Moisture Measurement From An In-Field Perspective

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ABSTRACT:-

The domnick hunter group manufacture and supply a range of refrigerant and adsorption compressed air dryers to suit a wide variety of applications and performance criterion to customers all over the world. The equipment is regularly supplied with moisture measurement or indication equipment so that the customer can check the outlet air quality The company have also been able to link the moisture measurement to a novel control system called 'Dewpoint Dependant Switching' [1] which is able to deliver significant energy savings to the end user of the equipment. This paper will briefly describe the installation, testing and in-field validation of humidity measurement equipment for the above purposes. Data gathered by monitoring real dryer installations around the world will be used to illustrate the discussion. This material is presented from the hygrometer user's point of view.

The paper was originally presented at the International Symposium on Humidity & Moisture, London, 1998. Here, the material has been updated to include some recent work on hygrometer comparison.

KEYWORDS : 'compressed air dryers', 'moisture measurement', 'energy savings'

1 .0 INTRODUCTION

1.1 Basic Dryer Function

Compressed air dryers, supplied as either fabricated steel or modular extruded aluminium units, remove water vapour using the adsorption process. Typically, two beds of adsorbent constitute the dryer, one bed of which is on-line removing water vapour from the process gas stream whilst the other bed is off-line undergoing regeneration. This is achieved by flushing the desiccant bed with a flow of purge air which may or may not be heated. The regeneration is undertaken at, or close to, atmospheric pressure. Thus the desiccant beds are cycled from being on-line and at pressure to being off-line and at atmospheric pressure, hence the term Pressure Swing Adsorption (PSA).

1.2 Hygrometer Installation

The customer is concerned with the moisture content in the outlet process gas flow as this is the air which is conveyed to the point of use in his plant. A small fraction of this air is sampled and monitored for its moisture content, usually expressed in terms of dewpoint [2]. Figure 1 shows a schematic representation of the hygrometer installation which is generally in line with industry recommendations [2].

Figure 1 : Hygrometer Installation

The hygrometers used for installation onboard the dryers are of the silicon substrate, electrical impedance type. They consist of a probe, placed in the sample gas stream to be measured, and an electrical output. For the equipment discussed in this paper, the analogue output from the driving circuit is fed into a microprocessor control unit. This analyses the signal, and controls the dryer's function by following instructions specified in software. Differing control regimes can be selected depending upon specific customer or site requirements. Self-diagnostic checks, programmed into the software, are continuously undertaken.

2.0 MOISTURE MEASUREMENT FOR PRODUCT DEVELOPMENT

As a company involved with the development and supply of compressed air drying machines, a stable test environment is essential. This allows tests to be set up and left running whilst the dryer achieves its equilibrium performance for the set inlet conditions. To test in this way requires stable pressure, temperature and humidity levels at the dryer inlet, not only for the duration of that particular test [3], but over time to allow several test results to be undertaken and compared. This is especially important when continually looking for process / product improvements. To this end, a sizeable investment has been made in an air treatment and conditioning system.

2.1 Moisture generation

The design of the dh moisture generator is similar in principle to that of the well known NPL Standard Humidity Generator (SHG). Both systems work by contacting air with water (and ice in the case of the SHG) at a controlled temperature in such a way as to fully saturate the air at the control temperature. In this way, the set temperature becomes the dewpoint of the air. The scale of the two generators, however, is totally different.

The domnick hunter moisture generator uses a single pass of the process air through a vertical packed column. Heated water is allowed to fall under gravity over the packings, transferring heat and water vapour to the upwardly flowing air. The packed column is sized to produce saturated air at a set temperature between workshop ambient (no cooling circuit included) and 60°C, 10°C above the normal maximum inlet temperature of the adsorption dryers. Temperature control is by a proportional integral controller and PT100 temperature sensor mounted in the outlet pipework. Table 1 compares the moisture generator with the SHG to give an impression of scale and the generator is shown in Figure 2.

		dh moisture generator	NPL SHG (4)
Operating pressure	bar a	upto 17	1
Draw off flow rate	l/min	11000	2
Dewpoint range	°C	+20 to +60	-75 to +80
Dewpoint uncertainty	°C	~3	>0.1 at 95% confidence

Table 1 : Comparison of Moisture Generator With NPL SHG

Although the uncertainty levels of the SHG are much better than those of the moisture generator, when the problems of scale are considered, the level achieved by the dh moisture generator represents an excellent test platform for product development. The higher inlet dewpoints at elevated line pressures allow development engineers to simulate the inlet air conditions of a compressed air dryer installed anywhere in the world.

Figure 2 : The dh moisture generator.

2.2 Hygrometers Comparisons

The dryers and moisture generator were used to make back to back comparisons of hygrometers of similar types from differing suppliers. To do this, sets of hygrometers were connected to a common air supply with as little interconnecting pipework and as few joints as possible. The air supply was then taken either from the moisture rig, from the dryer outlet or a mixture of both. This allowed a wide range of humidity levels to be measured. Figure 3 presents the comparisons.

Figure 3 :- Dewpoint Response Of Five Hygrometers Under Test

If the hygrometers were in perfect agreement, the chart would show a straight line plot running horizontally at the 0°C difference level. The dewpoint from the chilled mirror hygrometer is taken as the best estimate of the true dewpoint. Chilled mirror hygrometers are often used as transfer standard devices for calibration laboratories. An internal mirror is chilled by a refrigeration circuit and an optical device observes the formation of dew on the mirror. The temperature of the mirror is cycled until the dew is formed and the temperature of the mirror monitored by a high accuracy platinum resistance thermometer. Of course, this does not mean that chilled mirror hygrometer is giving a perfect reading, but it is used here as a reference for the comparison exercise.

It can be seen that for the range –60 to –5°C dewpoint, all the hygrometers had differences greater than 5°C at some point in the range. Variations of ±10 degrees dewpoint can be seen for most hygrometers in the sample. The variations can also be seen to follow no set pattern leaving the user only to postulate the correct dewpoint. It is recommended that these types of comparisons are made when considering hygrometer purchase.

3.0 MOISTURE MEASUREMENT FOR ENERGY SAVINGS

3.1 Dewpoint Dependant Switching (DDS)

Desiccant Dryers are always designed to remove the water vapour when operating at the worst that could be seen in a particular installation. This occurs when the inlet flow and temperature are at their highest and the inlet pressure is at its lowest. These are important when specifying the dryer. However, for most of the dryer's working life, it’s operating conditions will not be as arduous, and under these reduced load conditions, it is possible to make energy savings.

Consider the case of a dryer which has reached the end of its design half cycle whilst the on-line desiccant bed has remaining moisture adsorption capacity. This is usually caused by a favourable deviation of design conditions. In this case, the dryer controller interprets the hygrometer analogue output and causes a delay in desiccant bed changeover in order to utilise the spare desiccant capacity. This continues until the hygrometer monitoring the outlet detects the start of moisture breakthrough. When the dewpoint reaches a pre-determined level, desiccant bed changeover occurs. In a previous study, energy saving of between 30 and 80 % were observed [1]. Savings varied depending upon the actual conditions and shift patterns operated by the end user.

3.2 In-Field Dewpoint Measurements

The operation of the DDS system is illustrated by Figure 4 which shows a dewpoint trace taken from a desiccant dryer system installed in a UK specialist packaging plant operating 24 hours per day. Here, the compressed air comes into direct contact with the end product and the dryer / filtration package is used to prevent product spoilage. The switching level set in the controller was –42°C.

Figure 4 .- In-Field Dewpoint Trace Taken From UK Installation.

Between the hours of 08:00 and 16:00, the dewpoint can be seen to rise towards the end of every half-cycle at regular time intervals (for the modular aluminium dryers, this is every 45 minutes). However, outside of these hours, the time periods between the outlet dewpoint reaching the set point can be seen to extend eg a two hour period between 01:00 and 03:00. This coincides with a lower overnight inlet temperature (also shown) and flow demand , and hence lower moisture load. For this installation energy savings of 55 to 65% over a 3500 hour monitoring period were typical. This resulted in an annual running cost saving of £13,0001, a saving which would not be possible without moisture measurement.

In the graph above, the dryer inlet temperature has been presented to show typical diurnal cycles. Although not presented here, inlet temperatures will vary seasonally and fluctuations in flow and inlet pressure also effect the moisture load on the dryers, and offer further possibilities for savings.

The reliability of the moisture measurement and the mechanical / electrical reliability of the hygrometer are critical in delivering these savings to the end user. The hygrometers are expected to operate and monitor dewpoints as shown above for a period of several years. For example, a 10 degree dewpoint drift to the wet side would eliminate most of the energy saving periods and cost the end user between £10,000 and £13,000. Despite being advised otherwise, many end users do not appreciate the sensitivity of the hygrometers and often do not have them periodically re-calibrated.

4.0 . MOISTURE MEASUREMENT AT LOW DEWPOINTS

4.1 Low Moisture Levels

The previous two examples have been taken from installations operating at the –40°C dewpoint level (ISO 8573.1 quality class 2 [5]). The following example has been taken from a monitoring exercise undertaken on a dryer installation in a semi-conductor processing plant in Thailand (see Figure 5). Here the target dewpoint was –70°C (ISO 8573.1 quality class 1). In this case, the hygrometers were used to monitor this critical application, although subsequent work has had some success operating the DDS system at a -70°C control level. To give an example of the difference in moisture content at the differing dewpoint Table 3 has been included.

Dewpoint	°C	24 (*)	-40	-70
Moisture content	ppm (w)	18840	78	1.6

* typical ambient dewpoint in Thailand (30°C, 70% RH)

Table 3 : Comparison Of Moisture Content in ppm (w) At Differing Dewpoints

From the table it is possible to see that between the room and the outlet of the dryer, there is a reduction in moisture content of over 10,000: 1.

[1]Calculated assuming a 600/0 energy saving over 8000 hours operation per annum; 6 dryers modules at 13 KW as each; electricity charged at 3.5p/KW hr.

Figure 5 - In-Field Dewpoint Trace Taken From Thai Installation, January 1996

During the monitoring period, a planned maintenance check had to be carried out on one of the five dryer modules installed at the plant. This required the dryer in question, dryer no. 1, to be switched off and vented to atmospheric pressure whilst the checks were undertaken. As soon as the dryer was switched off (06:00), atmospheric moisture started to enter the hygrometer, via diffusion through the 'pig tail' fitted to the sensor exhaust (see Figure 1). Additionally, the extremely dry desiccant within the dryer will also draw moisture from the atmosphere via any available diffusion route driven by the very high moisture gradient between the room and dryer interior. The dewpoint can be seen to fall 15 degrees in the first 3 hours that the dryer was off-line (5 degrees / hour).

Figure 5 also shows the dewpoint recovery after the dryer had been put back on-line at 14:00. The dewpoint can be seen to recover to the –70°C level over the following 36 hours (0.36 degrees / hour). The well known differences in hygrometer probe response speed to wetting out and drying down are well illustrated by this example. In fact, wetting took place over 13 times faster than drying. Throughout the monitoring period, the other four dryer modules at this installation continued to supply air of the required quality to the customer's plant, as illustrated by the trace from dryer no. 2.

If we consider the interior volume of the sample line (2 mm id x 2 m length) and a flow rate of 1l/min over the sensor, the number of changes of air within the sensor line needed to recover a 'good' dewpoint reading can be seen to be approximately 1/3 million. This scales up to a dry down time from -50 to –70°C dewpoint for a typical pipe in a production facility of 6" nominal bore carrying 2500 m3/hour (ANR) at 7 barg through 100 m of 8 days! One can only guess how long it would take to dry down a new installation which starts its life full of atmospheric moisture and often a hydrostatic integrity test during which the pipe is completely filled with water!

SUMMARY

As this paper has outlined, accurate and reliable moisture measurement is critical to industry. domnick hunter rely on hygrometer manufacturers to provide high levels of performance in order that good dewpoint monitoring and energy savings can be delivered to end users. The drive for continuous product improvement is strong and hygrometers are not exempt.

REFERENCES

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