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NEW INTELLIGENT DEFROSTING APPARATUS

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NIDEA: NEW INTELLIGENT DEFROSTING APPARATUS

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Abstract

In refrigeration applications the defrost of unit coolers is a critical issue. Frequently to define the best set up of the defrost operation many attempts are needed. To avoid thick frost formation during toughest working conditions, usually, a high number of defrost with long phase are settled.

NIDEA has the aim to optimize the defrost process of unit coolers and avoid wasting energy, without reducing the functionality of the equipment. In the traditional system, based on a logic of precaution, the cycle is activated independently of the real need for defrosting. The new device, by using temperature and pressure probes, organizes dynamically the defrost cycles during time in accordance with the working conditions of the cold room.

In this paper is described the system technology, both hardware and software. A field test performance is presented as reference. In the analysis is compared the same plant operating with defrost managed with NIDEA and in traditional way. In the results, energy consumption and savings are discussed.

1. Introduction

It is well known that when humid air comes into contact with the surface of a heat exchanger operating at negative temperatures, frost inevitably forms on the exchange surfaces. This causes a number of negative consequences, which can be briefly summarized as follows: i) additional thermal resistance in the heat transfer between the refrigerant fluid and the air, which leads to a reduction of the overall exchange coefficient; ii) additional aerodynamic drag, which tends to reduce the airflow. The combination of the two effects leads to a progressive decrease of the thermal power exchanged, which results in a parallel increase in the specific consumption of the cooling cycle.

The decay is interrupted by performing a defrost cycle, which can be obtained using different techniques: the most widespread is electric defrost, obtained with a series of electrical heaters, located both in the finned pack, and in the drain tray. To minimize the defrost time, the electrical power required is considerable (about 30% of the thermal capacity).

In the real operation of a unit cooler, the phenomenon is complex and unpredictable: the optimal number of defrosts theoretically cannot be calculated. It is not constant, since it depends on a variety of factors, many of which are variable over time in an unpredictable way: the coefficients of utilization, characteristics of the apparatus, the thermodynamic conditions of the cold room (temperature, relative humidity), introduction of moisture into the cold room, number and length of door openings, defrost methods and efficiency, etc.

The refrigeration technician, who must set two values - (i) the time interval between one defrost and the other and (ii) the time to be allocated to each defrost cycle - will tend to set prudential values, namely a high number of defrosts per day, so as to avoid the risk of frost formation that is overly penalizing in the critical periods when the moisture introduced into the cold room and the coefficients of utilization are maximum and defrost times are long. This is done in order to prevent a situation in which, at the end of the defrost cycle, the surfaces are not perfectly free of frost, and which therefore could lead to a progressive blocking of the apparatus. The end result translates inevitably into an increase in energy consumption and related system management costs, caused by defrost cycles that are too frequent and therefore useless: a typical example is that of a cold room in which for long periods (e.g. the weekend) no moisture is introduced and for which the cooling capacity is dimensioned for loads much greater than the average values.

2. The NIDEA Logic

NIDEA is designed to be able to identify the optimum instant at which to suspend the operation of the compressor (or close the liquid line) and activate the defrost cycle; and to be able to identify the instant at which to terminate the defrost. The device is applicable to each apparatus (unit coolers or air coolers operating with any fluid), reliable and able, in the presence of anomalies (e.g., failure of a fan, a heater, or a sensor), to continue operating, indicating the alarm situation and automatically switching to a timed operation.

Determining the Defrost Start Point

The formation of frost on an apparatus can be indicated by multiple parameters. Among these are: a performance decay of the appliance (e.g. in terms of the ratio between the thermal power and the rise in temperature ΔT_1), a variation of the electrical power absorbed by the fan, an increase in the weight of the apparatus, the optical measurements of frost thickness, etc.

A first choice is based on the air-side increase in the difference of pressure through the coil, caused by the frost. An important advantage of this solution is that it is independent of parameters external to each individual apparatus, such as: the number of apparatuses supplied by a compression line, the number of compressors that supply the line, the condensing pressure variation correlated to the ambient temperature, the refrigerant fluid, the temperature and humidity of the cold room, etc. The only requirement is the constancy of the number of revolutions of the apparatus fan(s).

A second choice is the adoption of a self-calibration logic, based on the time required to complete the defrost procedure: (i) the Δp pressure loss through the coil is measured in “clean conditions” and it operates until the said Δp increases by a predetermined value; (ii) the defrost process starts, and measures the time required to defrost the apparatus: if this said time exceeds a predetermined value as input, NIDEA lowers the Δp threshold, whereas if the defrost occurs in less time, the threshold is raised. The situation is illustrated in Fig. 1.

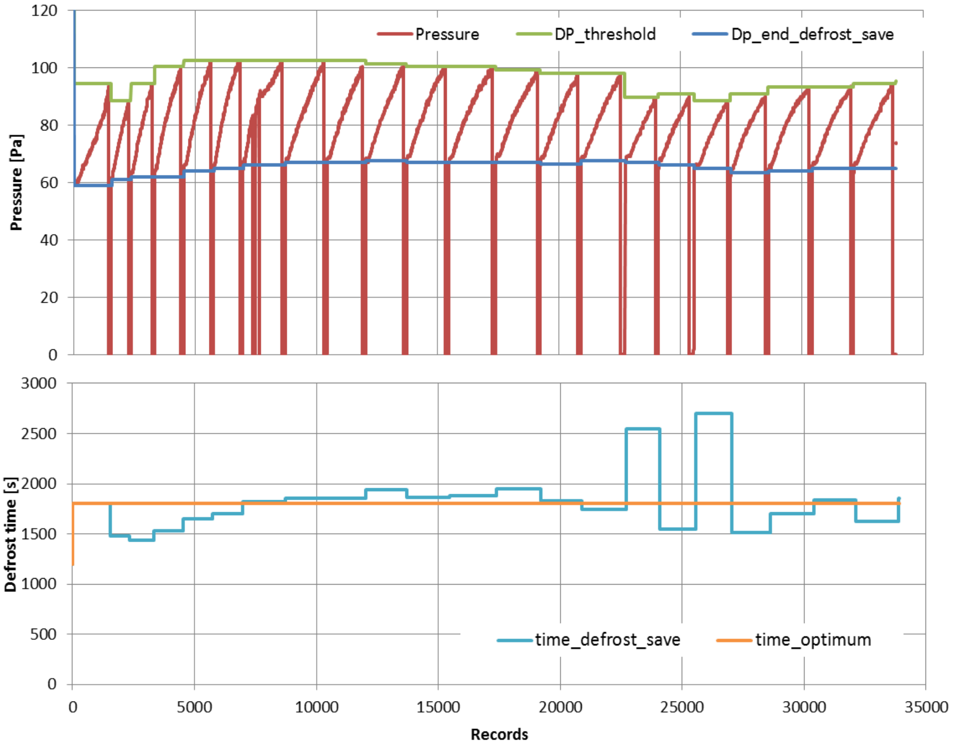


Figure 1

Experimental diagrams illustrating the NIDEA operating logic: it starts from an initial ∆p value in the first cycle and a ∆p threshold value is pre-set (in the example, 60 and 90 Pa respectively). The apparatus operates until it reaches the ∆p threshold (upper diagram). At this point a defrost is run. Once the defrost is finished, the time taken to finish the defrost cycle is measured and compared with the pre-set time (in the example, 30 minutes, lower diagram). If, as in the case in the figure, the defrost time is longer than the pre-set value, it means that the frost deposit is greater than the desired value, and the ∆p threshold value is decreased. In the next cycle, the new threshold value is reached and a new defrost is performed, this time shorter than the threshold value. Several cycles follow in which the threshold value continues to increase until it reaches the pre-set defrost time. Tracking continues, making small changes to the threshold value. At the beginning of each operation cycle, NIDEA memorizes the ∆p value: its increase beyond the tolerance limits signals an anomaly.

Determining the Instant in which the Defrost Cycle Terminates

In principle, the end of the defrost should occur when the heat introduced has allowed the elimination of any residual frost. The most widespread system for locating this moment consists of placing a temperature sensor inside the finned pack and fixing the temperature that the sensor must reach. The sensor placement is problematic because the frost settles unevenly and it is not easy to find the point where the temperature is representative of the effective achievement of complete defrost. Moreover, the measurement can be distorted by the proximity of the sensor to the heating elements.

NIDEA is fitted with two end-defrost temperature sensors, which are pre-assembled at the factory. The assembly system ensures an optimal thermal contact and insulation of the sensitive element, which must not be influenced by the irradiation of the heaters. Besides basing its concept on the temperature sensors, NIDEA presents a further possibility of verifying the validity of the defrost: it compares the pressure in the pack at the end of the defrost with the memorized value when the apparatus is clean. If anomalies are found, indicative of an incomplete defrost, it runs a new defrost, until ∆p is within the set tolerances. Otherwise, it signals the anomalous behaviour.

3. Application of NIDEA to a Real Case

The first application in a real context was undertaken in a cold storage room of frozen products, in which a unit cooler apparatus was installed, equipped with an electronic valve and controlled by NIDEA. The operation was constantly monitored by remote control.

If the behaviour of a pressure drop through the battery in a typical week, as depicted in Fig. 2, is examined, the significant difference from that recorded in the laboratory tests is noticed. In the laboratory, where the cold room was maintained at a constant temperature and humidity, a gradual increase in the pressure drop over time with the derivative almost constant, in this case recording long periods in which small changes in Δp occurs (e.g. during the weekend), interspersed with sudden peaks, coinciding with the opening periods of the cold room and consequent increases in humidity and the coefficient of load.

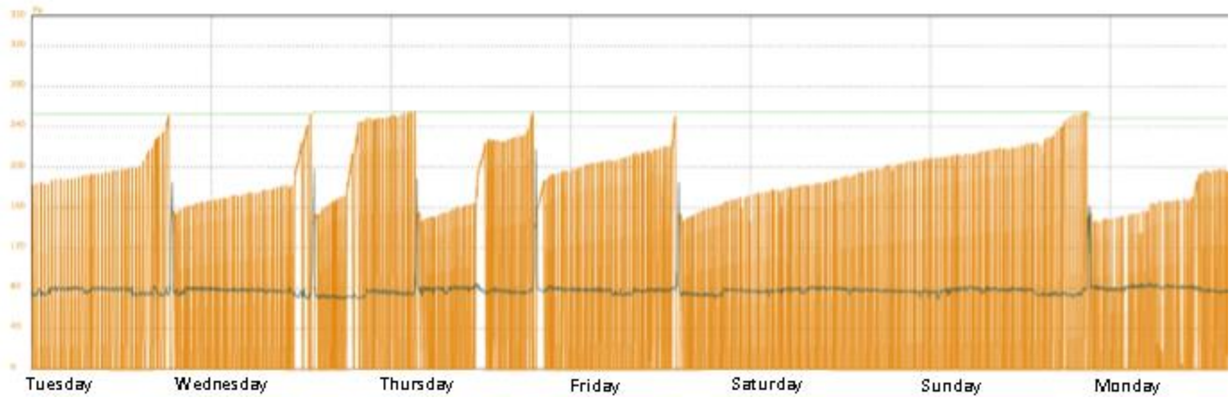
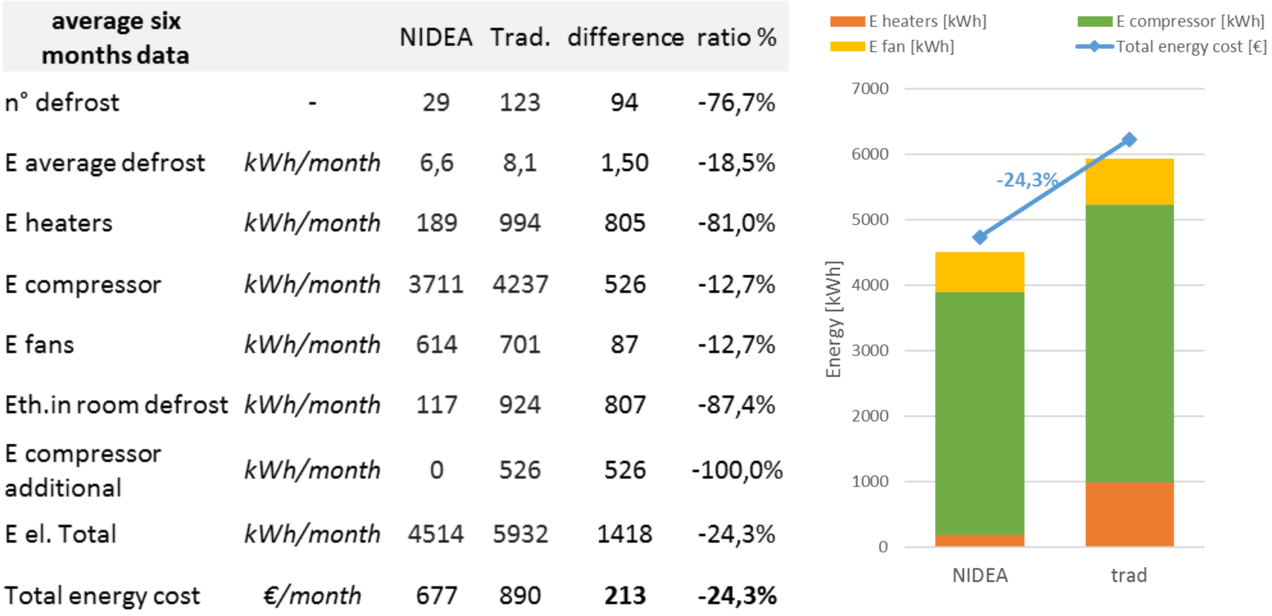


Figure 2 Trend of the pressure drop through the coil. The green line represents the Δp threshold; the blue curve represents the temperature of the temperature sensors

Despite this, NIDEA was perfectly able to follow the defrost status of the apparatus and carry out the defrosts in an optimal way.

The existing facility provided, before the installation of NIDEA, the operation of 4 defrosts per day, each with a set time of 30 minutes: a very conservative assumption, as revealed by the subsequent experimental campaign. It should also be noted that sometimes NIDEA performed defrosts even with shorter time intervals (two defrost cycles four hours apart were recorded, on the occasion of a period in which a prolonged loading of the cold room was performed).

The overall data collected from this experience is summarized in the following table, which show the key figures measured six months of operation. It can be noted that the number of defrosts chosen by NIDEA is approximately equal to one daily defrost (against the four of the “traditional” system, therefore with of 75% reduction), with average energy required by each defrost lower than the traditional value. The average monthly savings in energy consumption allowed by NIDEA vary 30-20% and are greatest in the colder months, where the compressor consumption levels are lower due to the lower condensing temperature. In the case in question, these energy savings lead to cost savings of € 2000/year.



average six months data		NIDEA	Trad.	difference	ratio %
n° defrost	-	29	123	94	-76,7%
E average defrost	*kWh/month*	6,6	8,1	1,50	-18,5%
E heaters	*kWh/month*	189	994	805	-81,0%
E compressor	*kWh/month*	3711	4237	526	-12,7%
E fans	*kWh/month*	614	701	87	-12,7%
Eth.in room defrost	*kWh/month*	117	924	807	-87,4%
E compressor additional	*kWh/month*	0	526	526	-100,0%
E el. Total	*kWh/month*	4514	5932	1418	-24,3%
Total energy cost	*€/month*	677	890	**213**	**-24,3%**

Figure 3 Field test energy data: average monthly values.

4. Conclusions

The article presents a new component, allowing optimization of the operation of each type of unit cooler or air cooler operating at negative temperatures and thus subject to the formation of frost. It makes it possible to identify the best instant in which to start the defrost cycle and the instant in which to terminate it, therefore eliminating, in the actual operation, all unnecessary and/or overly prolonged defrost cycles. NIDEA is self-calibrating, can be applied on any unit cooler or air cooler and is equipped with alarm logics which, in case of abnormal operation (e.g. failure of a heater or a sensor), report the event and automatically switch to perform timed defrosts. NIDEA can be pre-fitted in the factory and integrated with the electronic valve regulation system, ensuring optimum operation of the apparatus both in terms of maintaining the desired superheating of the refrigerant at the outlet, and in terms of defrost cycles.

In the article a real field test example is showed: the results indicate that there are always significant energy savings, which translate into lower operating costs of the refrigeration system. In fact, NIDEA always pays back in a very short time: the higher the cooling capacity of the unit cooler and the more variable the operation over time of the cold room in which it is inserted, the shorter the ROI time.