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Design of pulse-jet systems for milk powder baghouses

James O. Litchwark [a], James Winchester [b], Justin J. Nijdam [a]

[a] University of Canterbury, Christchurch, New Zealand
[b] Fonterra Research and Development Centre, Palmerston North, New Zealand

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ABSTRACT

A pilot scale pulse-jet baghouse was used to investigate the influence of several key pulse-jet design parameters on the overall effectiveness of the pulse. Firstly, the effect of pulse nozzle position on the acceleration of the filter fabric was measured using a lightweight accelerometer attached to the bag surface. Secondly, skim milk powder (SMP) was filtered in the baghouse, and the influence of pulse air supply pressure, nozzle position, and pulse duration on the cleaning effectiveness was determined by measuring the baghouse pressure drop before and after pulse cleaning. Results were compared to previous studies from other industries to provide guidelines for optimising baghouses for milk powder collection. Increasing the pulse air supply pressure was the most effective way to improve the pulse cleaning performance. Increasing the distance between the pulse nozzle and the bag opening was found to have no effect on the pressure drop after the pulse, despite previous studies with larger baghouses showing that a greater nozzle distance increases the entrainment of secondary air into the pulse. This difference was determined to be due to the small size of the clean air plenum in the baghouse used here, which restricted the entrainment of secondary air. Fabric deceleration was found to be a poor measure of pulse cleaning performance. Changes in the measured fabric acceleration did not correspond to changes in the pressure drop following the pulse. In addition, the tensile stresses on the cake caused by the acceleration were found to be insufficient to cause cake removal. While direct measurements of the bond strength between milk powder filter cakes and polyester filter fabrics are not available, estimates can be obtained from studies on similar systems. Effective pulse cleaning was achieved even when the tensile stress on the filter cake produced by the fabric deceleration was much lower than estimates of the bond strength, indicating that other mechanisms must be important to the cleaning process. Increasing the pulse duration from 0.1 s to 0.35 s had no effect on the baghouse pressure drop. This indicated that the cleaning effect of the pulse occurred during the initial expansion of the filter bag, while continued reverse airflow during the remaining duration did not contribute to the cleaning effect. The pulse duration should therefore be kept short to minimise the compressed air consumption.

1. Introduction

Pulse-jet baghouses are used in the dairy industry to collect milk powder after spray drying. A pulse of compressed air is periodically injected into the top of each bag, briefly inflating the bag and causing a reversal of flow through the filter fabric. This removes deposited powder from the bag and is essential to maintaining a low pressure drop across the filter. Pulse-jet systems have many different designs, and some aspects of the design are also relatively easy to modify retrospectively. A good understanding of pulse effectiveness therefore offers potential improvements in the performance of both new and existing baghouses.

There is a significant body of work from other industries on the performance of pulse-jet baghouses, and many previous findings are relevant to dairy baghouses. However, research specific to the dairy industry is very scarce, and the unusual powder properties and specific operational concerns create a need for more targeted research.

The transport properties of dairy powder differ substantially from the inorganic powders encountered in most other baghouse applications, as the complex multi-phase structure of the particles produces strong cohesive and adhesive interactions. Melted fat causes temperature-dependent cohesion due to liquid bridging [5,9]. Softening and crystallisation of amorphous lactose in the presence of moisture cause caking of particles [7,13], and can cause particles to adhere to surfaces [21,22]. In milk powder filtration, these mechanisms have been shown to affect the filter cake structure [14] and are likely to also affect the adhesion of the filter cake to the filter fabric. While similar cohesive interactions occur in other food powders, they do not occur in flue dust or mineral powders, and so discussion of these effects is lacking in the established baghouse literature.

The aim of this work was to develop guidelines for optimising the performance of pulse-jet systems in dairy baghouses. Experiments were conducted on a pilot scale baghouse using skim milk powder (SMP). Firstly, the acceleration of the filter fabric during a pulse was

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E-mail addresses: james.litchwark@pg.canterbury.ac.nz (J.O. Litchwark), James.Winchester@fonterra.com (J. Winchester), justin.nijdam@canterbury.ac.nz (J.J. Nijdam).

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measured for a range of nozzle positions by attaching a lightweight accelerometer to the bag surface and repeatedly firing the pulse jet. Secondly, the effects of variations in the pulse air pressure, pulse lance position, and pulse duration on the baghouse pressure drop were investigated. The results were compared to work from other industries to determine whether the unique properties of dairy powders necessitate modifications to traditional baghouse designs and operating conditions.

2. Materials and apparatus

Experiments were carried out on a pilot scale pulse-jet baghouse at the University of Canterbury, New Zealand. This baghouse contained a single filter bag, 3 m in length and 200 mm in diameter. The filter bag used for these experiments was made from a polyester needle-felt fabric with an area density of 550 g/m^2 and a singed surface. The filter bag was brand new at the start of the experiments, and the filter resistance (Darcy's Law constant) of the virgin fabric was approximately 7×10^7 m^{-1}. This material is identical to that used in many industrial milk powder baghouses. The bag was enclosed within a steel housing 350 mm in diameter (Fig. 1), which was electrically heated to maintain the air temperature in the baghouse. The filter bag was supported by an internal wire cage, with gaps between the wires 40 mm in width. The top of the support cage was clamped to the cell plate in order to prevent the bag from lifting during operation. The baghouse inlet was positioned centrally at the bottom of the baghouse chamber. A baffle surrounded the inlet to collect powder and prevent it from becoming re-entrained in the inlet stream.

A summary of the key operating parameters for the baghouse is given in Table 1. Air flow through the baghouse was controlled by a fan at the outlet, so that the system was operated under a partial vacuum. The temperature and humidity at the baghouse inlet were controlled by a Niro™ spray drier. The drier heated ambient air from the laboratory, and water were introduced through a rotary atomiser to raise the humidity. The humid air stream was conveyed to the bottom

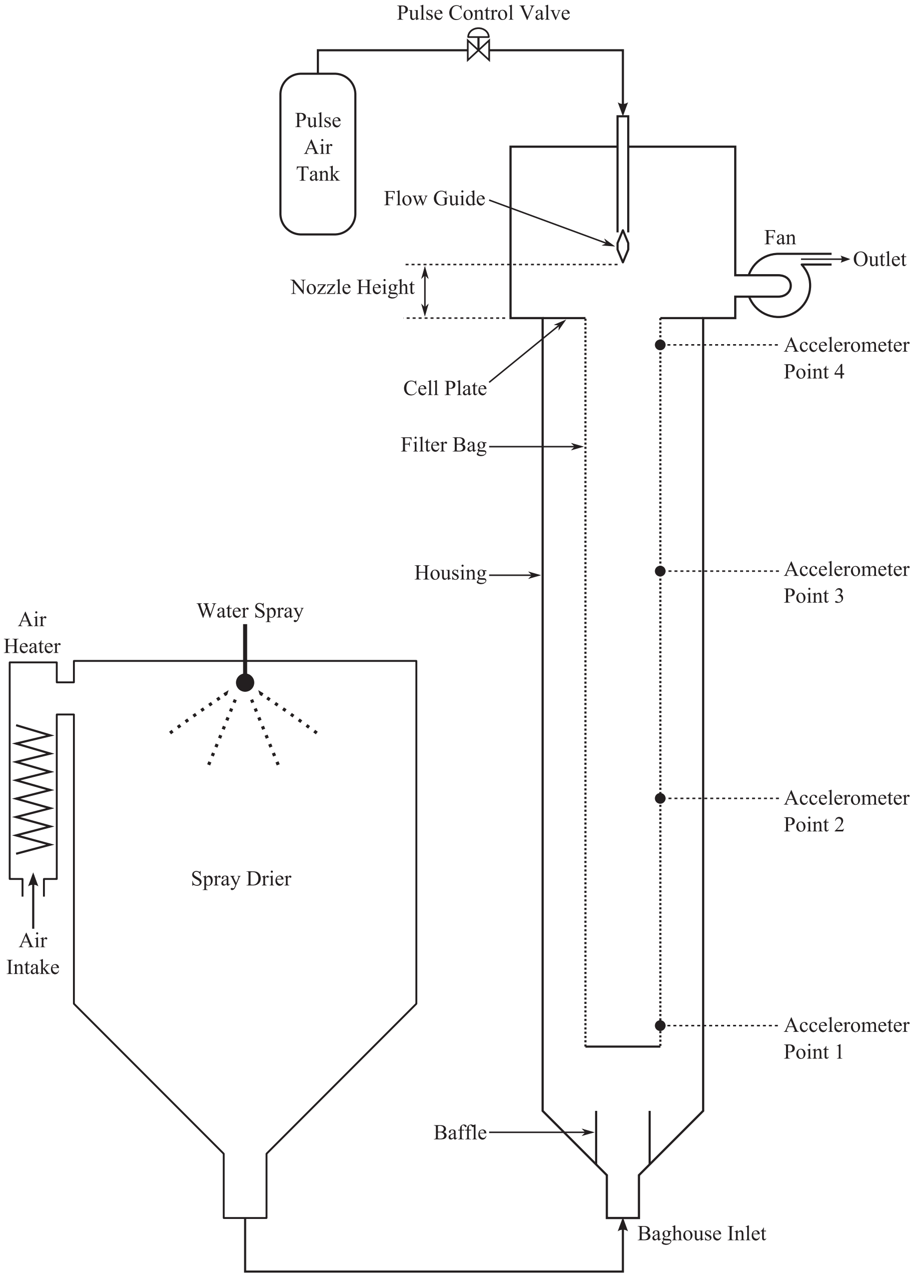

Fig. 1. Baghouse geometry.