ENERGY
MANAGEMENT
SERIES

17

FOR INDUSTRY
COMMERCE
AND INSTITUTIONS

Materials Handling and On-Site Transportation Equipment

To the Reader

These manuals provide detailed information on a wide range of energy management topics. Because they were produced in the late 1980s, references to energy prices and to some energy management techniques are dated. Nonetheless, the manuals provide practitioners with useful mathematical equations and general information on proven techniques and technologies, as well as examples of how to save energy.

Avis au lecteur

Ces manuels contiennent de l'information détaillée sur de nombreux aspects de la gestion énergétique. Comme ils ont été produits à la fin des années 80, les références aux prix de l'énergie et à certaines techniques de gestion énergétique ne sont plus à jour. Le lecteur y trouvera toutefois des équations mathématiques utiles et des renseignements généraux sur diverses techniques et technologies éprouvées, ainsi que des exemples de mesures à prendre pour économiser l'énergie.

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PREFACE

Much has been learned about the art and science of managing energy during the past decade. Today, energy management is a seriously applied discipline within the management process of most successful companies.

Initially, in the early 1970's, energy conservation programs were established to alleviate threatened shortages and Canada's dependency on off-shore oil supplies. However, dramatic price increases quickly added a new meaning to the term "energy conservation" — reduce energy costs!

Many industrial, commercial and institutional organizations met the challenge and reduced energy costs by up to 50%. Improved energy use efficiency was achieved by such steps as employee awareness programs, improved maintenance procedures, by simply eliminating waste, as well as by undertaking projects to upgrade or improve facilities and equipment.

In order to obtain additional energy savings at this juncture a greater knowledge and understanding of technical theory and its application is required in addition to energy efficiency equipment itself.

At the request of the Canadian Industry Program for Energy Conservation, the Commercial and Institutional Task Force Program and related trade associations, the Industrial Energy Division of the Department of Energy, Mines and Resources Canada, has prepared a series of energy management and technical manuals.

The purpose of these manuals is to help managers and operating personnel recognize energy management opportunities within their organizations. They provide the practitioner with mathematical equations, general information on proven techniques and technology, together with examples on how to save energy.

For further information concerning the manuals listed below or regarding material used at seminars/workshops including actual case studies, please write to:

Industrial Energy Division
Energy Conservation Branch
Department of Energy, Mines and Resources
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TABLE OF CONTENTS

INTRODUCTION

Materials handling and on-site transportation equipment plays a vital role in making Industrial, Commercial and Institutional facilities operate efficiently. The operating costs associated with materials handling and on-site transportation equipment are significant. However, this equipment is seldom evaluated on an energy utilization or energy economic basis. This creates opportunities for saving energy and money.

Purpose

The following summarizes the purpose of this module.

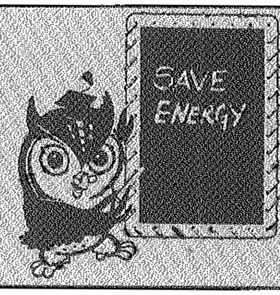
- To describe materials handling and on-site transportation equipment as used in the Industrial, Commercial and Institutional sectors.
- To draw attention to the Energy Management Opportunities present in existing facilities, and available when selecting new equipment.
- To show the benefits to be derived from effective energy management.
- To provide information that will encourage the review of Energy Management Opportunities in the materials handling and on-site transportation sectors.

Contents

The module is subdivided into the following sections.

- *Fundamentals*, which covers the objectives and general principles of materials handling and on-site transportation equipment.
- *Equipment/Systems*, which describes the equipment and systems most commonly encountered.
- *Energy Management Opportunities* are described and supported, where applicable, by estimated figures for energy and cost savings and simple payback calculations.
- *Appendices*, which include a glossary of terms, tables, conversion factors, and worksheets.

FUNDAMENTALS



Materials handling and on-site transportation can be defined as the methods of moving material from the yard or receiving facility, through the various stages of production to storage, and finally, to the shipping area for distribution. In recent years great emphasis has been placed on the use of mechanization. This has led to the widespread use of various types of materials handling and on-site transportation equipment ranging from simple gravity conveyors to computer controlled integrated systems.

The predominant use of this type of equipment is in the Industrial sector, however Commercial and Institutional facilities also use materials handling equipment on a regular basis.

In common usage the term "materials handling" is used to denote the handling of a solid product such as boxes or bags of sugar, dry powders, cereal grain, tires or other such objects. The movement of liquids and gases is normally considered as part of a liquid or gas piping system and is not covered in this module. For steam and condensate piping, reference should be made to Steam and Condensate Systems, Module 8. For water and compressed air piping, reference should be made to Water and Compressed Air Systems, Module 12.

The use of materials handling and on-site transportation equipment is not limited to goods or products. People are moved vertically by elevators, horizontally by moving sidewalks, or on an incline by escalators.

Objectives

The objectives of materials handling and on-site transportation equipment may be defined as follows.

- *Improve throughput* by ensuring that materials are efficiently moved and stored to avoid unnecessary production interruptions. This can be achieved through efficient planning of plant layout, receiving and shipping facilities and warehouse areas.
- *Improve safety* by using mechanical equipment that reduces physical effort and fatigue and helps avoid accidents.
- *Lower costs* by properly selecting and using mechanized equipment to achieve greater materials handling efficiency.

Principles of Equipment Selection

Proper equipment selection is important since it affects throughput, cost, utilization, down time, maintenance, durability, and flexibility of use. Basic materials handling requirements must be established, whether the system is to be engineered in-house, or by an outside consultant or the equipment manufacturer. The equipment selection process includes an assessment of future trends, possible new manufacturing techniques, internal long-range sales forecasts, and facility plans. The following is a useful checklist when considering new equipment.

- Research the market to be aware of available equipment and systems.
- Use standard equipment where possible.
- Minimize the types of equipment within the facility to simplify operation and maintenance.
- Ensure that spare parts are available and that supplier service is cost efficient.
- Investigate energy consumption and possible energy saving features.
- Review control methods, and consider using modern technology, such as microprocessor control.
- Ensure that systems have operational flexibility.
- Ensure that systems have expansion capability where growth projections are indicated.
- Compare available equipment to ensure good value.

Optimum long term performance can be assured only where the present and projected operations are studied, and the equipment requirements are carefully established before final equipment selection.

Plant Layout

Efficient use of facilities is most important and a review of the overall facility layout should be done on a regular basis. This review may indicate that changes in plant layout could reduce the use of materials handling equipment. The review may also indicate "bottleneck" locations in material flow through a plant because of limitations or constraints caused by production equipment layout. Revising the plant layout and adding or modifying the materials handling or on-site transportation equipment may relieve this condition.

Many older plants are operating in multistoried buildings and opportunities may present themselves for good energy management. Chutes can be used to transfer product downwards from floor to floor as long as the manufacturing or assembly operations are arranged to allow this type of flow to take place.

Waste Management

Reduction of waste should be a continuing objective in any plant operation. It is also recognized that a certain amount of waste is generated and its handling, removal or reuse should be carefully reviewed with particular emphasis on potential energy savings. In certain cases, waste material such as wood scraps or used lubricating oils can be used to fuel a system that provides energy for heating or process purposes.

Scheduling

Materials handling and on-site transportation equipment knits purchasing, production, warehousing and distribution into a cost effective system.

To make proper use of equipment it is essential that good scheduling be carried out to control the flow of materials through the facility. Lack of material movement control creates fluctuations in facility throughput and requires additional equipment for peak production times. Under these circumstances, the capital costs for plant equipment are greater and the equipment is underutilized during off peak periods. Controlled flow allows full use of the in-plant equipment and tends to eliminate fluctuations in facility throughput.

Scheduling of incoming and outgoing material, in-process material and finished product is also very important since these items all have an impact on the utilization of equipment and storage space requirements.

Production Operation Analysis and Automation

In many applications, the addition of modern material handling methods, equipment and microprocessor or computer control may be used to advantage. Levelling the flow of materials to production operations, and coordinating the starting and stopping of materials handling and production equipment can lead to improved plant operation and better energy management.

Reviewing of individual production operations with the intent of combining one or more into a sequenced production operation may allow the reduction of floor space required for in-process material storage. This could reduce associated handling costs of moving the material to and from the production areas.

Shipping and Receiving Facilities

Shipping and receiving facilities range from simple manual systems, to highly mechanized and automated operations. These are described according to indoor and outdoor arrangements.

Indoor

An indoor shipping or receiving facility allows the truck, trailer, or railcar to enter the building for loading or unloading purposes. While this type of operation provides maximum comfort for employees during cold or inclement weather, certain cost factors are involved.

- Higher capital cost for additional indoor space.
- Increased operating costs for heat and light.
- Increased building maintenance.
- Special monitoring and exhaust systems to maintain carbon monoxide at acceptable code levels.

Outdoor

For outdoor shipping or receiving facilities, product transfer takes place from the truck, trailer, or rail car through a door into the facility. The transportation unit remains outside the building. Outdoor facilities offer certain advantages.

- Lower capital cost, because there is no need to increase building size to accommodate the vehicles or rail cars.
- The lower capital cost per door permits more loading/unloading positions than with indoor facilities to accommodate peak traffic (more openings for dollars spent).

These facilities also have certain disadvantages which should be considered.

- Lower comfort level for employees during inclement weather.
- Greater heat loss from multiple doors and associated gaps because of air infiltration and exfiltration.
- Increased maintenance costs associated with multiple doors, dock seals, and shelters. These are normally higher than the maintenance costs associated with indoor facilities.
- Increased safety hazards because the entry of rain or snow creates slippery floors.

The general trend, based on economic considerations, is toward the outdoor shipping or receiving facility. Fortunately, there are methods that can be used to minimize certain disadvantages of the outdoor facility, while still retaining the cost advantage. These are described in the Equipment/Systems section.

Energy Audit Methods

Energy Management Opportunities can be found in many Industrial, Commercial or Institutional facilities. Many of these opportunities are recognizable during a *walk through audit* of the facility. This audit is usually more meaningful if a "fresh pair of eyes", generally familiar with energy management, is involved. Typical energy saving items noted during a walk through audit could be fork lift trucks idling unnecessarily, conveyors running unloaded, equipment operating when not required, conveyors running faster than required, damaged dock seals or other similar items. Alert management, operating staff, and good maintenance procedures can reduce energy use and save money. However, care must be taken to ensure that the implementation of any Energy Management Opportunity does not have a detrimental effect on the product being handled.

Not all items noted in a walk through audit are as easy to analyze. For example, it may be noted that a conveyor gallery passing between two buildings is not insulated, although the conveyor is carrying a warm product. At the discharge end of the conveyor, the material must be reheated prior to being processed. The immediate reaction is that the gallery should be insulated to reduce the product heat loss. Certain key questions arise.

- How much insulation?
- What type of insulation?
- Will the energy, and associated cost savings, pay for the insulation quickly enough?

A *diagnostic audit* is required to mathematically determine the existing energy loss and potential energy reductions. The reduction in energy use establishes dollar savings. With this, plus the estimated cost to supply and install insulation, simple payback calculations can establish the financial viability of the opportunity.

The implementation of Energy Management Opportunities can be divided into three categories.

- *Housekeeping*, refers to an energy management action that is *repeated on a regular basis and never less than once a year.*
- *Low cost*, refers to an energy management action that is *done once and for which the cost is not considered great.*
- *Retrofit*, refers to an energy management action that is *done once and for which the cost is significant.*

It must be noted that the dollar division between low cost and retrofit is normally a function of the size, type and financial policy of the organization.

Summary

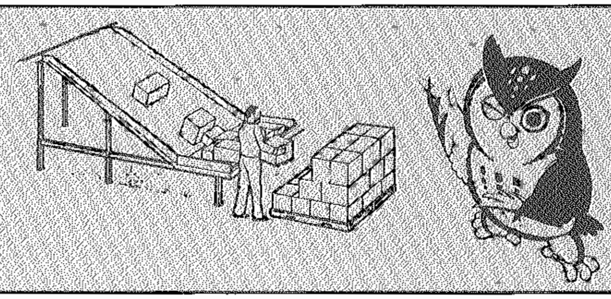
Materials handling and on-site transportation equipment can be found in most Industrial, Commercial and Institutional facilities. There are three prime objectives for the use of this equipment.

- Improved throughput (Process requirement).
- Improved safety (Safety requirement).
- Lower costs (Cost reduction requirement).

Normally, this equipment is installed to improve product handling capabilities and reduce labor requirements. However, Energy Management Opportunities do exist, and should be identified and implemented for existing and proposed equipment.

When selecting new equipment ensure that it is properly sized for the intended purpose. Use the knowledge available from equipment suppliers or other experts in this field to obtain the most energy efficient system for the required function.

EQUIPMENT SYSTEMS



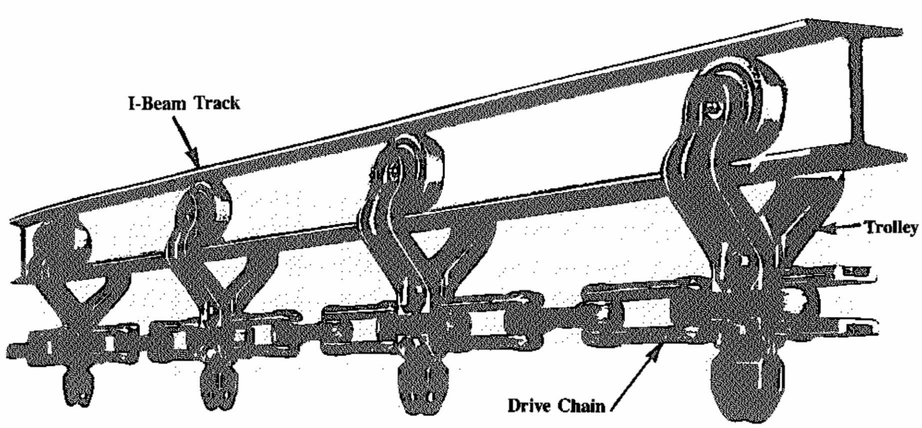
Materials handling and on-site transportation equipment can be found in practically all facilities within the industrial, Commercial and Institutional sectors. Common equipment types are described in this section, however, each application must be investigated on an individual basis to ensure that the equipment or system selected is correctly designed for its intended use. Energy use must be one of the considerations. Detailed information regarding specific equipment can be obtained from equipment manufacturers or other experts.

Conveyor Systems

Conveyor systems are widely used to transport raw materials, semifinished and finished products. These systems range from overhead and in-floor trolley and chain conveyors through gravity rollers, belt and live roller conveyors to bulk pneumatic handling systems. A brief description of each type of system follows.

Overhead Trolley and Chain Conveyors

Two types of overhead trolley and chain conveyors are in common use in many facilities. These are *heavy and medium duty overhead trolley conveyors* which consist of chain connected trolleys and an I-beam track (Figure 1)

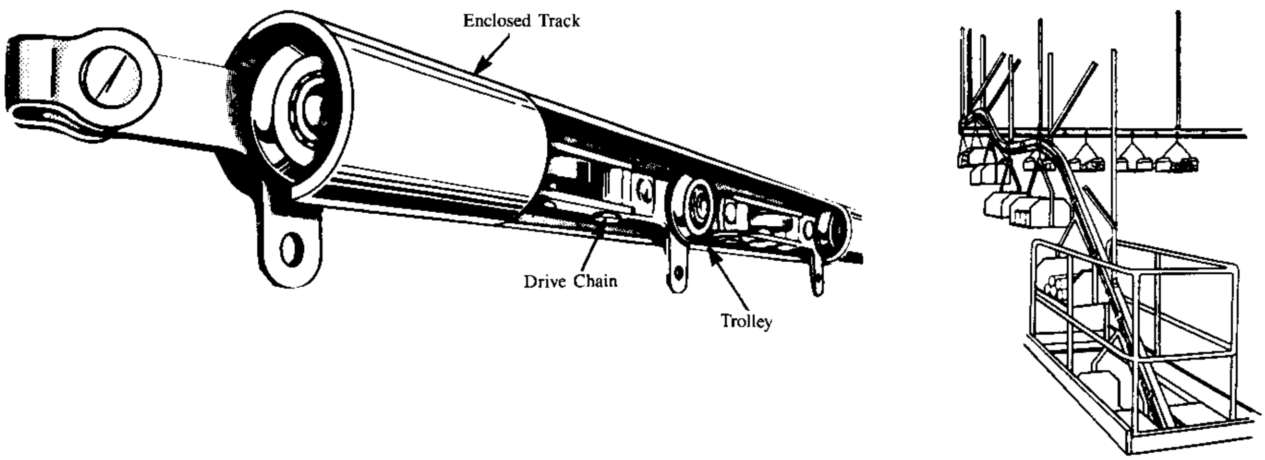


Overhead Trolley Conveyor System
Figure 1

and *light duty overhead systems* in which the trolley and drive chain operate in an enclosed slotted track (Figure 2). In both cases, special hooks or carriers suspended from the chain are used to transport the product. These systems range from simple systems used to transport items from one operation to another, to complex systems having the capability of multipath routing, intermittent operation, and accumulation of product. These systems also have the capability of providing off-floor surge storage between production operations.

Heavy and medium duty systems are commonly used in automotive and other manufacturing industries to move in-process products through various operations such as dip tanks and paint spray booths.

Light duty systems are used in many operations including plastic finishing, oven drying, degreasing and plating. The slotted track which surrounds the chain and trolley provides protection to these items and reduces the possibility of contamination damaging the chain and bearing surfaces.



Light Duty Overhead Conveyor System
Figure 2

In-Floor and Overhead Towline Systems

Large distribution facilities such as freight terminals, warehouses, manufacturing plants, shipping, receiving and a variety of plant processes are common users of *in-floor and overhead towline systems (Figure 3)*. These systems use chain pulled carts to transport the product. Special links on the chain engage the cart tow pin or mast to move the cart. They can be inserted or taken from the system at any point by engaging or disengaging the tow pin or mast from the chain. Carts may be standard design or custom built for specific applications.

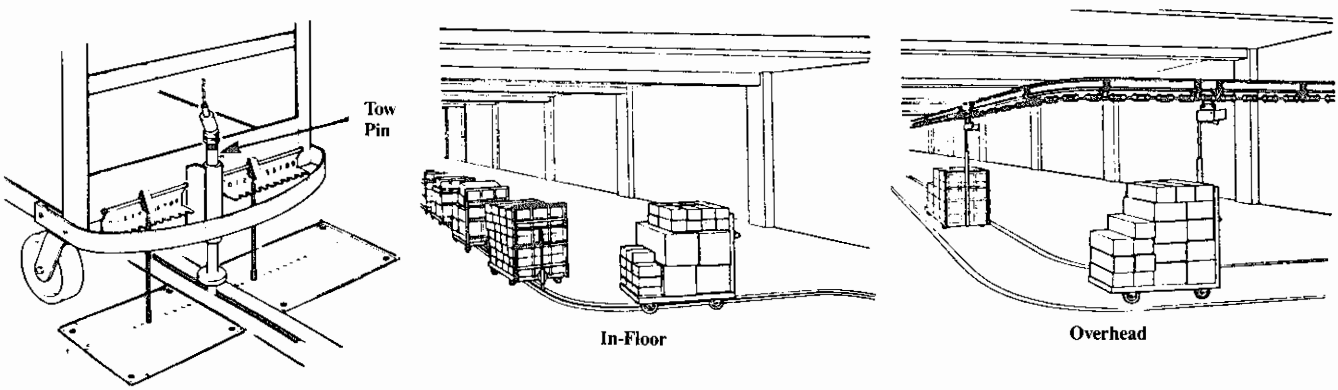
Towline systems have great flexibility and can be designed with storage loops and powered or nonpowered spurlines. They may contain some or all of the following components.

- Powered spurlines, which are small self-contained loops that engage and move the cart when it is diverted off the main loop. Carts for powered spurline applications must be equipped with tow pin or mast disengaging devices to disengage the tow pin or mast from the chain when contact is made with a cart or other object.
- Nonpowered or bump-off spurlines, which depend on the momentum of the cart, when diverted, to carry it off the main track, and along the spurline. The next diverted cart will then bump the one ahead to move it farther along the spurline.
- Assembly line systems, which can be equipped with automatic cart dumping devices, or carts with special platforms for assembly operations.
- Control systems, which use magnetic probes, optical scanners, and limit switches to confirm the presence of carts and control the overall operation of the system.

Most new facilities install towline systems during building construction. The overhead system is normally installed in existing buildings where it is not desirable or cost effective to install the in-floor track. However, the height constraint of the overhead system (approximately 2 metres) limits its use. The in-floor system, on the other hand, has the advantage of allowing freer movement of materials and transportation equipment.

The installation of an overhead towline in an existing building is much lower in cost than the installation of an in-floor system. This is because of the major cost involved for floor modifications required for the installation of the in-floor track and system drive.

From the standpoint of maintenance, overhead towline systems normally are less expensive to maintain than in-floor systems. In-floor systems are susceptible to material dropping into the track and causing damage, and are also susceptible to flooding in the event of spills onto the floor.



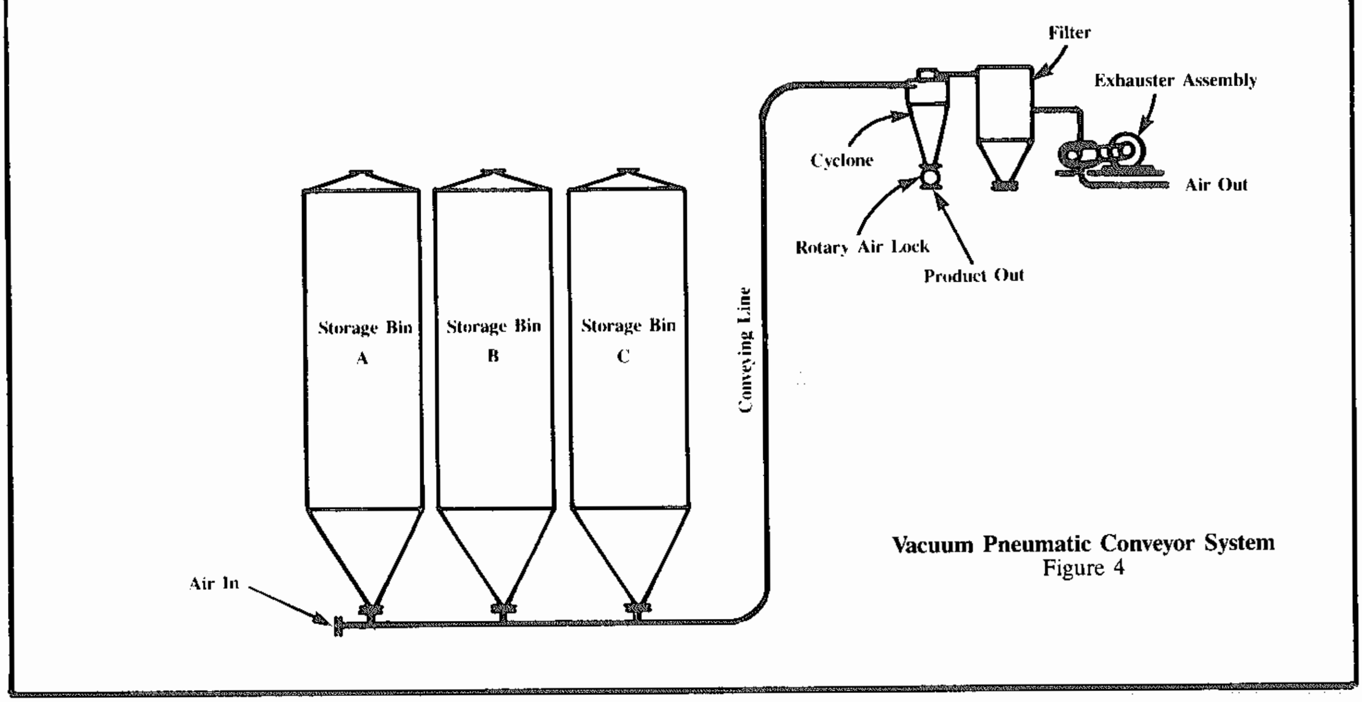
In-Floor and Overhead Towline Systems
Figure 3

Pneumatic Conveyors

Many dry materials such as plastic pellets, flour, sugar, starch and grain can be transported via hoses, pipes or tubes using air as the transport medium. These systems are commonly used to transfer products from a bulk carrier to storage silos, equipment and process operations.

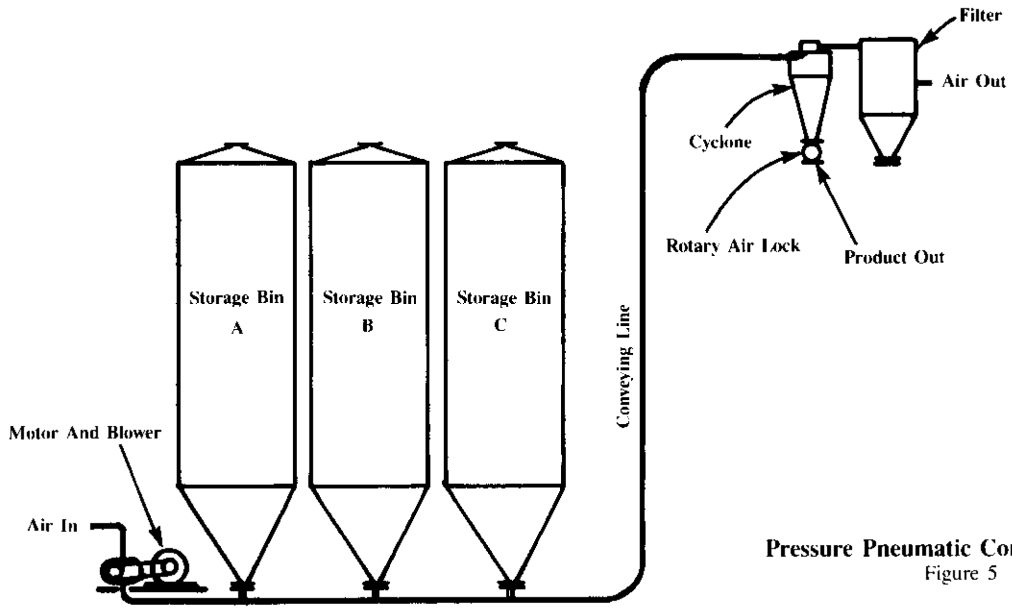
The three basic systems which may be encountered are listed.

- *Vacuum systems* are used to suck the product out of storage and require an exhauster assembly complete with a cyclone separator, rotary air lock, and dust filtration equipment at the discharge point (Figure 4). Since these systems are operating under vacuum conditions, dust leakage is not a problem, however leaks in the system will reduce the transport effectiveness downstream of the leak.



Vacuum Pneumatic Conveyor System
Figure 4

- *Pressure systems* introduce pressurized air into the transport pipe or duct upstream of the product storage, and a rotary valve is used to meter the product into the moving air stream (Figure 5). As with the vacuum system, a cyclone separator, rotary air lock and dust filtration equipment are required at the discharge point. These systems will leak dust and product at any joint, seam or crack that is not sealed.
- *Combination pressure and vacuum systems* are used to move material from areas such as bulk carriers (truck or railcar) to storage. Accessories include portable transfer units, dust filters equipped with dust release devices, rotary valves, and special silo discharge cones to improve the discharge flow of dry bulk products. The selection of one system over any other system is a function of the material being transported and the transportation distances involved. Pneumatic system manufacturers should be consulted at the initial system design stage.

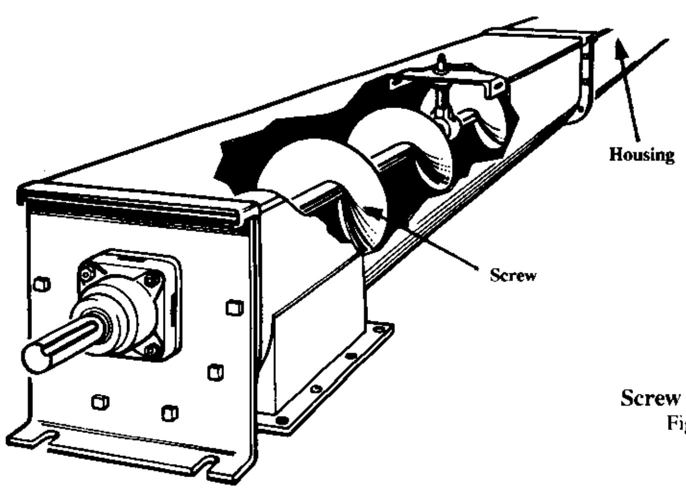


Pressure Pneumatic Conveyor System
Figure 5

Bulk Handling Conveyors

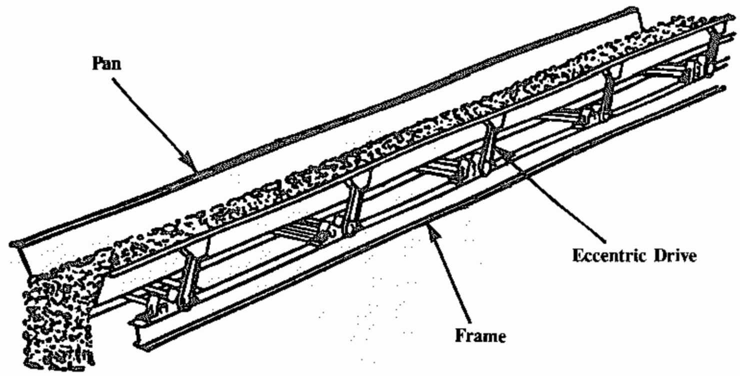
Bulk materials handling is a complex subject, particularly where heavy, wet, corrosive, abrasive, or sticky products are concerned. Detailed investigation and engineering design are required for each material to ensure proper handling. The following types of bulk handling equipment are commonly encountered.

- *Screw conveyors* consist of a screw inside an enclosed tube where the rotation of the screw causes the product to travel from inlet to discharge (Figure 6). They are economical and reliable, and are widely used for the movement of products such as chemicals, wood chips, coal, ashes, powders, grains, fertilizers, food products and cement. They are available in a variety of construction materials and screw designs, and are suitable for batching and mixing operations. They are space efficient, and the totally enclosed design minimizes dust and fume leakage.



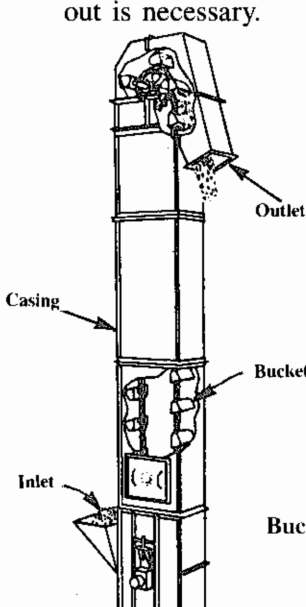
Screw Conveyor
Figure 6

- *Vibrating conveyors* are used for the horizontal movement of bulk materials (Figure 7). A pan is moved in a small arc so that material placed on it is indexed forward. The transfer pan is mounted on either leaf or coil springs and the vibrating motion is created by means of an eccentric drive unit connected to the pan. These conveyors are used to transport hot, heavy, and abrasive material in foundries, steel mills and cement plants. The conveyed material can be sized, screened, sorted, cooled, or heated by using special accessories. Because of the method of operation and materials conveyed, these units normally require considerable maintenance.

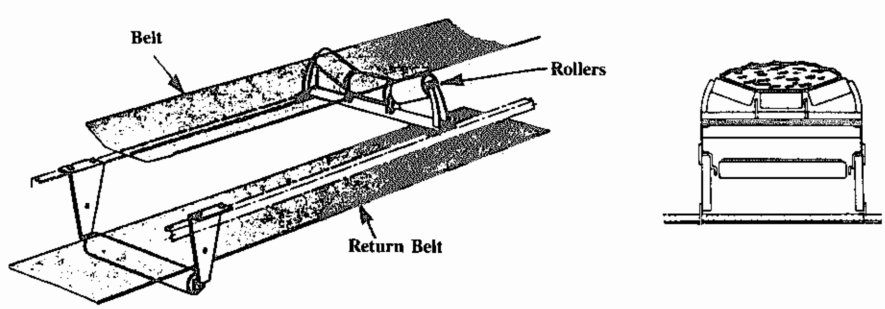


Vibrating Conveyor
Figure 7

- *Bucket elevators* consist of buckets connected to a vertical belt or chain (Figure 8). Loading is accomplished as the bucket scoops up the material, or by directly feeding the bucket at the inlet. This system is used for the vertical conveying of free-flowing products such as grain, coal and wood chips. The product is carried up and discharged over the top pulley. Belt-type bucket elevators are used in light duty applications with low product bulk density, and where the vertical lift does not exceed 40 metres. Chain type units are suitable for greater loads and vertical heights. Bucket design varies according to the product characteristics, such as abrasiveness, ability to flow, and tendency to pack. Bucket materials include malleable iron, steel, aluminum, plastic, and nylon. Material spillage is a normal occurrence in bucket elevator operation, and regular clean out is necessary.



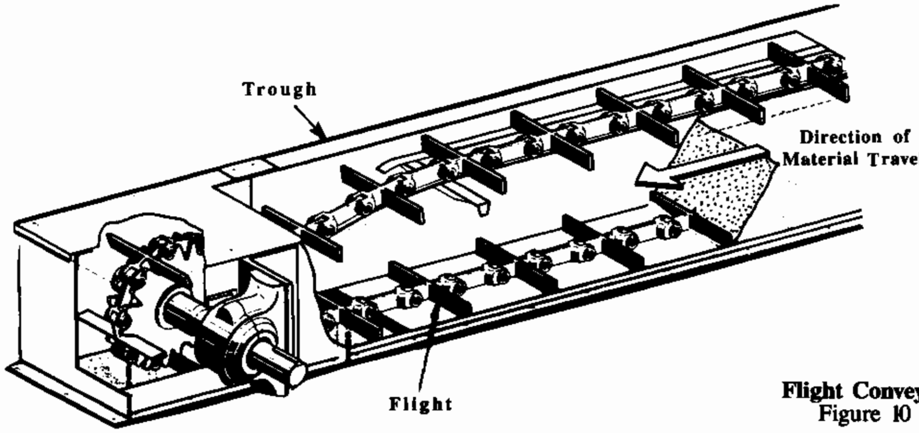
Bucket Elevator
Figure 8



Troughed Belt Conveyor
Figure 9

- *Troughed belt conveyors* are designed so that the edges of the belt are held in a trough configuration by rollers or metal sides to prevent the loose product from falling off the belt (Figure 9). This is one of the most common bulk handling systems, and it is used in a variety of heavy industries for the transportation of ore, sand, gravel, coal and other similar materials. Troughed conveyors are suitable for moving high volumes of product over substantial distances. Abrasion resistant belts of extreme durability, flexibility, and strength have been developed to handle the product load and horsepower requirements. Operating costs are relatively high.

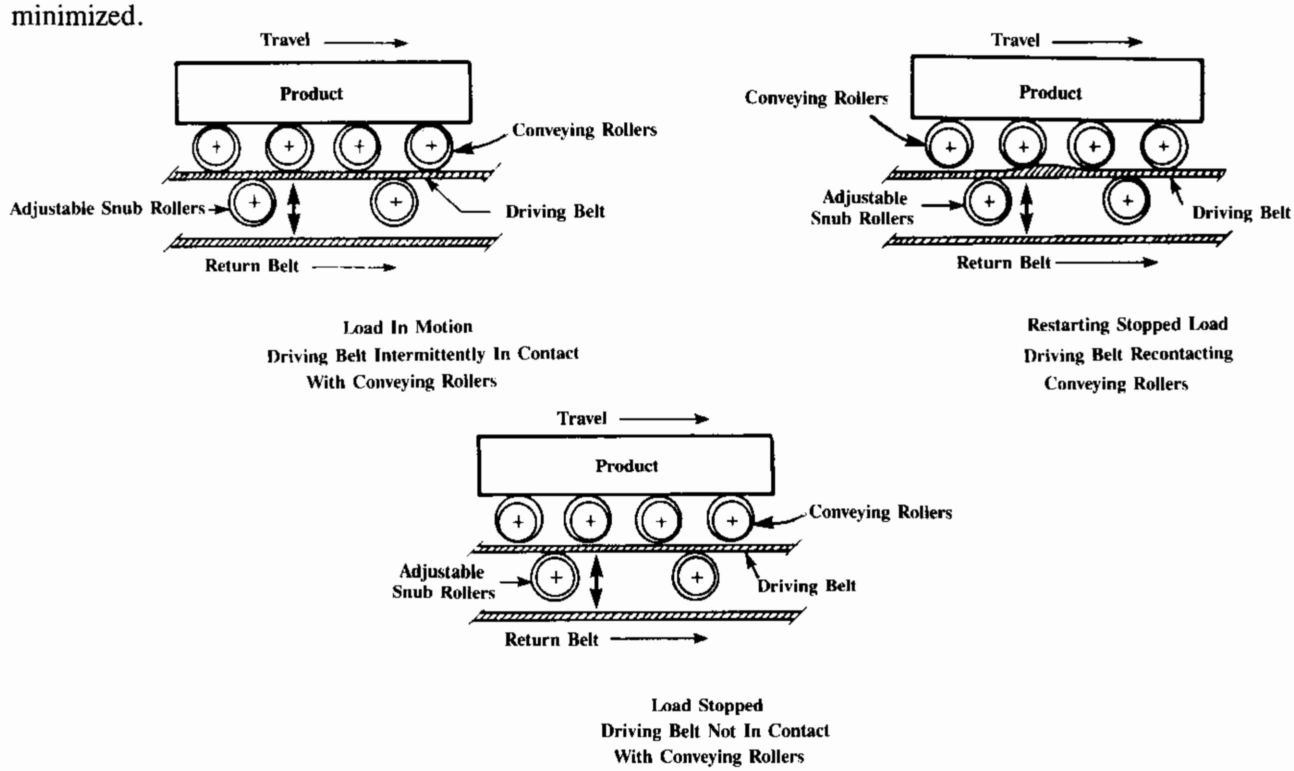
- *Flight conveyors* convey material in an enclosed trough by means of a series of flights (rectangular metal pieces) attached to a chain, chains, or cables running in the trough (Figure 10). Material is conveyed along the bottom of the trough and discharged by means of regulating gates. Horizontal or inclined arrangements are commonly used for bulk materials, such as cement clinkers and fertilizer.
- *Drag conveyors* are similar to flight conveyors, however, the flight is specially shaped according to the application. Drag conveyors are also capable of vertically transporting dry materials.



Flight Conveyor
Figure 10

Live Roller Conveyors

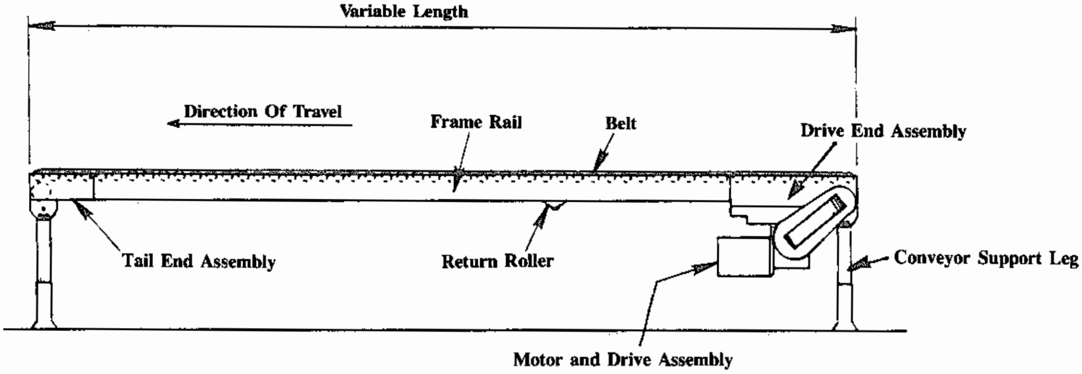
Live roller conveyors have carrying rollers which are powered from beneath (Figure 11). The product rides directly on the carrying rollers which are powered by a flat belt, V-belt, or other means. Usually, live roller conveyors are used when on-line accumulation is required between varying rate operations. Manufacturers have developed methods of adjusting the driving force on the carrying rollers so that the crushing effect on the accumulated product is minimized.



Live Roller Conveyor
Figure 11

Package Handling Powered Conveyors

Powered conveyors (Figure 12) must be considered where long runs and high volume activities make the use of nonpowered (gravity) conveyors unsuitable. Because of their versatility, and labour saving capabilities, powered conveyors are widely used. The system designer should consider the combined use of powered and gravity conveyors, as well as chutes to achieve an effective and economical system. Each conveyor and system must be designed with particular reference to the product being handled.



Powered Conveyor
Figure 12

Belt conveyors consist of a frame, drive unit, end pulleys, take-ups, and either a roller or slider bed complete with carrying belt (Figure 13). Belt conveyors are available in a variety of widths and lengths, belt materials and surface types, and can be used for horizontal, inclined, or declined applications.

The more common belt conveyor is one in which the belt is supported on rollers spaced to suit the load application.

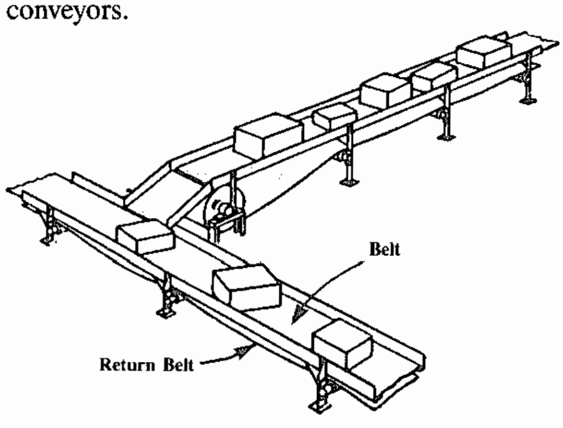
Rough top, cleated, and chevron belts, made from synthetic or natural materials, can be supplied for inclined transfer applications. Belt tension is maintained by means of screw, gravity, or adjustable air-operated tensioning take-up systems. Drive units usually consist of a motor driving a shaft-mounted or close-coupled reducer, which rotate the drive pulley by means of a chain or V-belt. The system design establishes the drive unit selection and location.

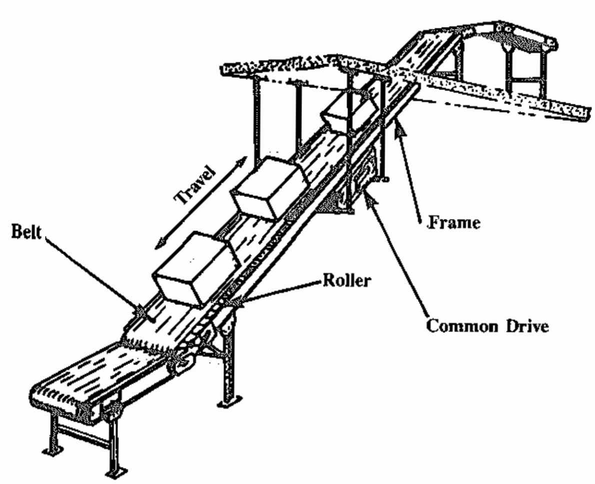
The slider bed supported belt conveyor (belt is supported on a smooth metal pan) is more economical to purchase and maintain. However, the horsepower requirement is greater because of increased friction between the belt and the slider bed. This type of conveyor system is limited to light loads and short lengths.

Where space is restricted a drum motor may be considered. Drum motors incorporate the motor and reducer within the shell of the pulley for a very compact arrangement.

Drive units can incorporate items such as gearmotors (integral motor and gear reducer), clutch assemblies to allow for frequent stop/starts, and brake assemblies to prevent roll back on inclined conveyors. Manual or automatic controlled variable speed drives can be used to adjust the conveyor speed to suit the required product transfer rate.

Additional examples of powered conveyors which may be encountered are chain driven roller conveyors and slat conveyors.





Powered Conveyor Applications
Figure 13

Power Requirements

To calculate the power required to drive a belt or slider bed conveyor certain factors must be established.

- Total live load (LL_T): Weight of product on the conveyor (kg).
- Dead load — Part 1 (DL_1): Weight of rollers and belting (kg). See Table 1.
- Dead load — Part 2 (DL_2): Weight of all drive pulleys and end rollers (kg). See Table 1.
- Total dead load (DL_T) $= DL_1 + DL_2$ (kg)
- Belt pull (BP): Force required to start and maintain the movement of all rollers, pulleys, belting and live load. (kg).

$$BP = (LL_T + DL_T) \times C_f$$

Where, C_f = coefficient of friction

$C_f = 0.05$ (for roller bed conveyors)

$C_f = 0.30$ (for slider bed conveyors)

If a conveyor is inclined, additional belt pull is generated and must be added to the previously calculated belt pull. Based on the angle of incline of the conveyor, this additional belt pull can be calculated.

Additional belt pull (BP_A) = Total live load on incline x Sine of incline angle (kg)

Table 2 lists the sine for various incline angles.

It must be noted that for declining conveyors, the additional belt pull should be calculated in the same manner.

The same forces act on a decline belt conveyor as on an incline. However, on a decline belt conveyor, the motor must resist the force, which requires practically the same power as the incline unit.

Using the previously defined factors, the total belt pull can be calculated.

Total belt pull (BP_T) $= BP + BP_A$ (kg)

To calculate the effective belt pull, it is normal to add 25 per cent to the total belt pull to allow for belt flexing, drive chain flexing and bearing friction losses in the end rollers, take-up and drive.

Effective belt pull (BP_E) $= 1.25 \times BP_T$ (kg)

The drive power requirements may now be calculated.

Power (kW) $= BP_E$ x Conveyor speed (m/s) x 0.0098

Where, 0.0098 = a factor to convert horsepower to kilowatts and for conversion to common units.

Worksheet 17-1 has been developed to assist in calculations for belt conveyor power requirements. Consider an inclined slider belt conveyor handling dry granular product. The following information is obtained from a diagnostic audit.

- Conveyor Length 30 m
- Product loading on conveyor 36 kg/m
- Conveyor speed (V_c) 0.508 m/s
- Conveyor width between frames 0.84m
- Angle of inclination 20°

Inserting this information on Worksheet 17-1, and completing the calculations indicates that the conveyor requires a 4.78 kW drive.

Calculation Of Belt Conveyor Power Requirements

Worksheet 17-1

Company: XYZ COMPANY   Date: FEB. 1986

Location: ANYTOWN   By: MBE

Conveyor No: 4

Type of Conveyor: ______ Roller bed ✓ Slider bed ______ Heavy duty roller bed

Material	PRODUCT 123	
Product loading on conveyor	36	kg/m
Conveyor length	30	m
For roller conveyor centre to centre distance between carrying rollers	N/A	m
Width between frames	0.84	m
Angle of incline (Table 2)	20	°
Conveyor Speed (V_c)	0.508	m/s
Coefficient of friction	0.30	

Total Live Load LL_T = Live load (kg/m) x Conveyor length (m)

= 36 x 30

= 1080 kg

Dead Load 1 (Table 1) DL_1 = Dead Load (Part 1) kg/m x Conveyor length (m)

= 5.95 x 30

= 178.5 kg

Dead Load 2 (Table 1) DL_2 = Dead Load (Part 2) kg

= 77.11 kg

Total Dead Load DL_T = DL_1 + DL_2

= 178.5 kg + 77.11 kg

= 255.61 kg

Calculation Of Belt Conveyor Power Requirements

Worksheet 17-1

Company: XYZ COMPANY Date: FEB. 1986

Location: ANYTOWN By: MBE

Belt Pull $BP = (LL_T + DL_T) \times C_f$

$= (1080 + 255.61) \times 0.30$

$= 1335.61 \times 0.30$

$= 400.68$ kg

Incline (Decline)

Belt Pull BP_A = Total live load on incline (kg) x Sine of angle

$= 1080 \times 0.34$

$= 367.2$ kg

$BP_E = (BP + BP_A) \times 1.25$

$= (400.68 + 367.2) \times 1.25$

$= 959.85$ kg

Power $= BP_E \times V_c$ (m/s) $\times 0.0098$

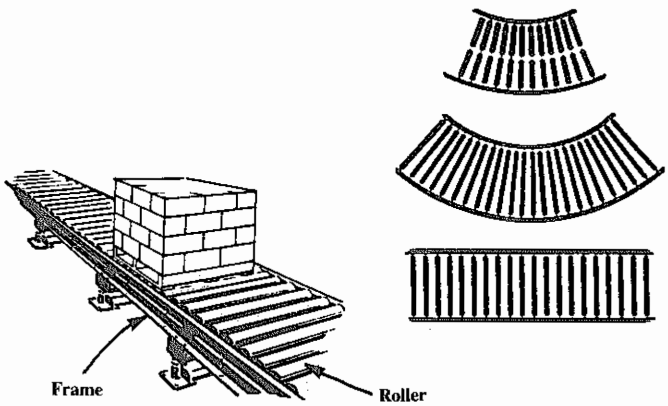
$= 959.85 \times 0.508 \times 0.0098$

$= 4.78$ kW

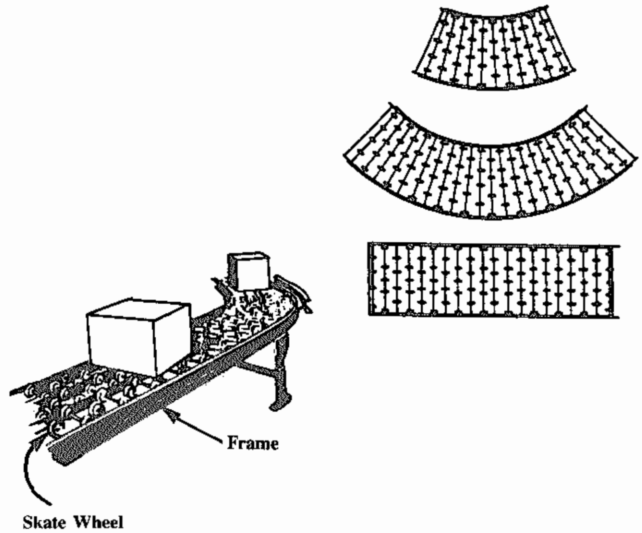
Nonpowered Conveyors

Gravity conveyors, consist of rollers (Figure 14) or small skate wheels (Figure 15) mounted on axles, and set between two frame rails. They are used in warehouse, distribution, and manufacturing facilities where the economics do not justify powered equipment or where powered equipment is not essential. Systems range from lightweight (usually aluminum) portable sections to heavier large roller units that are part of a permanent installation. Since these units are so efficient, they should be carefully considered versus powered conveyors.

Many shipping and receiving operations eliminate considerable manual effort by using one or two sections of lightweight portable gravity conveyor for loading and unloading trucks. An example would be at the shipping or receiving departments of a bottling plant.



Roller Type Nonpowered Conveyor
Figure 14



Skate Wheel Nonpowered Conveyor
Figure 15

Conveyor Control and Maintenance

The most important aspect of an efficient materials handling program is the development and implementation of a Preventive Maintenance (PM) program. A PM program for the specific equipment should be developed using manufacturers' supplied data and plant experience. A typical PM sheet (Table 3) is provided for ideas and guidance.

Items such as hours of use, environment, product type, weight, and method of product loading affect the equipment performance and maintenance requirements. Some of the desired routine maintenance activities are listed.

- Develop routine inspection procedures.
- Determine ideal frequency of inspection.
- Check belt and chain tensions and adjust where necessary.
- Develop routine lubrication programs.
- Ensure that proper types and grades of lubricant are being used. Equipment operating in a low temperature environment should have low viscosity lubricants that allow it to operate freely. Conversely, equipment that operates in above normal temperatures (drying and bake ovens) should use a lubricant that will not break down and cause excessive friction or seize-up.
- Listen for squeals, squeaks, or any other signs of inadequate lubrication.
- Be aware of abnormal equipment temperatures that indicate equipment overload or excessive friction.
- Develop equipment cleaning programs.
- Develop major overhaul programs to coincide with plant shutdowns.
- Inspect components and overhaul as required, to prevent downtime from equipment failure.
- Look for jams or hang-ups, torn or bent metal, loose bolts, rivets, or other sources of jams.
- Look for signs of spillage.
- Report areas that require additional guarding to prevent material spills or personnel injuries.

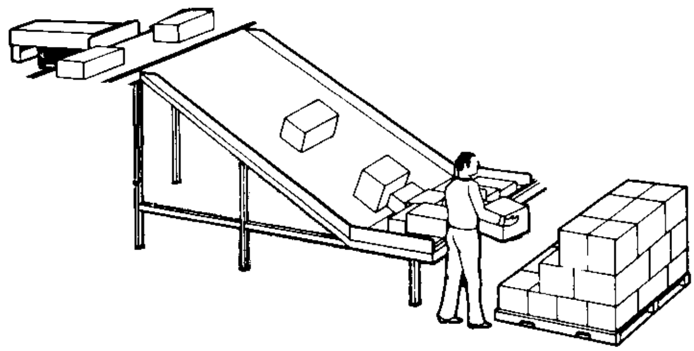
Chutes and Glacis

Chutes and glacis are made of sheet metal, plastic or fiberglass. They are effective and durable and are suitable for many applications in the bulk and package handling fields.

Since *chutes* (Figure 16) depend on gravity for product transfer, product mix, humidity, surface finish, slope angle and length must be carefully evaluated prior to installation.

The elimination of package damage requires careful analysis, particularly where there are variations in the weight and type of product wrapping. Chute performance can be improved by the proper application of a surface coating material such as teflon, which reduces the friction between the chute and the product being handled. Curtains, or similar devices, can also be used to slow the product descent and thereby reduce damage.

Single and double spiral chutes for vertical package handling are used in multistoried facilities to conserve space and minimize costs.



Chute
Figure 16

A *glacis* is another form of chute that is fairly common in post office and mail order operations. A glacis is a large, sloped area on which parcels or packages are stored prior to a sortation process. A conveyor distributes the parcels uniformly over the glacis by means of gates or deflectors. Product accumulation is controlled by photo cells or other similar devices.

Chutes and glacis are relatively low in capital cost and do not require energy for their operation.

Hoists and Cranes

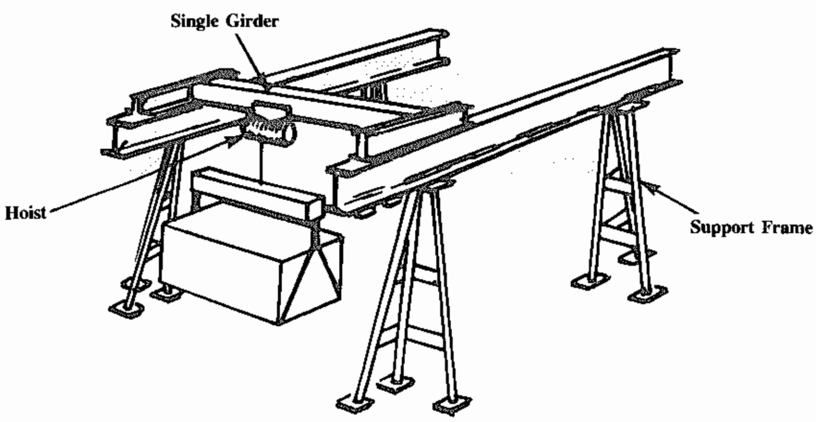
Hoists are manual, electric, or air operated devices mounted in an overhead location, and used to vertically raise or lower an item. They can be purchased for a wide range of lifting capacities and are usually suspended from a wheeled trolley that moves horizontally along a fixed I-beam track. Hoists are used as the lifting mechanism on cranes to expand the limited range of horizontal movement associated with a fixed track operation.

Jib cranes are light duty units that allow the hoist to rotate about a fixed pivot point. The hoist may be suspended from a fixed point on the jib, or connected to a trolley, which moves horizontally along the jib, providing adjustable lifting capability under the jib swing area.

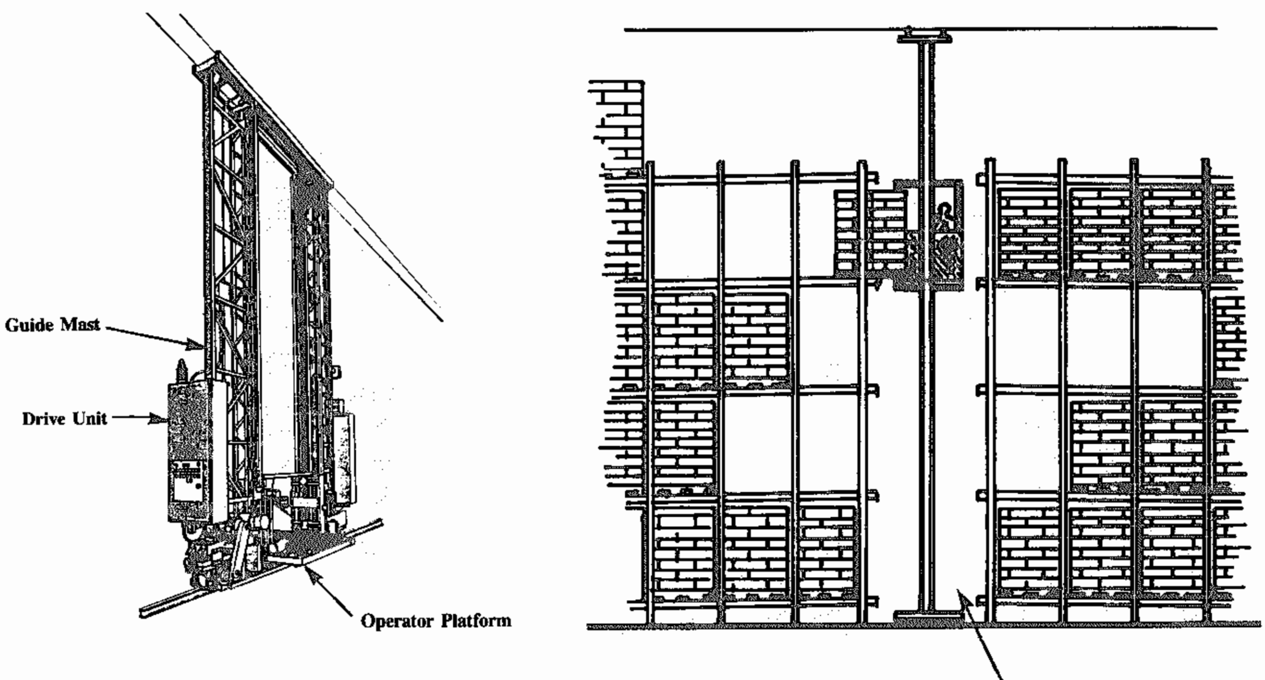
Bridge cranes (Figure 17), which can be operated from the floor or from an operator cab, are used extensively for the movement of heavy material such as structural steel fabrications, large coils of steel, or large fabricated pipe assemblies. A hoist supported by an overhead structure, (either single or double girder), travels the length of the plant or yard, and is capable of movement at right angles to the support girder.

Stacker cranes provide high density warehousing capabilities where narrow aisles and high (over 30 metre) storage heights are found (Figure 18). They can be suspended from an overhead structure, or supported from a set of rails, which are either embedded in the floor or connected to storage racks. The load transport mechanism is attached to an upright column to provide vertical and rotary movement. Stacker cranes can carry an operator who controls their movement or can be operated under remote computer control. These cranes have gained popularity in recent years because of their ability to improve the utilization of the internal space in a warehouse.

Gantry cranes are horizontal surface-supported devices, providing overhead lifting capability for container handling, and ship unloading. The crane can move along the dock face from ship to ship. The lifting mechanism is capable of vertical and horizontal movement to transfer product between the ship's hold and the dock.



Bridge Crane
Figure 17



Stacker Crane
Figure 18

Lift Trucks

A broad range of walkie and rider type pallet trucks are available. These manual or battery powered units are used to move wooden or metal pallets.

The *fork lift truck* is one of the most versatile and extensively used pieces of materials handling equipment used both inside the plant and in the yard. They are available in a variety of sizes and load capacities, and can be battery powered or powered by an internal combustion engine. They can also be fitted with a variety of special adapters to handle products like newsprint rolls, drums, and carpets. A rechargeable battery powered unit can be used where fumes, produced by an internal combustion engine, could be hazardous. The battery is normally recharged at regular intervals. Battery charging stations require special design attention because of environmental and labor code safety requirements.

Tables 4, 5 and 6 may be used in conjunction with Worksheet 17-2 to perform calculations which result in a comparison of the total annual cost of operation for gasoline, liquid propane gas and electrically (battery) operated lift trucks. This worksheet has been completed showing a typical example.

Annual Lift Truck Capital And Operating Cost Comparison

Worksheet 17-2

Page 1 of 1

Company: XYZ Company Date: Feb. 1986

Location: Anytown By: MBE

Annual Lift Truck Capital Cost Comparison

Item		Gas Engine	LPG Engine	Electric Engine
1 Truck Make & Model		Model A	Model B	Model C
2 Total Truck Price	$	21,500	21,950	23,900
3 Battery*	$	N/A	N/A	5,786
4 Battery Charger**	$	N/A	N/A	3,600
5 Total Equipment Cost	$	21,500	21,950	33,286
6 Equipment Life (Table 4)	yrs	2½	3	4
7 Equipment Cost Per Year	$	8,600	7,317	8,322

Annual Lift Truck Fuel Consumption Cost Per Shift Comparison

Item		Gas Engine	LPG Engine	Electric Engine
8 Fuel Cost Per Unit	$	0.25/Litre	0.20/Litre	0.05/KWh
9 Lift Truck Capacity	kg	1814	1814	1814
10 Fuel Consumption Per Shift (Table 5)		24 Litre	37.9 Litre	30 KWh
11 Fuel Cost Per Shift(8) x (10)	$	6.00	7.58	1.50
12 Number Of Days Operation Per Year		250	250	250
13 Annual Fuel Cost Per Shift	$	1,500	1,895	375

Annual Lift Truck Maintenance Cost Per Shift Comparison

Item		Gas Engine	LPG Engine	Electric Engine
14 Material Cost (Table 6)	$	715	625	609
15 Labor Hours Per Year (Table 6)	h	54	54	34
16 Labor Cost Per Hour	$	16	16	16
17 Total Labor Cost Per Year (16) x (15)	$	864	864	544

Annual Lift Truck Capital And Operating Cost Comparison

Item		Gas Engine	LPG Engine	Electric Engine
I Annual Equipment Cost (7)	$	8,600	7,317	8,322
II Annual Fuel Cost Per Shift (13)	$	1,500	1,895	375
III Annual Maintenance Cost Per Shift				
(a) Material (14)	$	715	625	609
(b) Labor (17)	$	864	864	544
Total (IIIa + IIIb)	$	1,579	1,489	1,153
IV Annual Maintenance And Fuel Cost Per Shift (II + III)	$	3,079	3,384	1,528
V Number Of Shifts		3	3	3
VI Annual Maintenance And Fuel Cost (IV x V)	$	9,237	10,152	4,584
VII Total Annual Cost Of Operation (I + VI)	$	17,837	17,469	12,906

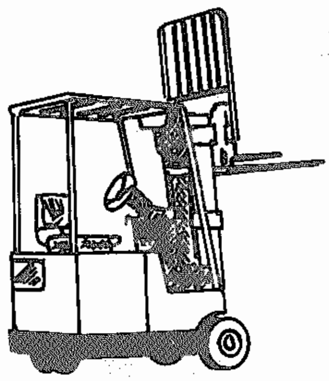
*For single shift operation include cost of one battery per truck. For two or three shift operation include cost of two batteries per truck.

**For single or multiple shift operation include cost of one battery charger per truck.

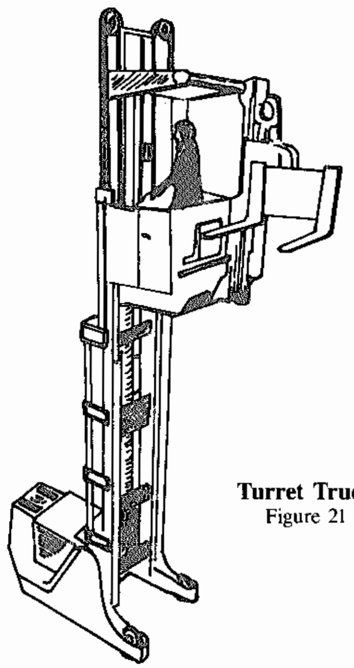
The following describes the two common types of fork lift trucks.

- The *counterbalanced truck* is a sit-down unit operating on either hard (cushion type) or pneumatic tires (Figure 19). It carries sufficient weight (vehicle and counterweight) behind the fulcrum point to allow the unit to handle the rated load. Features include a wide range of carrying capacities and lifting heights, combined with excellent travel speed and maneuverability. They may be used indoors or outdoors.
- *Narrow aisle straddle type trucks* were developed to improve building cube utilization and to make the operation of warehousing and storage areas more efficient (Figure 20). The improved cube utilization is achieved by narrower aisles and greater storage heights. This type of truck uses outriggers that extend forward to eliminate much of the length required in the counterbalanced truck. This, combined with stand-up driver operation, creates a unit that is considerably shorter than the conventional counterbalance truck. Thus, aisle widths in warehousing and storage areas can be reduced.

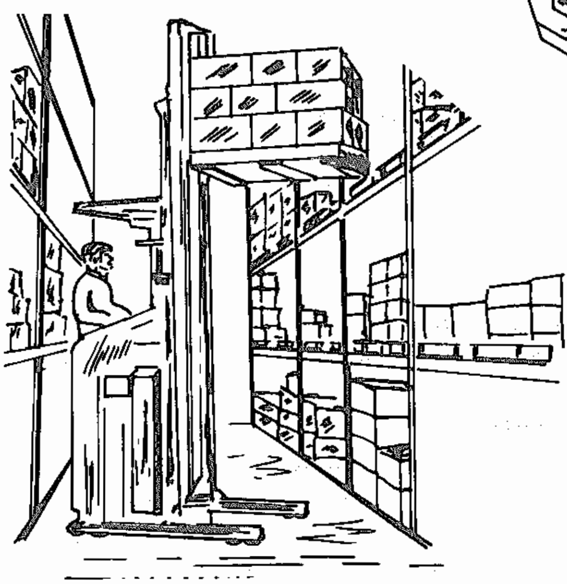
The *straddle truck* is limited in its ability to approach storage racks by the two outriggers. A scissor reach mechanism was developed, to allow the truck to extend the load forward as the scissor mechanism closes. Trucks have been developed to operate in, and to service both sides of, narrow aisles by rotating the forks 180°. These are commonly referred to as *turret trucks* (Figure 21), and, in many cases, the operator rides up and down with the carriage for better visibility and control.



Counterbalanced Fork Lift Truck
Figure 19



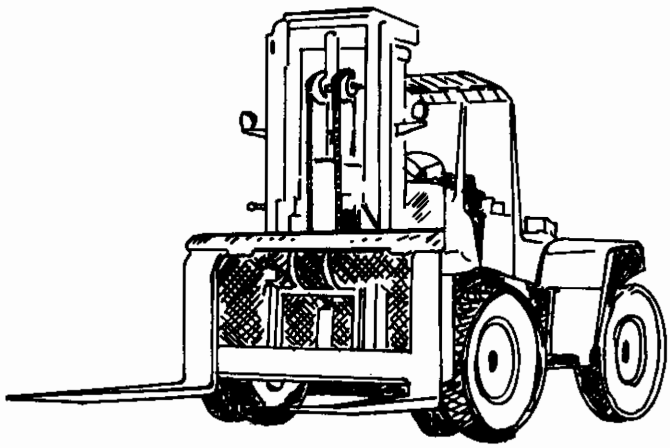
Turret Truck
Figure 21



Narrow Aisle Straddle Truck
Figure 20

Yard Fork Trucks

Counterbalanced yard fork trucks (Figure 22) are the workhorses of yard operations, and are powered by internal combustion engines or electric motors. Usually, the trucks are equipped with pneumatic tires and hydrostatic transmissions. The higher capacity units are often powered with diesel engines.



Counterbalanced Yard Fork Truck
Figure 22

Lift Truck Control and Maintenance

Energy savings relative to fork lift trucks can be realized with good control and maintenance practices.

- Implement a driver training program to reduce energy use and repair or replacement costs. A driver training program will teach the operator the proper use of the equipment, lubrication requirements, how to look for signs of impending problems, and safety procedures. Problems associated with overheating, running low on engine lubricant, low tire pressure, high speed over rough surfaces, and excessively rapid starts and stops will virtually be eliminated.
- Develop and implement PM programs. Equipment manufacturers should be consulted and preventive maintenance check sheets should be obtained for the specific lift trucks owned by the company.
- Keep proper records of fuel consumption, repairs, down time, operating hours (hour meter), battery purchases and battery recharge frequency.
- Charge batteries in off-peak periods to prevent additional demand charges from the electric utility.
- Use quality lubricants of correct type and viscosity.

Generally, internal combustion engine units are susceptible to more abuse than electric units because they are capable of higher speeds, greater range of travel, indoor and outdoor use, and handle a much broader range of product. Proper use of these units is most important to control down time and maintenance costs. Fuel use and cost is determined by the quality of maintenance and the method of operation.

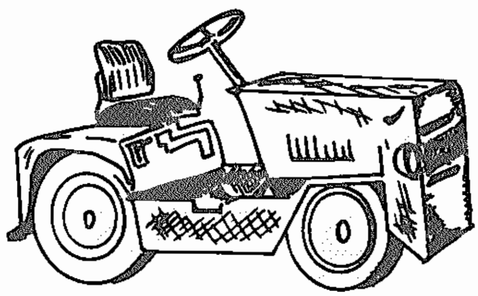
Miscellaneous Wheeled Vehicles

There are several other types of wheeled vehicles used in the Industrial, Commercial and Institutional sectors that can be considered part of materials handling and on-site transportation equipment.

- *Power sweepers and scrubbers* are used in many facilities to assist in the sweeping operations. They are available in walkie and rider type models, which are powered by propane, gasoline, or rechargeable battery. Sweepers are equipped with brooms or brushes selected for the specific job. Scrubbers use powered discs or scrubbing brushes and cleaning solutions. This solution is sprayed on, then removed from the floor along with the soil, by means of a squeegee and vacuum lift system. Combination sweeper/scrubbers and sweeper attachments that can be fastened to the front of a counterbalanced fork truck are also available.

- *Tow tractors* are three or four wheel sit- down units that are used to tow carts, or cart trains within facilities such as airports, large post offices, and distribution warehouses (Figure 23). They are powered by an internal combustion engine or battery powered electric motor and are often used in conjunction with an in-floor tow line system, to transport carts or cart trains beyond the range of the in-floor system.
- *Guided vehicle system* technology has progressed to the point where a single guided vehicle can travel off the guide path for a short distance to store or retrieve a load. Special vehicles can be used to load trucks or pallet racks, and perform other material handling functions. These systems offer minimum obstruction to personnel or vehicular traffic movement.

  Most guided vehicle systems use a wire guide path, but an optical path is also used where conditions do not cause sensing problems. The wire guide path is created by embedding a wire in the floor. A coil on the vehicle detects the fixed frequency current flowing through the wire and steering corrections are automatically made to keep the vehicle on track. The optical system depends upon a painted path on the floor. A controller works with a light source and sensor to provide corrective action to the steering mechanism. This guide system is easy to remove and change; however, the operation is vulnerable to dust and dirt. For this reason, the main application of the optically guided system is in facilities that have a clean environment.



Tow Tractor
Figure 23

Automated Storage and Retrieval Systems (AS/RS)

Computers have advanced the development of *automated storage and retrieval systems* for warehousing and distribution centres. These systems use the standard materials handling and on-site transportation hardware to provide a system that functions, with minimum labour, under computer control. The product can be taken from receiving docks, identified and sized, automatically placed into storage, and retrieved for distribution by means of computer controlled materials handling equipment.

These systems can be used in conventional warehouses where the system is independent of the building, or in warehouses where the racks support the building. They are capable of excellent cube utilization due to the narrow aisles and high lift heights. Initial capital cost is high, however, these systems are energy efficient and are used to reduce labor cost.

Freight and Passenger Elevators

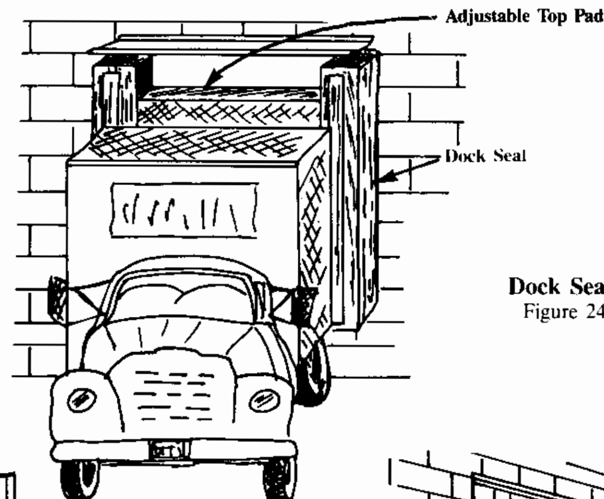
Freight and passenger elevators vertically transport material and people in multistoried manufacturing and warehousing buildings. They consist of an enclosed platform, operating vertically in a hoistway, complete with gates, safety devices, and a hoisting mechanism (usually motor, reducer, drum and cables).

For floor to floor transfer of tote boxes or small containers a short lift hydraulic or pneumatic unit could be used. Normally it would consist of arms or trays which are fed and discharged automatically by conveyors. The tote box or small container is automatically loaded, moved vertically, and automatically discharged.

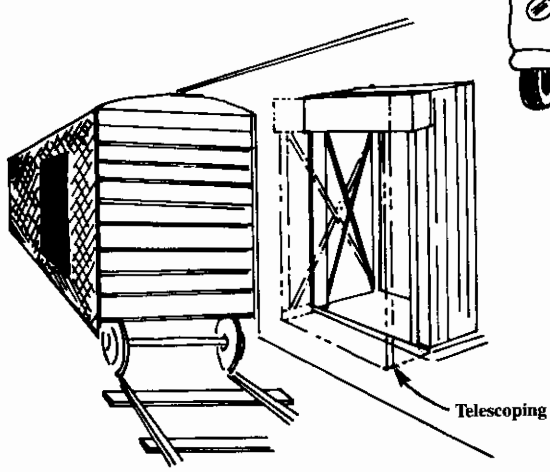
Dock Seals, Shelters, and Strip Doors

Outdoor receiving and shipping facilities are less expensive to build than indoor facilities with the same number of unload/load positions. However, there is potential for heat loss and employee discomfort if the interface between the transportation vehicle and the building is not sealed. Dock seals, dock and rail shelters, and strip doors provide effective sealing.

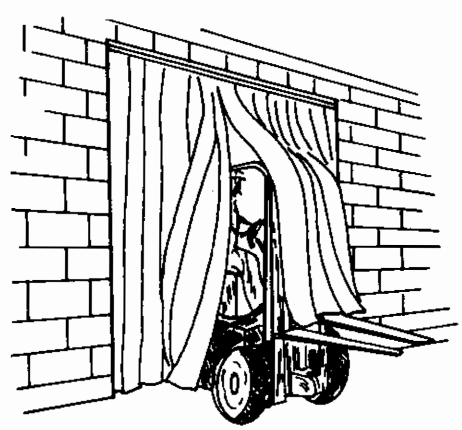
- *Dock seals* are covered foam pads installed along the top and the two sides of the door opening (Figure 24). Normally, the blocks of foam are attached to a hardwood frame and covered with fabric such as vinyl coated nylon, hypalon, or neoprene. The truck backs up to the opening, contacts the seal, and compresses it to reduce the gap between the rear of the truck and the building face. Variations of this device include adjustable top pads and curtains to improve the seal at the top of the opening. Dock seals are also available to suit the well type (inclined) shipping or receiving facility, where the rear of the truck or trailer is not parallel to the wall.
- *Dock shelters* serve the same function as dock seals. The major difference is that the sealing is achieved at the side and top of the vehicle, rather than at the rear. Dock shelters are used when the building door opening is considerably larger than the truck or trailer, or where full width rear vehicle access is required. Rigid, retracting, and rolling type dock shelters are available. Dock shelters are also available to suit the well type facility.
- *Rail shelters* are similar to the dock shelter, and provide an enclosed passageway between rail car and building by extending the shelter out to interface with the rail car sides (Figure 25). These are similar to the aircraft loading shelters used at airports to provide weather protection for passengers moving to and from the aircraft.
- *Strip doors* are designed for in-plant use (Figure 26). They consist of transparent vinyl or plastic overlapping strips hanging from the head of the opening. The strips create an effective climate control barrier between sections of a building, or different departments, yet provide excellent visibility, and easy passage for pedestrians or vehicles.



Dock Seals
Figure 24

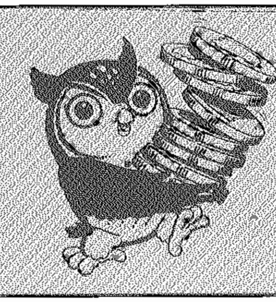


Rail Shelter
Figure 25



Strip Doors
Figure 26

ENERGY MANAGEMENT OPPORTUNITIES



Energy Management Opportunities is the term that represents the ways that energy can be used wisely to save money. A number of typical Energy Management Opportunities subdivided into Housekeeping, Low Cost, and Retrofit categories are outlined in this section with worked examples, or descriptive text, to illustrate potential energy savings. This is not a complete listing of the opportunities available for materials handling and on-site transportation equipment. However, it is intended to provide ideas for management, operating, and maintenance personnel, which will help them to identify additional opportunities in their own facility. The usefulness of this equipment is often highly emphasized, while the energy use is typically ignored. This emphasis on equipment utilization may make it more challenging to sell Energy Management Opportunities. There are energy saving opportunities that will not compromise good service and Energy Management Opportunity concepts must be regularily emphasized so that they become a part of normal daily activities. Appropriate modules in this series should be considered for Energy Management Opportunities existing within other types of equipment and systems.

Housekeeping Opportunities

Implemented housekeeping opportunities are energy management actions that are done on a regular basis and never less than once a year. In many cases the energy and dollar savings for each item are small, however, when they are combined, the results may prove substantial. The following are typical Energy Management Opportunities in this category.

1. Ensure that all personnel are aware of the objectives of energy management related to housekeeping.
2. Provide good aisle markings to keep aisles clear.
3. Keep manufacturing floor areas clear.
4. Shut off powered equipment when not in use.
5. Keep shipping and receiving doors closed when not in use, especially in cold or inclement weather to maintain the building environment.
6. Schedule incoming goods to avoid prolonged outdoor exposure in cold weather. This will reduce the quantity of cold product entering the facility.
7. Review schedules to reduce surge loading on materials handling equipment.
8. Review schedules to evaluate the possibility of reducing equipment running time.
9. Institute equipment check and preventive maintenance programs such as those described in the Equipment/Systems section.

Housekeeping Worked Examples

1. Staff Awareness of Energy Management Objectives

Many housekeeping energy management opportunities are easily observed by staff who have an awareness of the concepts of energy management. Conveyors operating when not being used, lift trucks left idling, shipping and receiving doors not fully closed when not in use, partially blocked aisles, and damaged wheels on powered or towed vehicles all lead to excess energy usage and higher energy costs.

2. Provide Good Aisle Markings and Keep Aisles Clear

Unless aisles are clearly marked, there is a tendency for material to be temporarily stored in areas which are intended to be used as passageways. When this occurs, in-plant vehicular traffic must either wait until the aisle is cleared or find alternative and possibly longer routes resulting in additional energy use and cost.

As an example, consider an industrial facility where aisles are not kept clean. Because of congestion, an average of two hours per shift is wasted in lift truck operation. During this period lift trucks are left idling until the congestion is cleared. The trucks are 1814 kg capacity gasoline engine units, which use 24 litres of fuel per shift, and we can estimate that an idling lift truck uses 20 per cent of its operating fuel rate. The wasted fuel per shift can be calculated.

$$\text{Wasted fuel} = 24 \text{ L/shift} \times \frac{2 \text{ h}}{8 \text{ h/shift}} \times 0.20$$

$$= 1.2 \text{ L/shift}$$

At a fuel cost of $0.25 per litre and with the facility operating 3 shifts per day, 5 days per week, 50 weeks per year, the annual fuel cost associated with idling time is calculated.

$$\text{Fuel cost} = 1.2 \text{ L/shift} \times 3 \text{ shifts/day} \times 5 \text{ days/week} \times 50 \text{ weeks/yr} \times \$0.25\text{/L}$$

$$= \$225 \text{ per year}$$

As well as the calculated energy saving a lift truck would be available if required for an additional two hours per day for productive work.

3. Keep Manufacturing Floor Areas Clear

In many manufacturing operations, the material to be processed at any particular operation is moved to the process operation by some type of transportation equipment and is stored close to the equipment. Keeping manufacturing floor areas clear will allow access by the shortest route, thus reducing waiting time while routes are cleared. The net result is energy saving as shown in the previous example.

4. Shut Off Powered Equipment When Not In Use

During a walk through review of a facility it was noted that a level, 61 metre long belt conveyor used to transport finished product to the packaging area ran continuously, even though the production department did not operate between 8 pm and 8 am. During this period the conveyor was empty. Investigation indicated that this happened 5 days per week, 50 weeks per year for a total of 3000 hours per year. Savings would also occur if the conveyor were stopped during nonproduction periods including lunch and coffee breaks.

- A diagnostic audit provided the following information.

Conveyor length	61 m
Width between frames	1 m
Center to center distance between belt carrying rollers	0.152 m
Belt speed	0.508 m/s

- From Table 1, the following information was obtained.

Weight of belt and rollers	20.53 kg/m
Weight of drive and end assembly	90.72 kg
Coefficient of friction	0.05

- The following information is known.

Weight of product on conveyor	0 kg
Angle of inclination	0 (conveyor is level)

Using Worksheet 17-1 the power required to operate the conveyor during the nonproduction period from 8 pm to 8 a.m. is 0.42 kW. With the cost of electrical power at $0.05/kWh, annual savings if the conveyor were shut down can be calculated.

$$\text{Annual savings} = \text{kW} \times \$/\text{kWh} \times \text{h}$$

$$= 0.42 \times 0.05 \times 3000$$

$$= \$63/\text{yr}$$

Since the conveyor can be manually stopped at 8 pm and started at 8 am, there are no modification costs. The savings are modest, but they could be representative of other potential savings within the same facility. Other cost benefits would be extended conveyor life and reduced maintenance, owing to a reduction in the conveyor running time.

5. Keep Doors Closed

During periods of cold weather, facility doors should be kept closed to maintain the building environment. Doors not fully closed lead to reduced internal building temperature, which, in turn, requires additional energy to maintain the working environment at acceptable temperature levels.

More information on this subject, as well as worksheets for calculating infiltration and exfiltration, may be found in Architectural Considerations, Module 18.

6. Review Incoming Material Schedules

Receiving schedules should be reviewed to ensure that materials arriving at the facility are unloaded as quickly as possible and are not left on the truck in the yard to cool to ambient temperature, especially during periods of cold weather. If materials are allowed to cool to ambient outdoor temperature and then moved into the facility, additional building energy will be used to reheat the product.

As an example, consider a facility which periodically receives paper shipments of 5000 kg from a warehouse where the paper is stored at an ambient temperature of 20°C. Since no specific receiving schedules have been established in this facility, the paper is allowed to remain on a truck in the receiving yard until needed. During winter months the average temperature of the paper drops to 0°C. This material is then brought into the facility where the ambient temperature is maintained at 21°C. The specific heat of paper is 1.89 kJ/(kg·°C). Additional heat is required to raise the temperature of paper from 0°C to 21°C.

$$\text{Heat required} = \text{Weight of paper} \times \text{Specific heat} \times \text{Temperature increase}$$

$$= 5000 \text{ kg} \times 1.89 \text{ kJ/(kg·°C)} \times 21\text{°C}$$

$$= 198\ 450 \text{ kJ}$$

$$\text{or } 198.45 \text{ MJ}$$

Based on electric heating, at a cost of $0.05/kWh, the cost to heat the paper back to facility ambient temperature is calculated.

$$\text{Additional energy cost} = \frac{198.45}{3.6} \times 0.05$$

$$= \$2.76 \text{ per load}$$

$$\text{Where, } 1 \text{ MJ} = \frac{1}{3.6} \text{ kWh}$$

If this paper is received twice per month over the four coldest months of the year, the additional heating cost is calculated.

$$\text{Additional heat cost} = \$2.76/\text{load} \times 2\ \text{loads/mo} \times 4\ \text{mo/yr}$$

$$= \$22.08\ \text{per year}$$

This cost may appear small, however if the same situation is occurring on a variety of products, the additional heating costs begin to be significant.

7. Review Schedules To Reduce Surge Loading

In many facilities adequate consideration is not given to the leveling of production schedules. This means that equipment is sized to handle the peak throughput rates, which may be substantially higher than a realistic average production rate. This results in oversizing of equipment and systems with a resultant increased power consumption charge and possibly an increased power demand charge. For additional information on power demand charges see Electrical, Module 3.

8. Review Schedules To Reduce Equipment Running Time

In many facilities equipment such as mixing tanks with electrically operated agitators are being used at less than full capacity. For example, a vessel with an agitator may have a mixing capacity of 2000 kg of material, however, only 1000 kg batches are being mixed. If the daily requirement of mixed material is fixed, and the mixing time for a 1000 kg batch is equal to three quarters of the mixing time for a 2000 kg batch, there exists a potential energy management opportunity.

Consider a facility which requires 10,000 kg/day of mixed material. Mixing time for a 2000 kg batch is one hour while for a 1000 kg batch it is 45 minutes. The mixer has a 10 kW motor. The facility operates 250 days per year.

$$\text{Annual mixing time for 2000 kg batches} = \frac{10\ 000\ \text{kg/day}}{2000\ \text{kg/batch}} \times 250\ \text{day/yr} \times 1\ \text{h/batch}$$

$$= 1250\ \text{h/yr}$$

$$\text{Annual mixing time for 1000 kg batches} = \frac{10\ 000\ \text{kg/day}}{1000\ \text{kg/batch}} \times 250\ \text{days/yr} \times \frac{45\ \text{min/batch}}{60\ \text{min/h}}$$

$$= 1875\ \text{h/yr}$$

$$\text{Annual power requirements for 2000 kg batches} = 1250\ \text{h/yr} \times 10\ \text{kW}$$

$$= 12\ 500\ \text{kWh/yr}$$

$$\text{Annual power requirements for 1000 kg batches} = 1875\ \text{h/yr} \times 10\ \text{kW}$$

$$= 18\ 750\ \text{kWh/yr}$$

$$\text{Annual power savings} = 18\ 750 - 12\ 500$$

$$= 6250\ \text{kWh/yr}$$

Based on electricity costing $0.05/kWh, annual savings may be calculated.

$$\text{Annual dollar savings} = 6250\ \text{kWh/yr} \times \$0.05/\text{kWh}$$

$$= \$312.50/\text{yr}$$

9. Institute Equipment Check and Preventive Maintenance Program

Equipment checking and preventive maintenance programs for materials handling and on-site transportation equipment can result in increased equipment operating time and reduced energy costs. Damaged wheels on rolling equipment, faulty bearings on conveyors, strings or other foreign material wrapped around rotating shafts, damaged conveyor belting, lack of or incorrect lubrication are only a few items that increase friction and require additional energy to overcome this increased friction. Additional energy means wasted dollars.

Low Cost Opportunities

Implemented low cost opportunities are energy management actions that are done once and for which the cost is not considered great. The distinction between low cost and retrofit Energy Management Opportunities is a means of classifying the cost of the action and will be different for each company. Examples of Low Cost Energy Management Opportunities follow.

1. Install automatic devices such as photo cells, limit switches, timers and proximity switches on materials handling equipment to shut down equipment when it is not required.
2. Slow down powered conveyors to reduce power requirements.
3. Insulate conveyor enclosures that are exposed to outside climatic conditions when the product being conveyed must be maintained at a specific temperature (i.e., avoid reheat or recool).
4. Repair or replace damaged dock seals, shelters or strip doors to reduce air infiltration/exfiltration.
5. Provide shrouds, curtains or strip doors where conveyors or other equipment enter or exit building sections that are at different temperatures.
6. Install carbon monoxide monitoring equipment for indoor shipping and receiving facilities so that exhaust fans are only activated when carbon monoxide concentrations reach a predetermined safety level.
7. Ensure that both warehouse and in-process materials are stored adjacent to areas of high utilization to reduce handling time and distances travelled.
8. Replace air operated hoists with electric or manual hoists.
9. Do not oversize lift trucks.
10. Review in plant materials handling equipment and methods.
11. Review waste handling, collection and disposal methods.

Low Cost Worked Examples

1. Install Automatic Shutdown Devices

During a walk through audit it was noted that an electrically operated agitator with a 10 kW motor was operating even though the mixing tank was empty. Investigation indicated that the agitator operated 16 hours per day, 50 weeks per year. A diagnostic audit indicated that the mixing tank was empty 8 hours per day, Monday to Friday and 24 hours per day on weekends. The cost of electricity was $0.05/kWh.

Total hours of operation = 16 x 7 x 50

= 5600 h/yr

Reduction in agitator operating hours if the agitator is shutdown when mixing tank is empty.

Reduction = (8 x 5 x 50) + (16 x 2 x 50)

= 2000 + 1600

= 3600 h/yr

Power savings = 3600 x 10

= 36 000 kWh/yr

Dollar savings = 36 000 x $0.05

= $1,800/yr

It was decided to install a level switch in the mixing tank to automatically shut down the agitator whenever the mixing tank was empty. The installed cost of the level switch and control was $2,000.

$$\text{Simple payback} = \frac{\$2{,}000}{\$1{,}800}$$

$$= 1.11 \text{ years}$$

In addition to the energy savings, a reduction in agitator operating time would result in lower maintenance costs and extended equipment life.

2. Slow Down Powered Equipment

In the Equipment/Systems section of this module, an equation was developed to calculate the power required to operate a roller bed, slider bed or heavy duty belt conveyor. As can be seen from the equation, for any specific conveyor operating at a constant load, a reduction in conveyor speed will result in a reduction in the power required to operate the conveyor and thus save money.

Worksheet 17-1 can be used to calculate effective belt pull and then power requirements can be calculated for various belt speeds.

3. Insulate Conveyor Enclosures

During a walk through audit it was noted that previously heated material, which was being conveyed between two buildings on a conveyor passing through an uninsulated gallery, was being cooled during transportation to the point where heat had to be added to raise the temperature back to the correct processing temperature. The material being conveyed was sand, which has a specific heat of 0.796 kJ/(kg·°C). The transport rate was 9000 kg/h and the average temperature drop during the 4 winter months was 15°C. This facility operated 120 hours per week, year round.

$$\text{Lost product energy} = 9000 \text{ kg/h} \times 120 \text{ h/week} \times 4 \text{ weeks/mo} \times 4 \text{ mo/yr} \times 0.796 \text{ kJ/(kg·°C)} \times 15\text{°C}$$

$$= 206\ 323\ 200 \text{ kJ}$$

$$\text{or } 206\ 323.2 \text{ MJ}$$

On the basis that the heat energy was replaced using electric heaters and the cost of electricity was $ 0.05/kWh, the additional energy cost to reheat the product is calculated.

$$\text{Cost} = 206\ 323.2 \text{ MJ} \times \frac{1 \text{ kWh}}{3.6 \text{ MJ}} \times \$0.05/\text{kWh}$$

$$= \$2{,}865.60 \text{ per year}$$

Insulating the conveyor gallery would reduce the temperature drop to 5°C and the heating energy and cost savings would be as follows.

$$\text{Lost product energy} = 9000 \text{ kg/h} \times 120 \text{ h/week} \times 4 \text{ weeks/mo} \times 4 \text{ mo/yr} \times 0.796 \text{ kJ(kg·°C)} \times 5\text{°C}$$

$$= 68\ 774\ 400 \text{ kJ}$$

$$\text{or } 68\ 774.4 \text{ MJ}$$

$$\text{Cost} = 68\ 774.4 \text{ MJ} \times \frac{1 \text{ kWh}}{3.6 \text{ MJ}} \times \$0.05/\text{kWh}$$

$$= \$955.20 \text{ per year}$$

Cost saving by insulating gallery = \$2,865.60 − \$955.20

= \$1,910.40 per year

It is estimated that the installed cost of insulation on the conveyor gallery would be \$4,000.

$$\text{Simple payback} = \frac{\$4{,}000}{\$1{,}910.40}$$

$$= 2.09 \text{ years}$$

4. Repair-Replace Damaged Seals, Shelters or Strip Doors

As indicated in Equipment/Systems, dock seals, shelters or strip doors are used to reduce infiltration or exfiltration, especially at receiving or shipping docks. If these units are damaged or missing, air leakage will take place and additional energy will be required to maintain the building temperature at adequate working levels. For additional information on infiltration and exfiltration refer to Architectural Considerations, Module 18.

5. Provide Shrouds, Curtains or Strip Doors

In many facilities, conveyors are used to transport finished product from the manufacturing area to the warehouse. Also, it is not uncommon for the warehouse area to be at a lower temperature than the manufacturing area, with the two areas separated by a wall.

If the conveyor passes through the wall, heat energy will flow from the manufacturing area to the warehouse and additional energy will be required to maintain the manufacturing area at the required temperature. The addition of a shroud, curtain or strip door at the opening in the wall will reduce the heat energy flow and save money.

6. Install Carbon Monoxide Monitoring Equipment

Many manufacturing plants and warehouses with indoor shipping and/or receiving facilities use exhaust fans to evacuate carbon monoxide gas. It is common to find these fans running even when the facility is not in use. While in operation these fans remove heat energy from the facility and additional heat energy is required to maintain the working environment at an acceptable level.

Consideration should be given to the installation of carbon monoxide monitoring equipment which would operate the exhaust fans when required. During periods of fan operation, the warm air being exhausted could be used to preheat fresh air make-up.

7. Review Location of Material Storage

As a result of plant expansions, equipment additions or relocations, or changes in manufacturing methods, in-process material is not always stored adjacent to the manufacturing area where the material is to be used. If plant layout and in-plant material flow is reviewed on an annual basis, items of this type should be noted to reduce material transportation time and distance thus saving energy.

8. Replace Air Operated Hoists With Electric or Manual Hoists

Electric hoists are more energy efficient than air operated hoists of the same capacity, since compressed air must be provided by an air compressor. System losses are associated with the compression of air and also in the air distribution system required to transport the air from the compressor to the point of use. For details of compressed air systems refer to Water and Compressed Air Systems, Module 12.

An electric hoist converts electricity into mechanical lifting force. The motor and drive losses associated with this conversion are normally lower than the compressor and distribution piping losses.

Each application must be looked at individually. If an adequate compressed air supply is available in a facility, or if an explosion hazard exists in a specific area, it may be advantageous to use an air operated hoist. However, if additional air compressor capacity would be required to allow operation of the air operated hoist, the electric unit should be considered.

Small or intermittent operations should be investigated to determine the benefits which could be obtained from manually operated hoists.

9. Do Not Oversize Lift Trucks

Lift trucks should be purchased and used with capacity based on the lifting requirements, and should not be oversized. The load requirements for each lift truck in a facility should be reviewed prior to lift trucks being purchased. Lift trucks should only be used for their intended purposes.

As an example, consider a lift truck application where a lifting capacity of 1500 kg is required, however, a 2722 kg capacity truck was being considered. The lift truck in use is an electric motor unit and is used three shifts per day, 250 days per year.

From Table 4 it is determined that the electricity required for a lift truck of 1814 kg capacity is between 25 - 35 kWh/shift. If a 2722 kg capacity lift truck were used, the electricity required would be 30 - 40 kWh/shift. The net result is a saving of approximately 5 kWh/shift. The additional cost of electricity for the larger unit can be calculated as follows based on electricity costing $0.05/kWh.

Additional electricity cost = 5 kWh x 3 shifts/day x 250 days/yr x $0.05/kWh

= $187.50 per year

Further to the additional electricity cost, the maintenance costs will also be greater for the larger truck. From Table 5 it can be seen that the approximate annual maintenance cost per shift for the 1814 kg truck would be $609 plus 34 hours of labor per shift of operation while, for the 2722 kg truck, the annual maintenance cost would be $717 plus 41 hours of labor per shift of operation.

Based on three shift operation, increased maintenance cost = 3($717 − 609) + 3(41 − 34)

= $324 + 21 hours labor

If a labor rate of $15 per hour is used in the above calculation,

Increased maintenance cost = $324 + (21 x $15)

= $324 + $315

= $639 per year

It should also be noted that the capital cost of the larger capacity lift truck would be greater.

10. Review In-Plant Materials Handling Equipment and Methods

During plant expansion planning, it was noted that minor modifications to the equipment layout in the existing facility would improve the flow of materials to the final inspection department. Relocation of five pieces of equipment would allow the removal of two belt transfer conveyors which ran fully loaded 50 per cent of the time. Each of these conveyors was powered with a 7.5 kW motor, and operated 6000 hours per year. Electricity cost was $0.05/kWh.

The energy savings can be calculated for the layout improvement.

Energy savings = Number of motors x kW/motor x Total hours of operation x Electricity cost x Utilization factor

= 2 x 7.5 kW x 6000 h/yr x $0.05/kWh x 0.5

= $2,250/yr

Estimated cost to relocate production equipment is $6,000.

$$\text{Simple payback} = \frac{\$6,000}{\$2,250}$$

= 2.67 years

Removal of these conveyors would also reduce maintenance material, and spare part costs. A further benefit would be the availability of the two conveyors for possible use elsewhere.

11. Review Waste Handling, Collection and Disposal Methods

The handling, collection and disposal of waste materials in any facility should be closely investigated to ensure that the waste material is handled in the most energy and cost efficient manner.

If the waste product is bulky, such as paper, cardboard boxes, or similar packing materials, consideration should be given to compaction of the material to reduce the volume and thus be able to handle a greater weight per unit of volume. This can reduce the number of trips required to move the material to the disposal site. Reduced trips means reduced energy consumption and dollars saved.

Also, if any waste product is saleable, consideration should be given to segregation of waste product during the collection phase. Even though this item is not truly an energy management opportunity, the sale of the otherwise waste material can generate revenue for the company.

Waste products should also be investigated for their potential use as a fuel source which could be used to reduce purchased energy.

Retrofit Opportunities

Implemented retrofit opportunities are energy management actions that are done once and for which the costs are significant. The following retrofit energy management opportunities are representative of those which should be considered.

1. Review total plant materials handling and processing operations when plant additions are being considered, to avoid the patchwork approach.
2. Upgrade yard areas to provide smooth surfaces for yard equipment. (Reduces rolling friction and maintenance costs).
3. Review use of microprocessors and computers for better control of the process and associated handling equipment.
4. Upgrade elevator operation by installing computer controls to avoid needless travel and unnecessary power consumption.
5. Reduce the frequency of deliveries to increase the efficiency of each order picking trip through the warehouse.
6. Use closed circuit television (CCTV) to monitor difficult-to-reach, or remote equipment and transfer points.
7. Investigate fuel efficient engines when purchasing or repowering existing equipment. Use up-to-date energy efficient equipment when replacements are necessary. Ensure that new equipment being purchased is sized to do the specific task for which it is required.
8. Consider consolidation of warehouses to reduce the number of facilities and duplication of equipment.

Retrofit Worked Examples

1. Review Plant Materials Handling and Processing Operations

In an attempt to hold capital costs to a minimum, materials handling equipment is installed to move the product through the facility with little or no consideration given to its energy utilization. Based on the escalating costs of energy today, consideration must be given to total plant layout and material flow with the objective of reducing or at least controlling energy costs. Consider Low Cost Worked Example 10. Relocation of certain pieces of production equipment resulted in both energy and maintenance savings, as well as freeing up equipment for possible use elsewhere in the facility. If the entire facility is looked at in the global sense, many other opportunities of this type may become apparent. Each opportunity will have to be investigated individually to ensure that the implementation of the opportunity does not have a detrimental effect on the total facility operation.

2. Upgrade Yard Areas

Yard area surfaces where lift trucks operate should be both hard and smooth. An asphalt or concrete surface will reduce rolling friction, thus saving energy. An added benefit will be a reduction in plant maintenance and housekeeping costs since the lift truck will be subjected to less severe operating conditions. Consideration should be given to establishing specific paved outdoor travel routes and paving outdoor storage areas.

3. Review Use Of Microprocessors and Computers For Control

In numerous installations, the addition of a microprocessor or computer can result in a reduction of energy use.

Consider a dry powder batch mixing operation where products from a series of storage bins are transported by conveyor to a manual weigh station where the individual components are weighed and then forwarded via a separate conveyor to the mixing equipment. Once all components have been added to the mixer, it is allowed to operate for a timed period. After mixing is completed, the mixer is discharged into another conveyor which transports the mixed material to a storage hopper.

A microprocessor and automatic weighing equipment could by installed to automatically start and stop the conveyors feeding from the individual component storage bins to the weighing equipment; automatically weigh the individual components; transfer the weighed components to the mixer; control the mixer operation; start and stop the mixer discharge conveyor and repeat the cycle as required. Equipment and conveyors would only be operated as required.

For additional information, refer to Automatic Controls, Module 16.

4. Install Automatic Controls on Elevator

Many elevators in use today, automatically return to the ground floor position if not in use. Automatic controls are available which will allow the elevator to remain at its last point of use, thus reducing needless travel and the associated unnecessary power consumption.

5. Reduce Frequency of Deliveries

Frequently, warehouse operations are set up on the basis that orders are filled as soon as they are received. In many instances, a powered vehicle circulates through the warehouse each time an order is placed.

It could be possible to reschedule warehouse operations in order to fill multiple orders during one warehouse circuit. Further, if the frequency of product delivery to customers can be reduced, fuel saving both from the warehouse and delivery vehicles would result.

Care must be taken prior to the implementation of any scheme of this type to ensure that a reduction in delivery frequency does not adversely affect customer satisfaction.

6. Use Closed Circuit Television (CCTV)

In many instances, difficult to reach equipment or transfer points in materials handling systems can be monitored by the use of CCTV. Jams, blockages or lack of transfer can be noted and equipment can be shutdown until the problem is cleared. This would eliminate hazardous operating conditions from both an equipment and product point of view.

7. Select Correctly Sized, Energy Efficient Equipment

As indicated in previous worked examples, oversizing equipment wastes energy and dollars. Care must be taken in the selection of new equipment or the purchase of replacement parts for existing equipment, to ensure that the most energy efficient items suitable for the application are chosen. In repowering lift trucks, the purchaser should investigate the various engine options since many of the newer designs of internal combustion engines are more energy efficient.

For the replacement of electric motors refer to Energy Efficient Electric Motors, Module 4, for additional information.

8. Consolidate Warehouse Operations

If multiple warehouses within close geographic vicinity are being operated by a company, it may be advantageous to consider combining some or all of the warehouses into a single central unit. Although transportation costs from the centralized warehouse to the customer may increase, offsets could occur through a reduction in building energy requirements, staffing and possible fleet delivery vehicles.

Calculation Of Belt Conveyor Power Requirements

Worksheet 17-1

Company: XYZ COMPANY Date: FEB. 1986

HOUSEKEEPING WORKED EXAMPLE 4

Location: ANYTOWN By: MBE

Conveyor No: 6

Type of Conveyor: ✓ Roller bed ____ Slider bed ____ Heavy duty roller bed

Material	FINISHED PRODUCT	
Product loading on conveyor	0	kg/m
Conveyor length	61	m
For roller conveyor centre to centre distance between carrying rollers	0.152	m
Width between frames	1	m
Angle of incline (Table 2)	0	°
Conveyor Speed (V_c)	0.508	m/s
Coefficient of friction	0.05	

Total Live Load LL_T = Live load (kg/m) x Conveyor length (m)

= 0 x 61

= 0 kg

Dead Load 1 (Table 1) DL_1 = Dead Load (Part 1) kg/m x Conveyor length (m)

= 20.53 x 61

= 1252.33 kg

Dead Load 2 (Table 1) DL_2 = Dead Load (Part 2) kg

= 90.72 kg

Total Dead Load DL_T = DL_1 + DL_2

= 1252.33 kg + 90.72 kg

= 1343.05 kg

Calculation Of Belt Conveyor Power Requirements

Worksheet 17-1

Company: XYZ COMPANY Date: FEB. 1986

Location: ANYTOWN By: MBE

Belt Pull $BP = (LL_T + DL_T) \times C_f$

= (0 + 1343.05) x 0.05

= 1343.05 x 0.05

= 67.15 kg

Incline (Decline)

Belt Pull BP_A = Total live load on incline (kg) x Sine of angle

= 0 x 0

= 0 kg

$BP_E = (BP + BP_A) \times 1.25$

= (67.15 + 0) x 1.25

= 83.94 kg

Power = $BP_E \times V_c$ (m/s) x 0.0098

= 83.94 x 0.508 x 0.0098

= .42 kW

APPENDICES

Glossary

Audit, walk through — The act of walking through a facility and observing where energy is or may be wasted.

Audit, diagnostic — The analysis of a potential opportunity to save energy which could involve the assessment of the current process operation and records, the calculation of savings and estimates of capital and operating costs so that the financial viability could be established.

Close Coupled Reducer — A gear reducer which has a motor mounted integrally with the reducer. The reducer is then connected to the item it is driving by a chain or belt drive.

Cube Utilization — A term used to represent the amount of used volume of any defined space compared to the total volume of the same space. The higher the cube utilization the greater the volume being used (more efficient use of space).

Cyclone Separator — A mechanical device used to separate solid particles from an air stream. The air stream is caused to rotate in the device and the solid particles drop out of the stream.

Energy — The capacity for doing work; taking a number of forms that may be transformed from one into another, such as thermal (heat), mechanical (work), electrical, and chemical; in customary units, measured in kilowatt-hours (kWh) or megajoules (MJ).

Energy Intensity — The amount of energy required to produce a product or group of products expressed in energy used per unit of production.

Energy Management Opportunities (EMO), housekeeping —Potential energy saving activities which should be done on a regular basis and at least once per year. This includes preventive maintenance programs.

Energy Management Opportunities (EMO), low cost — Potential energy saving improvements that are implemented once (i.e. not repeated on an annual basis) and the cost is not considered to be great.

Energy Management Opportunities (EMO), retrofit — Potential energy saving improvements that are implemented once and the cost is considered to be significant.

Energy Type — A specific fuel or energy form used by the facility (Examples are Oil, Electricity, Natural Gas, etc.)

Energy, Waste — Energy which is lost without being fully utilized. It may include the energy in the form of steam, exhaust gases, discharge waters or even refuse.

Lubricant — A material used for one or more of the following purposes:to reduce friction, to prevent wear, to prevent adhesion, to cool moving parts and to prevent corrosion.

Outrigger — Support members extending forward on either side of the lifting forks on a narrow aisle straddle truck. The outriggers reduce the overall truck length by reducing the lift truck counterbalance requirements.

Rotary Air Lock — A mechanical device used to remove the separated solids from a cyclone separator without allowing air to escape. Normally consisting of a star type wheel rotating inside a housing. The individual star sections fill with material at the bottom of the separator and discharge when they have rotated away from the separator.

Rotary Valve —A mechanical device similar to a rotary air lock used as a metering device to control powder or granular material product flow.

Shaft Mounted Reducer — A gear reducer mounted directly on the shaft which it is driving.

Surge Loading — An unregulated flow of product or material.

Yard — The area exterior to the building, and enclosed by the property fence.

CONVEYOR DEAD LOADS (DL)
TABLE 1

Belt Conveyor — Roller Bed

	Carrying Roller Centres	Distance Between Frames				
		0.38m kg/m	**0.53m kg/m**	**0.69m kg/m**	**0.84m kg/m**	**0.99m kg/m**
Dead Load Part 1	0.076m	14.28	19.05	24.4	29.16	33.93
	0.114m	10.27	13.84	17.86	21.43	25.0
	0.152m	8.33	11.31	14.58	17.56	20.53
	0.229m	6.7	8.78	11.31	13.69	16.07
	0.305m	5.36	7.44	9.67	11.76	13.84
Dead Load Part 2	Drive and End Assemblies	36.29 kg	49.9 kg	63.5 kg	77.11 kg	90.72 kg
	Power Feed Assemblies	34.02 kg	45.36 kg	56.7 kg	68.04 kg	79.38 kg

Belt Conveyor — Slider Bed

	Carrying Roller Centres	Distance Between Frames				
		0.38m kg/m	**0.53m kg/m**	**0.69m kg/m**	**0.84m kg/m**	**0.99m kg/m**
Dead Load Part 1		2.38	3.57	4.76	5.95	7.14
Dead Load Part 2	Drive and End Assemblies	36.29 kg	49.9 kg	63.5 kg	77.11 kg	90.72 kg
	Power Feed Assemblies	34.02 kg	45.36 kg	56.7 kg	68.04 kg	79.38 kg

Heavy Duty Belt Conveyor

	Carrying Roller Centres	Distance Between Frames				
		0.69m kg/m	**0.84m kg/m**	**0.99m kg/m**	**1.14m kg/m**	**1.3m kg/m**
Dead Load Part 1	0.076m	52.97	63.09	73.21	83.33	94.04
	0.114m	36.9	44.04	51.19	58.33	65.92
	0.152m	28.87	34.52	40.18	45.83	51.78
	0.229m	20.83	25.0	29.16	33.33	37.65
	0.305m	16.81	20.24	23.66	27.08	30.65
Dead Load Part 2	Drive and End Assemblies	113.4 kg	136.08 kg	158.76 kg	181.44 kg	204.12 kg
	Power Feed Assemblies	95.26 kg	113.4 kg	131.54 kg	149.69 kg	167.83 kg

SINES OF VARIOUS ANGLES
TABLE 2

Angle	Sine	Angle	Sine
4°	0.07	18°	0.31
6°	0.10	20°	0.34
8°	0.14	22°	0.37
10°	0.17	24°	0.41
12°	0.21	26°	0.44
14°	0.24	28°	0.47
16°	0.28	30°	0.50

TYPICAL POWER CONVEYOR MAINTENANCE CHECK SHEET
TABLE 3

Location: ______________________ Date: ______________________

Conveyor Name: ______________________ Serial No.: ______________________

Component	Remarks
A. Belt	
Condition	
Lacing	
Tracking	
Tension	
B. Motor	
Brushes	
Gear Case Oil	
Oil Breather	
Oil Seal Bearings	
Mounting (bolts)	
Sprocket	
Electrical (wiring, switches, boxes, etc.)	
C. Drive	
Pulley	
Bearings	
Mounting (bolts)	
Sprocket	
Chain	
D. End Assembly	
Pulley	
Pulley Bearings	
Bolts	
E. Rollers (Idler, Snubber and Carrrier)	
Condition	
Bearings	
F. Pop-Out Rollers	
Condition	
Bearings	
G. Bed	
Condition	
Bearings	
H. Supports & Trussing	
Mounting (bolts)	
Adjusting belts	
I. Guard Rails	
Condition	
Mounting (bolts)	
J. Electrical	
Wiring	
Connections & Boxes	
K. Feeder	
Belt	
Pulleys	
Bearings (Pulleys & Rollers)	
Supports (Nuts & Bolts)	
Chain & Sprockets	

NORMAL ECONOMICAL EQUIPMENT LIFE OF FORK LIFT TRUCKS
TABLE 4

Operating Shifts Per Day	Gasoline Engine	LPG Engine	Electric Engine
1	5 years (10,000 hours)	6 years (12,000 hours)	7 years (14,000 hours)
2	3 years (12,000 hours)	4 years (16,000 hours)	5 years (20,000 hours)
3	2½ years (15,000 hours)	3 years (18,000 hours)	4 years (24,000 hours)

ANNUAL FORK LIFT TRUCK FUEL CONSUMPTION PER SHIFT OF OPERATION
TABLE 5

Lift Truck Capacity	Gasoline Litres	LPG Litres	Electricity kWh
907 kg	17	25	15 - 25
1134 kg	17	25	15 - 25
1361 kg	17	25	15 - 25
1814 kg	24	37.9	25 - 35
2268 kg	24	37.9	25 - 35
2722 kg	31.8	49.2	30 - 40
3175 kg	32.9	49.2	30 - 40
3630 kg	34.1	49.2	35 - 45
4536 kg	45.4	58.7	35 - 45
5443 kg	53.0	58.7	40 - 50

APPROXIMATE ANNUAL FORK LIFT TRUCK MAINTENANCE COST
TABLE 6

Lift Truck Capacity	Gasoline Engine		LPG Engine		Electric Engine	
	Material $	Hours	Material $	Hours	Material $	Hours
907 kg	655	52	570	52	536	33
1134 kg	655	52	570	52	536	33
1361 kg	657	53	572	53	536	33
1814 kg	715	54	625	54	609	34
2268 kg	730	54	635	54	616	34
2722 kg	1,121	60	975	60	717	41
3175 kg	1,140	60	1,005	60	717	41
3630 kg	1,190	60	1,190	60	760	41
4536 kg	1,230	60	1,230	60	828	41
5442 kg	1,295	60	1,295	60	844	41

COMMON CONVERSIONS

1 barrel (35 Imp gal) (42 US gal)	= 159.1 litres
1 gallon (Imp)	= 1.20094 gallon (US)
1 horsepower (boiler)	= 9809.6 watts
1 horsepower	= 2545 Btu/hour
1 horsepower	= 0.746 kilowatts
1 joule	= 1 N-m
Kelvin	= (°C + 273.15)
1 kilowatt·hour	= 3600 kilojoules
1 Newton	= 1 kg-m/s^2
1 therm	= 10^5 Btu
1 ton (refrigerant)	= 12002.84 Btu/hour
1 ton (refrigerant)	= 3516.8 watts
1 watt	= 1 joule/second
Rankine	= (°F + 459.67)

Cubes

1 yd^3	= 27 ft^3
1 ft^3	= 1728 in^3
1 cm^3	= 1000 mm^3
1 m^3	= 10^6 cm^3
1 m^3	= 1000 L

Squares

1 yd^2	= 9 ft^2
1 ft^2	= 144 in^2
1 cm^2	= 100 mm^2
1 m^2	= 10000 cm^2

SI PREFIXES

Prefix	Symbol	Magnitude	Factor
tera	T	1 000 000 000 000	10^{12}
giga	G	1 000 000 000	10^9
mega	M	1 000 000	10^6
kilo	k	1 000	10^3
hecto	h	100	10^2
deca	da	10	10^1
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	u	0.000 001	10^{-6}
nano	n	0.000 000 001	10^{-9}
pica	p	0.000 000 000 001	10^{-12}

4138T/T33(-6)

UNIT CONVERSION TABLES
METRIC TO IMPERIAL

FROM	SYMBOL	TO	SYMBOL	MULTIPLY BY
amperes/square centimetre	A/cm^2	amperes/square inch	A/in^2	6.452
Celsius	°C	Fahrenheit	°F	(°C × 9/5) + 32
centimetres	cm	inches	in	0.3937
cubic centimetres	cm^3	cubic inches	in^3	0.06102
cubic metres	m^3	cubic foot	ft^3	35.314
grams	g	ounces	oz	0.03527
grams	g	pounds	lb	0.0022
grams/litre	g/L	pounds/cubic foot	lb/ft^3	0.06243
joules	J	Btu	Btu	9.480×10^{-4}
joules	J	foot-pounds	ft-lb	0.7376
joules	J	horsepower-hours	hp-h	3.73×10^{-7}
joules/metre, (Newtons)	J/m, N	pounds	lb	0.2248
kilograms	kg	pounds	lb	2.205
kilograms	kg	tons (long)	ton	9.842×10^{-4}
kilograms	kg	tons (short)	tn	1.102×10^{-3}
kilometres	km	miles (statute)	mi	0.6214
kilopascals	kPa	atmospheres	atm	9.87×10^{-3}
kilopascals	kPa	inches of mercury (@ 32°F)	in Hg	0.2953
kilopascals	kPa	inches of water (@ 4°C)	in H_2O	4.0147
kilopascals	kPa	pounds/square inch	psi	0.1450
kilowatts	kW	foot-pounds/second	ft-lb/s	737.6
kilowatts	kW	horsepower	hp	1.341
kilowatt-hours	kWh	Btu	Btu	3413
litres	L	cubic foot	ft^3	0.03531
litres	L	gallons (Imp)	gal (Imp)	0.21998
litres	L	gallons (US)	gal (US)	0.2642
litres/second	L/s	cubic foot/minute	cfm	2.1186
lumen/square metre	lm/m^2	lumen/square foot	lm/ft^2	0.09290
lux, lumen/square metre	lx, lm/m^2	footcandles	fc	0.09290
metres	m	foot	ft	3.281
metres	m	yard	yd	1.09361
parts per million	ppm	grains/gallon (Imp)	gr/gal (Imp)	0.07
parts per million	ppm	grains/gallon (US)	gr/gal (US)	0.05842
permeance (metric)	PERM	permeance (Imp)	perm	0.01748
square centimetres	cm^2	square inches	in^2	0.1550
square metres	m^2	square foot	ft^2	10.764
square metres	m^2	square yards	yd^2	1.196
tonne (metric)	t	pounds	lb	2204.6
watt	W	Btu/hour	Btu/h	3.413
watt	W	lumen	lm	668.45

4138T/T33(-4)

UNIT CONVERSION TABLES
IMPERIAL TO METRIC

FROM	SYMBOL	TO	SYMBOL	MULTIPLY BY
ampere/in^2	A/in^2	ampere/cm^2	A/cm^2	0.1550
atmospheres	atm	kilopascals	kPa	101.325
British Thermal Unit	Btu	joules	J	1054.8
Btu	Btu	kilogram-metre	kg-m	107.56
Btu	Btu	kilowatt-hour	kWh	2.928×10^{-4}
Btu/hour	Btu/h	watt	W	0.2931
calorie, gram	cal or g-cal	joules	J	4.186
chain	chain	metre	m	20.11684
cubic foot	ft^3	cubic metre	m^3	0.02832
cubic foot	ft^3	litre	L	28.32
cubic foot/minute	cfm	litre/second	L/s	0.47195
cycle/second	c/s	Hertz	Hz	1.00
Fahrenheit	°F	Celsius	°C	(°F-32)/1.8
foot	ft	metre	m	0.3048
footcandle	fc	lux, lumen/ square metre	lx, lm/m^2	10.764
footlambert	fL	candela/square metre	cd/m^2	3.42626
foot-pounds	ft-lb	joule	J	1.356
foot-pounds	ft-lb	kilogram-metres	kg-m	0.1383
foot-pounds/second	ft-lb/s	kilowatt	kW	1.356×10^{-3}
gallons (Imp)	gal (Imp)	litres	L	4.546
gallons (US)	gal (US)	litres	L	3.785
grains/gallon (Imp)	gr/gal (Imp)	parts per million	ppm	14.286
grains/gallon (US)	gr/gal (US)	parts per million	ppm	17.118
horsepower	hp	watts	W	745.7
horsepower-hours	hp-h	joules	J	2.684×10^6
inches	in	centimetres	cm	2.540
inches of Mercury (@ 32°F)	in Hg	kilopascals	kPa	3.386
inches of water (@ 4°C)	in H_2O	kilopascals	kPa	0.2491

UNIT CONVERSION TABLES
IMPERIAL TO METRIC (cont'd)

FROM	SYMBOL	TO	SYMBOL	MULTIPLY BY
lamberts	* L	candela/square metre	cd/m^2	3.183
lumen/square foot	lm/ft^2	lumen/square metre	lm/m^2	10.76
lumen	lm	watt	W	0.001496
miles (statute)	mi	kilometres	km	1.6093
ounces	oz	grams	g	28.35
perm (at 0°C)	perm	kilogram per pascal-second-square metre	$kg/Pa\text{-}s\text{-}m^2$ (PERM)	5.721×10^{-11}
perm (at 23°C)	perm	kilogram per pascal-second-square metre	$kg/Pa\text{-}s\text{-}m^2$ (PERM)	5.745×10^{-11}
perm-inch (at 0°C)	perm. in.	kilogram per pascal-second-metre	kg/Pa-s-m	1.4532×10^{-12}
perm-inch (at 23°C)	perm. in.	kilogram per pascal-second-metre	kg/Pa-s-m	1.4593×10^{-12}
pint (Imp)	pt	litre	L	0.56826
pounds	lb	grams	g	453.5924
pounds	lb	joules/metre, (Newtons)	J/m, N	4.448
pounds	lb	kilograms	kg	0.4536
pounds	lb	tonne (metric)	t	4.536×10^{-4}
pounds/cubic foot	lb/ft^3	grams/litre	g/L	16.02
pounds/square inch	psi	kilopascals	kPa	6.89476
quarts	qt	litres	L	1.1365
slug	slug	kilograms	kg	14.5939
square foot	ft^2	square metre	m^2	0.09290
square inches	in^2	square centimetres	cm^2	6.452
square yards	yd^2	square metres	m^2	0.83613
tons (long)	ton	kilograms	kg	1016
tons (short)	tn	kilograms	kg	907.185
yards	yd	metres	m	0.9144

* "L" as used in Lighting

4138T/T33(-2)

The following typical values for conversion factors may be used when actual data are unavailable. The MJ and Btu equivalencies are heats of combustion. Hydrocarbons are shown at the higher heating value, wet basis. Some items listed are typically feedstocks, but are included for completeness and as a reference source. The conversion factors for coal are approximate since the heating value of a specific coal is dependent on the particular mine from which it is obtained.

ENERGY TYPE	METRIC	IMPERIAL
COAL		
— metallurgical	29,000 megajoules/tonne	25.0×10^6 Btu/ton
— anthracite	30,000 megajoules/tonne	25.8×10^6 Btu/ton
— bituminous	32,100 megajoules/tonne	27.6×10^6 Btu/ton
— sub-bituminous	22,100 megajoules/tonne	19.0×10^6 Btu/ton
— lignite	16,700 megajoules/tonne	14.4×10^6 Btu/ton
COKE		
— metallurgical	30,200 megajoules/tonne	26.0×10^6 Btu/ton
— petroleum		
— raw	23,300 megajoules/tonne	20.0×10^6 Btu/ton
— calcined	32,600 megajoules/tonne	28.0×10^6 Btu/ton
PITCH	37,200 megajoules/tonne	32.0×10^6 Btu/ton
CRUDE OIL	38,5 megajoules/litre	5.8×10^6 Btu/bbl
No. 2 OIL	38.68 megajoules/litre	5.88×10^6 Btu/bbl $.168 \times 10^6$ Btu/IG
No. 4 OIL	40.1 megajoules/litre	6.04×10^6 Btu/bbl $.173 \times 10^6$ Btu/IG
No. 6 OIL (RESID. BUNKER C)		
@ 2.5% sulphur	42.3 megajoules/litre	6.38×10^6 Btu/bbl $.182 \times 10^6$ Btu/IG
@ 1.0% sulphur	40.5 megajoules/litre	6.11×10^6 Btu/bbl $.174 \times 10^6$ Btu/IG
@ .5% sulphur	40.2 megajoules/litre	6.05×10^6 Btu/bbl $.173 \times 10^6$ Btu/IG
KEROSENE	37.68 megajoules/litre	$.167 \times 10^6$ Btu/IG
DIESEL FUEL	38.68 megajoules/litre	$.172 \times 10^6$ Btu/IG
GASOLINE	36.2 megajoules/litre	$.156 \times 10^6$ Btu/IG
NATURAL GAS	37.2 megajoules/m^3	1.00×10^6 Btu/MCF
PROPANE	50.3 megajoules/kg 26.6 megajoules/litre	$.02165 \times 10^6$ Btu/lb $.1145 \times 10^6$ Btu/IG
ELECTRICITY	3.6 megajoules/kWh	$.003413 \times 10^6$ Btu/kWh

Calculation Of Belt Conveyor Power Requirements

Worksheet 17-1

Company: ______________________ Date: ______________________

Location: ______________________ By: ______________________

Conveyor No: ______________________

Type of Conveyor: ________ Roller bed ________ Slider bed ________ Heavy duty roller bed

Material	__________	
Product loading on conveyor	__________	kg/m
Conveyor length	__________	m
For roller conveyor centre to centre distance between carrying rollers	__________	m
Width between frames	__________	m
Angle of incline (Table 2)	__________	°
Conveyor Speed (V_c)	__________	m/s
Coefficient of friction	__________	

Total Live Load LL_T = Live load (kg/m) x Conveyor length (m)

= __________ x __________

= __________ kg

Dead Load 1 (Table 1) DL_1 = Dead Load (Part 1) kg/m x Conveyor length (m)

= __________ x __________

= __________ kg

Dead Load 2 (Table 1) DL_2 = Dead Load (Part 2) kg

= __________ kg

Total Dead Load DL_T = DL_1 + DL_2

= __________ kg + __________ kg

= __________ kg

Calculation Of Belt Conveyor Power Requirements

Worksheet 17-1

Company: ____________________ Date: ____________________

Location: ____________________ By: ____________________

Belt Pull $BP = (LL_T + DL_T) \times C_f$

$= ($ ________ + ________ $) \times$ ________

$=$ ________ x ________

$=$ ________ kg

Incline (Decline)

Belt Pull BP_A = Total live load on incline (kg) x Sine of angle

$=$ ________ x ________

$=$ ________ kg

$BP_E = (BP + BP_A) \times 1.25$

$= ($ ________ + ________ $) \times 1.25$

$=$ ________ kg

Power $= BP_E \times V_c$ (m/s) $\times 0.0098$

$=$ ________ x ________ x 0.0098

$=$ ________ kW

Annual Lift Truck Capital And Operating Cost Comparison

Worksheet 17-2

Company: ______________________ Date: ______________________

Location: ______________________ By: ______________________

Annual Lift Truck Capital Cost Comparison				
Item		Gas Engine	LPG Engine	Electric Engine
1 Truck Make & Model		________	________	________
2 Total Truck Price	$	________	________	________
3 Battery*	$	________	________	________
4 Battery Charger**	$	________	________	________
5 Total Equipment Cost	$	________	________	________
6 Equipment Life (Table 4)	yrs	________	________	________
7 Equipment Cost Per Year	$	________	________	________

Annual Lift Truck Fuel Consumption Cost Per Shift Comparison				
8 Fuel Cost Per Unit	$	________	________	________
9 Lift Truck Capacity	kg	________	________	________
10 Fuel Consumption Per Shift (Table 5)		________	________	________
11 Fuel Cost Per Shift(8) x (10)	$	________	________	________
12 Number Of Days Operation Per Year		________	________	________
13 Annual Fuel Cost Per Shift	$	________	________	________

Annual Lift Truck Maintenance Cost Per Shift Comparison				
14 Material Cost (Table 6)	$	________	________	________
15 Labor Hours Per Year (Table 6)	h	________	________	________
16 Labor Cost Per Hour	$	________	________	________
17 Total Labor Cost Per Year (16) x (15)	$	________	________	________

Annual Lift Truck Capital And Operating Cost Comparison				
I Annual Equipment Cost (7)	$	________	________	________
II Annual Fuel Cost Per Shift (13)	$	________	________	________
III Annual Maintenance Cost Per Shift				
(a) Material (14)	$	________	________	________
(b) Labor (17)	$	________	________	________
Total (IIIa + IIIb)	$	________	________	________
IV Annual Maintenance And Fuel Cost Per Shift (II + III)	$	________	________	________
V Number Of Shifts		________	________	________
VI Annual Maintenance And Fuel Cost (IV x V)	$	________	________	________
VII Total Annual Cost Of Operation (I + VI)	$	________	________	________

*For single shift operation include cost of one battery per truck. For two or three shift operation include cost of two batteries per truck.

**For single or multiple shift operation include cost of one battery charger per truck.