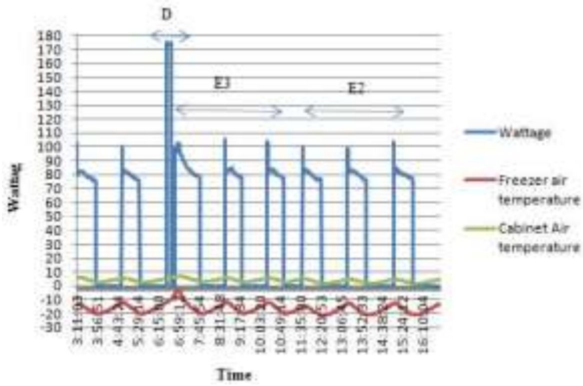

Fig.8 Terminology for Energy calculation

200
180 Variation of Pressure
160
140 High
120 pressure
100 S.V Pressure
80
60
40 Low
20 pressure
0

-201 45 89 133 177 221 265 309 353 397 441 485 529 573

Fig. 8 Evaporator temperature distribution

TABLE SHOWING % CONTRIBUTION OF DEFROST AND SCOPE OF ENERGY IMPROVEMENT											
[illegible]			[illegible]			[illegible]			[illegible]		
Test No	% contribution	%improvement	Test NO	% contribution	%improvement	Test NO	% contribution	%improvement	Test no	% contribution	%improvement
[illegible]	11.29	8.51	157081	7.18	4.48	[illegible]	8.58	6.40	[illegible]	6.66	4.80
[illegible]	9.73	7.00	157409	7.85	5.42	145981	9.40	7.01	148668	7.15	5.16
165618	7.86	6.10	151753	8.56	6.02	146071	7.03	4.68	138716	11.67	8.95
[illegible]	8.42	6.26	151829	9.27	6.51	146144	8.05	5.78	[illegible]	11.04	8.27

Fig. 9 Performance validation summary Conclusion

1 It has been concluded that there is 5-8% energy saving by using hot gas defrost
2 Poor Temperature distribution in terms of hot gas defrost compared with electrical heaters.
3 There are some issues releated to frost melting in dip tray area as surface temperature not getting increased in that zone.
4 Suction frosting durning defrost .wet vapour enters in compressor durning heavy defrost.

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