ENERGY SAVINGS IN PROCESS AIR TREATMENT

Fluid-bed coating process has been used for a number of purposes including improved stability and shelf life of products; controlled, sustained, or delayed release; taste or odor masking; dust control etc.

The coating processes require evaporative removal of an organic solvent or aqueous vehicle as the film coat is deposited. The speed of a film coat application is related to the drying capacity of the process. Fluid-bed film coating processes have a greater drying capacity than other coating systems due to a relatively high fluidizing air volume that is used to both circulate particles and evaporate the coating vehicle. This increased drying capacity translates to more efficient film coat application making it a popular choice in many industries including pharmaceutical and food.

Equilibrium Relative Humidity.

Knowledge of the water activity of pharmaceutical solids (proteins, drugs, and excipients) is essential to obtain a solid dosage form with optimal chemical, physical, microbial and shelf-life properties. Water activity (aw) influences the chemical stability, microbial stability, flow properties, compaction, hardness, and dissolution rate of dosage forms of pharmaceuticals, proteins, biopharmaceuticals, nutraceuticals and phytochemicals. The importance of the measurement of water activity has been long recognized by the food industry. The measurement of water activity is traditionally less common to the pharmaceutical industry.

Water associated with a substance is classified as either free or bound. Free water (sometimes called mobile or unbound) is loosely adsorbed on the surface of the substance and has properties of bulk water. Bound water is directly or tightly associated with a material and is not readily available for chemical interaction with other species. Additionally, some water is less tightly bound, with properties reflecting a much higher level of structure than bulk water but less than that of tightly bound water. Thus, the amount of free water rather than the amount of total water is critical to the chemical and physical stability of a drug substance that is moisture sensitive.

Poor environmental control, particularly in respect of humidity, can directly or indirectly affect the pharmaceutical production output in a number of ways.

For example tablet coatings with aqueous solutions require extremely tight control of air humidity to ensure that the coating does not dry too fast or too slowly
Unbound water in products is susceptible to change depending on the relative humidity it is exposed to. The process of drying requires the moisture to be removed contrary to this moisture addition may be necessary for some products.
During moisture addition (absorption) or moisture removal (desorption) if products are processed at Equilibrium Relative Humidity (ERH) excessive wetness or dryness of products does not occur. The final moisture content of the product can be controlled accurately. Rejections are significantly reduced. Another benefit of uniform processing is improved shelf life of products.

At equilibrium, the water activity of a material is equal to the relative humidity (RH) of the atmosphere in which it is stored. Knowledge of whether water will absorb or desorb from a particular component is essential to prevent degradation, especially if one of the substances is moisture sensitive. For example, two separate materials (initially at different water contents and aws) stored at 25% RH will reach a water activity of 0.25, although the final water content of the two materials will be different. If the materials are moved to a higher or lower RH then the water will increase or decrease, respectively until equilibrium is reached. Likewise, if two materials of differing water activities and the same water content are mixed together, then the water will adjust between the materials until an equilibrium water activity is obtained. Therefore, water activity over water content provides useful information for formulation design, manufacturing conditions and packaging requirements.

The relationship between water content and water activity is complex. An increase in aw is almost always accompanied by an increase in the water content, but in a nonlinear fashion. These curves are determined experimentally. Many disciplines use water content calculations to regulate product quality, however, water content measurement can be inaccurate and time-consuming, especially for pharmaceuticals. For example, a particular compound has a water content of 0.05% and measuring water content in this range is difficult and requires a precision balance. For this compound, changes as small as

0.02% in water content corresponded with a 0.2 change in aw. Clearly, the aw measurement permits much tighter control of the product's specifications.

Stability

Protein, enzyme and biopharmaceutical stability is influenced significantly by water activity due to their relatively fragile nature. Great care must be taken to prevent aggregation under pharmaceutically relevant conditions. Most proteins, enzymes and biopharmaceuticals also must maintain integrity to remain active. Maintaining critical water activity levels to prevent dissolution, aggregation and conformational changes from occurring is important to deliver the correct dosage

Water activity of powders effects the flow, caking, compaction and strength properties of solid dosage forms. Additionally, aw is used in the study of shelf-life, aging and packaging requirements.

Air Handling System

Air is required to be supplied to the process at a particular temperature and relative humidity depending on various factors like the heat sensitivity of the product, properties of the solvents or aqueous vehicle used for coating purpose, the Equilibrium Relative Humidity (ERH) of products being processed etc. etc.

Depending on the outside climatic conditions and those at which the air is required to facilitate the process the air is treated in the Air Handling System and the treatment would generally include most , if not all , of the following :

i) Filtration
ii) Cooling
iii) Dehumidification
iv) Heating
v) Humidification

As the process air is not recirculated the air treatment loads and energy costs are enormous. To achieve process efficiency and product consistency the equipment as

well the control systems need to be matched correctly to ensure air is supplied at or near the required conditions.

Usually the FBE equipment supplier is entrusted with the responsibility to supply the equipment as a complete package including the air handling system. However considering the criticality of the process it is advisable that a company specialized in the process air treatment be employed to ensure that the air treatment system developed is not only able to maintain constant supply air temperature and humidity irrespective of outside air condition but is also energy efficient and meets the regulatory requirements of cGMP.

The World Health Organization Guide specifies that only steam humidifiers should be installed for the purpose of humidification due to risks involved with cold water humidifiers like spray, cold mist (ultrasonic) and evaporative type. However even with steam humidifiers it is essential to continuously remove the condensate from the air handling system. The air being supplied is in direct contact with product being processed for a long time and carries a much larger risk of contamination than SAY a standard Class M 6.5 product filling area where the product is exposed for a very short duration. Present practice followed in the industry is to inject steam in the AHU and drain out the condensate from the AHU. In most cases the humidification section is inadequate in length leading to additional steam condensation which not only adds heat to the air but also is waste of energy as the amount of steam absorbed is less than the amount supplied. Solution is to instal a steam dispersion pipe or manifold having an integrated condensate removal arrangement. This ensures that condensate does not come in contact with the process air. Also if the humidification section is sufficient in length the required amount of steam will be fully absorbed by the air increasing its moisture content or humidity while eliminating the above stated risks.

Dehumidification using chilled water coils also carries a potential risk of contamination as cooling coils when used for dehumidification run wet. Condensate is collected in the drain pan and drained out. However effective condensate drain requires having proper slope in the drain tray towards the outlet and also adequate slope in the external drain line to facilitate quick removal of the condensate.

This process of dehumidification when applied to such systems is not energy efficient. The air is first cooled down to the required dew point and then reheated to the desired temperature.

To resolve this desiccant dehumidifiers can be installed at the inlet of the AHU to remove moisture down to required dew point and the air can then be sensibly cooled or heated (as required) to the required temperature. This will ensure a dry coil operation completely eliminating the risk of microbial contamination. However care should be taken to choose the correct desiccant dehumidifier. The dehumidifier should have silica gel chemically bonded to the rotor wheel to ensure that silica gel dust is not carried over by the air as this can lead to contamination of the product. Additionally such a desiccant drier should also be bacteriostatic and washable.

Energy Savings options

Dehumidification

A case study has shown a savings of 8.3 K.W. for a 3000 CMH system when the required conditions were 25 Deg. C DB temperature and 8 Deg. C Dew Point.
(Details available on request)

Humidification

Till a few year back cold water humidification was acceptable in pharmaceutical industry. Use of ultrasonic humidifiers was accepted as the energy requirement of such humidifiers is very low. However the new guidelines of World Health Organization (W.H.O.) state :

" 4.9.9 Where humidification is required, this should be achieved by appropriate means such as the injection of steam into the air stream. A product-contamination assessment should be done to determine whether pure or clean steam is required for the purposes of humidification."

It further adds :

"4.9.11 Humidification systems should be well drained. No condensate should accumulate in air-handling systems."

And also :

"4.9.15 Cold surfaces should be insulated to prevent condensation within the clean area or on air-handling components."

Whilst steam generation does require more energy than cold water generation it is a statutory requirement and must be followed.

Self-generating electric steam humidifiers are available for smaller duties upto 40 Kgs per hour. The power consumption would be 0.75 K.W./ Kg. of steam generated. Among the electric steam humidifiers resistive humidifiers are most suitable as they offer accuracy in control which can be as high as +/- 2% if required , do not have the maintenance and cylinder replacement expenditure like the electrode humidifier and most importantly steam can be generates using any water quality from untreated drinking water to Reverse Osmosis water. The electrode humidifier requires conductive water to pass current in order to generate steam.

Process humidification duties are usually very high - more than 100 Kgs of steam per hour even for smaller airflows like 3000 CMH. This of course depends on the RH to be maintained at a given temperature.

As most pharmaceutical companies have process steam available it is more economic to generate pure or clean steam at atmospheric pressure for humidification purpose. The actual savings can vary depending on the electricity rates per unit at place of installation.