BENDS IN PNEUMATIC CONVEYING SYSTEMS

By

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Historically, long radius bends must be used for pneumatic conveying systems. These bends have been obvious at many installations since they require routing of the conveying pipe several feet away from the sides of buildings and extending out of reach as the long, gentle bends sweep over the tops of the storage bins. Some ideas that might have led to this thinking are:

1) Avoid abrupt changes that might cause a pile up of material with a resulting line plug;

2) A gradual change in direction might minimize the contact between the material being conveyed and the pipeline, thus reducing the friction and wear;

3) We have always done it this way and so it must be correct.

A successful pneumatic conveying system is one that transports the required capacity of material from the pick up point to the end of the conveying line, over a reasonable period of time, with the minimum overall expenditure for operation and maintenance. The frequency and cost of repairs must be compared with the operating cost of the system to obtain the “One Best Conveying System”.

In a series of tests conducted at Fuller Company, a variety of designs of bends were evaluated for their wear resistance. After the best design was apparent, this was then evaluated for the effect on system capacity or horsepower. These tests included both vacuum and pressure conveying systems (a range of systems from 12” mercury vacuum to a Pressure of 30 psig); dilute and dense phase conveying; and materials including polyethylene pellets, sand, feldspar, Type I Cement and ground limestone.

Wear Characteristics

Special test bends were installed in a 400' long, 2” diameter conveying system. This system included (12) 90° turns. The special bends were all fabricated from a soft aluminum to reduce the operating time required for failure. Sand was conveyed at a pick up velocity of 4000 ft/min. and a line pressure of 10 psig. Conveying was continued with the recirculated sand until failure of all bends was determined. The bend configurations tested are shown on sketch “A” at the end of this report, and consist of: 48” radius 2” diameter aluminum bend; 10” radius 2” diameter aluminum bend; two 10” radius 2” diameter 45° bends with a 36” straight section between; 10” radius 2” diameter aluminum bend with the back removed and replaced with a 45° deflection plate and wear back area; 2” diameter fabricated “T” bend.
In studying the results of this wear test it is noted that the wear rate of a bend will be greater near the end of the conveying line since the velocity of the material is higher. It is generally accepted that the rate of erosion by impingement may be considered proportional to the cube of the gas velocity. For example, two identical 48" radius 90° bends were tested at different locations in the conveying system. The first was located at the #3 bend location while the other was installed at the #5 bend location. The first bend wore through after 20 hours and 16 minutes of operation while the second bend required only 12 hours and 13 minutes. In this case, location #3 has a lower velocity than point #5; due to the expansion of the air and therefore the reduced life would be expected.

The “T” bend was located in position #10 (near the end of the conveying system) and after 25 hours of operation had only slightly worn the pipe. It is estimated that an excess of 100 hours would have been required to wear through this bend. By proportioning the wear for the various locations, and rechecking by multiple installations, the following relative life of the various shape bends would be expected:

<table>
<thead>
<tr>
<th>Shape</th>
<th>Estimated Wear Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>10&quot; radius - 90° bend</td>
<td>5 hours 18 minutes</td>
</tr>
<tr>
<td>Upstream 10&quot; radius 45°</td>
<td>8 hours 10 minutes</td>
</tr>
<tr>
<td>Downstream 10&quot; radius 45°</td>
<td>14 hours 5 minutes</td>
</tr>
<tr>
<td>48&quot; radius - 90°</td>
<td>16 hours 15 minutes</td>
</tr>
<tr>
<td>“T” Bend</td>
<td>100 hours (estimated)</td>
</tr>
<tr>
<td>10&quot; radius - 90° with plate</td>
<td>17 hours (deflection plate was worn through, but time was not immediately detected)</td>
</tr>
</tbody>
</table>

Laboratory experience is only an indication of what can be expected in actual field practice. In the Fuller foundry, all ingredients are pneumatically unloaded and conveyed through the foundry. In the green sand handling system, a series of special long radius wear back or alloy bends were tested. The best of these bends lasted for slightly less than 6 months. A “T” bend was installed as a result of our laboratory test work and bend replacement has been eliminated over the past four years. “T” bends have been used in many sand, alumina, feldspar, etc. systems over the past four years with excellent success.

Another point to be presented in favor of the “T” bend is that it is much better to construct a conveying system from components which are available in the local plumbing supply house rather than having to special order the bends from some distant long time delivery vendor. Maintenance is also simplified since the standard cast pipe “T” is much smaller and lighter, usually facilitating replacement by two men without the need of overhead cranes.
To date, the point of anticipated wear with a “T” bend appears to be in the straight pipe after the bend. It is common practice to install a 3’ flanged spool piece after each bend for ease of replacement if or when this point wears through.

**Effect on Conveying**

Since the advantage for abrasion resistance and ease of replacement lies in favor of the “T” bends, their effect on conveying must be analyzed. In early studies made at Fuller Company to determine the pressure drop around various bend configurations, the long radius bend created the lowest pressure drop. However, in the first commercial installation of the “T” bend made by Fuller Company, three bends were changed to the “T” in a Feldspar handling system. The initial report was that no change in operation could be detected from this field installation. A similar result was obtained at the Fuller foundry as the various special long radius bends were replaced by “T” bends.

Upon careful testing in the laboratory, the previous results were substantiated, however, it was determined that the greater pressure drop created by the bend is in the acceleration of the material after the bend. To fully evaluate the effect of a bend, the total change in the system pressure would be a better indicator. This then propagated the next series of tests in the laboratory. Another question raised was what effect would the “T” bend have on a powdered material like Type I Cement.

The next series of tests conducted utilized a Fuller Kinyon pump, delivering 330 pounds per minute of material to a 4” diameter conveying line, 616’ long. This system contains (6) 90° bends. In this test program, the system initially contained all 6’ 5” radius bends. A series of tests were made at pick-up velocities from 950 to 2900 feet per minute. After this series was completed, the first bend was changed to a standard cast 4” elbow (6.5” radius). After each series of tests were completed another bend was changed. After all the bends were changed to the short radius elbow, they were all replaced by cast “T” fittings. These results have been averaged for the table on the following page.

From the following tabulation, it is apparent that the overall operation of the dense phase Fuller Kinyon system on Type I Cement improved in operation as the long radius bends were removed and the short radius elbows installed. The complete change to the “T” bends did very little to change this condition, since the overall shape of the “T” is similar to the elbow, and the material evidently lodges in the dead end forming the desired curvature to minimize pressure drop.

The results can be justified by technical information available for pressure drop for fluid flow through bends. The minimum total resistance to flow is obtained when the R/D is about 2.25 (radius of bend divided by diameter of pipe). For a 4” pipe, the optimum radius would be 9”. With a 6.5” radius the R/D is 1.6 and the equivalent length is reported as about 13, while the 6’5” radius bend has a R/D of 19.25 and an equivalent length of about 50.
At this point some questions still remained as to the effect of short radius bends on vacuum systems and on low pressure conveying systems; particularly when conveying materials like polyethylene pellets. For this study, a 240' long, 3" diameter conveying system was used which can operate either as a vacuum system or be a low pressure conveying system fed either by a rotary feeder or pressure tank. This system consists of (6) 90° bends. The original bends in this system were 48" radius. A set of six short radius bends with long tangents was constructed with 9" radius to replace the standard 48" bends.

Many runs were made with the vacuum system and the rotary feeder pressure system, both with the long and short radius bends.

In analyzing the vacuum conveying data, it is indicated that the short radius bends are detrimental to conveying and require a reduced capacity or increased vacuum. It is true that when operating at 10.5" Hg vacuum, the capacity at 4200 ft./min. was 170 pounds per minute for the long radius bends and only 147 for the short bends. This indicates a total of 13.6% reduction in capacity. However, it must be remembered this is the result of changing 6 bends and so the reduction per bend would average at slightly more than 2% reduction in capacity per bend changed.

Another comparison can be made that the capacity with the long radius bends at 9.0 Hg is about the same as the short radius bends operating at 10.5" Hg. This would show a required increase in operating vacuum of 16.6% when changing from the long radius to short radius bends, or slightly less than 3% penalty for each bend changed.
It must be pointed out that these results are the average of many runs made and that, even under laboratory conditions, it is difficult to reproduce the same capacities for a given system when all conditions remain unchanged. It is doubtful if a 5% change could be detected in the average field conveying system.

In comparing the data from the rotary feeder pressure system, the condition is reversed. Here the capacity with the short radius bends at 4200 ft./min. is 127 lb./min. at a line pressure of 7.0 psig, while the long radius bends at the same conditions had a capacity of only 102 lb./min. This shows a system increase in capacity of 24.4% or an average increase of slightly more than 4% per bend. Likewise, the capacity of the short bends on the 6 psig system was 108, or we might conclude that changing from the long to short bends would reduce the operating pressure required from 7 to 6 psig, which is a 14.3% reduction in pressure or an average of slightly more than 2% per bend changed.

If we further analyze the data, we see that the effect is more noticeable on the high velocity conveying in the vacuum system than in the low velocity data. For example, at 5600 ft/min., there is a 33% reduction in capacity for the 10.5" Hg vacuum operation, however there is only an 8.6% reduction at 3400 ft./min. pick-up velocity.

**Additional Short Bend Advantage**

When changing from a horizontal direction to a vertical line, a long radius bend has a section of the pipe that is tangent to 45°. In low velocity dense phase conveying, this is the most difficult condition to encounter. Material drops out, slides down the angle, and must be entrained. This has been responsible for many low velocity conveying systems to plug. A short radius bend or dead end “T” eliminates this completely or reduces the disturbance to an insignificant amount, thus eliminating this cause of line plugs.

Where this condition exists near the start of a conveying system, better operation will be obtained through the use of short turns rather than the long radius bends.

**Summary**

Both test results in the laboratory and field results from various customers indicate that the overall maintenance cost of a system using dead end “Tee” bends is less than any of the configurations utilizing long radius bends, including those of special wear resistant materials, wear back, bends, etc. It is also a great advantage to the customer to be able to replace these bends by components which can be carried by one man and replaced without the need for cranes or similar equipment. Another advantage to the customer is availability of replacement parts which can be obtained from a local plumbing supply house rather than requiring special order and long time delivery.
The change in the capacity of a conveying system when changing from the long radius bends to the short radius bends or "Tee" can be summarized as follows:

1. When replacing long radius bends with short radius bends or "Tee" bends, systems with low velocity conveying and/or high material to air ratios will result in increased capacity or reduced conveying pressure.

2. When replacing long radius bends with short radius bends or "Tee" bends, systems with high velocity and/or low material to air ratios will result in decreased capacity or increased conveying pressure.

Obviously, there must be a condition with certain materials and velocity of conveying and material air ratios that the bends can be interchanged without a detectable difference.

**Future Work Required**

1. Coarse materials (sand, polyethylene pellets) and ground rock products (cement, ground limestone) can be conveyed through short radius bends or "T" fittings. Materials with high moisture and a tendency to "snow ball" have not been tried and would appear to be doubtful for this application. Very fine materials (100% minus 2 micron) have a tendency to build up on the walls of conveying lines, and have not been evaluated in "T" bend applications.

2. A problem peculiar to some conveying systems is minimizing the conveyed material degradation. Fuller Company has not conducted any test work to date to determine the relative breakage of the conveyed material in a long radius bend system as opposed to the system using "T" bends. It has been shown, however, that in the handling of some plastic products, the generation of the streamers has been reduced through the use of the "T" bend.
BEND CONFIGURATIONS TESTED
AND WEAR PATTERNS ENCOUNTERED

Wear thru

3rd wear

2nd wear

48" Radius
90°

Wear thru

10" Radius
90°

Trace wear

Slight wear

"T" bend

Wear thru

10" Radius
90°
& Deflecting Plate

Wear thru

36" straight

2nd wear

10" Radius
45°

10" Radius
45°