Improvement of Paterson Kelly V-Blender Ventilation System

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Abstract *— This paper presents the successful improvement and implementation of ventilation system modifications in a Patterson Kelly V-Blender used in Upjohn (Pfizer Division) Pharmaceutical located at Barceloneta, Puerto Rico. The purpose of this research was analyzing and resolve the equipment reliability issues and flexibility generated by the introduction of new product with different formulation in the blending process. The piping changes and designed parts were made and installed by local manufacturers. Trials performed for each proposed model were performed using placebo material and executed in a pharmaceutical controlled area. Results were analyzed and documented in this paper. The research results show that the ventilation improvements preformed to the Patterson Kelly V-Blender system were capable of maintain the required process parameters without interruptions. Also, provide the flexibility of the system by running products with different formulation (solvent-based and water-based product) resulting in an increase manufacturing production.*

Key Terms *— Condenser, Dust Control, V-Blender and Volatile Organic Compounds.*

INTRODUCTION

The V-Blender equipment are commonly used in pharmaceutical industry for precise formulations. V-blenders are characterized by their V-shape that comes from having two connected blending shells. The V-shape creates more efficient blending of solids to solids or solids to liquids. This blender type use diffusion, or the random motion of solid particles, to get the job done. Diffusive blending is derived from the increased mobility of the individual particles, which are redistributed to produce relatively high states of homogeneity over time.

PROBLEM STATEMENT

Upjohn Pharmaceutical has a V-Blender used for wet granulation and drying solvent-base products (Ethanol Solvent). The V-blender system its composed of a glycol chiller, a main condenser, receiver tank, a vacuum pump and VOC (Volatile Organic Compound) condenser designed to reduce emission rates released to the environment during the process.

As part of the manufacturing products expansion a new product was included in the V-Blender process schedule. This product has a water-base composition in contrast to the current solvent-base composition.

The integration of the new product created interruptions between the wet granulation and drying phase of the process that impact the product supply during the first manufacturing lots.

RESEARCH OBJECTIVE

This research was focused in evaluate the Patterson-Kelley V-Blender operation and components to identify the root cause of the interruptions and proposed and implement a solution that can make more flexible the V-Blender operation with water-based products and solvent based products without interruptions.

Proposed improvements will provide a process flexibility resulting in manufacturing of products with different composition and the system reliability.

SYSTEM ANALYSIS

V-Blender process and operation was analyzed, and it was identified that the possible root cause of the interruptions between the granulation and drying phase occurs in the ventilation system by the water-based composition of the new product.

When the V-Blender is used to granulate water-based products the VOC Condenser, set at a temperature of 17°F, causing carry over water droplets until freeze and plug the VOC condenser. Figure 1 shows the V-blender ventilation schematic.

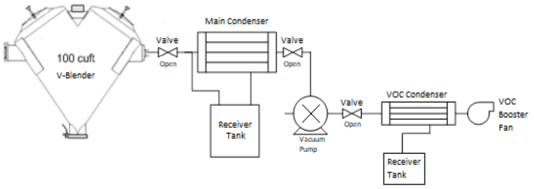

Figure 1
V-blender Ventilation System Schematic

The first step was confirming the reason for the plugging ice in the tubes of the condenser. Analysis shows that the ice was formed due to the water vapor coming out of the vacuum pump during the drying process and going to the VOC condenser. This system was designed to condense 95% of the Ethanol out of the drying process at lower temperatures, when water reaches the VOC condenser, it will freeze immediately. This was the root cause for the freezing in the condenser.

To solve the interruptions between the wet granulation and drying activities the new process requirements were analyzed and it was determined that the VOC condenser was not required for the water-based products because no solvents emissions will be release to the environment.

The proposal was designing a condenser for the water vapor based in the process parameters and install at the outlet of the vacuum pump bypassing the main condenser, the receiver tank and the VOC Condenser.

Since no fugitive emissions were expected, the ventilation was placed inside the utilities room. The water produced as a result of the knocked water vapor will be collected in portable drum of 55 gallons.

DESIGN PHASE

Form the previous studies evaluated as part of the research activities, Yeong-Jun Jang, Dong-Jae Choi, Sin Kim, Myung-Taek Hyun and Yeon-Gun Lee [1] performs an enhancement of condensation heat transfer rate of the air-steam mixture on a passive condenser system using annular fins. Xuan Zhang, Li Jia, Qi Peng and Chao Dang [2] performs an experimental study of condensation heat transfer in a condenser with a liquid-vapor separator. These studies evaluation shows that are not applicable to this research because the system conditions were different to the experimental.

For the proposed condenser, it was selected design a helical coil condenser based in the system parameters and the utilities availability in the process area. Condenser design calculations were performed taking in consideration a shell diameter six (6) inches because it bigger it would be categorized as a pressure vessel and will required the ASME certification. The following calculations were performed using the boundary conditions of the process and using ethylene glycol 50% of dilution as refrigerant.

Heat Loss (Q) was calculated using the following expression: [3]-[4]

$$Q = M*500*C_p*\Delta T \qquad (1)$$

where M was the water mass flow rate entering to the condenser, C_p was the specific heat of the water and ΔT was the temperature difference of the water.

Sensible Heat (Hs) was calculated as follows:

$$Hs = 1.08\ q\ \Delta T\ (\mathrm{Btu/Hr}) \qquad (2)$$

where q was the air volume flow (CFM).

To obtain the Glycol Outlet Temperature the following expression was used:

$$T_{2\mathrm{Glycol}} = (Q / M_{glycol} *500*C_{PGlycol}) + T_{1\mathrm{Glycol}} \qquad (3)$$

where Q was the Heat Loss, M was the mass flow rate of the glycol and C_p was the Specific Heat for Glycol.

Log Mean Temperature Difference (LMTD) was calculated with following equation:

$$LMTD = (\Delta T_1-\Delta T_2) / \ln(\Delta T_1/\Delta T_2) \qquad (4)$$

where ΔT_1 was greater temperature difference and $\Delta T2$ was Lesser temperature difference.

Heat transfer Surface Area was calculated using following expression:

$$A = Q / LMTD*U \tag{5}$$

where U was the Overall Heat Transfer Coefficient for Ethyl Glycol 50% that is three (3) times the Overall Heat Transfer Selected of Water.

Helical Coil condenser design specifications results are showed in Table 1.

Table 1
Helical Coil Condenser Design Specifications

Helical Coil Condenser	
Heat Loss = Q	76,198.08 BTU/Hr
Sensible Heat (Hs)	4,698 Btu/Hr
Heat transfer Surface Area	4.19 ft^2
Length of the Coil	64.09 ft
Theorical Number of N turns for coil	21 turns
Length of coil condenser shell	8 ft

TEST PHASE

Trial 1: To test the new condenser a trial run was conducted bypassing the main condenser and driving all the water vapor through a new condenser installed after the vacuum pump and recovering the water condensate in a drum installed in the utilities room. Figure 2 shows the V-blender ventilation schematic for the trial.

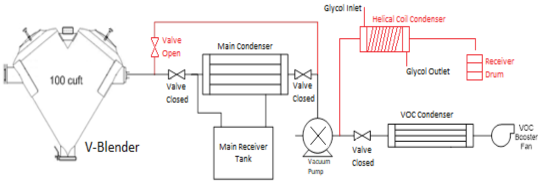

Figure 2
V-blender Ventilation System Schematic Trial 1

The trial objectives were complete the wet granulation and drying process maintaining the operational parameters; confirm the vacuum pump performance when handling water vapor and the condensing capacity of the new condenser.

During the wet granulation phase the system was capable to keep chiller the temperature at 40°F, the vacuum pressure at 760 mm Hg and the blender temperature at 135 °F as established in the process parameters. At starting the drying phase the vacuum set point was out of range (45 – 55 mm Hg). The vacuum pump was forced to handle saturated water vapor which raised the temperature of the pump above the normal operating temperature. This condition caused the water intrusion into the pump oil that creates the seal on the pump which in turn caused a loss in the vacuum.

New condenser was capable to condense the water vapor, but a backflow of condensate to the pump occurred due to lack of slope on the ventilation line and the condenser. In addition, the presence of product dust was observed in utilities room.

The trial run does not meet with the objectives and new evaluation need to be performed to control the product dust.

Trial 2: The trial was conducted using main condenser at temperature setpoint of 20°F with the shutoff valve half cranked to limit the amount of glycol to limit the condenser capacity and avoid freezing the water and to reduce the water condensate passing through the vacuum pump. The slope on the new condenser was corrected, the new receiver drum was covered and the ventilation on the drum was outfitted with a filter screen to avoid product dust in the utilities room. Figure 3 shows the V-blender ventilation schematic for this trial.

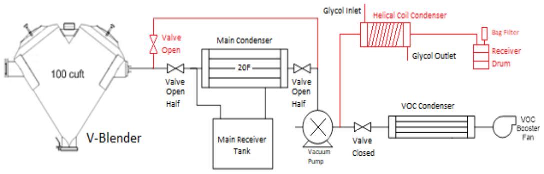

Figure 3
V-blender Ventilation System Schematic Trial 2

New trial objective was eliminating product dust in utilities room.

The wet granulation phase run as established in the process. At the beginning of the drying phase the vacuum pressure set point was out of range (45 – 55 mm Hg) but was it stabilized by adjusting a vacuum manual control valve in the system. The last two hours of the process the vacuum was stable at the setpoint of 50 mm Hg.

The main condenser condensate a total of 17 gallons of water from total of 19.3 gallons of water. However, there was the presence of product dust at the discharge of the ventilation to the drum although outfitted with a filter screen at the drum ventilation.

As result, the configuration was capable of keep the operational parameters during the drying process, but the product dust exposure at the utilities room area continued.

Trial 3: Since the previous trial the main condenser does not show any freezing conditions it was remained as in the second trial. To control the product dust at utilities room the vacuum connection from central dust collector was placed over the ventilation discharge of the new receiver drum to control the fugitive product dust. Figure 4 shows the V-blender ventilation schematic for this trial.

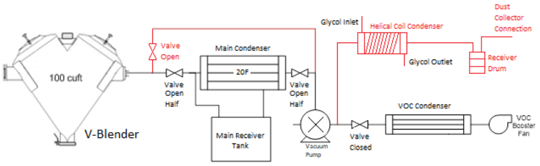

Figure 4

V-blender Ventilation System Schematic Trial 3

During the trial the wet granulation phase does not show changes. At the beginning of the drying phase the vacuum set point was out of range. To troubleshoot the problem the bypass to the main condenser was activated and the vacuum immediately dropped to the vacuum pressure setpoint of 50 mm Hg. This behavior tends to indicate that most probably ice had formed in the main condenser clogging the ventilation.

Water vapor was condensed on the new condenser, to continue with the trial and proof that the fugitive product was under control using the vacuum dust collector. However, the vacuum conditions fail due to the amount of water being passed through the vacuum pump because the water pass through the vacuum pump before arrives to the new condenser.

Trial 4: For the next run, it was determinate repeat the trial eliminating the new condenser because the water passing through the vacuum pump it was affecting the pump performance and pass all the water vapor through the main condenser at a temperature setpoint of 40 °F and connect the ventilation directly to the vacuum dust collector. Figure 5 shows the V-blender ventilation schematic for the trial.

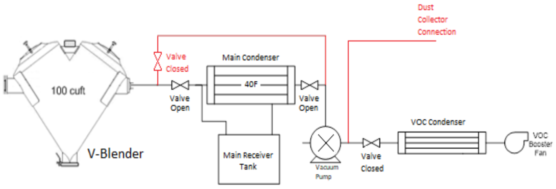

Figure 5

V-blender Ventilation System Schematic Trial 4

At the beginning of the trial the vacuum was very difficult to control. There was little to no condensation in the main condenser since all the water vapor was being carried though the vacuum pump and on to the vacuum dust collector. The oil in the pump was emulsified with water which indicates that a lot of water was passing through the pump.

After analyzing the trial results, it was concluded that the direct connection to the vacuum dust collector affect the vacuum conditions and the airflow. The vacuum dust collector has a high suction capacity (101 CFM) when compared to the VOC ventilation (5 CFM). The higher than normal suction in the ventilation causes an increase in the water vapor flow speed which reduces the contact time in the condenser, allowing for water vapor to make its way through the vacuum pump thus causing an increase in the vacuum reading (loss of vacuum) affecting the vacuum conditions and control. According to the vacuum pump curves, less vacuum can be achieved as the flow increases, Figure 6.

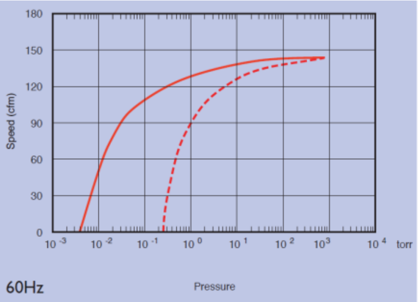

Figure 6

Vacuum Pump Model 212J Performance Curve [5]

Trial 5: For this trial a free suspended hood was designed based in the airflow generated during the drying process and reduce the vacuum dust collector suction. To obtain the actual volumetric flow rate (Q) in ft3/min or CFM of the hood the following expression was used. [6]

$$Q = V_h\,(10x^2 + A_h) \qquad (6)$$

where x was distance from the hood face to farthest point of particle release, V_h was the hood capture velocity at distance X (ft/min) and A_h was the area of hood opening (ft^2).

For the volumetric flow rate calculation an A_h of 1.77 ft^2 (16 x 16 in) was selected and a V_h of 50 ft/min was selected.

A volumetric flow rate (Q) of 442 CFM was calculated for the suspended hood.

The trial was conducted using main condenser of at a temperature setpoint of 40 °F. The vacuum dust collector suction was separate from the new receiver vent and free suspended hood housing was installed. This modification ensures that the vacuum dust collector do not interact with the discharge ventilation of the vacuum pump and thus will not affect the flow conditions. Figure 7 shows the V-blender ventilation schematic for this trial.

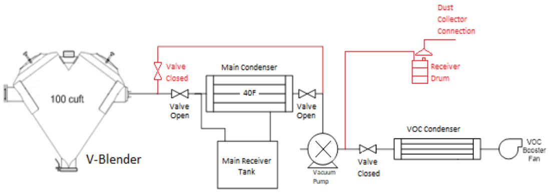

Figure 7
V-blender Ventilation System Schematic Trial 5

The wet granulation phase run established in the process parameters. The system was capable to keep chiller the temperature at 40°F, the vacuum pressure at 760 mm Hg and the blender temperature at 135 °F. During the drying process the vacuum set point of 50 mm Hg was reached and maintained for the four (4) hours of the process. The condenser was capable of condense a total of 19 gallons of water from total of 19.3 gallons of water and no presence of product dust in the utilities room.

As result, the condenser removal eliminates the water vapor passing through the vacuum pump and the suspended hood integration provide the process conditions to run the new water-based product without interruptions with a dust control in the utilities room.

Although the previous trial the system was capable to maintain the granulation and drying phase process parameters ventilation into the utilities room without fugitive dust and additional trial was performed using a filter instead the suspended hood and the receiver drum.

Form the previous studies evaluated a research of S. Y. Kim, Y. H. Yoon and K. S. Kim [7] performed an experimental study using an activated carbon-impregnated cellulose filters for indoor VOCs and dust control. Based in that study it was decide to perform a trial using an HEPA filter.

Trial 6: For the trial a “T” style vacuum filter was installed after the vacuum pump. The filter was selected based in the actual volume flow rate. Using the volume flow rate calculated for the hood, it was selected a filter housing, manufactured by Solberg Manufacturing Inc. [8], with a nominal flow rate of 520 CFM with a HEPA filter 99.97% of efficiency.

The trial was conducted using main condenser at the same conditions of the fifth trial.

The granulation phase run as established in the process. During the drying process the vacuum set point of 50 mm Hg was reached and maintained for the four (4) hours of the process. The main condenser was capable of condense a total of 19 gallons of water from total of 19.3 gallons of water and no presence of product dust in the utilities room.

With this additional implementation the V-Blender has a redundant component for the dust control inside the utilities room that could be changed as required by the system owner.

Energy Balance and Mass Balance calculation were performed for the trials 5 and 6 schematic layout of the V-Blender ventilation system.

Mass Balance for a condenser is: **MASS IN = MASS OUT**.

Energy Balance equation is the heat rate or cooling rate since no work is added and no potential and kinetical are involved in the process.

$$Q = M*\Delta H \qquad (7)$$

where H is the Enthalpy, for this case water vapor enthalpy and saturated water enthalpy.

The condenser has a cooling rate of 42,850.59 Btu/Hr (Average).

Total of Water Collected and Heat Removal Rate for Trials 5 and 6 are shown in the Figure 8.

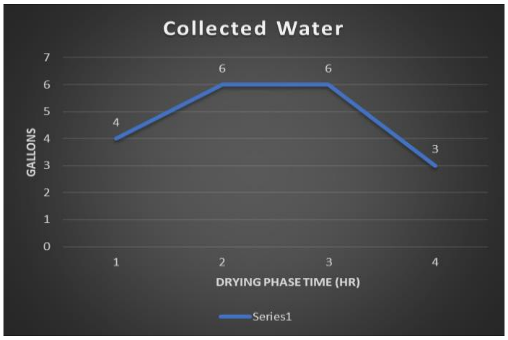

Figure 8
Collected water by Condenser during Trials 5 & 6

The condenser efficiency was 98% based in the water collected versus the waster added to the mix (19.3 Gallons).

The heat removal per hour of the condenser for Trials 5 and 6 are shown in the Figure 9.

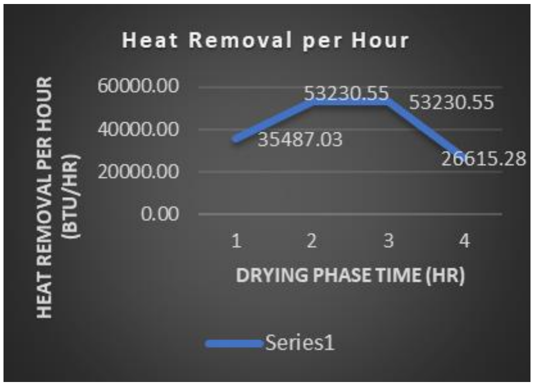

Figure 9
Heat Removal per Hour by Condenser during Trials 5 & 6

CONCLUSIONS

This study investigates the Patterson Kelly V-Blender process and solve the interruptions between granulation and drying phase caused by the water-based composition of the new product. New condenser and dust collector system were proposed, fabricated and tested under a production environment condition.

The condenser heat transfer analysis show that condenser requires an average cooling rate of 42,850 Btu/Hr for the drying phase of the process. From six (6) trials performed, trials 5 and 6 demonstrate that condenser was capable to maintain the average cooling rate. Heat removal per hour was calculate and show that the hours 2 and 3 are the higher condensation paths during the drying process.

Condenser efficiency was calculated based in the collected water versus the added water to the product mix. The condenser had an efficiency of 98% during trials 5 and 6.

Suspended hood installed at the ventilation exhaust was capable to collect a Volumetric Flow Rate of 442 CFM generated by the system and control the product dust in trial 5. In addition, the HEPA filter was installed instead the suspended hood. Trial 6 shows that HEPA filter was capable to replicate the performance of the suspended hood. Therefore, it can be used as an additional alternative instead the suspended hood since.

The improvements performed to the ventilation system of the Patterson Kelly V-Blender solves the stated problem under this study. Also, gives the flexibility of the system of run water-based product and solvent based product with a minimum change between the product lots.

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