Energy Savings From Heatless Desiccant Compressed Air Dryers Fitted With Dewpoint Dependant Switching

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SYNOPSIS

This paper describes the application of an energy saving technique for heatless desiccant air dryers. This technique is well established and the equipment used to implement the technique is well proven and operating successfully in many compressed air plants around the world. The energy savings arise as the cycle of the dryer is matched to the demands placed on it by the compressed air system. Several field studies were undertaken in the U.K., the results of which are tabulated. Pay-back periods averaging 12 months were often observed. Before the energy saving system is described, a brief outline of the operation of a standard PNEUDRITM desiccant compressed air dryer will be presented.

STANDARD CYCLE OF A DESICCANT DRYER

A desiccant dryer consists of two chambers, each filled with the desiccant material which adsorbs water vapour from the compressed air. At any time, one of these chambers is on line drying the process air, whilst the other is being regenerated, see Figure 1. The regeneration process uses a portion of the dried process air as a counter current purge. This purge air is used to drive desorbed water vapour from the chamber undergoing regeneration. and the production of this purge air by the compressor represents the energy consumed by the dryer. In a type of dryer commonly called heat regenerative, the quantity of purge air consumed is reduced and its effectiveness increased by adding heat energy. This has been discussed previously (ref. 1).

The benefits of a dewpoint switching energy saving system as applied to heatless desiccant dryers are potentially larger than those obtained from heat regenerative units. This is due to the cost of the purge air which the heatless dryers use in larger quantities than do heat regenerative types. Due to their lower capital cost and simplified construction, there is a large installed population of heatless dryers world-wide which opens the possibility of utilising the dewpoint switching system described here as a retrofit device.

The desiccant chambers of the dryer repeatedly remove water vapour from the compressed air and are then subsequently regenerated under some form of cyclical control. The drying / regeneration cycle is optimised for the rated air flow of the dryer at certain fixed inlet air conditions, usually 35 oC, 100 % relative humidity and 7 barg line pressure (ref. 2). The controller continually cycles the dryer whilst it is switched on, regardless of whether the moisture loading placed on it at that time, is high or low. This is where the benefits of a dewpoint switching system become evident.

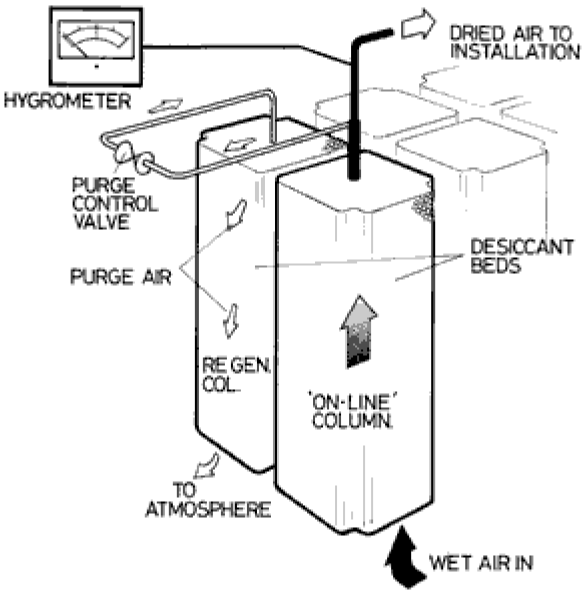


Figure 1 : Schematic Of A Desiccant Dryer

THE DEWPOINT SWITCHING SYSTEM

The adsorption capacity of the desiccant within the dryer is essentially constant whereas the moisture loading and the air flow through the dryer are continuously varying as ambient and plant conditions change. In order to maintain the specified air quality downstream of the dryer, it has to be sized for the worst case conditions, namely lowest pressure, highest flow and highest inlet temperature. These conditions may only occur for a small part of the service life of the dryer, for example, the highest inlet temperatures may only be present during the summer months. This means that the moisture loading on the desiccant beds is below the dryer's capacity for much of its service life eg. quiet periods in between shifts usually have lower air supply requirements.

To gain access to this dynamic adsorption capacity, a moisture sensor is fitted which continually monitors the downstream dew point. This interrupts the normal sequence of the controller, which is only permitted to change over when the desiccant has adsorbed moisture to its capacity. This effectively elongates the drying cycle. However, as regeneration has been optimised for a fully laden desiccant bed, this remains of constant duration resulting in a period of zero energy consumption i.e. purging is discontinued, see Figure 2. In this way, energy savings are obtained whilst maintaining a constant supply of clean dry air to the customer’s plant.

Perhaps an analogy will help our understanding. The desiccant beds can be thought of as buckets which are being filled with water. Due to the size of the buckets, they have a finite capacity. If the rate at which the bucket is filled is halved, it takes twice as long to fill, but the same time to empty. A standard controller empties the bucket after a fixed period of time, whether it needs to be emptied or not. The moisture sensor, however, is like a level detector; it tells you to empty the bucket when it is full but before water is spilt onto the floor.

ADVANTAGES OF HYGROMETER SENSING

In order to gain maximum energy savings from the dryer, all of the dynamic adsorption capacity of the on-line desiccant bed must be utilised without causing loss of dewpoint. The moisture sensing system must, therefore, be able to react to all of the changes in inlet conditions which may effect the adsorption process. It must also have a sufficiently rapid response time to detect the leading edge of the adsorption front before breakthrough has occurred.

The hygrometer is able to respond to changes in the inlet or process conditions, many of which have complex interaction mechanisms affecting the inlet moisture content. As the shape of the mass transfer front changes eg. for low dewpoint applications or throughout the service life of the desiccant, the dryer's cycle is automatically adjusted to suit. Sensing the moisture content of the effluent air using a hygrometer represents the only measurement which directly confirms the quality of the dry air produced by the dryer.

The sensing method described above has many advantages over alternative systems. In-bed capacitance probes infer the adsorbed moisture content of the desiccant by monitoring the electrical capacitance of a sample of the desiccant bed. The assumption made here is that the sample of the desiccant bed adjacent to the probe is representative of the whole, which may not be the case. Other systems attempt to infer when the dynamic capacity of the desiccant beds is fully utilised indirectly by monitoring the inlet air conditions using temperature and pressure measurements.

Another alternative energy saving system monitors the temperature of the exiting purge air and terminates regeneration when a pre-set temperature has been reached. This system focuses on the regeneration process rather than the delivered air quality and is prone to fluctuations in environmental conditions eg. ambient temperature and conduction and radiation to surrounding equipment and pipework.

These alternative systems may offer the advantage, in some cases, of lower initial sensor costs, but in comparison to the overall costs and energy savings obtained, their choice is, indeed, a false economy.

CASE STUDIES AND ENERGY SAVINGS

In order to estimate the energy savings available using this system, an experiment was started using the production air supply at domnick hunter. This is a fairly typical system utilising two 375 m3/hr (220 scfm) rotary screw compressors with filters and desiccant dryers. The dew point switching system was fitted to the desiccant dryer. Also fitted was an hours run meter which was activated whilst regeneration of either of the beds took place. The system is left on 24 hours a day, 7 days a week with the compressor left in automatic, pressure switching mode whilst production takes place utilising a single shift pattern.

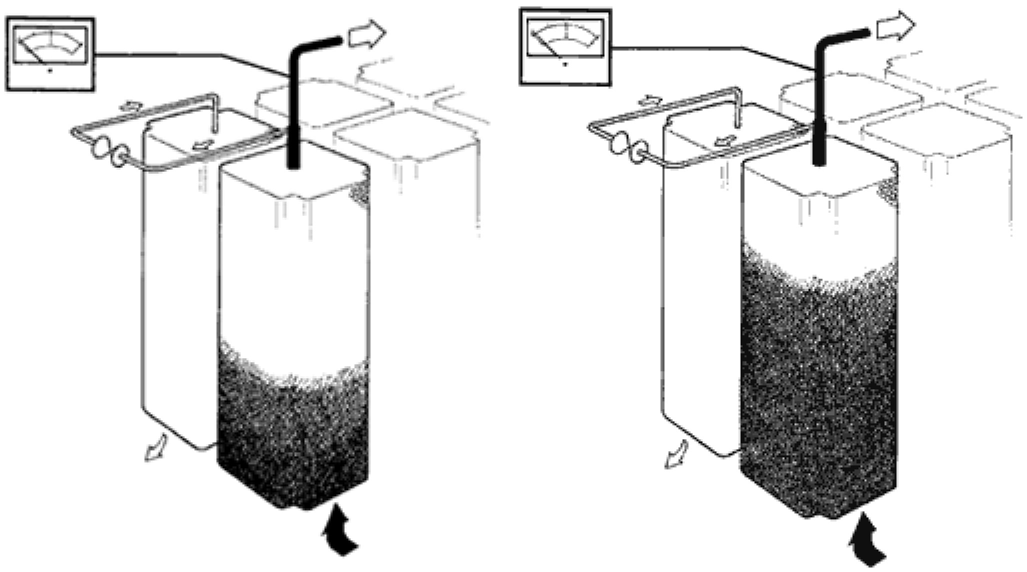
The hours run meter was set to zero at a fixed point in time. After a week, the elapsed time and the reading from the hours run meter were recorded. The difference between the readings represents the energy savings obtained during the test period, calculated as follows:-

$$\text{Energy Savings} = \frac{(T1 - T2)}{T1} * 100$$

where :-

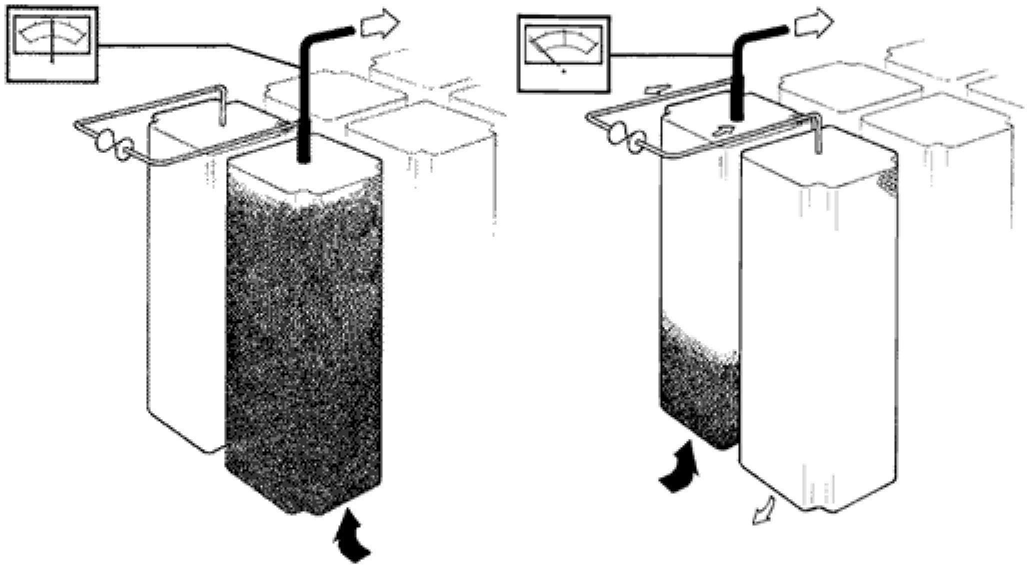
T1 = the elapsed time (mins)

T2 = the time spent regenerating (mins)



a) Desiccant Begins Absorbing Moisture.

b) End of normal cycle. Some residual desiccant capacity.



c) Moisture sensor detects change over point. No purge consumption during this period.

d) Regenerated bed comes 'on-line'.

Figure 2: Schematic Of Dewpoint Dependant Switching Operation.

Encouraging results were obtained and it was decided that the test should be continually monitored at weekly intervals. Measured energy savings averaging around 65% were repeatedly obtained. This equated to annual savings of approximately 49,500 KWh or £2475 (@ 5 p/KWh). As it was felt that field evidence across a range of installations would be desirable, the measurement was repeated at various customers sites, see Table 1.

This table shows the energy saved, expressed as a percentage, at each dryer installation. As it can be seen, the 7 sites investigated had energy savings ranging from 10 to 75% illustrating the manner in which the dewpoint switching dependant system adapts to particular site operating conditions. Unsurprisingly, the higher energy savings are obtained from dryers operating for only 1 shift per day. It is interesting to note that three of the installations investigated are fitted to Europe’s largest compressed air network, namely that of London Underground.

Site	Industry	Shifts/Day	Dryer	Investigation Period	Average Saving %	Energy Saving per year KWh
1	Transport	3	DX103	Feb to Mar 1995	60	34272
2	Transport	3	DX103	Feb to Mar 1995	36	20563
3	Transport	3	DX103	Feb to Mar 1995	10	5712
4	Gen. Mech. Eng	1	DX104	Sept 94 to May 95	65	49452
5	Medical Supplies	3	DX103	Sept to May 94	23	13138
6	Food Manufacture	3	DX106	Nov 94 to Jan 95	26	29682
7	Gas Separation	1	DX103	May to May 95	78	44554

Table 1 : Energy Saving Results From Dryers Installed At Customers Plants

Most of the dryers studied in this work are of the smaller size range of three or four columns. If we assume a typical energy saving value of 60%, this would equate to savings of 114144 kW or £5700 and a pay back period (based on UK list prices) of 6 months when fitted to a 10 column dryer.

References :-

1. ‘Energy Savings From Dewpoint Dependant Switching Systems On Heat Regenerative Desiccant Compressed Air Dryers’ by D Porter and R Fielding, presented at I.Mech.E.’s 1994 European Compressed Air Seminar.

2. ‘Compressed Air Dryers - Specification And Testing’ ISO 7183, 1986 E