In bulk solids fluidized-bed processes, we often use gravity as a pump to move fluidized particles from an upper vessel to a lower vessel, as covered in the February 2014 column. [Editor’s note: For information on obtaining previous columns, see “For further reading” later in this article.] The pressure change resulting from this gravity pump is what moves the particles from one vessel to another — building up enough pressure to overcome the pressure in the lower vessel while also forming a pressure seal (or pressure head) that limits the upward gas flow from the lower vessel’s fluidized bed to the upper vessel. The particles are typically moved between the vessels with a standpipe or dipleg. In this column, we’ll focus on the standpipe.

When designed correctly, a standpipe can give you many years of trouble-free operation. When poorly designed, however, the device can be your worst nightmare. Let’s look at how standpipes function, what problems they can cause, and how to design them to prevent these problems.

A standpipe is used to feed a powder by gravity from a lower-pressure fluidized bed to another fluidized bed at higher pressure, as shown in Figure 1. To successfully feed the powder while preventing upward gas flow requires building enough pressure in the standpipe to form a pressure seal.

The standpipe’s inlet can be at a fluidized bed’s top (called an overflow standpipe, as shown in Figure 2a) or bottom (called an underflow standpipe, as shown in Figure 2b). The overflow standpipe is filled with particles and gas, with the particles in a dilute condition in the standpipe’s upper region and a dense condition in the lower region. The particles in an underflow standpipe are in a dense condition along the standpipe’s whole length. Both standpipes operate best when the dense region remains somewhat fluidized. (A nonfluidized underflow standpipe also exists, but it’s beyond this article’s scope.)

A standpipe can be vertical, angled, or a combination of vertical and angled (called a hybrid standpipe), as shown in Figure 3. All have the same purpose — to transfer particles from a lower-pressure vessel to a higher-pressure vessel while limiting the amount of gas migrating from the higher-pressure vessel to the lower-pressure vessel. When the gas must be prevented from flowing up the standpipe, the standpipe’s design and operation need to ensure that the gas flows downward with the particle flow. This occurs when the particles are flowing faster than the gas.¹

Understanding the relationship between the particle and gas velocities

Because good standpipe flow requires the particles to be fluidized, the difference between the particle velocity, \( v \), and gas velocity, \( u \), should be at least equal to the minimum gas flowrate, \( \dot{n}_{\text{min}} \), that can fluidize the particles. This is true whether the gas flows upward or downward in the

Figure 1

Standpipe connecting two fluidized beds

Vessel 1 (lower pressure)

Gas vent

Incoming fluidizing gas

Vessel 2 (higher pressure)

Particle outlet

Standpipe

Figure 2

Standpipe inlet locations

a. Overflow standpipe

b. Underflow standpipe

Figure 3

A hybrid standpipe
standpipe, because either can provide good particle flow. If the gas flows upward, as shown in Figure 4a, then the downward particle velocity minus the upward gas velocity must be at least equal to the minimum fluidization velocity. You can have considerably higher upward gas velocity and still have good particle flow and standpipe pressure build (and thus, a good pressure seal), as shown in Figure 4b. When operated in this configuration, the standpipe behaves more like a fluidized bed, and so one potential problem to be aware of is that if too much gas enters the standpipe, large gas bubbles can form and can cause the particles to flow in slugs rather than in dilute phase.

The conditions illustrated in Figures 4a and 4b present another pitfall: In the system configuration shown in Figure 1, gas from vessel 2 can flow upward into vessel 1, which could be a problem in some applications. If the gas in vessel 2 needs to be isolated or sealed from vessel 1, then the gas in the standpipe must flow downward, as shown in Figure 4c. In this case, the particle velocity minus the gas velocity should be at least equal to the minimum fluidization velocity. If the downward gas velocity becomes greater than the particle velocity, as shown in Figure 4d, the standpipe will lose all of its pressure build, the flow through it will resemble the gas-and-particle flow in dilute-phase pneumatic conveying, and the pressure seal will be compromised.

Using aeration to maintain fluidization

If any standpipe section becomes defluidized, shear stresses will increase and allow the standpipe wall to support some of the particles, causing them to flow more slowly and reducing the pressure build in the standpipe. Thus it’s important to maintain fluidization in your standpipe. You can often achieve this with aeration — adding gas at the standpipe wall. This will keep the particles fluidized at least along the wall, preventing lateral stress due to downward pressures. Adding gas at the wall also lowers the particle concentration at the wall, thereby reducing wall friction and resulting in an even greater increase in particle flow and pressure build.²

When you need to add gas to keep particles fluidized in the standpipe, how to add it will depend on the particle size and density. If your powder is a Geldart group A material, with a particle size from about 30 to 125 microns and density from 800 to 2,500 kg/m³, you need uniform aeration for best results. How far apart to space the gas taps on the standpipe for uniform gas distribution depends on the expected particle flowrate and defluidization time of the particles in the standpipe and is usually about 4 to 6 feet. If your powder is a larger or heavier Geldart group B material, with a particle size from about 125 to 500 microns and density from 1,500 kg/m³, you need uniform aeration for best results. How far apart to space the gas taps on the standpipe for uniform gas distribution depends on the expected particle flowrate and defluidization time of the particles in the standpipe and is usually about 4 to 6 feet.
to 4,000 kg/m³, it will have a much higher permeability than group A particles. In this case, you typically need to add only one gas tap, at the standpipe bottom.

You also need to optimize the amount of gas added to the standpipe. Too little results in defluidization, and too much results in large gas bubbles. Large bubbles restrict the available cross-sectional area in the standpipe for particle flow and reduce the fluidized bed’s density, which reduces the pressure build.

Eliminating bubble problems
To achieve good particle flow through the standpipe, you should design its inlet to prevent bubbles from entering it. If bubbles are located near the standpipe inlet, the particle momentum at the inlet could drag these bubbles into the standpipe and cause the same problems as having too much aeration. To prevent this, you can fit the standpipe inlet with a cone or deflector plate or locate it well below any gas source.

In a hybrid standpipe, bubbles can be trapped at the transition from the angled section to the vertical section, restricting the particle flow. Gas accumulates at the top of the angled section, flows upward along the section’s upper portion, and forms bubbles, which then hang up at this transition. You can alleviate this problem by using a burp tube that allows the gas to flow directly from the standpipe’s angled section to a lower-pressure vessel, as shown in Figure 5, and thus bypass the transition.

Summing it up
Often, flowrate limitations when transferring particles from one fluidized bed to another result from a poorly designed or poorly operated standpipe. However, with the proper design and operational discipline, this doesn’t need to be the case. Aeration is critical for a standpipe, and the standpipe’s entrance region needs to be designed so that bubble intake is minimal.

Next time, we’ll look at how a dipleg can act as a cyclone’s fluidized overflow standpipe, moving particles from a cyclone to a fluidized bed.

Ray Cocco is president of Particulate Solid Research Inc. (773-523-7227, ray.cocco@psrichicago.com) and holds a PhD in chemical engineering from Auburn University in Auburn, Ala. He has more than 20 years experience in particle technology, holds several patents, and has published numerous technical articles on particle technology topics.

Particulate Solid Research Inc.
Chicago, IL
www.psrichicago.com

The author will answer your questions in future columns. Direct questions to him at ray.cocco@psrichicago.com, or to the Editor, Powder and Bulk Engineering, toneill@cscpub.com.

References

For further reading
Find more information on this topic in articles listed under “Fluid-bed processing” in Powder and Bulk Engineering’s article index in the December 2013 issue and in the Article Archive on PBE’s website. All articles in the archive are available for free download to registered users. You can also find books and webinars on this topic in the website Store.