SECTION 1

FOUNDATIONS OF SAFE BULK-MATERIALS HANDLING

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Chapter 1

**TOTAL MATERIAL CONTROL**

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Figure 1.1
Control of material movement is critical to clean, safe, and productive material handling.
In this Chapter…

In this chapter, we describe some of the problems that occur as a result of fugitive materials: reduced operating efficiency, plant safety, product quality, and employee morale along with increased maintenance cost and scrutiny from outside agencies. We also identify the costs from this loss. As a way to address these problems, we discuss the need for total material control, which forms the basis for this book (Figure 1.1).

A bulk-materials handling operation is designed to accept the input of a certain amount of raw material and to reliably deliver that same amount of material at a predetermined rate to one or more points at the other end of the process.

Unfortunately, this seldom happens. Material losses, spillage, emissions, flow restrictions, and blockages can all occur in the handling process, resulting in the loss of production and creating other, associated, problems. These problems will cost billions of dollars annually across industries handling bulk materials worldwide.

This book seeks to identify many of the causes of material-handling problems and suggest practical strategies, actions, and equipment that can be applied to help increase efficiency in materials handling. This is a concept called Total Material Control®.

Total Material Control and TMC are registered trademarks of Engineering Services & Supplies PTY Limited (ESS), a Martin Engineering licensee, located inCurrumbin, Australia (Reference 1.1).

CONVEYORS AND FUGITIVE MATERIALS

Escape of materials from conveyors is an everyday occurrence in many plants. It occurs in the forms of spillage and leakage from transfer points or carryback that adheres to the belt past the discharge point and drops off along the conveyor return. It also occurs in the form of airborne dust that is carried off the cargo by air currents and the forces of loading and then settles on structure, equipment and the ground. Sometimes the nature of the problems of a given conveyor can be determined from the location of the pile of lost material (Figure 1.2). Carryback falls under the conveyor, spillage falls to the sides, and dust falls on everything, including systems and structures above the conveyor. However, many conveyors show all of these symptoms, making it more difficult to place the blame on one type of problem (Figure 1.3).

Another problem besetting materials-handling operations is flow restrictions. A materials-handling plant is designed to operate at a certain rate of throughput. While much attention has been paid to the cost of spillage, the cost of restricted throughput and delayed production cannot be ignored.

Chute or bin blockages can bring a production process to a standstill, causing delays that cost thousands of dollars per hour in downtime and in lost opportunities. Chute blockages often cause material boolver, with materials overflowing the...
chute. Chute or bin hang-ups often cause sudden material surges, in which amounts of material suddenly drop through the vessel and onto the receiving belt. Both boilovers and surges are major contributors to spillage. Material lying under the head end of a conveyor is often mistakenly identified as carryback, when it can actually result from surges and boilovers. Carryback will generally be fine material, so the presence of lumps greater than 10 millimeters (0.39 in.) will often pinpoint the cause of the fugitive material as a surge or boilover.

**PROBLEMS FROM FUGITIVE MATERIALS**

**Results of Fugitive Materials**

Fugitive materials have been around plants since conveyors were first put into operation; therefore, their presence is often accepted as a part of the industry. In fact, maintenance and production employees who are regularly assigned to cleaning duties may see this work as a form of “job security.”

As a result, the problem of materials escaping from bulk-materials handling systems is often regarded with resignation. While it is recognized as a mess and a hazard, it is believed that no effective, practical, real-life systems have been developed to control it. Therefore, spillage and dust from leaky transfer points and other sources within plants are accepted as routine, unalterable courses of events. Fugitive materials become a sign that the plant is operating: “We’re making money, so there’s fugitive material.”

At one time, pollution—whether from smokestacks or from conveyor transfer points—was seen as a sign of industrial strength. Now these problems are recognized as an indication of possible mismanagement and waste. This pollution and waste offer an opportunity for improvements in both efficiency and bottom line results.

Left unchecked, fugitive materials represent an ever increasing drain on a conveyor’s, hence a plant’s, efficiency, productivity, and profitability. Materials lost from the conveyor system cost the plant in a number of ways. The following are just a few:

A. Reduced operating efficiency
B. Increased conveyor maintenance costs
C. Reduced plant safety
D. Lowered employee morale
E. Diminished product quality
F. Heightened scrutiny from outside agencies and other groups

These costs will be more thoroughly covered in the sections that follow.

**Reduced Operating Efficiency**

It can be said the most expensive material in any operation is the material spilled from the belt. At a clean plant, “all” the material is loaded onto a conveyor belt at one end and then it is “all” unloaded at the other end. The material is handled only once: when it is placed on the belt. This, of course, equates to high efficiency: The plant has handled the material as little as possible. Material that has spilled or otherwise become fugitive, on the other hand, is material that has been received, processed (to some extent), and then lost. It has been paid for, but there will be no financial return.

In fact, fugitive material may prove to be a continuing drain: It degrades equipment, such as conveyor idlers, over time, and it might require additional labor to reprocess it before it can be returned to the system—if it can be returned to the process. However, once fugitive, it may be contaminated and unsuitable for return to the system. If fugitive material cannot be reclaimed, efficiency decreases more dramatically. In many places, even basic materials such as limestone or sand that fall from the belt are classified as hazardous waste and must be disposed of at a significant cost.
Fugitive materials also prove to be a drain in efficiency by requiring additional labor to clean up. Production materials can be handled by large machinery in significant quantities in large batches, in massive bucketfuls, and by the railcar load, often automatically or under remote controls. Fugitive materials, in contrast, are usually picked up by a skid steer, an end loader, or a vacuum truck—or the old-fashioned way, by a laborer, one shovel at a time.

**Increased Conveyor Maintenance Costs**

The escape of materials from conveyors leads to any number of problems on the conveyor system itself. These problems increase maintenance expenses.

The first and most visible added expense is the cost of cleanup. This includes the cost for personnel shoveling or vacuuming up material and returning it to the belt (Figure 1.4). In some plants, cleanup means a man with a shovel; in others, the cost is escalated, because it includes equipment hours on wheeled loaders, “sucker” trucks, or other heavy equipment used to move large material piles. A factor that is harder to track, but that should be included, is the value of other work not being performed because personnel have their attention diverted to cleanup activities. This delay in maintenance activities may result in catastrophic failures and even additional expense.

As materials escape, they accumulate on various conveyor components and other nearby equipment. Idlers fail when clogged or buried under materials (Figure 1.5). No matter how well an idler is constructed, fines eventually migrate through the seal to the bearing. Once the bearings seize, the constant movement of the belt across the idler can wear through the idler shell with surprising rapidity, leaving a razor-sharp edge on the seized roll, posing a threat to the life of the belt (Figure 1.6). “Frozen” idlers and pulleys increase the friction against the belt, consuming additional power from the conveyor drive motor.

Seized idlers create other even greater risks, including the possibility of fires in the system. A coal export facility in Australia suffered damage from a fire on a main in-loading conveyor. The fire was caused by a seized roller and fueled by accumulated spillage. The fire destroyed much of the head end of the conveyor, causing the failure of the 1600-millimeter (60-in.) belt and burning out the electrical cables and controls. Repairs were completed in four days to restore operation, but the total cost of the fire was estimated at $12 million USD.

Another risk is that material buildup on the face of pulleys and idlers can cause the belt to run off center (Figure 1.7). An accumulation of materials on rolling components can lead to significant belt-tracking problems, resulting in damage to the belt and other equipment, as well as the risk of injury to personnel.
A mistracking belt can move over into the conveyor structure and begin abrading the belt and the structure. If this condition is not noticed right away, great lengths of valuable belting can be destroyed, and the structural steel itself can be destroyed. Belt wander creates interruptions in production, as the belt must be stopped, repaired, and retrained prior to resuming operations.

A particularly ugly circumstance is that fugitive materials can create a problem and then hide the evidence. For example, accumulations of damp materials around steel conveyor structures can accelerate corrosion, while at the same time making it difficult for plant personnel to observe the problem (Figure 1.8). In a worst-case scenario, this can lead to catastrophic damage.

What is particularly troubling about these problems is that they become self-perpetuating: Spillage leads to buildups on idlers, which leads to belt wander, which leads, in turn, to more spillage. Fugitive materials truly create a vicious circle of activities—all of which increase maintenance costs.

**Reduced Plant Safety**

Industrial accidents are costly, in terms of both the health of personnel and the volume and efficiency of production. In 2005, the National Safety Council in the United States listed $1,190,000 USD as the cost of a work-related death; the cost of a disabling injury assessed at $38,000 USD includes wage and productivity losses, medical expenses, and administrative expenses. These figures do not include any estimate of property damage, and should not be used to estimate the total economic loss to a community.

Statistics from the Mine Safety and Health Administration (MSHA) in the United States indicate that roughly one-half of accidents that occur around belt conveyors in mines are attributable to cleanup and repairs required by spillage and buildup. If fugitive materials could be eliminated, the frequency at which personnel are exposed to these hazards would be significantly reduced. Excessive spillage can also create other, less obvious, safety hazards.

In Australia, a Department of Primary Industries safety seminar advised that in the six-year period from 1999 to 2005, a total of 85 fires were reported on conveyor belts in underground coal mines in the state of New South Wales. Of these, 22 were identified as attributable to coal spillage, and 38 to conveyor tracking. Included among the twelve recommendations of the report were: “Improve belt tracking” and “Stop running the conveyors in spillage.”

In 2006 in the United States, a conveyor belt fire in an underground coal mine caused two deaths. The cause of this fire was attributed to frictional heat from a mistracking belt that ignited accumulations of coal dust, fines, and spillage, along with grease and oil.

Many countries now enforce regulatory safety procedures on companies. Included is the requirement to conduct hazard analyses on all tasks. Codes of practice in design and in plant operation require that once a hazard has been identified, it must be acted upon. The hierarchy of controls
for hazards will usually advise that the most appropriate action will be to “design out the hazard.” The control will depend on the severity of the hazard and the layout of the existing equipment.

Lowered Employee Morale

While the specific details of an individual’s job have much to do with the amount of gratification received at work, the physical environment is also a significant influence on a worker’s feelings toward his or her workplace.

A clean plant provides a safer place to work and fosters a sense of pride in one’s workplace. As a result, employees have better morale. Workers with higher morale are more likely to be at work on time and to perform better in their assignments. People tend to feel proud if their place of work is a showplace, and they will work to keep it in that condition. It is hard to feel proud about working at a plant that is perceived as dirty and inefficient by neighbors, friends, and, especially, the workers themselves.

It is recognized that jobs involving repetitive and unrewarding tasks, such as the cleanup of conveyor spillage, have the highest levels of employee absenteeism and workplace injuries. It is a mind-numbing exercise to shovel away a pile of spillage today, knowing that the pile will be back again tomorrow.

Diminished Product Quality

Fugitive materials can contaminate the plant, the process, and the finished product. Materials can be deposited on sensitive equipment and adversely influence sensor readings or corrupt tightly controlled formulas.

Fugitive materials impart a negative image for a plant’s product quality and set a bad example for overall employee efforts. The most universal and basic tenet of many of the corporate “Total Quality” or other quality improvement programs popular in recent years is that each portion of every job must be performed to meet the quality standard. Each employee’s effort must contribute to, and reflect, the entire quality effort. If employees see that a portion of the operation, such as a belt conveyor, is operating inefficiently—making a mess and contaminating the remainder of the plant with fugitive material—they will become used to accepting less than perfect performance. A negative attitude and lax or sloppy performance may result. Fugitive materials provide a visible example of sloppy practices that corporate quality programs work to eliminate.

Heightened Scrutiny from Outside Agencies and Other Groups

Fugitive materials act as a lightning rod: They present an easy target. A billowing cloud of dust draws the eye and the attention of concerned outsiders, including regulatory agencies and community groups. Accumulations of materials under conveyors or on nearby roads, buildings, and equipment sends a message to governmental agencies and insurance companies alike: The message is that this plant is slack in its operations and merits additional inspections or attention.

If a plant is cited as dirty or unsafe, some regulatory agencies can mandate the operation be shut down until the problems are solved. Community groups can generate unpleasant exposure in the media and create confrontations at various permit hearings and other public gatherings.

A clean operation receives less unwanted attention from regulatory agencies; it is also less of a target for environmental action groups. Cost savings can result from fewer agency fines, lower insurance, reduced attorney’s fees, and less need for community relations programs.

The Added Problem of Airborne Dust

Serious concerns arise when dust becomes airborne and escapes from conveyor systems. Dust is a greater problem than spillage: Whereas spillage is contained on
the plant’s ground, airborne dust particles are easily carried off-premises (Figure 1.9).

In its series, *Best Practice Environmental Management in Mining*, Environment Australia (the Australian government’s equivalent to the US Department of the Environment) issued a report on dust control in 1998 (*Reference 1.2*). The report analyzed the sources of airborne dust in various mineral processing plants. The report indicated that the primary sources of dust were as follows:

Crushing .................................. 1-15 percent
Screening ................................. 5-10 percent
Stockpiling ............................. 10-30 percent
Reclaiming .............................. 1-10 percent
Belt Conveyor Systems ........ 30-60 percent

In the Clean Air Act, the United States Environmental Protection Agency (EPA) is required by law to reduce the level of ambient particulates. Most bulk-materials handling facilities are required to maintain respirable dust levels in enclosed areas below two milligrams per cubic meter (2.0 mg/m³) for an eight-hour period. Underground mining operations may soon be required to meet levels of 1.0 mg/m³. Failure to comply with air-quality standards can result in stiff penalties from federal, state, and local regulatory agencies.

The Occupational Safety & Health Administration (OSHA) in the United States has determined that airborne dust in and around equipment can result in hazardous working conditions. When OSHA or MSHA inspectors receive a complaint or an air sample that shows a health violation, litigation may follow.

Respirable dust, particles smaller than 10 microns in diameter, are not filtered out by the natural defenses of the human respiratory system and so penetrate deeply into the lungs—where they can get trapped and lead to serious health problems. These health issues could be seen in the workforce and might even occur in neighborhood residents.

A frightening possibility that can arise from airborne dust is the risk of dust explosions. Dust can concentrate to explosive levels within a confined space. One incident of this nature—while tremendous in repair, replacement, regulatory fines, and lost productivity costs—can result in the greatest cost of all: the cost of someone’s life.

**ISO 14000 and the Environment**

The continuing globalization of commerce promises more unified standards. Just as ISO 9000 developed by the International Organization for Standardization (ISO) has become a worldwide standard for codifying quality procedures, the development of ISO 14000 will set an international agenda for an operation’s impact on the environment. ISO 14000 prescribes voluntary guidelines and specifications for environmental management. The program requires:

A. Identification of a company’s activities that have a significant impact on the environment
B. Training of all personnel whose work may significantly impact the environment
C. The development of an audit system to ensure the program is properly implemented and maintained

**Regulatory Limits**

While no regulatory agency has established specific limits on the amount of fugitive materials allowed—the height of a pile beside the conveyor or the amount of carryback under an idler—there have been limits specified for quantities of airborne dust. OSHA has determined Permissible...
Exposure Limits (PELs) and Threshold Limit Values (TLVs) for about 600 regulated substances.

These regulations specify the amount of dust allowed, as expressed in parts per million parts of air (ppm) for gases and in milligrams per cubic meter (mg/m³) for particulates such as dust, smoke, and mist. It is the company’s responsibility to comply with these standards or face penalties such as regulatory citations, legal action, increased insurance rates, and even jail time.

These OSHA procedures note that inspectors should be aware of accumulations of dust on ceilings, walls, floors, and other surfaces. The presence of fugitive materials serves as an alarm to inspectors and drives the need for air sampling to address the possibility of elevated quantities of airborne dust.

While ISO and other agencies/groups continue to push for regulatory limits, these limits will continue to differ from country to country. It seems safe to say that environmental regulations, including dust control, will continue to grow more restrictive around the world. These guidelines will almost certainly be extended to include fugitive materials released from conveyors.

**ECONOMICS OF MATERIAL CONTROL**

**How a Little Material Turns into Big Problems**

Fugitive materials escaping from conveyors present a serious threat to the financial well-being of an operation. The obvious question is: “How can it cost so much?” A transfer point spills only a very small fraction of the material that moves through it. In the case of a transfer point on a conveyor that runs continuously, a little bit of material can quickly add up to a sizable amount. Relatively small amounts of fugitive materials can accumulate to large quantities over time (Table 1.1).

In real life, fugitive materials escape from transfer points in quantities much greater than four grams per minute. Studies performed in Sweden and the United Kingdom examined the real losses of fugitive materials and the costs of those losses.

**Research on the Cost of Fugitive Materials**

In a report titled *The Cost to UK Industry of Dust, Mess and Spillage in Bulk Materials Handling Plants*, eight plants in the United Kingdom handling materials such as alumina, coke, limestone, cement, and

<table>
<thead>
<tr>
<th>Accumulation of Fugitive Material Over Time</th>
<th>Accumulation</th>
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<tbody>
<tr>
<td><strong>Fugitive Material Released</strong></td>
<td>Hour (60 minutes)</td>
</tr>
<tr>
<td>“packet of sugar” (4 g) per hour</td>
<td>4 g</td>
</tr>
<tr>
<td></td>
<td>(0.1 oz)</td>
</tr>
<tr>
<td>“packet of sugar” (4 g) per minute</td>
<td>240 g</td>
</tr>
<tr>
<td></td>
<td>(8.5 oz)</td>
</tr>
<tr>
<td>“shovel full” 9 kg (20 lb_m) per hour</td>
<td>9 kg</td>
</tr>
<tr>
<td></td>
<td>(20 lb_m)</td>
</tr>
<tr>
<td>“bucket full” 20 kg (44 lb_m) per hour</td>
<td>20 kg</td>
</tr>
<tr>
<td></td>
<td>(44 lb_m)</td>
</tr>
<tr>
<td>“shovel full” 9 kg (20 lb_m) per minute</td>
<td>540 kg</td>
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<tr>
<td></td>
<td>(1200 lb_m)</td>
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</table>

*Table 1.1*
china clay were examined. The costs have been adjusted to reflect an annual increase for inflation. This study, compiled for the Institution of Mechanical Engineers, established that industrial fugitive materials add costs amounting to a one percent loss of materials and 40 pence ($0.70 USD) per ton of throughput. In short, for every ton carried on the conveyor, there is a loss of 10 kilograms (or 20 lbs lost for every short ton of material), as well as substantial additional overhead costs.

This overall cost was determined by adding four components together. Those components included:

A. The value of lost material (calculated at one percent of material)
B. The cost of labor devoted to cleaning up spillage, which averaged 12.8 pence ($0.22 USD) per ton of output
C. The cost of parts and labor for additional maintenance arising from spillage, which averaged 8.6 pence ($0.15 USD) per ton of output
D. Special costs peculiar to particular industries, such as the costs of reprocessing spillage and the cost of required medical checkups for personnel due to dusty environments, representing 19.7 pence ($0.33 USD) per ton of output

Note: This loss includes fugitive materials arising from problems such as spillage and conveyor belt carryback along with fugitive materials windblown from stockpiles.

A similar study of 40 plants, performed by the Royal Institute of Technology in Sweden, estimated that material losses would represent two-tenths of 1 percent of the material handled, and the overall added costs would reach nearly 13 Swedish Krona ($2.02 USD) per ton.

It is interesting that in both of these surveys, it was actual material loss, not the parts and labor for cleanup and maintenance, which added the largest cost per transported ton. However, the indirect costs of using labor for time-consuming cleanup duties rather than for production are not included in the survey. Those figures would be difficult to calculate.

It is easier to calculate the actual costs for the disruption of a conveying system that, for example, lowers the amount of material processed in one day. If a belt runs 24 hours a day, each hour’s production loss due to a belt outage can be calculated as the amount and the market value of material not delivered from the system’s total capacity. This affects the plant’s revenues and profits.

**The Economics of Material Control**

The cost of systems to control fugitive materials is usually considered three times during a conveyor’s life. The first is during system design; the second, at system startup; and the third, during ongoing operations, when it is discovered the initial systems did not prevent fugitive materials.

It is often very difficult, with new installations, to predict the precise requirements for material control. In most cases, only a guess can be made, based on experience with similar materials on similar conveyors, indexed with “seat of the pants” engineering judgments. An axiom worth remembering is this: “A decision that costs $1 to make at the planning stage typically costs $10 to change at the design stage or $100 to correct on the site.” The lesson: It is better to plan for worst-case conditions than to try to shoehorn in additional equipment after the initial system has been found to be under-designed.

The details of conveyor transfer points, such as the final design and placement of chute deflectors, are sometimes left to the start-up engineer. It may be advantageous to allow the suppliers of specialized systems to be responsible for the final (on-site) engineering, installation, and start up of their own equipment. This may add additional start-up costs, but it is usually the most effective way to get correct installation and single-source responsibility for equipment performance.
Plants are often constructed on a rate of cost per ton of fabricated steel. Even if the best materials-handling controls are not put into place at the time of design, it costs little extra to ensure structures and chutes are installed that will allow for the installation of superior systems at some future date. The consequences of penny-wise, pound-foolish choices made in the initial design are the problems created: fugitive materials and chute plugging, compounded by the additional expense of doing it over again.

**RECORD-KEEPING FOR TOTAL MATERIAL CONTROL**

A great deal of attention is paid to the engineering of key components of belt conveyors. Too often, other factors affecting the reliability and efficiency of these expensive systems are ignored. The cost of fugitive materials is one such factor.

Record-keeping on the subject of fugitive materials is not part of standard reporting done by operations or maintenance personnel. The amount of spillage, the frequency of occurrence, maintenance materials consumed, and labor costs are rarely totaled to arrive at a true cost of fugitive materials. Factors—such as cleanup labor hours and frequency; the wear on conveyor skirtng and conveyor belting; the cost of idler replacement including purchase price, labor, and downtime; even the extra power consumed to overcome stubborn bearings seizing from accumulations of materials—should all be calculated to determine a true cost of fugitive materials. Components whose service-life may be shortened by fugitive materials, such as idlers, pulley lagging, and the belt itself, should be examined to determine service-life and replacement cycle.

Computerized maintenance programs could easily include a field for cause of failure of any replaced parts. Pull-down prompts in these programs should include causes such as spillage, dust ingress, water ingress, and wear from material abrasion (for rollers). This would allow computer-generated reporting of cost versus cause of component failures. This program should include data on belt-cleaning and belt-sealing devices, so accurate costs can be determined for the system installed.

Some contract maintenance services maintain conveyor databases on customers’ conveyors, recording system specifications, details of equipment status, and service procedures performed. This information is helpful in scheduling preventative maintenance activities and in determining when outside resources should be utilized. This information can be used to better manage an operation’s equipment and budget.

The measurement of fugitive materials at transfer points is difficult. In an enclosed area, it is possible to use opacity measuring devices to judge the relative density of dust in the air. For transfer points in the open, dust measurement is more challenging, although not impossible.

A basic technique is to clean a defined area and weigh or estimate the weight or volume of material cleaned and the time consumed in cleaning. Follow up is then conducted with repeat cleanings after regular intervals of time. Whether this interval should be weekly, daily, or hourly will depend on plant conditions.

What will be more difficult to determine is the point of origin of the lost materials. Fugitive materials can originate from conveyor carryback, spillage due to belt wander, skirt-seal leakage, spillage from loading surges or off-center loading, leakage through holes in chutework caused by corrosion or missing bolts, or even from floors above.

The individual making a fugitive material study has to bear in mind the number of variables that may influence the results. This requires the survey to be conducted over a reasonable time frame and include most of the common operating conditions, including: environmental conditions, operating schedule, material moisture content,
and other factors that create or complicate problems with fugitive materials.

Record-keeping of the amount of spillage—and of the costs of labor, parts, and downtime associated with it—should be a key part of the management information system for the operation of belt conveyors. Only when armed with such records covering a period of operation will an engineering study of fugitive materials and recommendations for total material control seem reasonable.

For many conveyor systems, the costs associated with lost materials will easily justify corrective measures. In most cases where adequate records have been kept, it has been shown that a modest improvement in material control will rapidly repay the costs of installing improved systems. Savings in labor expense alone often offsets the cost in less than one year of any retrofit equipment installed.

**ADVANCED TOPICS**

**The Management of Risk and the Risk for Management**

Many countries are starting to hold management personally accountable for failing to mitigate conditions such as spillage and dust resulting from poorly designed, operated, or maintained conveyors. In Australia, for example, the maximum penalty for failing to take corrective action to a known problem that causes death or grievous bodily harm is a $60,000 (AUD) fine and two years in prison for the manager, as well as a $300,000 (AUD) fine levied against the company. There is no doubt that a substantial number of accidents around conveyors are directly related to cleaning spillage and carryback, and it is also known that there are methods and products to control these problems. Consequently, any manager who chooses to ignore these problems and, as a result, risks the health of workers runs the risk of these penalties.

Using a standard industrial “Hazard Analysis” format—to determine the probability and consequence level of “hazards” experienced in cleaning spillage and carryback from under and around conveyors—provides a determination of the risk for employees and managers (Table 1.2).

Most conservative operators and maintenance people would evaluate the “Probability” of a safety incident taking place when cleaning spillage and carryback from under and around belt conveyors as “B: Has happened or near miss has happened” or “C: Could occur or I have heard of it happening,” with the “People Consequence” rated as “2: Serious Injury.” By moving these “Probability” and “People Consequence” values to the “Level of Risk Reckoner,” a rating of Level 5 or Level 8 places the cleanup activities in the category of “Extreme Risk” of a serious injury (Table 1.2).

These ratings demonstrate a situation in which the risk management for the operations manager means proper diligence must be exercised by putting systems in place to eliminate or minimize these hazards.

Consequently, managers must do all within their power to eliminate the occasions (such as conveyor cleanup) that put employees in harm’s way, both for the well-being of their employees and for the reduction of their own personal risks.

**THE OPPORTUNITY FOR TOTAL MATERIAL CONTROL**

**In Closing...**

When the costs created by fugitive materials are understood, it becomes obvious that controlling materials at conveyors and transfer points can provide major benefits for belt conveyors and to the operations that rely on these conveyors. This control has proven difficult to achieve—and more difficult to retain.

A planned and maintained approach is needed to aid in total material control. This is an opportunity to reduce costs and to increase efficiency and profitability for many operations.
Total material control means that materials are kept on the belt and within the system. Materials are moved—where they are needed, in the condition they are needed, at the flow rate they are needed—without loss or excess energy consumption, and without premature equipment failures or excessive maintenance costs. Total material control improves plant efficiency and reduces the cost of ownership.

This book presents many concepts that can be used in a program to achieve total material control for belt conveyors.

**Looking Ahead...**

This chapter about Total Material Control, the first chapter in the section Foundations of Safe Bulk-Materials Handling, introduced the need for and benefits of reducing spillage and dust. The following chapter, Safety, continues this section and explains the importance of safe practices around bulk-materials handling equipment as well as ways in which total material control will increase safety in the plant.

**REFERENCES**

1.1 Engineering Services & Supplies PTY Limited. Australian Registration #908273, Total Material Control and Registration #716561, TMC.


### Risk Matrix System

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<thead>
<tr>
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<th>Step 2: Determine Consequence (Higher of the Two)</th>
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<tr>
<td></td>
<td>People Consequence</td>
</tr>
<tr>
<td><strong>Probability</strong></td>
<td><strong>1 Fatality, permanent disability</strong></td>
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<tr>
<td>A Daily: Common or frequent occurrence</td>
<td></td>
</tr>
<tr>
<td>B Weekly: Has happened or near miss has happened</td>
<td>2 Serious injury or illness (lost time)</td>
</tr>
<tr>
<td>C Monthly: Could occur or I have heard of its happening</td>
<td>3 Disability or short-term injury (lost time)</td>
</tr>
<tr>
<td>D Annually: Not likely to occur</td>
<td>4 Medical treatment injury</td>
</tr>
<tr>
<td>E Once in 5 Years: Practically impossible</td>
<td>5 First aid or no injury</td>
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**Step 3: Level of Risk “Reckoner”—Calculate Risk**

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<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tr>
<td>1</td>
<td>EXTREME</td>
<td>EXTREME</td>
<td>EXTREME</td>
<td>SIGNIFICANT</td>
</tr>
<tr>
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<td>EXTREME</td>
<td>EXTREME</td>
<td>EXTREME</td>
<td>MODERATE</td>
</tr>
<tr>
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<td>SIGNIFICANT</td>
<td>MODERATE</td>
<td>LOWER</td>
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<tr>
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<td>LOWER</td>
</tr>
<tr>
<td>5</td>
<td>SIGNIFICANT</td>
<td>MODERATE</td>
<td>LOWER</td>
<td>LOWER</td>
</tr>
</tbody>
</table>

*Table 1.2*  

**Typical example of a risk matrix system as used in Australia, origin unknown.**
Chapter 2

SAFETY

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In this Chapter...

In this chapter, we focus on the importance of safety practices and training for those working on or around conveyors. Potential causes of accidents are examined along with the costs of accidents, both direct and indirect. General safety procedures are described as well as specific safety practices. The importance of proper training, for both new employees and veterans, and appropriate content for such training are also discussed. The chapter concludes with a review of personal responsibility required for preventing accidents on and around conveyors.

Conveyors apply large amounts of mechanical energy to what is basically a giant rubber band, stretched tight and threaded through a maze of components (Figure 2.1). This band is burdened with a heavy load and then pulled at high speed. The forces applied are significant and potentially dangerous. By their very nature, belt conveyors feature fast-moving bulk materials and “pinch” points. These characteristics can create risks to personnel who are working on or near belt conveyors. Anyone who may be required to come into close proximity of a belt conveyor must always be aware of the power of that system and maintain a healthy respect for its potential to injure or kill an untrained or unwary individual.

A conveyor system may have a drive of 450 kilowatts of power (600 hp)—as well as all the inertia and potential energy of its load of tons of material. It is easy to see how a moving conveyor belt will easily win a tugging match with a worker, resulting in the chance for serious injury or death.

All forms of bulk transport—from mine haul trucks to trains to ships—carry their own hazards and safety concerns. While they also present some risks, properly designed, operated, and maintained conveyors can provide a safe and effective method of material movement.

Accidents can happen, but they can also be prevented. Conveyor safety begins with designs that avoid foreseeable hazards. Management must specify equipment that is safe and easy to maintain, and workers must follow the rules. The establishment and maintenance of safe practices in the design, construction, operation, and maintenance of conveyors and conveyor transfer points will aid greatly in the prevention of accidents. Proper training is a key to promoting safety for workers whose jobs bring them into the vicinity of belt conveyor systems.

THE RECORD AND THE PROBLEMS

How Conveyor Safety Relates to Dust and Spillage

Fugitive material from belt conveyors increases safety risks in many ways (Figure 2.2). Fugitive material creates the need for personnel to clean and to perform maintenance on and around conveyors. Placing personnel in close proximity to the moving belt creates the opportunity for an inadvertent contact to turn into a serious injury or death (Figure 2.3).
Conveyors and Safety: A Look at the Record

Because of the size of their material cargos, the speed of their operation, and the amount of energy they consume and contain, conveyors pose a unique set of hazards. As a result, conveyors have shown to be a leading cause of industrial accidents, including serious injuries and fatalities.

A report from the Mine Safety and Health Administration (MSHA) in the United States examined conveyor accidents in metal/nonmetal mines recorded over the four-year period from 1996 to 2000. The MSHA report (Reference 2.1) listed the following worker activities related to those accidents:

A. Working under or next to poorly guarded equipment
B. Using hand or tool to remove material from moving rolls
C. Trying to free stalled rolls while conveyor is moving
D. Attempting to remove or install guards on an operating conveyor
E. Attempting to remove material at head or tail pulley while belt is in operation
F. Wearing loose clothing around moving belt conveyors
G. Not blocking stalled conveyor belt prior to unplugging (both flat and inclined belts) as energy is stored in a stalled conveyor belt
H. Reaching behind guard to pull V-Belt to start conveyor belt

An analysis of the document (Reference 2.1), covering a total of 459 accidents of which 22 were disabling and 13 were fatal, shows 192 (42 percent) of the reported injuries (including 10 fatalities) occurred while the injured worker was performing maintenance, lubricating, or checking the conveyor. Another 179 (39 percent) of the reported injuries (including 3 fatalities) occurred while the subject was cleaning and shoveling around belt conveyors (Table 2.1).

The MSHA report found no differentiation in the likelihood of accidents based on age, experience, or job title of the accident victim.

A preliminary study of 233 fatal mining accidents in the United States during the years 2001 to 2008 revealed there were 48 fatalities in 47 incidents involving conveyors (Reference 2.2). The data were compiled from reports by the Mine Safety and Health Administration of the US Department of Labor.

The activities most frequently listed as leading to the conveyor-related fatalities were listed as Maintenance, e.g., replacing idlers or belting or clearing blockages with 35 percent (or 17 deaths), with Cleanup, e.g., shoveling or hosing spillage or clearing buildup at an idler second with 27 percent (or 13 deaths). Many of these fatalities resulted from the victim becoming caught in the moving belt by getting too close to an unguarded pinch point or working on a moving conveyor.

<table>
<thead>
<tr>
<th>Table 2.1</th>
<th>1996-2000 MSHA Conveyor Accident Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cause of Injury</strong></td>
<td><strong>Fatal</strong></td>
</tr>
<tr>
<td>Caught in Moving Belt</td>
<td>10</td>
</tr>
<tr>
<td>Maintenance, Lubrication, or Inspection</td>
<td>10</td>
</tr>
<tr>
<td>Cleaning and Shoveling</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

*Note: The total figure in each column is not the sum of that column, as there may be multiple causes cited for any specific accident (Reference 2.1).*
In South Africa, the Conveyor Belt Systems Safety in Mines Research Advisory Committee’s report examined more than 3000 accidents (including 161 belt conveyor fatalities) between 1988 and 1999 (Reference 2.3). In findings that echoed the above-cited MSHA report, the document noted that “people working on moving conveyors, inadequate guarding, and ineffective locking out stand out as major causes of conveyor accidents.” According to the report, injuries most frequently result from people working at the tail pulley, head pulley, idlers, and loading chute.

The Cost of Conveyor Accidents

Some of the direct costs arising from accidents—such as medical treatment, lost
wages, and decreased productivity—can be identified. Less evident expenses associated with accidents are known as “indirect” or “hidden” costs and can be several times greater than the value of direct costs. These hidden costs include:

A. Expense and time of finding a temporary replacement for the injured worker
B. Time used by other employees to assist the injured worker
C. Time used by supervision to investigate the mishap, prepare accident reports, and make adjustments to work schedules
D. Property damage to tools, materials, and equipment
E. Delays in accomplishment of tasks

In 2005, the National Safety Council in the United States listed $1,190,000 USD as the cost of a work-related death; the cost of a disabling injury was assessed at $38,000 USD. Their accounting includes wage and productivity losses, medical expenses, and administrative expenses. The figures do not include any estimate of property damage.

It is easy to see that even a slight reduction in the number of conveyor-related accidents can save significant amounts of money for an operation.

**CONVEYOR SAFETY PRACTICES**

**General Conveyor Safety Practices**

There are certain safety practices that should be observed regardless of the design of the conveyor or the circumstances of its operation. They include:

A. Lockout / tagout / blockout / testout procedures

Lockout / tagout / blockout / testout procedures must be established for all energy sources of the conveyor belt, as well as conveyor accessories and associated process equipment. Bulk materials on the belt may present danger from falling lumps or potential energy that can cause the conveyor to move even when the system has been de-energized. Lockout and tagout alone may not be enough to ensure a worker’s safety; therefore, it is important that after lockout and tagout, the worker blocks out the conveyor (blockout) and tests to make sure it cannot move (testout). These procedures should be followed before beginning any work—whether it is construction, installation, maintenance, or inspection—in the area.

B. Inspection/maintenance schedule

A formal inspection and maintenance schedule must be developed and followed for the material-handling system. This program should include emergency switches, lights, horns, wiring, and warning labels, as well as the conveyor’s moving parts and accessory components.

C. Observance of operating speed and capacity

The design operating speed and capacity for the conveyors, chutes, and other material-handling equipment must not be exceeded.

D. Safety “walk around”

All tools and work materials must be removed from the belt and chute before restarting a conveyor. A safety “walk around” is recommended prior to resuming conveyor operation.

E. Emergency controls

All emergency controls must be close to the system, easy to access, and free of debris and obstructions.

F. Personal protective equipment (PPE) and attire

Appropriate personal protective equipment and attire, in accordance with local requirements (often including a hard hat, safety glasses, and steel-toe shoes) must be worn when in the area of the conveyor. Loose or bulky clothing is not allowed; nor is loose long hair or jewelry.

G. Safe practices while the system is in operation
It is important to never poke, prod, or reach into a conveyor or other material-handling system or attempt to clean or adjust rollers or other components while the system is in operation.

H. No personnel on conveyor

Personnel should never be allowed to sit on, cross over, or ride on an operating material-handling conveyor. (In some parts of the world, man-riding belt conveyors are the accepted method for workers to reach their assigned areas; in other regions, it is strictly forbidden. For simplicity’s sake, this volume will hold man-riding conveyors separate from its discussion of belt conveyors for bulk materials.)

Safety Standards for Conveyor Design and Operation

The above practices are not intended to replace the more detailed safety guidelines published by the American Society of Mechanical Engineers (ASME) in ASME Standard B20.1-2006 Safety Standard for Conveyors and Related Equipment and B15.1 Safety Standard for Mechanical Power Transmission Apparatus in the United States—by appropriate regulatory and safety agencies around the world, or the rules of a specific plant. Consult those references, as well as the safety instructions provided by the manufacturers of specific systems.

In Australia, Australia Standard (AS) specification AS1755-2000 Conveyor Safety Equipment applies to the design, construction, installation, and guarding of conveyors and related systems for the conveyance of materials.

These references and/or their national or international equivalent should be consulted as a guide for the design and construction of any belt conveyor system.

Conveyor Electrical Systems and Safety

The electrical systems of conveyors often involve high voltages and complex control and communication systems. The electrical trade is almost always considered a separate group within a plant’s maintenance department. Only workers who are specially trained and certified should work on conveyor electrical supply and control systems.

Pre-Job Safety Assessment

Prior to commencing any work on belt conveyors, it is recommended that a pre-job safety assessment be performed. This assessment should include all equipment that may be interlocked with the actual piece of equipment to be serviced. This pre-job assessment should make sure that the entire area is safe for workers and the proper equipment is available to perform the work safely. In addition, the pre-job safety inspection should include close inspection of the surrounding work area for fire hazards, tripping hazards, or falling objects.

One item often overlooked in the pre-job safety inspection is the coordination of all employee activities on the belt conveyor. For example, workers in the head chute changing belt-cleaner blades could be injured if workers changing the belt were to move the belt.

Lockout/Tagout Procedures

A crucial part of a conveyor safety program is the lockout/tagout procedure. In the United States, lockout/tagout is an Occupational Safety & Health Administration (OSHA) requirement; MSHA has adapted a similar version of this rule. To achieve complete safety in the face of the potential

Figure 2.4

Lockout/tagout rules require that power to the conveyor system (and any accessory equipment) be shut down, locked, and tagged by the person who will be performing work on the system.
energy stored in belt tension or elevated bulk materials, the additional components of blockout and testout are recommended.

The lockout/tagout rules require that power to the conveyor system (and any accessory equipment) be shut down, locked, and tagged by the person who will be performing work on the system (Figure 2.4). Only the person who locked out the system can unlock it. This prevents someone from starting the conveyor belt unknowingly while someone else is working on it.

**Typical lockout/tagout procedures follow:**

A. **Own lock**
   Each worker is required to place a personal lock on the de-energizing switch or switches. This may require one lock bar or multiple lock bars (Figure 2.5).

B. **Own key**
   Only the employee who places each lock has the key to that lock, and only that employee can remove the lock.

C. **Multiple locks**
   If a number of employees are working in a given area, each should place a lock on the power source. Some equipment will have numerous locations that may require lockout.

D. **Own tag**
   Each employee who placed a lock should also place a tag that includes the employee’s name and contact information.

**Blockout Procedures**

Even when a belt conveyor has been properly locked out and tagged out, there may still be significant amounts of tension or potential energy present in the system. One easy-to-understand scenario is if an inclined belt had an emergency shutdown with material loaded on the belt, the weight of the material will cause the belt to roll backward. Both the movement of the belt and the potential cascade of material off the downhill end of the conveyor cause risk of injury to the unlucky or unwary employee.

Lifting the gravity take-up’s counterweight might not release these tensions: This method should not be relied upon. Properly installed brakes and backstops may help prevent this roll back. However, a plant should not rely on the backstops or brakes to prevent a belt from moving on its own. There have been instances in which the belt has moved due to the internal tensions by the belt stretch.

Blocked chutes, material trapped at load zones, material under the belt, or bad bearings may stall the belt sufficiently to create considerable belt tensions. The belt may move in either direction, based on the conditions present at the time of the work; these conditions can and do change as the work progresses.

If employees are required to be on the belt or near pinch points on the conveyor, the belt should be physically restrained from moving under its own power. This
is called “blocking” the conveyor belt, or blockout. Belt clamps, chains, and come-alongs (ratchet lever hoists) can be used to physically restrain the belt by securing the blocking device to a structural member of the conveyor capable of restraining the expected forces (Figure 2.6).

It is recommended that engineered equipment be purchased that will securely clamp to the belt to prevent movement.

**Testout Procedures**

A testout procedure provides a final check to make sure the system is secure and de-energized before work proceeds. It is a good practice to try to start the belt conveyor or interlocked equipment after the lockout lock has been placed. This should include both local start/stop stations and the system’s remote controls. This ensures that the correct breakers were de-energized.

**Equipment Guards**

It is important that pinch points—on rotating equipment like head pulleys and on equipment that allows sudden movements, like gravity take-ups—be equipped with guards to prevent accidental or unwise encroachment by employees (Figure 2.7).

It is becoming more common for conveyors to be totally enclosed in guard barriers along walkways to protect personnel who are required to use the walkways (Figure 2.8). These guards are fabricated of metal mesh or screen that allows observation of moving parts and pinch points without allowing personnel to get so close as to pose a risk of injury (Figure 2.9).

While each nation has its individual requirements that must be met when it comes to the proper placement of guards on equipment, local and industry requirements should also be thoroughly investigated and implemented.

At the same time, it must be remembered that service access must be provided to the various pieces of equipment. The physical
barriers installed to shield this equipment must be carefully designed, or they will interfere with maintenance efficiency. Removing the guards should require a special tool to prevent untrained individuals from entry into the system. The guards must be sufficient to prevent an employee from reaching in, or around, the guards to gain access to the pinch point.

After service procedures are completed, it is important that guards be returned to position prior to restarting the conveyor.

Emergency Stop Switches

To protect personnel working near the belt, the conveyor should be equipped with “pull-rope” emergency stop switches. These safety switches should be conveniently mounted along conveyor catwalks and right-of-ways (Figure 2.10). The system should run the full length of both sides of the conveyor if there is access, or a walkway, on both sides of the belt. The switches should be wired into the belt’s power system so that in an emergency, a pull of the rope interrupts the power to the conveyor, stopping the belt.

In 1995, MSHA in the United States alerted mine operators about potential failures of emergency-stop pull-cord systems along conveyors. After tests of over 1100 systems, MSHA noted a failure rate of two percent. MSHA attributed these problems to several factors:

A. Spillage around the switch that prevents deactivation of the conveyor
B. Broken pull cords or excessive slack in cords
C. Frozen pivot bearings where the switch shaft enters the enclosure
D. Failure of electrical switches inside the enclosure
E. Incorrect wiring of switch or control circuits

The solution to this problem is proper service attention and testing drills similar to school fire drills, when the operation of the conveyor safety equipment can be checked. These tests should be performed monthly.

Safety Signage

Safety stickers and warning labels should be affixed at pinch points, service access doors, and other hazardous areas on conveyor equipment (Figure 2.11). It is the responsibility of the manufacturer to supply—and whenever possible, apply—safety warnings to equipment. These signs must be kept clean and legible, and should be reapplied appropriately to suit changes in equipment or procedures. It is the responsibility of operations management to replace worn, damaged, or unreadable safety warnings. It is the responsibility of the employee to comply with safety signage.

Signs warning of equipment that can be remotely started should be placed prominently along the conveyor. Many times the conveyor belts start automatically or when triggered by an operator in a remote control room, nowhere near the conveyor.

Chutes that have flow aid devices such as air cannons, that can seriously injure employees when discharged, must be clearly marked. This situation also requires the chute to be marked with restrictions for vessel entry. Flow aids must be de-energized and properly locked out / tagged out / blocked out / tested out and chutes cleaned prior to chute entry.

Safety stickers and signs are available from reputable manufacturers of conveyors and related equipment, as well as safety supply houses. In the United States, the Conveyor Equipment Manufacturers Association (CEMA) has a variety of safety
and precautionary labels available for bulk-material conveyors and several common accessories. These labels can be viewed and ordered from the organization’s website at http://www.cemanet.org.

Signage incorporating pictograms may be required to protect all workers in plants where multiple languages are spoken (Figure 2.12). If required, translation of the messages of safety signage should be performed locally to ensure accurate meaning. (The International Organization for Standardization has a goal to eliminate words that need to be translated and use signs that incorporate only pictures.)

**Safety Considerations at New Conveyor Startup**

Start-up time for new conveyors can be one of the most dangerous times, because the system may not behave as expected, and safety equipment such as startup horns and signals may not work properly. It is recommended that multiple spotters be stationed along the conveyor route prior to starting the belt. They should have radio communication with the control room or person starting the belt conveyor.

Adjustments that may be required to get the belt running smoothly should be made only while the conveyor is properly locked out / tagged out / blocked out / tested out. Making even a simple adjustment while the belt is running may result in an accident.

**Hazardous Thinking**

Many operations forbid working on the conveyor system when it is running. Nevertheless, the same operations require working around the conveyor while it is in operation. Workers come to the conveyors for inspection and maintenance procedures and to clean up fugitive material.

As Richard J. Wilson (Reference 2.5), of the Bureau of Mines Twin Cities Research Center, noted:

Most procedures require locking out the main power switch at the head pulley or control room. As this could be quite some distance from the work site, compliance could require a considerable amount of time and effort. It is not difficult to imagine maintenance personnel rationalizing that it is all right to quickly perform some routine repair work without locking out the belt when implementing the lockout procedure would take much longer than the job itself.

This “shortcut” creates the opportunity for accidents and injuries.

**SAFETY TRAINING**

The South African report (Reference 2.3) noted: “Most accidents can be attributed to a lack of an understanding of the inherent risks of conveyor systems and the safe use of such systems.”

The best approach to accident prevention is a well-designed safety program combined with effective, and repeated, training.
Conveyor Training for New Employees

Conveyor belt safety must start with the newest employee. The tendency is to send “the new kid”—the least-experienced, most-recently hired—out to do “the job that nobody wants:” clean up around moving belt conveyors. Prior to assigning a new employee the task of working around a conveyor belt, the employee should attend a minimum of four hours of classroom instruction specific to belt conveyors.

The Conveyor Training Course

Each plant should have in place a program of training for individuals whose positions will require them to work on or near conveyors (Figure 2.13). This program will discuss the risks of, and safe procedures for, working in the vicinity of belt conveyors. The training should include a thorough understanding of the variety of belt conditions that can influence belt operations, fugitive material, and personnel safety. By understanding different conditions of the conveyor, accidents can be reduced.

This comprehensive training should include as a minimum the following:

A. General safety practices around belt conveyors
B. Personal protective equipment (PPE)
C. Proper personal grooming and apparel
D. Proper shoveling techniques
E. Safe inspection and maintenance practices
F. Conditions of the conveyor that cause problems (leading to maintenance and safety issues)
G. Belt selection to match structure and conditions
H. Identification of the sources of fugitive material
I. Elimination of fugitive material (dust and spillage)
J. Belt-tracking procedures

Refresher and Reminder Training

In addition to new employees, veteran employees also need training. Senior employees have probably had little or no training about conveyor belts or conveyor belt safety. Seminars such as Martin Engineering’s Foundations™ Workshop have proven effective in providing focused conveyor training to personnel ranging from operations and maintenance workers to conveyor engineers and plant managers. The corresponding Foundations™ Certification Program provides a self-guided conveyor learning experience.

Periodic reminders between the regular training and retraining sessions are also beneficial. Agencies such as the US MSHA are a source for case histories on conveyor belt accidents that can provide effective refresher training materials.

The Importance of Personal Responsibility

In many ways, plant safety is like plant cleanliness: They are both matters of attitude. Plant management can set a tone for the overall operation; however, it is the response of each individual worker that will have the greatest impact on a plant’s safety record.

Safety is not just the responsibility of a plant’s safety department or a governmental agency. Rather, it is the responsibility of each worker to ensure safety for oneself and for one’s co-workers.

Personal responsibility includes:

A. Use of personal safety equipment, including dust masks and respirators,
hearing protection, hard hats, and steel-toe shoes  

B. Attention to safety practices  

C. Good standards of housekeeping to provide a clean and safe work area  

D. Thorough review of equipment manuals to learn safe operations and maintenance procedures  

E. Willingness to stop unsafe actions by other workers and to coach others in proper safety procedures  

### ADVANCED TOPICS  

**"New Generation" Guarding Systems and Conveyor Stopping Time**  

There is a question as to whether or not the “new generation” guarding technologies can react quickly enough to prevent injury when compared to conventional barrier guarding. The determining factors are the detection range of the equipment, the guarding device’s speed of response, the distance of the protection device from the nearest moving part, the conveyor belt’s stopping time, and the person’s speed of movement.  

Almost every conveyor design program calculates the stopping time for the conveyor based on control of the belt tension for optimizing the drive components. Instantaneous stopping, starting, or reversing of the belt can cause serious dynamic problems with the conveyor and accessories. Even on short conveyors, where dynamic concerns are not considered, it is common for a belt to take 5 seconds to come to a stop. On long systems, where dynamic issues are a concern, it is common for the conveyor to take 30 seconds to come to a stop. Simple reaction time for a person is usually defined as the time required for an observer to detect the presence of a stimulus. Given that the reaction time for the average person is approximately 0.2 seconds and that a conveyor belt will take time to stop, there is more than enough time to entrap a person in the conveyor.  

Therefore, it is highly likely that if a worker has violated the safety rules and/or systems and becomes entrapped, the conveyor cannot be stopped in time to prevent serious injury or death.  

### DOUBLE BENEFIT OF CONVEYOR SAFETY  

**In Closing...**  

Is it possible to eliminate accidents involving conveyors? Probably not. However, we can work toward zero accidents with a two-pronged approach:  

A. Training new-hires and veteran employees about how to work safely on and around belt conveyors  

B. Eliminating many of the problems that require the employee to work in close proximity to belt conveyors  

Bear in mind that the cost of one accident can easily exceed the cost of bringing a training program into the organization, or even the annual salary of a full-time training person.  

Providing training on conveyor operations and maintenance to improve conveyor safety has the potential to also improve operating results. In fact, training in safe conveyor operations provides the best of both worlds: It presents an opportunity to provide worker safety and simultaneously improve a facility’s operating efficiency.  

**Looking Ahead...**  

This chapter about Safety, the second chapter in the section about Foundations of Safe Bulk-Materials Handling, follows Total Material Control and explains how accidents can be caused by a lack of total material control. The next three chapters focus on Conveyors 101, beginning with Conveyor Components, followed by The Belt and, finally, Splicing the Belt.
REFERENCES


2.4 Ontario Natural Resources Safety Association. Safety Reminder, newsletter. P.O. Box 2040, 690 McKeeown Avenue, North Bay, Ontario, Canada, B1B 9PI Telephone: (705) 474-SAFE.


Chapter 3

CONVEYORS
101—CONVEYOR COMPONENTS

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Figure 3.1
The belt conveyor is the basic building block of bulk-materials handling.
In this Chapter

In this chapter, we describe the most common components of the belt conveyors used in handling bulk materials and provide an equation for calculating the power required to operate the conveyor belt. Three methods of designing transfer points are explained, along with the benefits of using a systems-engineering approach to aid in material control.

Belt conveyors have been used for decades to transport large quantities of material over long distances. Conveyors have proven time and time again that they are a reliable and cost-effective method for material movement. Belt conveyors can transport materials up steep inclines, around corners, over hills and valleys, across bodies of water, above ground, or below ground. Belt conveyors integrate well into other processes, such as crushing, screening, railcar- and ship-loading and unloading, and stockpile and reclaim operations.

Belt conveyors have shown the ability to transport materials that vary from large, heavy, sharp-edged lumps to fine particles; from wet, sticky, slurry to dry, dusty powder; from run-of-mine ore to foundry sand; from tree-length logs to wood chips, and even potato chips.

Of all materials-handling systems, belt conveyors typically operate with the lowest transport cost per ton, the lowest maintenance cost per ton, the lowest energy cost per ton, and the lowest labor cost per ton. These advantages may not be realized if careful consideration of the bulk material to be handled and of the overall process is not taken when specifying a conveyor system.

Many designs of conveyor systems are available. Many are developed to solve unique and difficult problems specific to a particular industry or bulk material. With any choice, certain design fundamentals can determine the success or failure in controlling the spillage or dusting of fugitive material.

This chapter will describe the most common components used in bulk-materials handling.

COMPONENTS OF A STANDARD CONVEYOR

The Basics

For many plants, the belt conveyor is the basic building block of bulk-materials handling (Figure 3.1). In essence, a belt conveyor is a large reinforced rubber band stretched around two or more pulleys, traveling at a defined rate of speed, carrying a specified quantity of material(s). Complications arise as the line of travel becomes inclined or curved, when the conveyor must be added into a sophisticated process or plant, or when it needs to meet material feed-rate requirements or other operational constraints.

A belt conveyor is a relatively simple piece of equipment (Figure 3.2). Its basic design is so robust that it will convey material under the most adverse conditions—overloaded, flooded with water, buried in fugitive material, or abused in any number of other ways. The difference, however, between a belt conveyor that is correctly engineered, operated, and maintained and a dysfunctional system usually becomes quickly apparent in the system’s operating and maintenance costs.

Common belt conveyors for bulk materials range in width from 300 millimeters (12 in.) to 3000 millimeters (120 in.), with belts 5000 millimeters (200 in.) wide seen in applications such as iron ore pellet plants. The conveyors can be any length. Cargo capacity is limited by the width and speed...
of the conveyor belt, with conveyors often moving several thousand tons of material per hour, day in and day out.

Every bulk-materials handling belt conveyor is composed of six major elements:

A. The belt
   Forms the moving surface upon which material rides

B. The pulleys
   Support and move the belt and control its tension

C. The drive
   Imparts power to one or more pulleys to move the belt

D. The structure
   Supports and aligns the rolling components

E. The belt-support systems
   Support the belt’s carrying and return strands

F. The transfer systems
   Load or discharge the conveyor’s cargo

Another part of every conveyor is the ancillary equipment installed to improve the system’s operation. This would include such components as take-ups, belt cleaners, tramp-iron detectors, skirtboards and seals, belt-support systems, plows, safety switches, dust-suppression and dust-collection systems, and weather-protection systems.

**Components of a Standard Belt Conveyor**

Although each belt conveyor is somewhat different, it shares many common components ([Figure 3.3](#)). A conveyor consists of a continuous rubber belt stretched between terminal pulleys. One end is the tail. This is usually where the loading of the cargo takes place, but loading may take place anywhere along the length of the conveyor, and conveyors with multiple load zones are relatively common. The other end of the conveyor is called the head. The cargo is usually discharged at the head, but with the use of plows or trippers, the load may discharge anywhere along the conveyor’s length.

The belt is supported along the top (carrying) side with flat or troughing rollers called idlers. Troughing rollers form the belt into a U-shape that increases the cargo capacity of the conveyor. On the bottom (return) side of the conveyor, where the belt returns to the loading point, the belt is supported with return idlers. The rolling components are mounted in frames and supported by a steel structure called the stringers. In some applications, such as underground or overland conveyors, the rolling components of the conveyor are mounted on suspended wire ropes.

**Figure 3.3**

Although each belt conveyor is somewhat different, all conveyors share many common components.
Usually electrically powered, conveyors’ drive motors are most often located to turn the conveyor’s head pulley. The motor(s) can be located at any point along the conveyor. Multiple motors are often used on long or heavily-loaded conveyors.

A tensioning device, called a take-up, is used to make sure that the belt remains tight against the drive pulley to maintain the required tension in the belt to move the belt and cargo. Most common is an automatic tensioning device referred to as a gravity take-up, which uses a counterweight to create tension in the belt. The gravity take-up is often installed near the drive pulley on the return side of the belt. Bend pulleys are used to direct the belt into the take-up pulley, which is attached to the counterweight of the gravity take-up.

Another type of pulley, called a snub pulley, is often placed immediately after the head pulley on the return side of the belt to increase the contact of the belt with this pulley, allowing a smaller drive pulley to transmit the required tension to the belt.

The cargo is usually loaded near the tail end in an area referred to as the loading zone. The components of the loading zone will likely consist of a loading chute, tail pulley, idlers, belt-support systems, skirtboards, wear liners, dust seals, entry seals, and exit seals.

A conveyor’s head, or discharge, end will usually consist of the head pulley, a discharge chute along with a belt-cleaning system, a dribble chute, and other equipment to monitor and maintain flow.

A transfer point is where the bulk material moves from one piece of equipment to another. A transfer point can be either a loading or discharge zone, or in the case where one conveyor is feeding another, one transfer point can contain both the loading and discharge zones. However, a transfer point could also be where a belt feeds another bulk-materials handling or processing system. These systems might be storage vessels of any type; cargo carriers such as trucks, railcars, barges, or ships; or other pieces of process equipment.

Depending on the conveyed material, a variety of other ancillary equipment may also be installed along the run of the conveyor or in the transfer point at either end.

**Conveyor Drive Power**

As discussed above, conveyors are driven by the attachment of a motor to the drive pulley. Determining the power requirement of the conveyor (that is, specifying the size of the motor required) is a question of the tension to drive the belt and the speed of the belt.

The sixth edition of Conveyor Equipment Manufacturers Association’s (CEMA) *BELT CONVEYORS for BULK MATERIALS* provides an equation, originally developed by Deutsches Institut für Normung (DIN), for determining the power requirement of a “Basic Conveyor.”

The factors with the largest influence on conveyor power requirements are the weight of the cargo and the amount of elevation the cargo must be lifted. Friction of the various conveyor components is normally a small part of the power requirement. When the belt is horizontal, this friction becomes the most important consideration. The tension is used to find the power required to operate the conveyor belt (Equation 3.1). The ∆T value is the sum of all positive and negative tensions in the system that must be transferred to the belt by the drive pulley to overcome the resistance of the components and transport the load. Each of the calculations for the component tension can be found in this book or in the sixth edition of CEMA’s *BELT CONVEYORS for BULK MATERIALS*. The tension added to lift the actual material and conveyor belt is calculated in CEMA’s *BELT CONVEYORS for BULK MATERIALS*.

Once the tension for each component is found, they can be added to arrive at
Section 1 | Foundations of Safe Bulk-Materials Handling

**Equation 3.1**

Calculation for Power Required

\[ P = \Delta T \cdot V \cdot k \]

**Given:** 5400 newtons (1200 lb.) of tension is added to a belt traveling at 3 meters per second (600 ft/min). **Find:** The power required to operate the conveyor belt.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Metric Units</th>
<th>Imperial Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P )</td>
<td>Power Required</td>
<td>kilowatts</td>
</tr>
<tr>
<td>( \Delta T )</td>
<td>Net Tension Added to the Belt</td>
<td>5400 N</td>
</tr>
<tr>
<td>( V )</td>
<td>Belt Speed</td>
<td>3 m/s</td>
</tr>
<tr>
<td>( k )</td>
<td>Conversion Factor</td>
<td>1/1000</td>
</tr>
</tbody>
</table>

Metric: \( P = \frac{5400 \cdot 3}{1000} = 16 \) kW

Imperial: \( P = \frac{1200 \cdot 600}{33000} = 22 \) hp

or to its structure, decreasing its operating efficiency. If material is allowed to escape, this fugitive material will cause numerous maintenance problems, again leading to reduced production efficiency and increased operating and maintenance costs.

**The Value of the Conventional Conveyor**

There are a variety of advanced conveyor systems that provide alternatives for material handling. (See Chapter 33: Considerations for Specialty Conveyors.) For general purposes, the conventional troughed-idler belt conveyor is the performance standard and the value leader against which these other systems must be evaluated. Troughed-idler belt conveyors have a long history of satisfactory performance in challenging conditions.

The overall success of a belt conveyor system greatly depends on the success of its transfer points. If material is loaded poorly, the conveyor will suffer damage to the belt, to its rolling components, and/or to its structure, decreasing its operating efficiency. If material is allowed to escape, this fugitive material will cause numerous maintenance problems, again leading to reduced production efficiency and increased operating and maintenance costs.

**TRANSFER POINTS: PROBLEMS AND OPPORTUNITIES**

**The Challenge of the Transfer Point**

A typical transfer point is composed of metal chutes that guide the flow of material (Figure 3.4). It may also include systems to regulate the flow, to properly place the flow within the receiving structure (whether belt, vessel, or other equipment), and to prevent the release of fugitive material.

Transfer points are typically installed on conveyors for any or all of the following reasons:

A. To move the material to or from storage or process equipment
B. To change the horizontal direction of the material movement
C. To divert the flow to intermediate storage
D. To allow effective drive power over a distance that is too long for a single conveyor

The method and equipment for loading the belt contribute much toward prolong-
ing the life of the belt, reducing spillage, and keeping the belt running in the proper path. The design of chutes and other loading equipment is influenced by conditions such as the capacity, the characteristics of material handled, the speed and inclination of the belt, and the number of loading zones on the conveyor.

To minimize material degradation and component wear, an ideal transfer point would place the specified quantity of material on the receiving belt by loading:

A. In the center of the belt  
B. At a uniform rate  
C. In the direction of belt travel  
D. At the same speed as the belt is moving  
E. After the belt is fully troughed  
F. With minimum impact force

At the same time, it would provide adequate space and/or systems for:

A. Edge sealing and back sealing  
B. Carryback removal  
C. Fugitive material management  
D. Inspection and service

But in Real Life…

Achieving all these design goals in a single transfer-point design is difficult. The accommodations required by actual circumstances are likely to lead to compromises. The loading point of any conveyor is nearly always the single most critical factor in the life of the belt. It is here where the conveyor belt receives most of its abrasion and practically all of its impact. It is at the conveyor transfers where the forces that lead to spillage or dust creation act on the material and the belt. An optimal transfer point is essential to the conveyor’s throughput and control of fugitive material (Figure 3.5).

The problem is that transfer points are the center for the interaction of many and often conflicting requirements, some arising from the materials passing through and others from the belts that run into and out of the load zones. Material characteristics, air movements, and impact levels add forces that must be addressed by any system designed to prevent the escape of fugitive material. In addition, many requirements imposed by the plant’s overall process will subject transfer points to additional forces and limitations.

The Engineering of Transfer Points

There are three basic approaches taken to the design of transfer points. The first and most common is the conventional method of drafting a solution using “rules of thumb” to fit the master layout of conveyors. This would be the drafted solution (Figure 3.6). The second method is to specify the critical components of the transfer point and design the overall conveyor layout to minimize transfer-point problems. This is the specified solution (Figure 3.7).
The third method is an engineered solution. This method is used to analyze the characteristics of the bulk material and produce custom-engineered chutes, which minimize the disruption of the bulk material trajectory and place the material on the next belt in the proper direction and at the speed of the receiving belt. This third class of transfer points is typified by specifications that require the bulk material to be tested for its flow properties. The transfer of material from one belt to another is engineered using fluid mechanics to minimize the dust, spillage, and wear. This engineering can be done for new construction, or it can be done as re-engineering for existing transfer points (Figure 3.8).

Specifications for an engineered transfer point should include:

A. Material characteristics and flow rates
B. Minimum performance requirements in terms of hours of cleanup labor and/or amount of spillage per hours of operation
C. Maximum budget requirements for annual maintenance and periodic rebuild at supplier-specified intervals
D. Ergonomic requirements of access for cleanup and maintenance
E. Engineering drawings and specifications for wear parts as well as complete maintenance manuals

SYSTEMS ENGINEERING

One Step Forward, One Step Back...

Unfortunately, improving the operation of complex systems like conveyor transfer points is not a question of solving one narrowly-defined problem. Rather, the attempt to solve one problem in these sophisticated operating systems typically uncovers or creates another problem. This second problem can prove as difficult to solve as the original, if not more.

It is never easy to achieve total material control, because fugitive materials problems often combine multiple causes and multiple effects. For example, a new edge-sealing system may provide an immediate improvement in the prevention of material spillage from a transfer point. However, if there is no wear liner present inside the chute, the force and/or the weight of material on the skirting will create side pressure that abuses the new seals, leading to abrasion and premature failure. Eventually, the amount of spillage returns to its previous unacceptable level. Spillage will continue to extract its high price from the efficiency of the conveyor and the overall operation.

The Systems Approach

The key to any engineering improvement is a detailed solution that encompasses all components of the problem. The costs of undertaking such a systems approach will prove higher than those of upgrading any single component. However, the return on investment will justify the expense.

Talking “systems engineering” is easy; it is the application of this approach that proves difficult. Development of a comprehensive approach requires knowledge of the material; understanding of the process;
commitment of the resources to properly engineer, install, and operate a system, and consistent maintenance to keep that system operating at peak efficiency and to achieve total material control.

In Closing...

Belt conveyors handling bulk materials are simple machines, governed by the universal laws of physics. However, they are also complex, as they are vulnerable to a variety of uncertainties arising from the large quantities of otherwise unconfined material moving through them and the energy they impart to that material. Poorly contained, this material in motion can spread across a facility as spillage, carryback, and dust, reducing efficiency, shortening equipment life, and raising costs. Understanding the basics of material properties and equipment performance, and applying the remedies discussed in this book, can provide significant improvements in materials-handling efficiency and profitability.

Looking Ahead...

This chapter about Conveyor Components, the third chapter in the section Foundations of Safe Bulk-Materials Handling, is the first of three chapters pertaining to Conveyors 101. Chapters 4 and 5 continue this section about the basics of belt conveyors and the control of material for reduced dust and spillage, describing The Belt and Splicing the Belt.

REFERENCES

3.1 Any manufacturer and most distributors of belting can provide a variety of materials on the construction and use of their specific products, as well as on conveyor belts in general.


3.3 The website http://www.conveyor-beltguide.com is a valuable and non-commercial resource covering many aspects of belting.
Chapter 4

CONVEYORS
101—THE BELT

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Figure 4.1
Conveyor belts are key factors in the overall productivity of the entire plant.
In this Chapter...

This chapter continues the discussion of the foundations of safe bulk-materials handling and the basics of conveyors by focusing on the construction and proper use of belts. Considerations for belt selection are included, along with the importance of proper storage and handling. In addition, various types of belt damage are discussed, as well as methods to repair and preserve the life of the belt.

A belt conveyor system is composed of many components; however, none is more important than the belt (Figure 4.1). The belting represents a substantial portion of the cost of the conveyor, and its successful operation may be the key factor in the overall productivity of the entire plant in which the conveyor is located. Therefore, the belting must be selected with care, and all possible measures should be employed to safeguard its usefulness.

This chapter focuses on the heavy-duty belting typically used in bulk-materials handling. The most common types of belting for bulk handling are made with covers of rubber or polyvinyl chloride (PVC) and an internal tensioning carcass of synthetic fabric or steel cables.

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**PLANT SAFETY AND BELTING**

**Conveyor Belt Fire Resistance**

A conveyor belt fire is a significant risk. The belting itself can burn; however, it is the length and movement of the belt that poses risks that a belt can spread a fire over a great distance within a facility in a very short time.

Fires on conveyor belting are most commonly ignited by the heat generated from friction induced by a pulley turning against a stalled (or slipping) belt or by the belt moving over a seized idler. Other conveyor fires have occurred when hot or burning material is inadvertently loaded onto the belt. Best practices for minimizing the fire risk of any conveyor belt include:

A. Conducting regular belt examinations
B. Removing all accumulations of combustible materials along the conveyor belt
C. Correcting potential sources of fire such as seized rollers, overheated bearings, or belt misalignment

With this risk of fire, compounded by the toxic gases, thick smoke, and noxious fumes that can result from a conveyor fire, belting is regulated in those applications where

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**SAFETY CONCERNS**

As with any moving machinery, the conveyor belt must be treated with respect and with the knowledge that it does cause injuries. There are a number of risks for personal injury from the conveyor belt that can lead to death or serious injury. Most of these concerns arise from the movement of the belt through the conveyor systems, such as contact burns and the risk of entrapment from contact with the moving belt. Particular care should be taken when observing a moving belt to look for damaged areas or check its tracking.

Rolls of belting are large and unwieldy and should be handled carefully. When transported, they should be secured so they cannot break loose, and they should be maneuvered with the appropriate equipment and safeguards.

Repairing a belt exposes workers to heavy lifting, sharp tools, and industrial chemicals. Appropriate lockout / tagout / blockout / testout procedures should be followed before beginning any work on or around the conveyor.

Appropriate PPE must be used, and manufacturers’ procedures for handling chemicals must be followed.
these conditions are most dangerous—underground mining and, particularly, underground coal mining. Many countries replaced the earlier requirement for flame-retardant belting, belting that passes a smaller Bunsen Burner Test, by mandating the use of self-extinguishing belting in underground applications.

It should be noted that ALL conveyor belts will burn given sufficient heat and airflow. However, standardized laboratory tests have been accepted by governmental regulatory bodies to measure and categorize the burning characteristics of different conveyor belts. In very general terms, “self-extinguishing” is considered to be a belt that will not propagate a fire in a laboratory setting once the ignition source has been removed.

Self-extinguishing belting is higher in cost than flame-retardant belting. This cost premium is generally 10 to 50 percent, but it will vary depending on the carcass construction and cover gauges.

With the exception of the United States, fire-safety standards for conveyor belting are similar in the largest coal mining countries, including Australia, Canada, China, Germany, India, Indonesia, Poland, Russia, and South Africa. In Germany, for instance, strict requirements were implemented more than 30 years ago.

There are numerous international regulatory and advisory organizations and governmental agencies that provide guidance and direction. Those agencies include, but are not limited to: British Standards Institution (BSI), Conveyor Manufacturers Equipment Association (CEMA), Deutsches Institut für Normung (DIN), European Standards (EN), and the International Organization for Standardization (ISO).

The tests in these and most other countries include:

A. Drum Friction Test (DIN 22100 et. al)

The drum friction test measures whether the surface temperature remains under a required maximum after a specific time and under a specific tension. The test procedure simulates a belt slipping over a jammed pulley or a pulley rotating under a stationary conveyor belt. To pass this test, the surface temperature of the belting must remain below 325 degrees Celsius (617° F) with no flame or glow visible.

B. Surface Resistance Test (ISO 284/EN 20284/DIN 20284)

An electrostatic charge may build up on the conveyor belt surface and ignite a mixture of flammable gases and air. By keeping the surface resistance of the belting low (making the belt cover more conductive), the conveyor belt allows the charge to flow freely, eliminating the risk of sparks.

C. High-Energy Propane Burner Test (EN 12881)

To determine whether a conveyor belt will propagate fire, a belt sample 2.0 to 2.5 meters long by 1200 millimeters wide (80 to 100 in. by 48 in.) is ignited by a propane burner. After the ignition source has been removed, the flames must self-extinguish within a certain amount of time, leaving a defined area of belt undamaged.

D. Laboratory Scale Gallery Test (DIN 22100 and 22118)

A specimen of belting 1200 millimeters long by 120 millimeters wide (48 in. by 4.8 in.) is placed over a propane burner. After the ignition source is removed, the flames must self-extinguish, and a defined undamaged length must remain.

In the United States, conveyor belt flammability standards can be considered less stringent than those used in other countries, because a total-system approach is taken to fire suppression. The US regulations include not only conveyor belting but air monitoring and motor-slip detection devices.
The present flame resistance requirement in the United States for applications for everything except underground coal mines, as published in the Code of Federal Regulations (CFR), is quite simple:

**Bunsen Burner Test. (CFR Part 30 Section 18.65)**

A small (approximately 150 by 12 millimeters) (6 by ½ in.) piece of a belt is held over a Bunsen burner flame for one minute, after which time the flame is removed and an airflow applied for three minutes. After a set length of time, the duration of the flames is recorded. The average of four samples must not burn for more than one minute or exhibit afterglow for more than three minutes.

This test, which was implemented per the 1969 Federal Coal Mine Health and Safety Act, is similar to a standard for underground conveyor belts that was in force in Europe until the mid 1970's. However, with the advent of the more stringent regulations, flame-retardant belts have been allowed to be used in Europe only in applications above ground; self-extinguishing belts are required underground.

The United States now has a more stringent standard for flame-resistant belts in underground coal mines. In December 1992, the US Department of Labor, Mine Safety and Health Administration (MSHA), proposed a new rule for conveyor belt test requirements (Federal Register, Vol. 57, No. 248) that would bring safety standards up to the international level. Nearly ten years later, in July 2002, this proposed rule was withdrawn. The reasons cited for withdrawal were that the number of conveyor belt fires had significantly declined and that improvements in belt monitoring were being implemented.

Recommendations from the Mine Improvement and New Emergency Response (MINER) Act of 2006 resulted in a new rule for underground coal mines (CFR Part 30 Section 14.20) effective December 2008 that includes the Belt Evaluation Laboratory Test (BELT), a laboratory-scale flame resistance test based on the work done for the 1992 proposed rule. In order for a belt to pass the BELT method, it must have improved fire-resistant capability, which greatly limits flame propagation.

The test requires that three belt samples, approximately 152 by 23 centimeters (60 by 9 in.), be placed in a test chamber 168 centimeters (66 in.) long by 456 centimeters (18 in.) square. After applying the burner flame to the front edge of the sample for 5 minutes and the flame is extinguished, each tested sample must exhibit an undamaged portion across its entire width.

At the time of this writing, the final rule published by MSHA requires conveyor belts placed in service in underground coal mines to be more flame resistant than those previously required beginning December 31, 2009. The rule also requires existing belting to be replaced within ten years. MSHA or a reputable belting supplier can be contacted for additional, updated information.

**Other Belting Safety Concerns**

Other standards are sometimes in place. Some countries have even more stringent requirements regarding, for example, the belt’s toxicity, hygiene, or cover roughness. The exact specifications can be found in the standards in a given geographic region or industry. Procedures and standards are offered under DIN, EN, ISO, BSI, CEMA, and other standards. Of course, it is imperative that the belting be compatible with the materials to be transported on it.

**BELT CONSTRUCTION**

**The Belt Carcass**

Conveyor belting is composed of two parts: the inside carcass and the outside covers. The carcass is the most important structural section of the belt, as it contains the tensile member to handle the load of cargo carried on the conveyor. The primary purpose of the carcass is to
transmit the tension necessary to lift and move the loaded belt and to absorb the impact energy unleashed by the material as it is loaded onto the belt. No matter what belt-support system is employed, if the belt carcass cannot handle the initial impact energy, the belt will fail prematurely. The carcass must be adequate to allow proper splicing techniques and strong enough to handle the forces that occur in starting, moving, and stopping the loaded belt. The carcass also provides the stability necessary for proper support between idlers and for maintaining alignment.

Most carcasses are made of one or more plies of woven fabric, although heavy-duty belting may incorporate parallel steel cables to replace some or all of the fabric. Carcass fabric is usually made of yarns woven in a specific pattern. The yarns that run lengthwise, parallel to the conveyor, are referred to as warp yarns and are the tension-bearing members. The transverse or cross fibers are called weft yarns and are primarily designed for impact resistance, mechanical fastener holding, load support, and general fabric stability.

Years ago, conveyor belts typically used yarns made of cotton as the textile reinforcement. For improved cover adhesion and abuse resistance, a breaker fabric was often placed between the cover and the carcass. Throughout the 1960s and 1970s, carcass reinforcements underwent a change. Today, most belt carcasses are made with manmade fabrics such as nylon, polyester, or a combination of the two. These fabrics are superior to the older natural fabrics in nearly all respects, including strength, adhesion, abuse resistance, fastener holding, and flex life. Presently, fabrics incorporating aramid fibers are used for some applications in conveyor belting. The aramid fabrics offer high strength, low elongation, and heat resistance. Breaker fabrics are rarely used with these man-made fabrics, because little or no improvement is achieved.

### Carcass Types

There are four types of belt carcasses:

**A. Multiple-ply belting**

Multiple-ply belting is usually made up of two or more plies, or layers, of woven cotton, rayon, or a combination of these fabrics, bonded together by an elastomer compound. Belt-strength and load-support characteristics vary according to the number of plies and the fabric used. The multiple-ply conveyor belt was the most widely used belt through the mid-1960s, but today it has been supplanted by reduced-ply belting.

**B. Reduced-ply belting**

Reduced-ply belts consist of carcasses with either fewer plies than comparable multiple-ply belts or special weaves. In most cases, the reduced-ply belt depends on the use of higher-strength synthetic textile fibers concentrated in a carcass of fewer plies to provide higher unit strength than in a comparable multiple-ply belt. The technical data available from belt manufacturers generally indicate that reduced-ply belting can be used for the full range of applications specified for multiple-ply belting.

**C. Steel-cable belting**

Steel-cable conveyor belts are made with a single layer of parallel steel cables completely embedded in the rubber as the tension element. The carcass of steel-cable belting is available in two types of construction. The all-gum construction uses only the steel cables and rubber; the fabric-reinforced construction has one or more plies of fabric above and/or below the cables but separated from the cables by the cable rubber. Both types have appropriate top and bottom covers. Steel-cable belting is produced using a broad range of cable diameters and spacing, depending primarily on the desired belt strength. Steel-cable belting is often used in applications requiring operating tensions beyond the range of fabric belts. Another
application is on conveyors where, due to limitations in the distance the take-up system can travel, the belting cannot be allowed to stretch significantly.

D. Solid-woven belting

This type of belting consists of a single ply of solid-woven fabric, usually impregnated and covered with PVC with relatively thin top and bottom covers. The surface of PVC belts is often rough on purpose to aid in conveying on inclines, but the rough surface makes belt cleaning more difficult. The abrasion resistance of PVC is lower than rubber, so some solid-woven belts are made with a combination of a PVC core and rubber covers.

Top and Bottom Covers

Covers protect the carcass of the belt from load abrasion and any other conditions that could contribute to belt deterioration. The top and bottom covers of the conveyor belt provide very little, if any, structural strength to the belt. The purpose of the top cover is to protect the carcass from impact damage and wear. The bottom cover provides a friction surface for driving and tracking the belt. Usually, the top cover is thicker than the bottom cover and more durable for abrasion, impact damage, and wear, due to its increased potential for damage. Abrasion and cutting may be so severe that a top cover as thick as 18 millimeters (0.75 in.) or more is required. In any case, the goal of cover selection is to provide sufficient thickness to protect the carcass to the practical limit of carcass-life.

The covers can be made of a number of elastomers, including natural and synthetic rubbers, PVC, and materials specially formulated to meet special application requirements such as resistance to oil, fire, or abrasion.

Users might be tempted to turn a belt over when the carrying side has become worn. In general, it is better to avoid inverting the belt after deep wear on the top side. Turning the belt over presents an irregular surface to the pulley, resulting in poor lateral distribution of tension, and may lead to belt wander. Another problem is that there may be cargo fines embedded into what was formerly the belt’s carrying surface; when the belt is turned over, this material is now placed in abrasive contact with pulley lagging, idlers, and other belt-support systems. In addition, after years of being troughed in one direction, the belt tends to take a “set” (a predisposition to a direction) and will resist the necessary reversing of trough needed to invert the belt. Sometimes this can take weeks to overcome and can lead to belt-tracking problems.

A specific mention must be made of the practice of some belting manufacturers of stamping their logo into the carrying surface of the belt (Figure 4.2). Even when near the belt edge, this recessed area becomes a trap for conveyed material, and the roughness of the area can abuse the belt-cleaning and sealing systems under which the embossed area will pass. It is recommended that users specify that these supplier logos be positioned on the return, non-carrying side of the belting.

Aspect Ratio

Whereas some belts have the same cover thickness on both sides, most belts are fabricated with the pulley-side cover somewhat thinner (lighter in gauge) than the carrying side of the belt, because of the difference in wear resistance needed. The difference in thickness between the top and bottom covers is referred to as a belt’s aspect ratio. However, the difference in thickness between the two covers cannot be too great, or the belt may cup.
The problem with belts with poorly-designed aspect ratios is that the larger mass of rubber will shrink more than the smaller. Consequently, if a belt has an inordinately large top-to-bottom cover ratio, and the top cover shrinks due to age, exposure to ultraviolet light, or other factors, the belt will cup up, reducing the area of the bottom cover in contact with the idlers. This will make it more difficult to keep the belt running in alignment. This problem is most likely to occur when, in the interest of getting a thick top cover to extend service-life, a plant orders belting with a top cover that is too thick for the bottom cover. To provide consistent shrinkage and more consistent tracking, an aspect ratio of 1.5-to-1 is recommended for belts up to 900 millimeters (36 in.), with a 2-to-1 aspect ratio recommended for belts from 1000 to 1600 millimeters (42 to 60 in.). For belts above 1600 millimeters (60 in.) a 3-to-1 aspect ratio is recommended. Belting with a 3-to-1 aspect ratio is suitable for many purposes and is the ratio mostly commonly stocked at belting distributors.

Cleats, Ribs, Chevrons, and Lugs

Raised elements are sometimes used on a belt surface to assist in the carrying of material (Figure 4.3). These cleats, ribs, chevrons, and lugs are generally used to allow a conveyor to carry material at a higher angle of incline than would generally be possible with a flat belt. This is particularly useful with lumps or stones that could easily roll down an unobstructed incline.

Cleats, or ribs, can be seen as walls or shelves installed perpendicular to the lines formed by the belt edges. Chevrons are in a V-shaped arrangement. Lugs are individual “islands” or pillars in the belt’s surface. All are available in a variety of patterns and styles, with heights determined by the application. They can be molded integrally into the surface during the belt’s original manufacture, or they can be bolted or vulcanized to the surface of the belt.

Bear in mind that the taller the cleats, ribs, chevrons, or lugs are, the more vulnerable they are to damage and the harder the belt is to clean and seal.

One way to increase traction between the belt and the conveyed material is to use a top cover that features inverted chevrons. Instead of extending above the belt cover, inverted chevrons are recessed into the top cover, like the tread on a tire. The grooves are cut into the belt cover with a router; the grooves can be at a chevron angle or straight across the belt 90 degrees to the edge. This design allows greater success in cleaning and sealing the belt with traditional systems, although it is possible to fill the recessed cleats with material.

Grades of Beltimg

Various national and international bodies have established rating systems for the belting used in general-purpose bulk-materials handling. Designed to provide a reference for end users as to what grades to use in different applications, the ratings specify different laboratory-test criteria without providing any guarantee of performance in a specific application.

In the United States, the Rubber Manufacturers Association (RMA) has established two standard grades of belting covers. RMA Grade I belting meets higher rubber tensile and elongation requirements, typically indicating improved cut and gouge resistance over the performance of Grade II covers. It should be noted that grade rating does not necessarily denote overall abrasion resistance.
The International Organization for Standardization (ISO) has similarly established a grading system under ISO 10247. This standard includes Category H (Severe Cut and Gouge Service), Category D (Severe Abrasion Service), and Category L (Moderate Service). Category H is roughly comparable to RMA Grade I; Categories D and L approximate RMA Grade II belting.

In addition, there are belting types manufactured to meet specific requirements of stressful applications, such as service with hot materials, in underground mines, or with exposure to oil or chemicals. As with most things, it is best to acquire an understanding of the operating conditions and then consult with reputable suppliers before selecting categories of belting.

**Abrasion Resistance in Belting**

There are two types of abrasion that occur on conveyor belts. One is caused by the material rubbing against the belt cover. As a woodworker sanding an object, this wear is relatively even under the influence of the material pressing against the surface. The actual rate of abrasion will depend on the nature of the material, as modified by the density of material loading and the speed of the belt. This is called impingement damage.

A more aggressive form of abrasion is the damage to the surface by sharp-edged materials that cut or gouge the belt. This is generally called impact damage.

There are two types of tests used to measure belt-cover wear. One is the ISO 4649 Types A and B Abrasion Test Methodology (formerly DIN 53516). This test uses a sample of the rubber cover and holds it against a rotating abrasive drum for a fixed interval. The cover sample is weighed before and after to calculate volume loss. The lower the number (the less material lost), the more resistance to abrasion.

A second method of testing is the Pico Abrasion Test, also referred to by the American Society for Testing and Materials (ASTM) as ASTM Test Method D2228. In this test, tungsten carbide knives are used to abrade a small sample of the belt cover. As above, the sample is weighed before and after the procedure, and the weight loss is calculated. Results are given as an index, so the higher the number, the better the abrasion resistance.

Most references caution that neither test should be seen as a precise prediction of actual performance in field applications.

**New Developments in Belting**

A recent innovation is the development of energy-efficient belt covers. Called Low Rolling Resistant (LRR) Covers, these bottom covers reduce the tension required to operate the belt, because there is less roller indentation resistance as the belt moves over the idlers. According to manufacturers, this belting can produce operating energy consumption savings of 10 percent or more. The savings occur where the rubber belting meets the conveyor system’s idlers. The energy-efficient cover has less rolling resistance, because the bottom cover returns to a flat configuration more quickly than conventional belts, which deform as they go over the conveyor’s rolling components.

The manufacturers note that the benefits of this energy-efficient cover can best be realized on long horizontal conveyors utilizing wide, fully-loaded belts carrying high-density material, where the friction of the system is dominated by idler-related resistances. The LRR compound is at a premium cost over other cover compounds. However, on those installations where the benefits can be fully realized, the compound compensates for its additional expense through a reduction in power costs and, on new systems, by allowing the conveyor to be equipped with smaller motors, pulleys, gear boxes, shafts, bearings, idlers, and steel structures.

Users cannot assume that an LRR cover will reduce operating expenses, nor can they just specify LRR, as each belt is...
compounded for a specific application. The relationship between the power consumption with an LRR belt and temperature conditions is not linear, and there is typically a small window of application. A specific LRR bottom cover designed to save energy at 20 degrees may cost more to operate at 0 or 30 degrees, so each belt must be designed for the climate conditions of each application.

Another new development in belt construction is the use of non-stick belt covers, to prevent belt-borne carryback. This belting is created by applying a non-stick coating to the belt to prevent the accumulation of carryback material on the belt. This coating should reduce the need for belt cleaning, thereby extending belt-life by reducing cover wear. This coating is also resistant to oil and grease and unaffected by weathering and aging. It should be noted that conventional belt cleaners (scrapers) should be removed if using non-stick belting, as the “cleaning edge” of even “soft” urethane pre-cleaners might remove the coating.

Conveyors are designed as a system, and any changes from the original belt specification can adversely affect the operation of a conveyor. Belting manufacturers should be consulted to determine which belting type is most appropriate for any application.

Cut Edge or Molded Edge

There are two methods to create the edges on a belt: molded edges or cut edges.

A molded-edge belt is manufactured to the exact width specified for the belt, so the edges of the belt are enclosed in rubber. As a result, the carcass fabrics are not exposed to the elements. Because a molded-edge belt is made for a specific order, it will probably require a longer lead-time and is generally more costly than a cut-edge belt.

A cut-edge belt is manufactured and then cut or slit down to the specified width required to fulfill the order. Using this method, the manufacturer may hope to fill two or three customer orders out of one piece of belting produced. As a result, this makes cut-edge belting more cost-effective (hence economical) to manufacture, so this type of belt has become more common. The slitting to the specified width may occur at the time of manufacture, or it may be done when a belt is cut from a larger roll in a secondary operation, either at the manufacturer or at a belting distributor.

A cut-edge belt can be cut down from any larger width of belting. This makes it more readily available. However, there are some drawbacks. At the cut edge(s) of the belt, the carcass of the belt is exposed; therefore, the carcass is more vulnerable to problems arising from abusive environmental conditions in storage, handling, and use. In addition, the slitting process is vulnerable to problems. Dull slitting knives can lead to problems such as belt camber—a curve in the edge of the belt. In addition, there are the unknowns that come with buying used or re-slit belting, including its age, environmental exposure, and application history.

Steel-cable belting is manufactured to a pre-determined width, so it has molded edges. Fabric-ply belting is available with either a molded edge or a cut edge.

**BELT SELECTION**

**Specifying a Belt**

The selection and engineering of the proper belting is best left up to an expert, who might be found working for a belting manufacturer or distributor or as an independent consultant. A properly specified and manufactured belt will give optimum performance and life at the lowest cost. Improper selection or substitution can have a catastrophic consequence.

There are a number of operating parameters and material conditions that should
be detailed when specifying a conveyor belt. Material conditions to be detailed include:

A. Thickness
   Limit variations in thickness to a sliding scale of \( +/- 20 \) percent for thin covers such as 2,4 millimeters (0.094 in.), and \( +/- 5 \) percent for cover gauges greater than 19 millimeters (0.75 in.).

B. Camber or bow
   Limit camber or bow to one-quarter of one percent (0.0025). This allows a camber or bow dimension of \( +/- 25 \) millimeters in 10 meters (0.75 in. in 25 feet). Camber is a convex edge of the belt; bow is a concave edge of the belt. RMA defines bow (and camber) as the ratio of the distance, midway between two points along the belt edge that are 15 to 30 meters (50 to 100 feet) apart, between the actual belt edge and a tape or string stretched straight between the two points. To express this in percent, calculate the ratio in hundredths and multiply by 100. For example, if 30 meters of belting was out of true by 450 millimeters (by 0.45 meters), this would equal a camber of 1.5 percent. In Imperial measurements, a distance of 18 inches (1.5 ft) over 100-foot length of belting would be a 1.5 percent camber.

C. Belt surface
   Specify the belt surface to be smooth, flat, and uniform \( +/- 5 \) hardness points. Hardness is measured in the United States in Shore A Durometer. Readings range from 30 to 95 points—the higher the durometer number, the harder the compound. The International Rubber Hardness Degrees (IRHD) scale has a range of 0 to 100, corresponding to elastic modulus of 0 (0) and infinite (100), respectively.

D. Manufacturer’s mark
   Require the manufacturer’s mark to be eliminated or molded into the bottom rather than the top cover, where it will not interfere with belt cleaning and sealing systems.

Operating parameters to be detailed when specifying a conveyor belt include:

A. Hours of operation loaded and unloaded
B. Details of the transfer point, including trough angle and transition distance, as well as information on material trajectory, drop height, and speed
C. Description of material to be handled as completely as possible, including lump sizes and material temperature range
D. Description of belt-cleaning system to be used
E. Description of chemical treatments (e.g., de-icing agents or dust suppressants) to be applied
F. Description of atmospheric contaminants (from nearby processes or other sources)
G. Specification of local weather extremes that the belt must withstand

Know Your Structure, Know Your Belt

Placing any belt on a conveyor structure without understanding the characteristics of the belt will impair the performance of the system and reduce the performance of the belt. There can be problems in the form of mistracking, shortened belt-life, damaged splices, unscheduled downtime, and added maintenance expenses.

A detailed analysis of the conveyor structure and rolling components is required to ensure that the belt used on the system is the right choice. It is recommended that all parameters be fully understood prior to selecting and installing a belt on an existing structure. It is always wise to consider the advice of belting suppliers.

Compatibility with Structure and Rolling Components

Buying belting is like buying clothing. To fit best, it must be tailored to the existing
Conveyor belts are designed for different capacities, lengths, widths, trough angles, and tensions. A belt must be compatible with the conveyor structure, and there is more to compatibility than belt width.

Unfortunately, this is not commonly understood at a plant’s operating level. Too often, there is a “belting is belting” philosophy in place. This originates from an incomplete understanding of the complexity of the belting equation. This philosophy becomes practice at times when there is a need to economize or to provide a faster return to service. The typical response in these cases is to use belting from stock, either a leftover piece or a spare belt found in maintenance stores, or to use belting readily available from an outside source, like a belting distributor or a used-equipment dealer.

It is a false economy to use a “bargain” belt that is not fully compatible with the conveyor system. Incompatibility of belt to structure is a common problem leading to poor belt performance and a poor return on the belting investment. This incompatibility could well be the most common cause of the tracking problems seen on conveyors where a replacement belt has been installed or pieces have been added to the existing belting. Understanding the basics of compatibility is essential to ensuring good performance of the belt and conveyor.

Specifying a conveyor belt is an important undertaking. It is in an operation’s best interest to allow an expert to take ownership of this part of the conveyor process. This expert will be familiar with the capabilities of the belts provided by manufacturers and know the proper questions to ask.

Belt-Tension Rating

Each belt is rated as to its strength—the amount of pulling force that it will withstand. The strength of a belt (or more accurately, the tension it is able to withstand) is rated in the United States in Pounds per Inch of Width, commonly abbreviated as PIW. In other parts of the world, the belt is rated in ultimate breaking-strength in the metric units of newtons per millimeter (N/mm) or kilonewtons per meter (kN/m).

The strength rating is a function of the reinforcement included in the carcass of the belt and the number of, and type of, material in the fabric plies, or, if it is a steel-cable belt, the size of the cables. As noted above, a belt’s top and bottom covers provide very little of the belt’s strength or tension rating.

The belt’s strength, either carcass tension rating or ultimate breaking-strength, represents the amount of force that can be applied to the belting. Putting greater demands in the form of material load, take-up weight, and incline gravity against this belt would cause severe problems, including the possibility of breaking the belt. The higher the rated tension of the belt, the more critical the compatibility of the belt with the structure and rolling components becomes.

Each conveyor structure will require a belt with a specific tension rating. Factors affecting this decision are:
A. Length of structure
B. Incline angle of the conveyor
C. Desired capacity
D. Width of belt
E. Drag and inertia of rolling components

Minimum Bend Radius

Belting is designed with a minimum pulley size specified by the manufacturer. Bending a belt over a radius that is too small can damage the belt. This may result in separation of plies, ply failure, or cracking of the belt’s top cover. Inadequate pulley size can also lead to the pullout of mechanical splices. The minimum pulley diameter is determined by the number and material of plies, whether steel or fabric-reinforced, the rated tension of the belt, and the thickness of the top and bottom cover.
When a conveyor system is originally designed, the desire to use a thicker belt on a conveyor system (to extend belt-life in the face of high impact levels in the loading zone, for example) may require the installation of larger-diameter pulleys.

A common mistake occurs when an operation notices some type of surface damage to the carrying side of the belt. The immediate reaction is to install an even thicker belt on the conveyor in the expectation of getting a longer service-life. If the thicker belt has a minimum pulley size that is larger than the pulleys on the structure, the belt may actually yield a shorter life, worsening the problem the thicker cover was selected to solve.

**Trough Angle**

Belts are troughed to allow the conveyor to carry more material. As the trough angle is increased, more material can be carried. All flat rubber or PVC belts can be formed into a trough by idlers. The type of belt carcass, the thickness of the belt, the width of the belt, and the tension rating of the belt determine the maximum trough angle. On belting manufacturers’ technical data sheets, troughability is typically shown as the minimum belt width allowed for the various trough angles.

Exceeding the maximum trough angle of a particular belt can cause the belt to permanently deform into a cupped position. Cupping can make a belt difficult to seal, difficult to clean, and almost impossible to track. As the cupping increases, the surface contact between the conveyor’s rolling components and the belt is reduced, diminishing the ability of the rolling component to steer the belt properly.

If the belt’s troughability is exceeded, the belt may not form the trough correctly, creating sealing and tracking problems. If a belt is too stiff and will not properly trough, it will not steer (track) properly through the system. This will quickly evolve into spillage off the sides of the conveyor and damage to the edges of the belt (Figure 4.4).

Another problem that may occur if the belt’s troughing capability is exceeded is damage to the top and bottom covers and to the carcass in the idler-junction area.

In addition, if the belt’s troughability is not compatible with the troughing idlers, it might take more power to operate the conveyor than originally designed.

**Transition Distance**

The belt travels across the tail pulley in a flat position. As the belt leaves the tail pulley and moves into the loading zone, the belt edges are elevated, forming the trough (Figure 4.5). Exceeding its troughing capability can result in damage to the belt. (Figure 4.4)

Transition idlers are used to raise the belt edges and form the trough that carries the cargo. (Figure 4.5)

Figure 4.4
Exceeding its troughing capability can result in damage to the belt.

Figure 4.5
Transition idlers are used to raise the belt edges and form the trough that carries the cargo.

Figure 4.6
Junction-joint failure is caused by an improper transition distance (center of terminal pulley to first full troughing roll).
where the material is carried (Figure 4.5). This trough is formed with transition idlers—idlers set at angles between flat and the conveyor’s final trough angle.

There is a similar, but reverse, transition area at the conveyor’s head pulley, where the conveyor is taken from a troughed to a flat profile just before it reaches the discharge point.

As the belt is formed into a trough, the outer edges of the belt are stretched more than the center of the belt. If the transition is made over too short a distance, damage may occur in the idler-junction areas of the belt—the points over the intersection between the flat central roller and the angle wing roller (Figure 4.6).

It is common to see a conveyor that has a transition area that is shorter than what is required. There are a number of reasons for this: faulty engineering or failure to understand the importance of transition, lack of space, or desire to reduce costs. So it is even more critical not to increase the problem by applying a replacement belt that requires a longer transition distance.

It might be possible to lengthen a conveyor’s transition area. There are two ways to do this. One is moving the tail pulley back to extend the distance before the load zone. The second method is adapting a two-stage transition area, where the belt is partially troughed before it enters the loading zone and then completes its transition to the final trough angle after the cargo has been loaded. (See Chapter 6: Before the Loading Zone.)

More commonly, however, circumstances, such as lack of available space and limits of available budget, preclude lengthening a conveyor’s transition area. The most common solution is to make sure the belting is suitable for the existing transition distance. It may not be the most economical solution when all costs—such as loading problems, increased edge tension, and belt damage—are included. A poorly designed transition area will increase costs and decrease the life of the belt.

**BELT STORAGE AND HANDLING**

The conveyor belt has long been the most economical and most efficient form of bulk-materials handling for many industries. However, if this important part of the plant is to perform as expected, it must be carefully stored and handled from the time of its manufacture until the time of its installation on the conveyor system. Improper storage techniques can lead to a damaged belt that will perform poorly when installed on the conveyor structure. As the length of storage time increases, and as the size of the roll of belting increases, so does the importance of following the correct procedures. The costs for handling, shipping, and storing the conveyor belt are minor compared to the purchase price of the belt; therefore, the correct procedures should be followed to protect the investment.
The following are the key storage and handling guidelines:

A. Rolled on a core

As the belt leaves the manufacturer or the supplier, the belt should be rolled carrying side out on a core with a square opening (Figure 4.7). The core gives the belt protection from being rolled into a diameter that is too small and protection when the belt is lifted through the center. It also provides a means for unrolling the belt onto the conveyor. The core size is determined by the manufacturer, based on the type, width, and length of the roll of belt. The core size can be smaller than the belt’s minimum pulley diameter, as the rolled belt is not in a tensioned state. The lifting bar should be square to closely match the square opening in the core.

B. Properly supported

The conveyor belt should never be stored on the ground (Figure 4.8). Ground storage concentrates the weight of the roll onto the bottom surface. The belt carcass is compressed in this small area and not compressed equally from side to side. The carcass may be stretched more on one side or the other. This is a likely cause of belt camber, a banana-like curvature of the belt, running the length of the belt.

Under no circumstances should a roll of belting be stored on its side (Figure 4.9). The weight of the roll may cause that side of the belt to expand, creating camber problems. Moisture may migrate into the carcass through the cut edge of the belt, creating carcass problems or belt camber.

The belt should be supported in an upright position on a stand, off the ground (Figure 4.10). This places the stress of one-half of the roll’s weight on the core, relieving the load on the bottom. This support stand can be utilized during shipping to better distribute the weight of the belt. The support stand can then be utilized in the plant for storage, or the belt can be transferred to an in-plant storage system that properly supports the roll. It is important that the roll be properly supported from the time of manufacture to the time of installation.
C. Rotated on its stand

If the support stand is designed correctly, the roll of belt can be randomly rotated every 90 days. This will more evenly distribute the load throughout the carcass. The reel of belting should have been marked at the factory with an arrow to indicate the direction of rotation. Rotating the belt in the opposite direction will cause the roll to loosen and telescope.

D. Properly protected

During shipping and storage, the roll of belt should be covered with a tarp or wrapped in an opaque water-resistant material. Covering the roll of belting protects it from rain, sunlight, or ozone. The covering should remain in place during the entire storage process.

The roll of belt should be stored inside a building to protect it from the environment. The storage area should not contain large transformers or high-voltage lines that may create ozone and affect the belt. The building does not have to be heated, but it should be relatively weather tight.

E. Lifted correctly

When lifting a roll of belt, a square lifting bar of the correct size should be placed through the core. Slings or chains of the correct size for the weight of the roll should be used. A spreader bar should be utilized to prevent the chains or slings from damaging the edges of the conveyor belt (Figure 4.11).

Additional guidelines are given in ISO 5285; belting manufacturers can provide guidance for their specific products.

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**BELT DAMAGE**

**Extending Belt Life**

As noted above, the cost of the belt will easily exceed the cost of other conveyor components and may reach the point where it approaches the cost of the steel conveyor structure. A key to providing a reasonable return on the investment in belting is avoiding damage and prolonging its service-life. Obviously, all systems installed around the conveyor—whether to feed it, receive material from it, or assist in its material transport function—must be designed to present the minimum risk to the belt.

Damage to belting can be a major drain on the profitability of operations using conveyors. This expense, which occurs regularly in plants around the world at costs of thousands of dollars, can often be prevented. Unfortunately, relatively little effort is put into the analysis of the life of the belt and the reasons for a belt not reaching its optimum life, because of the difficulty of identifying and measuring all the variables that affect belt-life.

The types of belt damage can be divided into two groups: normal wear and avoidable damage. Wear due to the normal operation of the conveyor can be managed and minimized to prolong the belt-life, but a certain amount of wear is considered acceptable. Perhaps avoidable damage cannot be totally prevented, but it can be minimized through proper equipment design and maintenance management.
The first step in preventing belt damage is to identify the cause or source(s) of the damage. A step-by-step analysis can almost always lead to the “culprit.”

**Types of Belt Damage**

The following is a brief review of the major types of belt damage:

A. Impact damage

Impact damage is caused by large, sharp conveyed material striking the top cover of the belt. The result of this impact is a random nicking, scratching, or gouging of the top cover (Figure 4.12). A large frozen lump of coal may cause this type of damage. If the impact is severe enough, the belt can actually be torn completely through. This type of damage is usually seen under crushers or in mines on conveyors handling run-of-mine (ROM) material.

Long material drops without some method to help the belt absorb the energy can also lead to impact damage. (See Chapter 8: Conventional Transfer Chutes and Chapter 10: Belt Support.)

B. Entrapment damage

Entrapment damage is usually seen as two grooves, one on each side of the belt, near the edge where the belt runs under the steel conveyor skirtboard (Figure 4.13). Many times this damage will be blamed on pressure from a skirtboard-sealing system. However, extensive study has shown this type of belt damage is more likely due to the entrapment of conveyed material between the sealing system and the conveyor belt.

This material entrapment occurs when the belt is allowed to sag below the normal belt line and away from the sealing system. Material becomes wedged into this “pinch point,” forming a spearhead to gouge or abrade the surface of the belt as it moves past (Figure 4.14). This leads to any of several negative events:

- **Scallopng**
  The trapped material will form a high-pressure area, causing excessive wear on the sealing system (seen as scalloping in the seal at each idler).

- **Grooves**
  Grooves will be worn along the entire length of the belt under the skirtboard (Figure 4.15).

- **Material spillage**
  Material will be forced off the sides of the belt, leading to piles of material spillage under the load zone.
Material entrapment can also be caused when the skirting is placed inside the chutewall in the path of the material flow. Not only does this arrangement cause material entrapment and belt damage, it also reduces the cross-sectional area of the chutewall, in turn reducing conveyor capacity. This same damage can be seen when installing leftover or used belting as a dust seal, as the carcass is more abrasive than the belt cover and will wear the cover away. Incorrectly installed wear liners can also cause entrapment points, creating this type of wear.

One way to prevent sag is to use bar support systems to support the belt and stabilize the path in the entire skirted area. (See Chapter 10: Belt Support.)

C. Belt-edge damage

Edge damage is usually seen as frayed edges on one or both sides of the belt (Figure 4.16). If edge damage is not identified and corrected, it can be severe enough to actually reduce the width of the belt to a point where it will no longer carry the rated capacity of the conveyor.

Belt mistracking is probably the leading cause of belt-edge damage. There are numerous reasons why a belt might mistrack. These causes range from out-of-alignment conveyor structures, off-center belt loading, accumulations of material on rolling components, or even the effect of the sun on one side of the belt.

There are many techniques and technologies that can be used to train the belt. These would include laser surveying of the structure, adjustment of idlers to counter the belt’s tendency to mistrack, and installation of self-adjusting belt-training idlers that use the force of the belt movement to steer the belt’s path.

The key to good belt tracking is to find the cause for the mistracking and then remedy that cause, rather than spending time and money turning one idler one direction and another idler a different direction in pursuit of better tracking. (See Chapter 16: Belt Alignment.)

D. Belt delamination

Another form of damage seen at the belt edge is delamination, in which the plies of the carcass separate, or the covers pull away from the carcass (Figure 4.17). This can be caused by belting being wrapped around pulleys that are too small. The entry of moisture, chemicals, or other foreign materials into the edge of the belt can contribute to this problem.

E. Worn top cover

Damage to the top cover is seen when the top cover of the belt is worn in the load carrying area of the belt or even across the entire top (Figure 4.18). Several factors can contribute to worn top covers.

One cause can be abrasion from material loading. There is an abrasive or grinding action on the belt cover created
from the material falling onto the moving belt.

Another cause can be carryback. This is material that clings to the conveyor belt past the discharge and then drops off along the conveyor return. If not controlled, this fugitive material can build up on the ground, in confined spaces, and on rolling components. These accumulations can quickly build to a point where the belt runs through a pile of fugitive material that wears away the top cover. This damage will happen more quickly when the materials have sharp-edged particles and higher abrasion levels.

Faulty belt-cleaner selection and improper cleaner mounting can also lead to top-cover damage. Belt cleaners must be mounted properly to avoid chattering. Belt-cleaner chatter can quickly remove the top cover of the belt if not corrected immediately.

Research has shown that even properly installed belt-cleaning systems can cause some wear on the cover of the belt. This would qualify as a portion of the “normal wear” of the belt. With properly tensioned cleaning devices, this wear is modest and has been shown to be less than the abrasion from one idler seizing due to material buildup.

Slow moving, feeder-type belts that convey materials from vessels under high “head loads” can also suffer top-cover damage. Reducing this downward pressure from the material load onto the belt will reduce the potential for damage.

F. Rips and grooves from foreign objects

Damage in the form of rips and grooves is caused by stray pieces of metal, ranging from packing-crate strapping to the teeth from loader buckets (Figure 4.19).

These metal pieces can become wedged into the conveyor structure, forming a knife to gouge or slit the belt. This damage can be the most difficult type to control, because it occurs very quickly and often with catastrophic effects. There are a number of ways to minimize, but not totally eliminate, the amount of “tramp iron” in the material flow. These methods include grizzly screens, metal detectors, and video monitors. Regardless of the effectiveness of the precautions, the belt is still vulnerable.

G. Belt-cleaner damage

Conveyor belts often have a paradoxical relationship with belt cleaners. Cleaning systems are required to remove carryback, which reduces fugitive material along the conveyor and so preserves the...
life of the belt; however, belt cleaners can also have negative effects. Like any foreign object, cleaners can damage a belt, particularly when the cleaning system is poorly applied or poorly maintained. Damage can come from too much pressure or out-of-alignment installation. Chattering cleaner blades can remove pieces from the belt surface (Figure 4.20).

Any damage on the surface of the belt or on the cleaning edge of the belt cleaner can create additional vibration, expanding the movement and perpetuating the cycle.

H. Top-cover cracking

Short random cracks in the top cover running perpendicular to the direction of belt travel may be caused by a mismatch between the belt and the pulley diameters (Figure 4.21).

Each belt, depending on the manufacturer, number of ply, reinforcing materials, and thickness, will require a different minimum-bend radius. This type of damage occurs if the belt is not matched to all pulley diameters of the structure. Bending a belt in too small of a radius will cause stress on the top cover. This undue stress on the top cover will cause the rubber to crack, exposing the reinforcing materials of the belt, which can lead to damage to the belt’s internal carcass.

Any change from the original belt specifications should also be done in conjunction with a rerun of the belt specification program which includes a study of the conveyor’s pulley diameters and tension required to drive the belt.

Installing a thicker belt on an existing system to improve life by preventing other types of belt damage, such as impact, may dramatically shorten the life of the new belt if the diameters of the conveyor pulleys are smaller than recommended by the manufacturer. It is important to always check with the belt manufacturer to ensure this design parameter is met.

I. Heat damage

Conveying hot materials may also cause the top cover to crack or the plies to separate. The cracks from heat damage may run either parallel or perpendicular (or both) to the direction of belt travel (Figure 4.22). If the conveyed material is hotter than the belt can handle, holes may be burned through the belt. Using high-temperature belting may reduce this heat cracking and increase belt-life. The only true solution is to cool the material prior to conveying it or to use some other method of moving the material, at least until it is cooled sufficiently.

J. Junction-joint failure

As the belt moves along the conveying system, going from flat to troughed at the terminal pulleys, the outer one-third of the belt is required to travel farther than the center one-third of the belt.

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**Figure 4.22**
Carrying hot material may lead to cracks in the belt’s top cover.

**Figure 4.23**
Junction-joint failure can be seen as a “W” or “M” shape in the belt as it passes over a return roller.
Thus, the outer one-third of the belt must stretch more than the inner one-third. If this stretching takes place in too short of a distance, the belt can become damaged at the point where the outer wing rolls meet the center flat roll. This damage is termed junction-joint failure.

Junction-joint failure appears as small stretch marks running the entire length of the belt in the areas which pass over the points where the wing rollers and the flat rollers meet. (These stretch marks run parallel to the belt, approximately one-third of the belt width in from each edge). In early stages, it can be seen as a “W” or “M” shape in the belt as it passes over a return roller (Figure 4.23). This type of belt damage may be so severe as to actually tear the belt into three separate pieces.

Junction-joint failure is caused by too large a gap between idler rollers and enough tension or load to force the belt to deform into the gap. A transition distance that is too short and/or an idler-junction gap of more than 10 millimeters (0.4 in.) or twice the belt thickness may cause junction-joint failure. Belt thickness, reinforcing materials, materials of construction, and trough angles all determine the transition distance of a specific belt. When designing a new system, contemplating a change in belt specifications, or increasing trough angles, it is important to check with the belting manufacturer to ensure that proper transition distances are maintained at both the head and tail pulleys.

K. Belt cupping

A cupped belt happens when the belt has a permanent curvature across its face, perpendicular to the line of travel (Figure 4.24).

Belt cupping can be caused by heat, by transition distances not matched to the belt, or by too severe a trough angle for the type of belt being used. Another cause of cupping is over-tensioning the belt. The presence of chemicals such as deicers or dust surfactants can also cause a belt to cup up or down, depending on whether the chemical shrinks or swells the elastomer in the belt’s top cover. Aspect ratios that are too great (where the top cover is too thick for the bottom cover) can also cause a belt to cup.

Cupped belts are extremely difficult to track, as the frictional area, the surface where the belt contacts the rollers, is drastically reduced.

L. Belt camber

Camber is a longitudinal curve in the belt when the belt is viewed from the top. The Rubber Manufacturers Association defines camber as the convex edge of the belt; the concave side of the belt is called the bow (Figure 4.25). If a belt is composed of more than one section,
it may have more than one camber or even conflicting cambers.

This type of damage can be created during manufacture or from improper storing, splicing, or tensioning of the belt (Figure 4.26). Proper storage and handling are essential from the time of manufacture to the time of installation.

These curves in the belt produce tracking problems that are often confused with a crooked splice. Camber and bow will produce a slow side to side movement; a crooked splice produces a more rapid “jump” in the belt’s tracking. However, a crooked splice has a short area of influence, whereas the curve of a camber or bow is from one end of a belt section to the other.

Belt Repair

Repair of Conveyor Belting

For most operations, conveyor belt-life is measured in years. To achieve the lowest operating cost, inspection of the belt should be a scheduled maintenance procedure. Any belt damage noted during these inspections should be repaired promptly to prevent small problems from becoming big trouble. Damage to a belt can permit the entrance of moisture or foreign materials into the belting, and thus promote premature failure of the belt. To preserve the belt, it is important to make prompt and effective repairs of any damage.

Vulcanized repairs can be made during scheduled maintenance outages when sufficient conveyor downtime is available to allow the long time required to make a vulcanized joint. In nearly all cases, a vulcanized repair requires removal of a complete section of belt and then either re-splicing the remainder or adding an additional piece of belting, often called a “saddle.”

Fortunately, many forms of damage lend themselves to relatively simple methods of repair. Repairable forms of damage include:

A. Grooves in which the top cover is worn away by abrasion from material or a foreign object
B. Longitudinal rips in which the belt is slit by a fixed object, such as a metal bar becoming wedged into the conveyor structure
C. Profile rips in which a small tear in the belt edge extends inward
D. Edge gouges in which blunt objects tear chunks of rubber out of the belt edge, generally caused by the mistracking of the belt into the conveyor’s structure
Repairs can be made with self-curing, adhesive-like repair materials to keep moisture or foreign material out of the carcass. Mechanical fasteners are another method for repairing damaged belting to restore service without significant downtime and extend the service-life of expensive belts.

**Belt Repair Using Adhesives**

Adhesives provide a cost-effective means to repair conveyor belting with a high quality bond. Use of adhesive compounds will save downtime and money in maintenance budgets without requiring heavy vulcanizing equipment or creating obstructions with repair hardware in the belt (Figure 4.27). Adhesive repair compounds offer simple solutions for belt maintenance that are durable, reliable, and easy to use. There are a number of products available to do this. They include solvent-based contact cements, heat-activated thermoplastics, and two-component urethane elastomers.

All of these systems require some degree of surface preparation, ranging from a simple solvent wipe to extensive grinding or sandblasting. Some may need an application of a primer to improve adhesion.

Most commonly used for standard cold-vulcanized splices, solvent cements are also used for bonding repair strips and patches over damaged areas.

Thermoplastic compounds are “hot melts” that are heated to a liquid state and then harden as they cool, forming a bond. As they cool quickly from their application temperature of 120 to 150 degrees Celsius (250° to 300° F), the repair must be performed quickly, before the adhesive returns to the hardened (non-adhesive) condition. Problems encountered with thermoplastic adhesives include the possibility of shrinkage as the adhesive cools and the risk that high-temperature operations or cargo may cause a softening of the adhesive, leading in turn to failure of the repair.

Urethane products are typically two-component systems that the user can mix and then spread like cake frosting directly onto the area to be repaired. They typically achieve operating strength in a short period, one to two hours, but will continue to cure for eight to twelve hours until full cure strength is reached.

All adhesive systems offer fairly simple applications, assuming the instructions are followed. Of course, it is critical that the adhesive manufacturer’s instructions be followed carefully as to surface preparation, component mixing, pot life, application technique, and cure time. The length of time for an operating cure and full cure may provide the basis for selecting any particular product.

It is important to get the profile of the repaired area down to match the profile of the original belt in order to preserve the repair and avoid more damage to the belt.

It is also important to identify and resolve the cause of the problem, removing the obstruction or correcting the mistracking that led to the belt damage in the first place. Otherwise, the resumption of operations after repair merely initiates a waiting period until the damage recurs and the repair must be made again.

**Mechanical Fasteners for Belt Repair**

Because of their comparative ease of installation, mechanical splices are often used in emergency repair situations when a new piece of belting must be added to an old belt or when a belt must be patched or a rip closed (Figure 4.28). In these cases, the mechanical fasteners are used as a “band-aid” to cover damage and close a
hole, allowing the conveyor to begin running again.

Mechanical splices can be used effectively for belt repair, providing care is used to properly install and recess the fasteners. Of course, the problem with all temporary repairs is that too quickly the “temporary” part becomes forgotten. The system is running; the plant personnel have moved on, at least mentally, to solving other problems. It must be remembered that these repairs are only temporary stopgaps and are not designed for permanence. It is always important to solve the root cause of the problem in order to prevent recurrence.

Recovery from belt damage does not have to involve lengthy downtime. Mechanical rip repair fasteners offer an inexpensive and fast repair. They can be installed with simple tools and without discarding any belting. As soon as the fasteners are in place, the belt can be returned to service without waiting for any “cure” time. They can be installed from the top side of the belt, without removing the belt from the conveyor.

One-piece, hammer-on “claw” style fasteners can provide temporary rip repair where the speed of repair and return to operation is critical (Figure 4.29). These rip-repair fasteners can also be used to fortify gouges and soft, damaged spots in the belting to prevent these spots from becoming rips. For repair of jagged (“zig-zag”) rips, splice suppliers recommend alternating two- and three-bolt fasteners (Figure 4.30) along the repair. The larger (two-bolt) side of the three-bolt fasteners should be placed on the “weaker” flap side of the rip to provide greater strength. For straight rips, standard two-bolt mechanical fasteners are acceptable.

**PRESErvINg ThE lIFE OF ThE bElT**

**Rip-Detection Systems**

Increasing numbers of operations are acting to preserve the life of their belting by installing rip-detection systems. In the event of a rip in the belt, these systems sound an alarm and/or automatically shut down a conveyor.

These systems are designed for the situation in which a belt-length rip—arising from a piece of tramp iron or a wedged lump of material that slits the belting into two independent, or nearly independent, pieces—would require the entire replacement of a costly belt. Without a rip-de-
tection system, a belt rip may continue for hundreds or thousands of feet.

Rip-detection systems are most commonly seen on very expensive, production-critical conveyors. In these circumstances, the operation would be shut down for the time required to acquire and install a new belt or make a repair to a belt-length rip.

The rip-detection systems are particularly valuable on long conveyors, where the 60 meter (200 ft) length typically damaged before the conveyor can be shut down is an insignificant loss compared to the value of the length of belting saved by the automatic shutdown.

Although there are differences in operating principles for the various rip-detection systems, each system basically embeds a sensor or signaling agent at places in the conveyor belt. As the belt moves, these indicators pass over the detection points—typically installed at the places where it is likely for a conveyor rip to occur: the loading zone and discharge. When the rip in the belt causes the signal to be interrupted, the alarm is sounded and the belt stopped.

These systems will minimize belt damage and allow the plant to reduce the amount of belting it needs to keep in inventory.

**Monitoring of Conveyor Belting**

As operating plants push to extend production periods, windows of opportunity for maintenance continue to shrink. Conveyor supply and support companies can now help to accommodate this situation by providing tools that give a better understanding of the condition of conveyor belting.

In addition to the rip-detection systems mentioned above, there are services which will provide a comprehensive monitoring of the condition of a belt. Factors analyzed include the condition of the carcass; the condition and wear of the top cover; including its thickness and its estimated remaining life; and the condition of the splice(s).

Early detection, mapping, and monitoring of damaged areas and of splice strength allow planners to schedule maintenance windows in advance and extend the service-life of the conveyor systems under their control.

**BELTING IS THE KEY**

**In Closing...**

The conveyor system is a key to the efficiency of an entire operation; the belting is the key to a conveyor’s productivity. Consequently, preservation of the capabilities and life of the belt is essential. Considering the size of the initial investment in conveyor belting, the importance of preserving a belt through regular inspection and repair activities cannot be overstated. The relatively minor costs for careful inspection and belt repair and the somewhat more significant expense of a conveyor outage to allow that repair to be made will be paid back many times over by an extended belt-life.

**Looking Ahead...**

This chapter, The Belt, was the second chapter regarding basics of conveyors in the section Foundations of Safe Bulk-Materials Handling. The next chapter, Splicing the Belt, concludes this section, describing various types of belt splices and their impact on fugitive materials.

**REFERENCES**

4.1 Any manufacturer and most distributors of belting can provide a variety of materials on the construction and use of their specific products, as well as on conveyor belts in general.


4.3 The website http://www.conveyor-beltguide.com is a valuable and non-commercial resource covering many aspects of belting.
Chapter 5

CONVEYORS 101—SPICING THE BELT

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In this Chapter...

In this chapter, we will discuss the methods used to join the belt, including mechanical splices and hot and cold vulcanization (Figure 5.1). The chapter will review the advantages and disadvantages of the various systems while emphasizing the importance of proper installation, inspection, and maintenance.

Conveyor belting is shipped from the factory on a roll, and before its use, the two ends of the belt must be joined together to provide a continuous loop. The two methods for splicing the ends of the belt together are vulcanization and mechanical fasteners.

Both techniques are employed around the world. In North America, mechanically splicing the belt is more prevalent; outside North America, vulcanization is more common. For reasons that will be discussed in this section, vulcanization is preferred for the control of fugitive materials; however, in many cases, the need to return a conveyor to service promptly will mandate the use of mechanical splices.

VULCANIZED SPLICES

Vulcanization is the process of curing raw rubber by combining the rubber with additives in the presence of heat and pressure (“hot” vulcanization). Bonding of the belt ends with adhesives is known in the belting trade as “cold” vulcanization.

Vulcanization is generally the preferred method of belt splicing, due to the superior strength, longer service-life, and cleaner operation it offers. Vulcanized splices are really the only option for the long-term performance of high-tension steel-cord belting. Operations that require frequent additions or removal of sections of belting, such as extendable underground belts or conveyors with limited take-up capabilities that require shortening of the belt to maintain tension, are not suitable for vulcanized splices.

Due to their superior strength, vulcanized splices allow the application of maximum belt tension, resulting in better pulley-to-belt traction. A vulcanized splice has no internal weaving, braiding, sewing, welding, or other mechanical link. The splice is solely dependent on rubber adhesion to the carcass or steel cords, as the tensile members of the splice, textile plies or steel cords, do not touch each other. Adhesion is obtained through use of an intermediary rubber or rubber-like material called tie gum, installation gum, or cement.

Steps in Vulcanizing a Belt

Step-by-step procedures for vulcanized splices vary between manufacturers (Figure 5.2). In general, there are three steps:

A. Preparation of the belt ends
In the first step for a fabric carcass belt, the ends are cut at the correct angle and then stripped or pulled apart to expose the various plies to be joined. Care must be taken not to damage the plies or cords. The process for a steel-cable belt involves cutting back the rubber cover (Figure 5.3).

B. Application of cement, gum, or other intermediary material
The second step provides the buildup of the layers, much like the making of a sandwich, which will form the completed splice. For steel-cable belts, the cords are overlapped, and then appropriate bonding agents are applied to the exposed cables. Fill and cover rubbers are
then laid in place, and the belt is cured in the same manner for both steel-cable and fabric belts.

C. Curing of the splice
The assembled materials are pressed together and cured, through the application of heat, pressure, and/or time, to form the finished splice.

Typically, the materials used for a vulcanized splice—cement, tie gum, strings of rubber called noodles, or cover stock, all depending on belt style and construction—are available in kit form. Kits from the belt manufacturer are sometimes preferred, although there are generic kits available for the most common belt grades. The materials in the kit are perishable; they have a specified shelf life in storage and a limited “pot life” when they are mixed into the ready-to-apply state.

There are two types of vulcanization: hot and cold. In hot vulcanization, the layers of a belt are stripped in a stair-step or finger fashion and overlapped with glue and rubber. A heated press or “cooker” then applies heat and pressure to “vulcanize” the belt into an endless loop. In cold vulcanization (technically called chemical bonding), the belt’s layers are joined with an adhesive or bonding agent that cures at room temperature. Vulcanization, particularly hot vulcanization, is usually performed by outside contractors who have the specialized equipment and expertise to perform the required procedure.

**Hot Vulcanization**

In hot vulcanization, a special press (Figure 5.4) applies both heat and pressure to the splice to cure the intermediary and cover materials into a high-strength joint. The press applies pressure consistently across all surfaces. Pressure can range from 34 to 1200 kilopascal (5 lb./in.² to 175 lb./in.²), depending on the belt. Cooking temperatures range from 120 to 200 degrees Celsius (250° to 400° F), depending on belt type and rubber compound. The time required to cure will depend on belt thickness and compound: Belt manufacturers normally include time and temperature tables in splicing manuals. Although the equipment is automated, the process may require constant human attention to achieve the best results. Portable vulcanizing presses for curing the splice are available in sizes to match various belt widths. Small fabric belt splices can often be cured in a single setup. Larger fabric belt splices can be cured in two, three, or more settings of the vulcanizing press without problems. With steel-cord belts and finger splices, it is important that the press be large enough to cure the splice in a single setup to avoid undesirable rubber flow and cord displacement.

When the vulcanization procedure, or “cook,” is completed, the resulting splice should be inspected for any visible defects that might indicate a weakness. It is common practice to grind or buff away any surplus rubber from the splice to improve the performance of the joint as it passes through belt cleaners and other conveyor components.
Cold Vulcanization (Chemical Bonding)

In cold vulcanization, the belt is joined using adhesives or bonding agents that will fuse the ends of the belt together to form a continuous loop.

In cold splicing, the joint is not cured in a press. The belt ends are carefully laid together in proper alignment with the adhesive, and full contact is achieved with hand rollers, pressure rollers, or hammering in a prescribed pattern. The bond can often be improved by simply putting weights on the belt during the cure interval. Most cold vulcanization cements require at least four hours for a usable cure and 24 hours for a full cure. Best results are achieved by following the manufacturer's recommendations. The belting manufacturer is the best source of information on proper vulcanization techniques and materials.

Splice Pattern

Vulcanized splices require the cutting away of layers of rubber covers and fabric carcass to let the belt ends be overlapped and joined. In general, the geometry of a splice can be the same whether the joint will be vulcanized hot or cold.

Bias splices are most common, as the angle increases the length of the bonding surface and reduces stress on the splice as it wraps around the conveyor’s pulleys. The bias angle also serves to reduce the chance of tearing open the leading edge of the splice. This bias angle is generally 22 degrees; most vulcanizing presses are manufactured with this bias angle built in (Figure 5.5).

A splice design that is seeing increasing acceptance, particularly with high-tension fabric belts, is the finger splice (Figure 5.6). This design involves cutting the two ends of the belt into a number of narrow triangular “fingers.” The fingers—each typically 30 or 50 millimeters (1-3/16 or 2 in.) wide at the base and between 850 to 1200 millimeters (33 to 48 in.) in length,
chemically bonds the belt into an endless piece with no possibility of material sifting through the splice, from the standpoint of control of fugitive material, vulcanization is the splice of choice. A properly-performed vulcanized splice will not interfere with rubber skirting, idler rolls, belt-support structures, or belt cleaners.

Cold vulcanization offers some advantages over hot vulcanization. There is no heating source nor press required, the equipment is easier to transport, and no special electricity is required. Therefore, cold vulcanized splices can be performed even at remote sites where access is difficult and power is unavailable. Only small hand tools are required, so the cost to purchase and maintain the splicing equipment is low.

Hot and cold vulcanized splices take roughly the same amount of time to prepare the belt and complete the joining process; however, the cold splice may require more downtime than hot vulcanization due to the long cure time of the adhesive bond.

The finger splice can provide the best mix of splice strength and dynamic life in applications on high-tension belting. This system keeps all the factory belt plies in place, without any steps cut into the belt. A finger splice can be cut square or on a bias across the belt.

**Disadvantages of Vulcanized Splices**

The disadvantages of vulcanization that must be considered are the higher initial cost and the length of time required to perform the splice when compared to a mechanical splice. The peeling back of layers of belting to prepare for both hot vulcanization and cold chemical bonding can be difficult. It can take over 24 hours to return a conveyor to service by the time the splice is prepared, heated, and cooled sufficiently to allow the finished joint to be handled or even longer for the cold chemical bond to cure.

This added time to complete a vulcanized splice will be particularly troubling (and expensive) in cases where an emergency repair is required to allow the resumption of operations. In this case, the delay required for hiring and bringing on-site an outside crew and equipment increases the cost of the downtime by extending the outage and adding “emergency response” surcharges.

Due to time and cost pressures, vulcanized belt splices cannot be justified in applications where frequent extensions or retractions of the conveyor length are required. The same is true where the take-up allowance does not allow enough belting for a vulcanized splice, and a short section of belting, often called a saddle, must be added, requiring two splices.

Vulcanizing can be more difficult and less reliable on older, worn belts. In applications on conveyors that are utilized in the process of transporting hot materials, it is important that all material be discharged from the belt prior to stopping the belt. Hot material left on a stopped belt can “bake” a splice and reduce its life.

Installation of a vulcanized splice can consume a considerable length of belting, as much as 2.4 to 3 meters (8 to 10 ft) in some cases, particularly when a bias splice is used on a wide belt. This installation may require a longer belt to be purchased or a new section of belt, or saddle, to be added.

When designing new conveyor systems that will incorporate vulcanized belts, it is wise to include a take-up pulley mechanism, designed to take up slack in the belt. The take-up pulley should have sufficient movement to account for belt stretch, thus avoiding the need to shorten the belt with a time-consuming new splice.

**MECHANICAL SPLICES**

**Mechanical Fasteners**

Today there are many types of mechanical fasteners available for belt splicing. They all work on the principle of joining the two ends of the belt together with a
hinge-and-pin or plate design. Mechanical fasteners are now fabricated from a variety of materials to resist corrosion and wear and to match the conditions of application.

For many years, mechanical splices were considered the low-quality alternative to Vulcanization as a method of joining the belt. Recent developments have moved mechanical fasteners into a better position versus vulcanization. These innovations include the use of thinner belts (made possible by the use of synthetic materials in belting), improvements in design and materials used in fasteners to increase strength and reduce wear, and the development of tools to recess the profile of the splice.

**Types of Mechanical Splices**

Mechanical fasteners for bulk material handling belts are available as hinged fasteners or plate fasteners, with options within each group.

**Hinged Fasteners**

In hinged-fasteners splices, a strip composed of top and bottom plates joined on one side by metal loops is placed on each of the two belt ends (Figure 5.7). These strips are attached to the belt by staples, bolts, or rivets. The belt is then joined by passing a linking pin through the alternating hinge loops.

Hinged fasteners are usually supplied in continuous strips to fit standard belt widths. These strip assemblies ensure proper spacing and alignment. The strips are fabricated so pieces can be snapped off to fit non-standard belt widths.

The chief advantage of hinged fasteners is that the belt can be separated by removing the linking pin. This way the belt can be shortened, extended, removed from the structure, or opened to allow maintenance on conveyor components.

Hinged fasteners provide several other benefits. Installation on the two belt ends can be done separately and even performed off-site. While it is not a recommended practice to join belts of different thicknesses—because of problems it can create, including sealing, tracking, and cleaning—hinged loop fasteners would allow different thicknesses of belting to be combined using fasteners matched to their respective belt halves.

**Solid-Plate Segments**

A second type of mechanical splice is performed with plate fasteners (Figure 5.8). This class of fastener makes a strong, durable joint with no hinge gap for fines. Plate fasteners are effective in the most rugged conveying applications in mines, quarries, and steel mills. In applications where the belt is thicker than 22 millimeters (7/8-in.), plate fasteners are the only choice for mechanical fastening. Solid-plate segment fasteners are intended for permanent joints only and are not recommended for belts in applications that require opening of the joint to change belt length or location.
Solid-plate segment fasteners are typically provided as individual pieces packed loose in a box or bucket. The plate segments are installed from one belt edge to the other using staples, rivets, or bolts.

Bolted solid-plate fasteners have some unique advantages. They can be applied diagonally across the belt to allow use on pulleys that are smaller than the size recommended for the fastener. They can also be installed in a V-shaped pattern (Figure 5.9), which may be the only choice for using fasteners to join the thick, high-tension belts designed for vulcanization.

One problem with bolt-fastened solid-plate segment fasteners is that they typically use only two bolts on each plate, with one on each side of the splice. Tightening down on the ends of the splice means the leading and trailing edges are more compressed than the middle of the plate. This allows the middle to crown, creating a wear point in the fastener and in belt cleaners or other systems that contact the belt as it moves on its path through the conveyor.

Riveted solid-plate fasteners are designed for the most demanding, highest-tension applications. The multi-point attachment on each side of the hinge provides the highest holding power of any mechanical fastener. They can be installed without power tools, using a hammer to set the rivets and break off any heads above the belt. This is an advantage in remote or underground locations.

A problem arises if the conveyor uses pulleys that are smaller than 300 millimeters (12 in.) in diameter. In this case, solid-plate fasteners may be too large to bend around the pulley, causing components of the splice to pull out or break.

Flexible-Matrix Plate Splices

One additional splicing technique is flexible-matrix plate splices. This system uses self-tapping screws driven through an H-shaped (or perhaps I-beam-shaped) hinge matrix. To form this joint, the two belt ends are skived on a bias down to the fabric carcass and then inserted into the open ends of the H-shaped reinforced-rubber hinge matrix. The matrix (which runs the full width of the belt) is then fastened to the belting using up to 240 screws per meter of belt width.

This system offers relatively quick and easy installation, using only skiving tools and a power screwdriver (Figure 5.10). The splice can be installed in any weather and in locations where a vulcanizing press or other splicing tools would be difficult to use. It requires no cure time and can be used for joining or repairing belts. If it is used for a temporary repair, the matrix can be removed and reused.

A benefit of the flexible-matrix splice is that it is leak-proof, as there are no openings between belt ends or holes in the belting that allow material to sift through.
This system is presently used for joining fabric carcass belts; the supplier is attempting to develop and secure approval for use on steel-cable belts.

Selecting the Proper Fastener

Most fasteners are available in a range of sizes. In all cases, the manufacturer’s recommendations should be checked to ensure the fastener size is matched to the pulley sizes and belt thickness.

If the belt is to be skived in order to countersink the fastener down to the surface of the belt, this skived thickness should be considered when thinking about fastener size. The fastener should be selected based on the diameter of the smallest pulley in the system.

Fasteners are available in a variety of different metals to meet the requirements of special applications. These properties include non-sparking, non-magnetic, abrasion-resistant, and/or corrosion-resistant materials. Hinge pins are available in a similar selection. The manufacturer should be contacted for the proper recommendation for any specific application.

Training for selection and installation of splices should be carried out by qualified personnel. When installed in accordance with manufacturers’ instructions, mechanical splices can provide an economical method of joining the belt. When incorrectly specified or applied, mechanical splices can create expensive and recurrent problems.

Proper Installation of Fasteners

Mechanical splices can be installed relatively easily by plant personnel; however, as a consequence, they can be easily misapplied, particularly by untrained personnel or in an emergency “get running in a hurry” situation. It is critical that plant personnel be trained in the proper installation of mechanical fasteners.

It is a common but incorrect practice to stock only one size of mechanical splices in the maintenance supply room. Over the years, the specifications for the belts used within a plant may have changed, but the mechanical fasteners kept on hand in the storeroom have stayed the same, which can lead to a variety of problems, including splice failure and damage to conveyor components. Installing a mechanical fastener properly requires using the correct fastener, proper tools, and attention to detail.

Squaring the Belt Ends

Where belt ends are joined with mechanical fasteners, the first requirement of a good joint is usually that the belt ends be cut square. Failure to do so will cause the belt's splice area to run to one side of the structure at all points along the conveyor. This is usually seen as a quick side-to-side motion as the spliced area passes over any point on the structure. Using the belt edge as a squaring guide is not recommended, as the belt edge may not be straight. Used belting may have an indistinct edge due to wear, so one of the following procedures is recommended:

A. Centerline method

To find the belt’s average centerline, measure from one belt edge to the other at five points along the belt, each roughly 300 millimeters (12 in.) farther from the end of the belt. Mark a series of points at the center of the belt, and connect these points using a chalk line or ruler to determine the average centerline (Figure 5.11).

Draw the cut line by using a square. Draw a line across the belt perpendicular to the average centerline. This line can be used for the cut line (Figure 5.12).

B. Double-arc method

For greater accuracy, or on belts with worn edges, a “double intersecting arc” method can be employed. After establishing an average centerline as above, pick a point on the centerline two to three times the belt width from the belt
end. Using a string with a nail on the centerline as a pivot point, draw an arc across the belt so the arc crosses the edge of the belt on both sides (Figure 5.13). Now, create a second pivot point on the centerline much closer to the belt end. Strike a second arc across the belt, this one facing the opposite direction, so the second arc crosses the first arc on both sides of the average centerline near the belt edges (Figure 5.14). Draw a line from the intersection of the arcs on one side of the belt to the intersection of the arcs on the other side (Figure 5.15). This new line is perpendicular to the centerline of the belt and becomes the cut or splice line.

Checking the Accuracy of the Squared Ends

Regardless of which method is used, checking the accuracy is necessary. To check the accuracy of the squared end, measure a given distance (say, 1 meter or 36 in.) away from the line on both sides of the belt. Then measure diagonally from these new points to the end of the cut on the opposite side of the belt, so a diagonal measure is taken. The two diagonal lines should intersect on the belt’s centerline, and the diagonal lines should be the same length (Figure 5.16).

The Importance of Skiving

For a mechanical splice to function in a transfer point and allow effective sealing and cleaning, both the top and bottom splice sections must be recessed sufficiently into the belt to keep the belt thickness constant and the splice surface smooth, to avoid damage to components and the splice.

Cutting down the covers of the belt, typically called skiving, mounts the fasteners closer to the fabric of the belt carcass for a firmer grip (Figure 5.17). Skiving requires the top and bottom covers be cut down to the belt carcass. As the carcass provides the strength of the belt, and the top and bottom covers provide very little strength, this
will not reduce the integrity of the belt or splice. Great care is required when skiving the belt, as any damage to the carcass of the belt can weaken the splice and therefore reduce the strength of the belt. When the splice is properly recessed, the metal components of the mechanical hinge will move without incident past potential obstructions such as impact bars, rubber-edge skirting, and belt-cleaner blades. Skiving is recommended to ensure the integrity of the belt, splice, and other conveyor components. Skiving the belt reduces noise in the conveying operation, as clips are now recessed and do not “click clack” against the idlers as the belt moves through the system.

Skiving equipment can be purchased from most splice suppliers.

**Dressing a Mechanical Splice**

If for some reason, such as limited belt thickness, belt damage, or limited time to complete a repair, it is impossible to properly recess a mechanical splice by skiving, the splice can be dressed. This can be done by either lowering its projecting surfaces by grinding or submerging the raised surfaces by encapsulating.

With the first approach, grinding away the high spots will ensure the leading edge or bolts and rivets do not protrude above the splice. Care must be taken when grinding the splice to avoid digging into the belt or removing too much of the splice.

The second approach is the encapsulation of the splice in a material to protect both it and the cleaner from impact damage (Figure 5.18). This is usually accomplished with an adhesive or elastomer applied like putty onto the belt and splice. Although the cleaning system will still have to ride up and over the mechanical clips, the splice surface will be smoother, without obstacles like fastener heads in the cleaner’s path. The downside of this procedure is that because the mechanical splice is covered, the joint is harder to inspect and repair.

**Notching the Trailing Side**

To protect the corners of the belt at the splice, it is often useful to notch, or chamfer, the corners of the belt at the joint. On one-direction belts, it is necessary to notch only the trailing belt end. The notch is cut in the belt from the first fastener on each end of the splice out to the belt edge at a 60-degree angle. The notch will help prevent the corners of the belt from catching on the conveyor structure and damaging the splice or tearing the belt (Figure 5.19).

![Figure 5.17](image-url)

If properly recessed, the top of the mechanical fastener will be even with or lower than the top of the belt.

![Figure 5.18](image-url)

Dressing the splice will protect both the mechanical fasteners and belt cleaners. This can be done by either lowering its projecting surfaces by grinding or submerging the raised surfaces by encapsulating. Top photo: before encapsulation. Bottom photo: after encapsulation.
Getting Along with Belt Cleaners

Mechanical belt fasteners sometimes conflict with aggressive belt-cleaning systems, especially where hardened metal blades are used. Many operators prefer to use non-metallic (e.g., urethane) belt-cleaner blades on belts with mechanical splices for fear of wearing or catching the splice and ripping it out. Most of these types of problems with belt-cleaning systems can be traced to improper selection or installation of mechanical splices.

New developments help make mechanical fasteners more scraper-friendly. One is the development of tools for skiving that easily remove a uniform strip of belt cover material, leaving a smooth, flat-bottomed trough with a rounded lip to receive the splice. These devices are much faster and safer than earlier methods that used knives or grinders.

A second development is new designs for “fastener friendly” cleaners, offering special blade shapes, materials, and mounting methods that minimize impact problems with fastener plates. The recent introduction of “scalloped” mechanical clips, designed to allow belt-cleaner blades to “ramp” over the plates without damage to the cleaner or the splice, offers the possibility of improvement in durability of both blade and fastener.

There are no empirical studies on the wear of splices due to interaction with bulk material and with the cleaning and sealing systems. If good installation and maintenance practices are observed, the cleaning and sealing systems and the splices should be chosen on the basis of the performance required, rather than any worries over their life expectancy.

Advantages of Mechanical Splices

The principal advantage of mechanical splicing is that it allows the belt to be separated easily. This separation of the splice allows extension or shortening of the belt in applications like mining; and it enables service to other conveyor components, such as pulley lagging, idlers, or impact cradles to be more easily completed.

An additional advantage of mechanical fasteners is that they minimize repair downtime. These splices can often be installed in an hour or two, whereas a vulcanized joint can easily take a full day or more to complete. Fasteners are easily installed by available plant maintenance personnel, using only hand tools or simple portable machines; in contrast, vulcanizing usually requires calling independent contractors with specialized equipment. The fastened joint will cost a few hundred dollars and consume only a few millimeters of belting, whereas the vulcanized joint can cost several thousand dollars and consume several meters of belting.

Mechanical fasteners provide a splice that is simple to perform and easy to inspect. If regularly inspected, a mechanical splice will normally provide notice of an impending failure. Mechanical splices are low cost and can be stored for long periods. They allow quick installation and enable easy lengthening or shortening of the belt.

It is important to make sure that fastener selection follows the recommendations of manufacturers of both the belt and the fasteners.

Disadvantages of Mechanical Splices

If the materials to be conveyed are hot, the transmission of heat through a metal fastener may be a factor that leads to the selection of a vulcanized splice. When the material temperature exceeds 121 degrees
Celsius (250° F), the amount of heat passing through the metal fastener into the belt carcass can weaken the fibers, ultimately allowing the fastener to pull out. In these applications, a vulcanized splice would be preferable.

Failure to inspect fasteners and the resulting failures of those fasteners can result in severe belt damage. If the fasteners begin pulling out on a portion of the splice width, longitudinal ripping of the belt may occur. When belt and fasteners have been properly selected, pullout is usually due to insufficiently tight bolts or worn hooks or plates. Plate-type mechanical fasteners typically allow the replacement of individual plates, which, if performed when damage is first observed, may eliminate the need to cut out and replace the entire joint.

Using the wrong size or type of mechanical fastener can greatly reduce the operating tension capacity of a belt. The extra thickness of a mechanical splice not properly recessed or of the wrong specification will make sealing the transfer point almost impossible. Splices that are oversized and too thick to pass through the transfer-point area can catch on the wear liner or skirtboard, abusing the splice and shortening its life. These splice issues sometimes require the wear liner and skirtboard to be higher above the belt, allowing more material to reach the edge-sealing system. This, in turn, results in accelerated wear and spillage. Often, the fasteners used in the splice will not be properly trimmed, and these extended rivets or bolts can catch on other components like skirtboard-sealing systems or belt cleaners.

SAFETY CONCERNS

Any untrained individual attempting to use belt splicing equipment for vulcanization or mechanical fastening runs the risk of injury as well as the likelihood of creating a poor splice. A significant risk of an improperly performed belt splice is the likelihood that the splice will fail under the tension of application conditions. Splice failure could result in personnel injury and equipment damage.

Pre-work inspections should be completed, and manufacturer’s instructions should be followed, when using any splicing tools, machinery, or chemicals.

All chemicals, including solvents, primers, and cements, should be stored and handled properly, in accordance with manufacturer instructions, including special attention to shelf-life limitations.

Proper protective clothing, including suitable gloves and eye protection, should be worn, and the work area should be properly ventilated.

Sharp hand tools and power grinders are used for cutting the rubber and preparing the joint: They pose cut and abrasion hazards to the workers.

Conveyor-belt splicing is often performed under somewhat hazardous conditions, such as inside underground mines, on inclined or elevated structures, or in areas with limited access. As always, proper lockout / tagout / blockout / testout procedures are required. Proper blockout by clamping the belt to the structure is necessary to prevent any belt movement. Clamping fixtures that are engineered for the specific size and weight of the belt being spliced should be purchased from reputable suppliers.
Most, if not all, mechanical splices will allow some small quantity of the conveyed material to filter through the joint itself. This material will fall along the run of the conveyor, resulting in cleanup problems and the potential for damage to idlers, pulleys, and other conveyor components. Plate-type fasteners, in a well-made joint, are quite free of material leakage. The hinge-type fasteners are all subject to problems with fine materials sifting through the joint; this problem is eliminated with vulcanized splices.

While it does provide greater strength, the V-shaped splice does have its costs. It can require up to 3 meters (10 ft) of belting for completion. That may be a significant amount of expensive belting to be discarded.

Mechanical splices are used on fabric belts for making the belt endless or for repairing rips and holes; however, on steel-cable belts, they can be used only for temporary repairs.

SAFE SPlice DESIGN

Both mechanical and vulcanized splices must be designed with factors of safety when compared to the expected belt tension. These design factors for mechanical fasteners are built into the manufacturers’ selection tables. Vulcanized splices on high-tension steel cable belts are often individually designed by the belt manufacturer or consultant. Failure to match the splice with the belt and account for the correct service and safety factors can result in catastrophic splice failures leading to injury, death, loss of production, and equipment damage.

MAINTENANCE AND INSTALLATION STATIONS

Some operations develop what is called a belt-splicing station along the conveyor. Here, tools and equipment are stored for splice maintenance, and the space and work surfaces are available for splice installation. This may also be the point at which a new belt is pulled onto the conveyor.

A splice station should be located where there is plenty of room, ideally including workspace on both sides of the conveyor structure. The station should provide protection for the belt from climate conditions and fugitive material. The space should be placed at a point where there is a distance of at least five belt widths of straight conveyor stringer on either side of the point where the splice will be made. Power should be readily available, including outlets for hand tools.

INSPECTION AND MONITORING

Splice Inspection and Service

Where bolt-style fasteners are used, it is important that the plates be kept properly tightened. The most practical way to achieve this is to tighten the bolts so that the rubber behind the plate slightly swells. Care must be taken not to over-tighten fasteners or “bury” the plates into the belt cover, as this could cause damage to the plies of the belting. Manufacturers generally suggest retightening the fasteners after the first few hours of operation, again after the first few days of operation, and then at intervals of two or three months of operation.

Splices should normally be inspected on a weekly basis, with replacement of any fasteners that look worn, watching for crosswise breaks on the back of fasteners, and checking for fastener pullout.

Splice-Monitoring Systems

Newer technologies are now available which allow the remote evaluation of splices by measuring any elongation of the splice. These systems are based on the principle that the lengthening of a splice is an indication of an impending failure. The system is installed on vulcanized belts by placing small magnetic targets into the belting at a set distance on either side of
splices; if the belt has mechanical fasteners in place, the system can use those as the targets. The system will monitor the distance between the paired targets each time a splice passes the scanner. This distance is measured, and if a splice falls outside the set limits, the monitoring system will shut down the belt or alert plant personnel to check the problem. In addition, the system can help identify if a clip has suffered severe damage and must be replaced.

**THE IMPORTANCE OF THE SPlice**

**In Closing...**

Whether it is vulcanized or uses mechanical fasteners, a properly designed, well-applied and maintained splice is critical to the success of a belt conveyor’s operations. Improper application of a splice will shorten the life of the belt and interfere with the conveyor’s operating schedule and efficiency. Care in applying the proper splice in the correct fashion will provide benefits for the entire plant. In the words of an old axiom: “If you don’t have the time to do it right, how are you going to find the time to do it over?”

**Looking Ahead...**

This chapter, Splicing the Belt, explaining how delayed or improper splicing can allow fugitive materials to escape from the belt, concludes the section Foundations of Safe Bulk-Materials Handling. The following chapter begins the section related to Loading the Belt and addresses the area Before the Loading Zone, looking at tail pulleys and transition areas.

**REFERENCES**

5.1 Any manufacturer and most distributors of belting can provide a variety of materials on the construction and use of their specific products, as well as on conveyor belts in general.


5.3 The website http://www.conveyor-beltguide.com is a valuable and non-commercial resource covering many aspects of belting.