Training Module

Describe and Operate Beam Pump

Module B
Describe and Monitor Pumpjack and Prime Mover

HDC Human Development Consultants Ltd.

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This training kit consists of the following parts:

- Training Module and Self-Check
- Knowledge Check and Answer Key
- Blank Answer Sheet
- Walkthrough

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Foreword

Beam pumps are used to lift a variety of liquids from subsurface wells to the surface. Beam pumps are commonly used at:

- oil wells to lift the oil to the surface
- gas wells to remove accumulated water which would prevent the gas from entering the wellbore
- coal bed methane wells to remove water from coal seams

While HDC's *Describe and Operate Beam Pump* series of training kits addresses beam pumping oil wells, the content applies to any beam pumping application.

The series consists of four modules, listed below. These modules are designed to address the needs of oil well operators responsible for operating, monitoring, and optimizing *existing* beam pumping oil wells. The modules are task focused (i.e., center around *what* the operator does, *why* he/she does it, *when* he/she does it, and *how*). The modules are sequential: Module A is a prerequisite to Module B and so on.

The four modules in the series are:

- Module A—*Describe and Monitor Wellhead, Sucker Rod String, Subsurface Pump*
- Module B—*Describe and Monitor Pumpjack and Prime Mover*
- Module C—*Describe Beam Pump Operation*
- Module D—*Optimize Beam Pump Operation*

Modules A and B include:

- descriptions and principles of operation of typical surface and subsurface beam pumping oil well equipment
- operating variables
- reasons for specific operating requirements
- causes for variables to change, consequences, symptoms, and operator responses to abnormal operations
- monitoring tasks related to the equipment
- a walkthrough where the operator identifies the equipment at his/her site
- self-check review questions
- a stand-alone knowledge check

Module C provides:

- a description of a typical beam pump wellsite
- an overview of beam pump oil well safety
- production monitoring and record keeping
- a description of routine beam pumping tasks:
  - respond to oil well shutdowns
  - start up pumpjack oil well (engine)
  - start up pumpjack oil well (motor)
  - check pressure safety switch
  - pig flowlines
  - put sucker rod pump on tap
  - shut down pumpjack oil well; lock out; secure for maintenance
  - change pumpjack stuffing box
- self-check review questions
- a stand-alone knowledge check
- a stand-alone checklist for monitoring beam pump operation

Module D provides:

- a description of well performance analysis
- a description of pumping system analysis
- a description of pumping oil well diagnostics:
  - fluid level detector
  - dynamometer
  - pumpjack load analysis
- a description of pumping unit adjustments:
  - balance the pumping unit
  - change pumping speed
  - change stroke length
  - lower/raise sucker rod string
  - adjust casing gas or downstream pressure
- a description of the operator's role in optimization
- self-check review questions
- a stand-alone knowledge check
- a stand-alone troubleshooting table for beam pump operation

Contents

Contents (continued)

Training Objectives

Upon completion of this training kit, you will be able to:

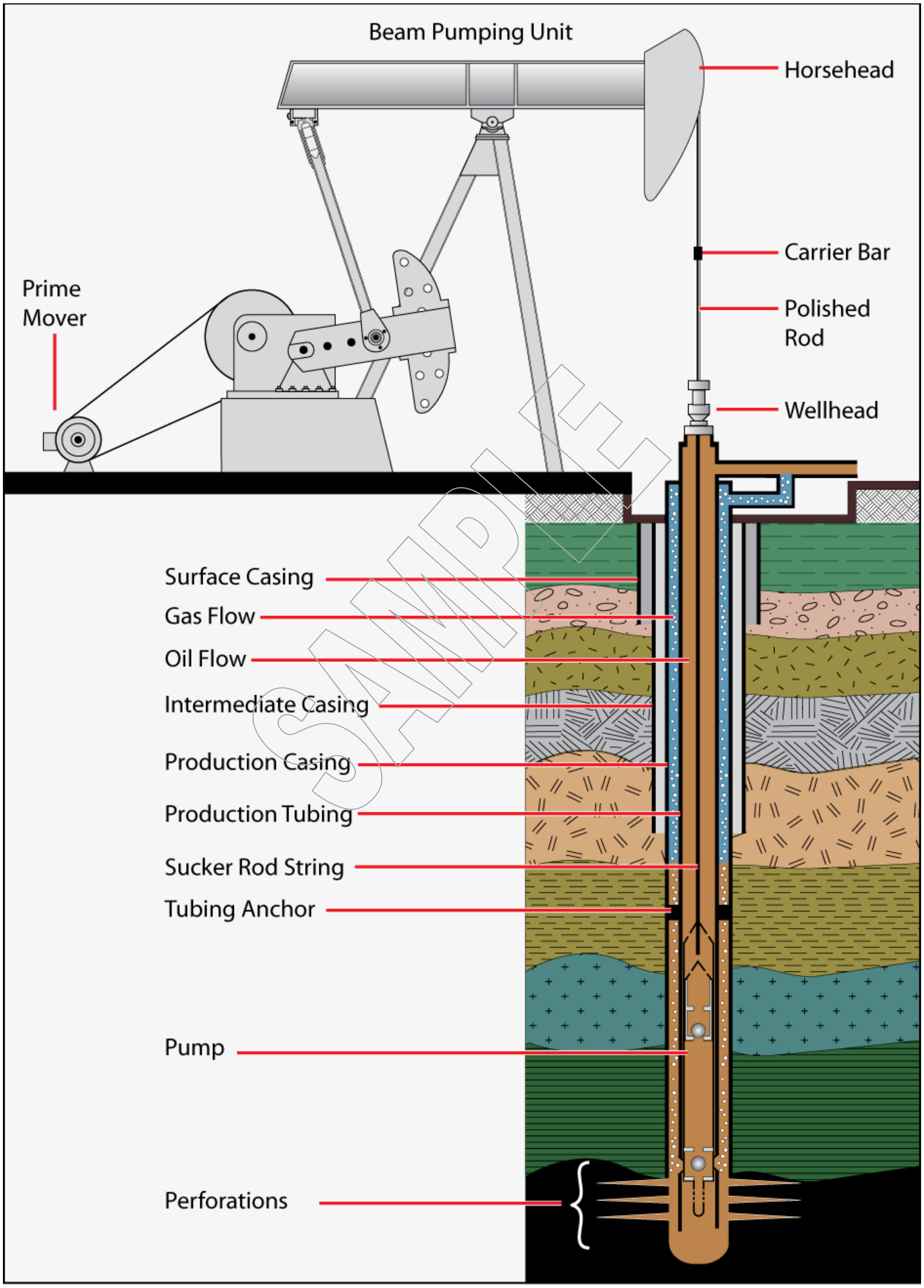
- Describe the pumpjack:
  - principle of operation
  - jack type
  - size and capacity
  - pad and base
  - samson post, walking beam, and horsehead
  - bridle and carrier bar
  - crankshaft assembly and counterweights
  - gear reducer
  - sheaves and V-belts
  - jackshaft
  - brake
- Monitor pumpjack operation and condition
- Describe electric prime movers:
  - electrical distribution system
  - power consumption; peak hours
  - electrical lockout
  - high pressure safety shutdown
  - maintenance
- Describe internal combustion prime movers:
  - engine types
  - major systems
  - engine control
  - engine safety devices
  - maintenance
- Monitor the prime mover

1 Introduction

Beam pumping systems consist of (see Figure 1):

- a beam pumping unit (pumpjack) at the surface
- a pump at the bottom of the well
- a sucker rod string which connects the pumpjack and pump
- a prime mover (electric motor or internal combustion engine) which provides the energy for pumping the well

Figure 1—Beam Pumping System at a Cased Oil Well



This module provides an introduction to *typical* beam pumping oil well equipment and operator monitoring requirements. Because every oil well is different, the **Walkthrough** which accompanies this module is an important part of the training kit. The Walkthrough allows the operator, working with a coach, to identify the *specific* equipment at the site and describe site-specific operating and safety concerns.

2 Pumpjack

The beam pumping unit (pumpjack):

- transfers the prime mover's rotary motion to the reciprocating (up/down) motion required to operate the subsurface pump
- converts the prime mover's high-speed, low-torque output to the low-speed, high-torque output essential for operating the pumping system
- counterbalances the combined weights of the rod string and oil in the tubing

2.1 Pumpjack Principle of Operation

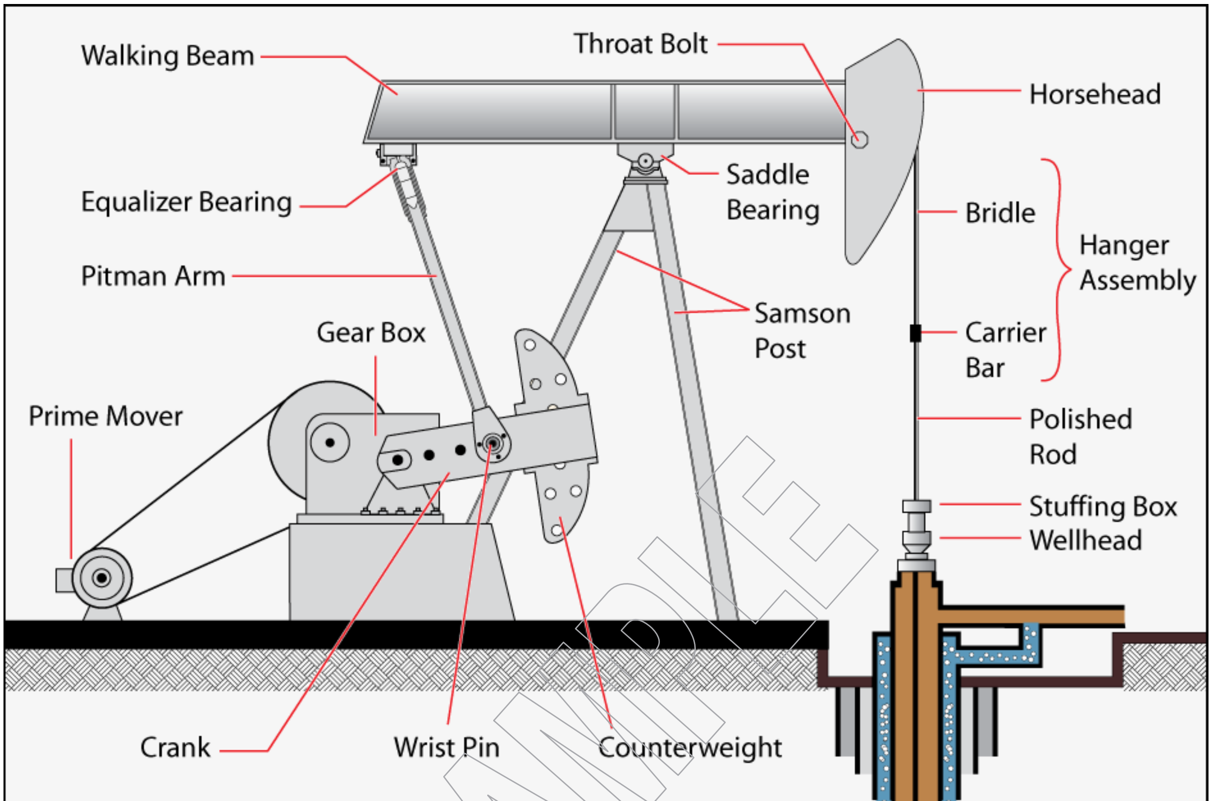
Figure 2 shows the parts of a crank-balanced beam pumping unit.

The prime mover, acting through a gear reducer, drives the crank (see Figure 2) in a rotary motion. The pitman arms, connected to the crank at one end and the walking beam at the other end, convert the crank's rotary motion into a reciprocating, up/down motion.

A pumping cycle consists of one upstroke and one downstroke:

- On the upstroke, the head of the pumping unit moves upward, lifting the sucker rod string and the load of oil the length of the pump stroke. The upstroke requires energy.
- On the downstroke, the rod string moves downward; the weight of the rods is the driving force. The downstroke delivers energy.

Figure 2—Crank-Balanced Beam Pumping Unit



The counterweights offset (balance) the weight of the rod string and the load of oil to reduce the amount of force the driver has to exert on the pumpjack. Using counterweights reduces the size of driver required to operate the pumpjack.

2.2 Pumpjack Type

In a **Class 1 lever**, the fulcrum is between the effort and the load.

In a **Class 3 lever**, the fulcrum is at one end, the load is at the other end, and the effort is between the load and the fulcrum.

The two main categories of beam pump depend on the location of the fulcrum (saddle bearing, pivot point) relative to the equalizer bearing (see Figure 2) and the well load:

- mid-beam category (Class 1 lever); for example:
  - crank-balanced pumping unit
  - Lufkin's Reverse Mark pumping unit
  - beam-balanced pumping unit
- end-of-beam category (Class 3 lever); for example, Lufkin's Mark II Unitorque pumping unit

Four different types of beam pumps are briefly described below. Other types of beam pumps include:

- air-balanced units, which use a cylinder of compressed air instead of counterweights. Air-balanced units have smaller drivers and larger-diameter main shafts, and are often used for deep wells pumping heavy loads.
- low profile units, used when the height of a standard pumpjack would interfere with overhead structures, irrigation systems, or sight lines
- slant-hole units, which can pump wells slanted at up to a 45° angle

Mid-Beam (Class 1 Lever) Category

Crank-Balanced Pumping Units

Crank-balanced units (often called conventional units) have crank-type counterweights and usually have double reduction gear trains (described in Section 2.8). As shown in Figures 2 and 3, the saddle bearing is centered on the walking beam and the wrist pin is centered on the crank arm. Approximately half of the crank's rotation (180°) is used on the upstroke and half is used on the downstroke. Most types of crank-balanced units can be run either clockwise or counterclockwise.

Figure 3—Crank-Balanced (Conventional) Pumping Unit

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Crank-balanced pumping units are the most widely used type of beam pump and are described in detail in this module. The module does not describe the other types of pumping units in detail. However, most descriptions in the module apply to all types of beam pumps.

Reverse Mark Pumping Units

Torque is the force that causes rotation about an axis. The prime mover (motor/engine) produces the torque; V-belts and gears transfer the torque to the pumping unit.

Several manufacturers make pumpjack models that are variations of the conventional crank-balanced design; Lufkin's Reverse Mark (RM) model is one example. The RM looks almost the same as a conventional pumping unit. However, on an RM unit, the saddle bearing is off-center on the walking beam and the wrist pins are off-center on each crank arm. This configuration reduces power and torque requirements (compared with conventional units). Therefore, RM units have smaller drivers and smaller gear reducers.

Beam-Balanced Pumping Units

On beam-balanced pumping units (Figure 4), the counterweight is at the end of the walking beam, behind the equalizer bearing.

Figure 4—Beam-Balanced Pumping Unit

Courtesy of Husky Energy

Beam-balanced pumping units are generally smaller than conventional crank-balanced units and are typically used for shallow, low-production wells.

End-of Beam (Class 3 Lever) Category

End-of-beam pumping units (Figure 5) have crank-type counterweights that are offset on the crank arm.

Figure 5—End-of-Beam Pumping Unit

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The first end-of-beam pumping unit developed was Lufkin's Mark II Unitorque; this model is still widely used. Mark II beam pumps always rotate in a counterclockwise direction. More than half of the crank's rotation (195°) is used on the upstroke and less than half (165°) is used on the downstroke. This means that the unit has decreased acceleration on the upstroke and a correspondingly lower peak sucker rod load. The reduced load enables using smaller drivers and smaller gear reducers.

2.3 Pumpjack Size and Capacity

The **type** of pumping unit is usually abbreviated; for example:

- C Conventional
- RM Reverse Mark
- B Beam-Balanced
- M Mark II Unitorque
- A Air-Balanced

API Standard 11E—*Pumping Units* covers the design and rating of beam pumping units. Standard 11E outlines a system for expressing pumping unit size and capacity, using the following characteristics.

- **gear reducer peak torque rating** at the output shaft in thousands of inch-pounds. This rating is for descriptive purposes only (i.e., not for operating purposes).
- **gear reducer type** (e.g., D for double reduction gear reducer)
- **polished rod/structure load rating** in hundreds of pounds
- **maximum stroke length** in inches (i.e., the distance between the horsehead at its highest and lowest positions)

For example, a beam pumping unit labeled "C-456D-256-120" has the following characteristics:

- conventional pumping unit
- gear reducer peak torque rating = 456,000 inch-pounds
- double reduction gear reducer
- polished rod/structure load rating = 25,600 pounds
- maximum stroke length = 120 inches

A pumpjack's API number is stamped on the gearbox.

2.4 Pad and Base

The beam pumping unit and prime mover are mounted on steel skids; the steel skids are securely bolted to a base of steel pile, pre-cast concrete, poured-in-place concrete, or wood (see Figure 6). The base is installed on a level pad (foundation) of crushed rock or gravel, depending on soil and drainage conditions and wellsite location. Piles are often installed under the pads to provide additional support for units that will work under severe pumping conditions (e.g., heavy loads, higher pumping speeds).

The base is designed to meet the specific requirements of the pumping unit and prime mover. For example, the base may be smaller for an electric-driven beam pump; the motor is usually mounted on an elevated skid, closer to the gearbox, so that a shorter belt can be used.

Figure 6—Steel Skid Bolted to Base

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Pad and base deficiencies are a major source of pumpjack problems. Common deficiencies include:

- pumpjack skid rails breaking out of the concrete pad, usually caused by over-tightened tie down bolts
- pumpjack movement due to loose or broken tie down bolts
- pad settling and frost heaving, which can shift the base. When the base is not completely level, the polished rod may not be perfectly aligned with the wellhead. Most (some authorities say as many as 99%) polished rod breaks are a result of improper bridle and carrier bar alignment. As described in Module A, when the polished rod is not perfectly centered in the stuffing box, stuffing box leaks may occur and the polished rod may be damaged.

If a stuffing box starts to leak continuously, the base may have shifted off-level. To determine which way the pumpjack is leaning, place a level on the polished rod at different points (*top*, *middle*, and *bottom)* of the stroke cycle. The rod will be tipped in the direction the pumpjack is leaning (e.g., if the rod is tipped forward, the pumpjack is leaning forward).

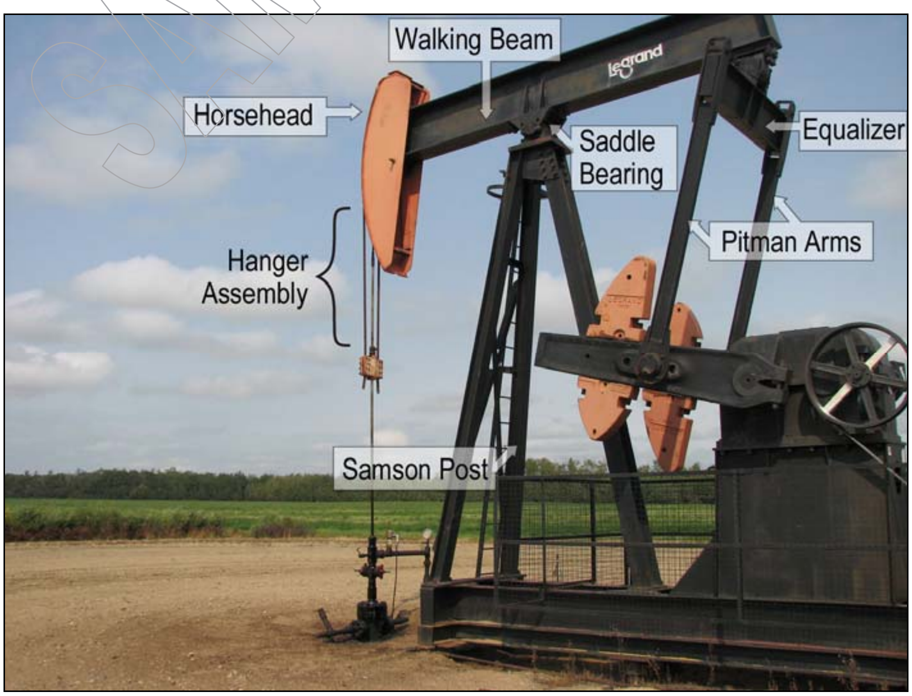
The actions needed to re-align an off-level pumpjack vary, depending why and how severely the unit is leaning. For example:

- If the unit is leaning slightly forward, placing shims at the front of the unit or under the pad may be all that is needed.
- If the rod is leaning markedly forward, the pumpjack skid may have to be moved back along the rails, or the base may have to be reworked and re-levelled.
- If the rods move backwards and forwards within each stroke cycle, the unit's geometry (e.g., horse head arc) may be the problem; the unit or major components may need to be modified.

2.5 Samson Post, Saddle Bearing, Walking Beam, and Horsehead

The **samson post** (sometimes written *sampson*) consists of three or four legs of rolled steel, sufficiently strong to support the walking beam, horsehead, equalizer, pitman arms, and more than twice the peak sucker rod load.

Figure 7—Samson Post, Saddle Bearing, Walking Beam, and Horsehead



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The **saddle (center) bearing**, which is bolted to the top of the samson post, supports the walking beam. Saddle bearings need periodic lubrication using a lithium soap-based grease with an extreme-pressure additive. It is important to use the correct lubricant, which will be listed in the specific well records. At some installations, an accessible grease fitting hose is used to lubricate the saddle bearing. When using a hose to grease the saddle bearing:

- check to ensure the hose is properly connected and is not leaking
- be aware that the grease in the hose can deteriorate during hot, sunny days

Saddle bearings can be damaged by:

- operating with the improper amount or wrong type of lubricant
- inappropriate operation, such as fluid pounding, tapping bottom, overloading, or pumping too fast
- structural problems, such as pumpjack misalignment and loose or over-tightened bolts

The **walking beam** transmits energy from the prime mover to the sucker rod string.

The **horsehead** (also known as the *mulehead*) is attached to one end of the walking beam and is positioned so that the polished rod is directly over the wellhead:

- a throat bolt should be installed to keep the horsehead securely attached to the walking beam. Notify maintenance personnel if the throat bolt is missing.
- many larger pumpjacks have a centralizer for adjusting the angle of the horsehead in relation to the walking beam.

2.6 Bridle and Carrier Bar

A **hanger assembly**, consisting of the bridle and carrier bar, connects the horsehead to the polished rod/sucker rod string (described in Module A).

The **bridle** (also known as the *wireline* or *harness*) hangs vertically from the horsehead and is fastened to the carrier bar. The bridle is a wire cable which tends to wear where it contacts the horsehead: replace the cable at the first sign of broken strands.

As the horsehead moves up and down in a curved path, the **carrier bar** moves in a perfectly vertical line, directly over the wellhead (see Figure 8). The polished rod passes through the carrier bar and is secured by a polished rod clamp.

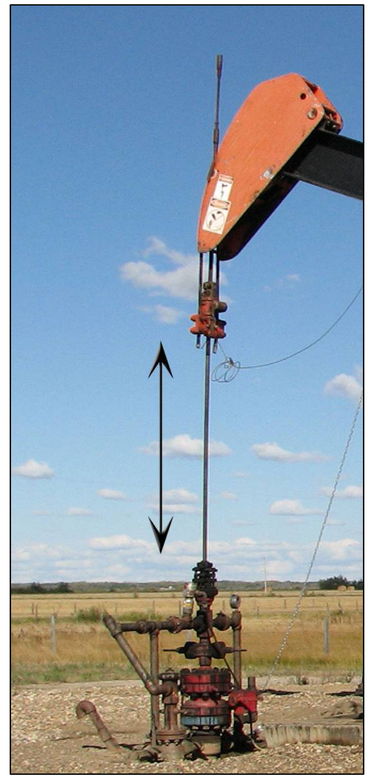


Figure 8—
Carrier Bar Moves in Vertical Line

HDC Photo

After the bridle is installed, check to ensure the bridle's:

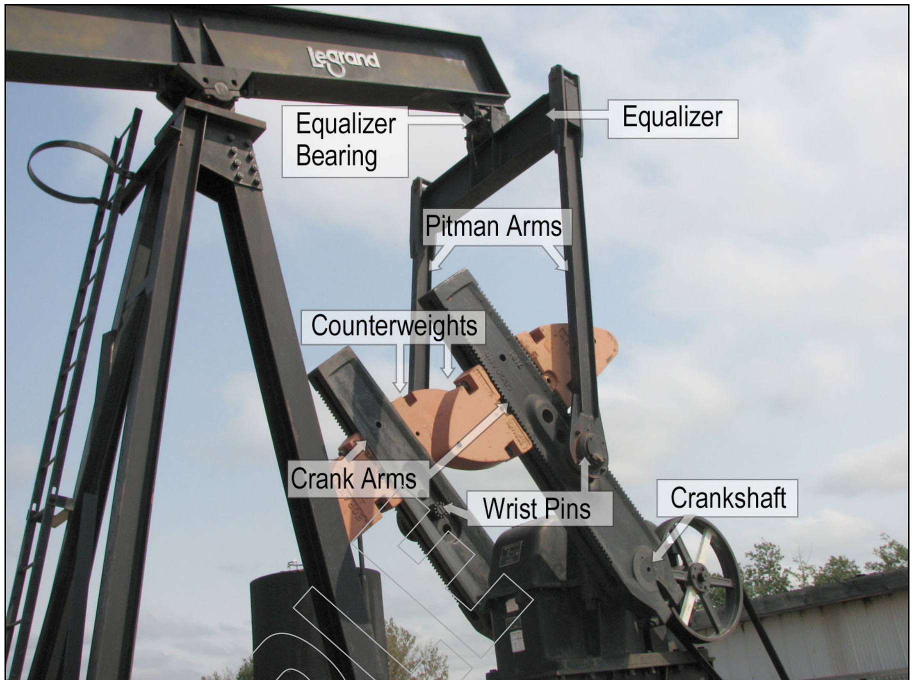
- length allows sufficient clearance between the horse's head and stuffing box (i.e., is sized to prevent pinch points). If rod rotators are used, additional clearance must be provided.
- cut-off ends do not protrude more than 6 inches below the carrier bar. The sharp ends are potential hazards for personnel working on the wellhead.

2.7 Crankshaft Assembly and Counterweights

Crankshaft Assembly

The crankshaft assembly consists of the crankshaft, two crank arms, two wrist pins (also known as crank pin bearings), two pitman arms, an equalizer, and an equalizer (tail) bearing (see Figure 9).

Figure 9—Crankshaft Assembly and Counterweights



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The crank arms are connected to the crankshaft. The crank arms each have three or four holes for attaching the pitman arms, depending on the desired stroke length. Each pitman arm is connected to the crank arm with a wrist pin. The top end of each pitman arm is connected to the equalizer. The equalizer bearing (tail bearing) connects the equalizer to the walking beam.

Because the pitman arm rotates around the wrist pin, wrist pin operation is critical to pumpjack operation. Wrist pins require careful monitoring and periodic lubrication. It is important to use the correct lubricant; consult the specific well records.

When a thin white line is painted across the wrist pin nut and crank arm, any movement at the pin will be visible.

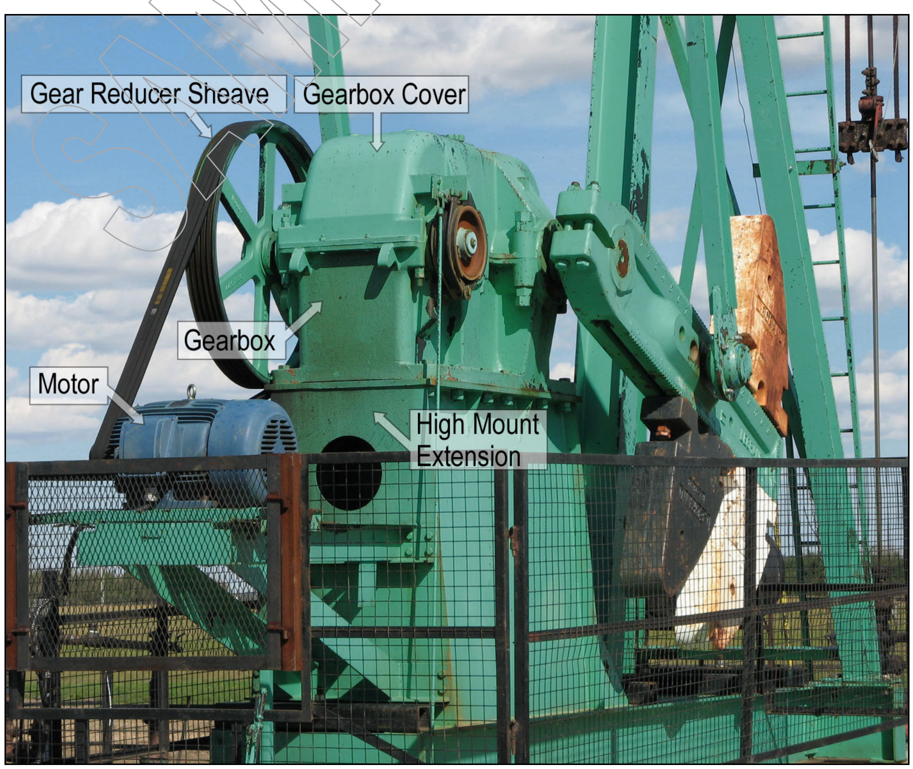
Counterweights

The **counterweights** are attached to the crank arms and rotate with the crankshaft. On the upstroke (i.e., as the horsehead moves up), the counterweights rotate downwards, reducing the amount of energy needed to lift the sucker rod string and oil. On the downstroke, the weight of the dropping sucker rod string provides the energy to lift the counterweights; the counterweights rotate upwards, storing the energy.

2.8 Gear Reducer

The gear reducer (speed reducer) has gears to convert the prime mover's high-speed, low-torque output to the low-speed, high-torque output that the pumping unit needs. The gear reducer is housed inside a gearbox; for motor-driven pumpjacks, the gearbox and motor are often mounted high to keep moving parts clear of debris, vegetation, and snow (Figure 10).

Figure 10—High-Mounted Gearbox and Motor



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Most conventional pumping units use double reduction gear trains, which reduce speed in two stages. Deeper wells using lower pumping speeds may use triple reduction gear trains. Single reduction gear trains may be used with low-speed prime movers.

The gear train has two external shafts:

- The gear reducer shaft receives the rotary motion of the prime mover via the V-belts and a sheave (pronounced *shiv*) (described in Section 2.9).
- The crankshaft drives the crank arms.

NOTE

Most gearboxes are equipped with mechanical locks to prevent gear/crank arm movement during pumpjack maintenance. If gearbox locks are not provided, crank arms must be chained to prevent movement.

On double reduction gear trains, the smallest (highest speed) gear is mounted on the gear reducer shaft. The smallest gear turns an intermediate gear on an internal shaft. The intermediate gear turns the largest (lowest speed) gear, mounted on the crankshaft.

Gear load varies with pumping speed (strokes per minute, spm). For example, for heavy oil:

- at a speed of 6 spm or higher, rod travel matches crank rotation. A flywheel effect develops, which reduces the gear load as the cranks are lifted.
- at speeds lower than 3 spm, rod travel cannot keep up with crank rotation. There is no flywheel effect and gears are overloaded as the cranks are lifted.

2.8.1 Effective Gear Operation

The gearbox is the most costly pumpjack component and is responsible for more than half of all beam pumping failures. Common sources of gear problems are improper lubrication, shock loads, and overloading.

Lubrication

Reducer gear bearings operate in an oil bath which provides continuous lubrication. A lube oil pump is not needed.

Lube oils are specially formulated for ambient temperature conditions. It is important to use the correct lubricant; consult the specific well records.

The operator ensures the gearbox lube oil level is between the low and high marks on the lube oil gauge. When filled correctly, the slow speed and high speed gears dip into the oil and provide continuous lubrication to the gear mesh.

When the pumpjack operates at less than 5 spm, high speed gear wipers may be required to ensure the intermediate and high speed bearings are receiving adequate lubrication.

Inadequate gear lubrication can cause a variety of problems:

End of Sample

A full licensed copy of this kit includes:
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