Chapter 3

Excavating and Lifting

Part 2
3-4 DRAGLINES

- Operation and Employment
- Production Estimating
- Job Management
FIGURE 3-10: Components of a dragline.

https://www.youtube.com/watch?v=TFIS4YxeJS0
Operation and Employment

– The *dragline* is a very **versatile machine** that has the **longest reach** for digging and dumping of any member of the crane-shovel family.

– It can dig from above machine level to significant depths in soft to medium-hard material.

– Bucket teeth and weight produce digging action as the drag cable pulls the bucket across the ground surface.
• Digging is also controlled by the position at which the drag chain is attached to the bucket.

FIGURE 3-11: Dragline bucket.
• It does not have the positive digging action or lateral control of the shovel. Because of that:
  – the bucket may bounce or move sideways during hard digging.
  – More spillage must be expected in loading than would occur with a shovel

• The maximum bucket size to be used on a dragline depends on machine power, boom length, and material weight.
  – Therefore, use the dragline capacity chart provided by the manufacturer instead of the machine's lifting capacity chart to determine maximum allowable bucket size.
Table 3–7 Ideal dragline output—short boom [BCY/h (BCM/h)]. (This is a modification of data published in Technical Bulletin No. 4, Power Crane and Shovel Association, Bureau of CIMA, 1968.)

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>$\frac{3}{4}$</th>
<th>1</th>
<th>$\frac{1}{4}$</th>
<th>$\frac{1}{2}$</th>
<th>$\frac{3}{4}$</th>
<th>2</th>
<th>$\frac{3}{4}$</th>
<th>3</th>
<th>$\frac{3}{4}$</th>
<th>4</th>
<th>5</th>
</tr>
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<tr>
<td></td>
<td>(0.57)</td>
<td>(0.75)</td>
<td>(0.94)</td>
<td>(1.13)</td>
<td>(1.32)</td>
<td>(1.53)</td>
<td>(1.87)</td>
<td>(2.29)</td>
<td>(2.62)</td>
<td>(3.06)</td>
<td>(3.82)</td>
</tr>
<tr>
<td>Light moist clay or loam</td>
<td>130</td>
<td>160</td>
<td>195</td>
<td>220</td>
<td>245</td>
<td>265</td>
<td>305</td>
<td>350</td>
<td>390</td>
<td>465</td>
<td>540</td>
</tr>
<tr>
<td>Common earth</td>
<td>125</td>
<td>155</td>
<td>185</td>
<td>210</td>
<td>235</td>
<td>255</td>
<td>295</td>
<td>340</td>
<td>380</td>
<td>455</td>
<td>530</td>
</tr>
<tr>
<td>Tough clay</td>
<td>(96)</td>
<td>(119)</td>
<td>(141)</td>
<td>(161)</td>
<td>(180)</td>
<td>(195)</td>
<td>(226)</td>
<td>(260)</td>
<td>(291)</td>
<td>(348)</td>
<td>(405)</td>
</tr>
<tr>
<td>Wet, sticky clay</td>
<td>105</td>
<td>135</td>
<td>165</td>
<td>190</td>
<td>210</td>
<td>230</td>
<td>265</td>
<td>305</td>
<td>340</td>
<td>375</td>
<td>445</td>
</tr>
</tbody>
</table>

*Based on 100% efficiency, 90° swing, optimum depth of cut, material loaded into haul units at grade level.

Table 3–8 Optimum depth of cut for short boom. (This is a modification of data published in Technical Bulletin No. 4, Power Crane and Shovel Association, Bureau of CIMA, 1968.)

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>$\frac{3}{4}$</th>
<th>1</th>
<th>$\frac{1}{4}$</th>
<th>$\frac{1}{2}$</th>
<th>$\frac{3}{4}$</th>
<th>2</th>
<th>$\frac{3}{4}$</th>
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<th>5</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(0.57)</td>
<td>(0.75)</td>
<td>(0.94)</td>
<td>(1.13)</td>
<td>(1.32)</td>
<td>(1.53)</td>
<td>(1.87)</td>
<td>(2.29)</td>
<td>(2.62)</td>
<td>(3.06)</td>
<td>(3.82)</td>
</tr>
<tr>
<td>Light moist clay, loam, sand, and gravel</td>
<td>6.0</td>
<td>6.6</td>
<td>7.0</td>
<td>7.4</td>
<td>7.7</td>
<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
<td>9.5</td>
<td>10.0</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>(1.8)</td>
<td>(2.0)</td>
<td>(2.1)</td>
<td>(2.2)</td>
<td>(2.3)</td>
<td>(2.4)</td>
<td>(2.6)</td>
<td>(2.7)</td>
<td>(2.9)</td>
<td>(3.0)</td>
<td>(3.3)</td>
</tr>
<tr>
<td>Common earth</td>
<td>7.4</td>
<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
<td>9.5</td>
<td>9.9</td>
<td>10.5</td>
<td>11.0</td>
<td>11.5</td>
<td>12.0</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td>(2.3)</td>
<td>(2.4)</td>
<td>(2.6)</td>
<td>(2.7)</td>
<td>(2.9)</td>
<td>(3.0)</td>
<td>(3.2)</td>
<td>(3.3)</td>
<td>(3.5)</td>
<td>(3.7)</td>
<td>(4.0)</td>
</tr>
<tr>
<td>Wet, sticky clay</td>
<td>8.7</td>
<td>9.3</td>
<td>10.0</td>
<td>10.7</td>
<td>11.3</td>
<td>11.8</td>
<td>12.3</td>
<td>12.8</td>
<td>13.3</td>
<td>13.8</td>
<td>14.3</td>
</tr>
<tr>
<td></td>
<td>(2.7)</td>
<td>(2.8)</td>
<td>(3.0)</td>
<td>(3.2)</td>
<td>(3.4)</td>
<td>(3.6)</td>
<td>(3.7)</td>
<td>(3.9)</td>
<td>(4.1)</td>
<td>(4.2)</td>
<td>(4.4)</td>
</tr>
</tbody>
</table>
Table 3-9 Swing-depth factor for draglines. (This is a modification of data published in Technical Bulletin No. 4, Power Crane and Shovel Association, Bureau of CIMA, 1968.)

<table>
<thead>
<tr>
<th>Depth of Cut (% of Optimum)</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>75</th>
<th>90</th>
<th>120</th>
<th>150</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.06</td>
<td>0.99</td>
<td>0.94</td>
<td>0.90</td>
<td>0.87</td>
<td>0.81</td>
<td>0.75</td>
<td>0.70</td>
</tr>
<tr>
<td>40</td>
<td>1.17</td>
<td>1.08</td>
<td>1.02</td>
<td>0.97</td>
<td>0.93</td>
<td>0.85</td>
<td>0.78</td>
<td>0.72</td>
</tr>
<tr>
<td>60</td>
<td>1.25</td>
<td>1.13</td>
<td>1.06</td>
<td>1.01</td>
<td>0.97</td>
<td>0.88</td>
<td>0.80</td>
<td>0.74</td>
</tr>
<tr>
<td>80</td>
<td>1.29</td>
<td>1.17</td>
<td>1.09</td>
<td>1.04</td>
<td>0.99</td>
<td>0.90</td>
<td>0.82</td>
<td>0.76</td>
</tr>
<tr>
<td>100</td>
<td>1.32</td>
<td>1.19</td>
<td>1.11</td>
<td>1.05</td>
<td>1.00</td>
<td>0.91</td>
<td>0.83</td>
<td>0.77</td>
</tr>
<tr>
<td>120</td>
<td>1.29</td>
<td>1.17</td>
<td>1.09</td>
<td>1.03</td>
<td>0.98</td>
<td>0.90</td>
<td>0.82</td>
<td>0.76</td>
</tr>
<tr>
<td>140</td>
<td>1.25</td>
<td>1.14</td>
<td>1.06</td>
<td>1.00</td>
<td>0.96</td>
<td>0.88</td>
<td>0.81</td>
<td>0.75</td>
</tr>
<tr>
<td>160</td>
<td>1.20</td>
<td>1.10</td>
<td>1.02</td>
<td>0.97</td>
<td>0.93</td>
<td>0.85</td>
<td>0.79</td>
<td>0.73</td>
</tr>
<tr>
<td>180</td>
<td>1.15</td>
<td>1.05</td>
<td>0.98</td>
<td>0.94</td>
<td>0.90</td>
<td>0.82</td>
<td>0.76</td>
<td>0.71</td>
</tr>
<tr>
<td>200</td>
<td>1.10</td>
<td>1.00</td>
<td>0.94</td>
<td>0.90</td>
<td>0.87</td>
<td>0.79</td>
<td>0.73</td>
<td>0.69</td>
</tr>
</tbody>
</table>
To estimate dragline production using the tables,

- determine the ideal output of the dragline for the machine size and material (Table 3-7),

- then adjust this figure by multiplying it by a swing-depth factor (Table 3-9) and a job efficiency factor, as shown in Equation 3-3.

- Expected production =
  
  = Ideal output \times \text{Swing-depth factor} \times \text{Efficiency} \quad (3-3)

- Notice the conditions applicable to Table 3-7 given in the footnote.
• To use Table 3-9, it is first necessary to determine the optimum depth of cut for the machine and material involved from Table 3-8.

• Next, divide the average depth of cut by the optimum depth and express the result as a percentage.

• The appropriate swing-depth factor is then obtained from Table 3-9,
  – interpolating as necessary.
EXAMPLE 3-4

- Determine the expected dragline production in loose cubic meter LCM per hour based on the following information.
  - Dragline size = 1.53 $m^3$
  - Swing angle = $120^\circ$
  - Average depth of cut = 2.4 m
  - Material = common earth
  - Job efficiency = 50 min/h
  - Soil swell = 25%
Solution

Ideal output = 176 BCM/h (Table 3-7)
Optimum depth of cut = 3.0 m (Table 3-8)
Average depth/optimum depth = 2.4/3.0 × 100 = 80%
Swing-depth factor = 0.90 (Table 3-9)
Efficiency factor = 50/60 = 0.833
Volume change factor = 1 + 0.25 = 1.25
Estimated production =

\[ = 176 \times 0.90 \times 0.833 \times 1.25 = 165 \text{ LCM/h} \]
Job Management

• Trial operations may be necessary to select:
  – the boom length,
  – boom angle,
  – bucket size and weight, and
  – the attachment position of the drag chain that yield maximum production.

• As in shovel operation, maximum production is obtained with a minimum swing angle.

• Special bucket hitches are available which shorten the drag distance necessary to obtain a full bucket load.

• Deep cuts should be excavated in layers whose thickness is as close to the optimum depth of cut as possible.
3-5 CLAMSHELLS

- Operation and Employment
- Production Estimating
- Job Management
FIGURE 3-13: Components of a Clamshell

https://www.youtube.com/watch?v=KtQSPBy831s
Operation and Employment

• When the crane-shovel is equipped with a crane boom and clamshell bucket, it becomes an excavator known as a *clamshell*.

• The clamshell is capable of excavating to *great depths*.

• The shovel and backhoe is better than clamshell because of:
  – lacks the positive digging action and
  – precise lateral control.
Clamshells are commonly used for:

- excavating vertical shafts and footings,
- unloading bulk materials from rail cars and ships, and
- moving bulk material from stockpiles to bins, hoppers, or haul units.
FIGURE 3-14: Clamshell bucket
Bucket penetration depends on bucket weight assisted by the bucket teeth.

Therefore, buckets are available in light, medium, and heavy weights, with and without teeth.

1. **Heavy buckets**: are suitable for digging medium soils.

2. **Medium buckets**: are used for general-purpose work, including the excavation of loose soils.

3. **Light buckets**: are used for handling bulk materials such as sand and gravel.
• The orange peel bucket is principally utilized for underwater excavation and for rock placement.
• Because of its circular shape, it is also well suited to excavating piers and shafts.
• It operates on the same principle as does the clamshell.

FIGURE 3-15: Orange peel bucket (Courtesy of ESCO Corporation)
Production Estimating

- No standard production tables are available for the clamshell.
  - Thus production estimation should be based on the use of Equation 2-1.
  - The procedure is illustrated in Example 3-5.
EXAMPLE 3-5

- Estimate the production in loose cubic meter per hour for a medium-weight clamshell excavating loose earth.
  - Heaped bucket capacity is 0.75 m³.
  - The soil is common earth with a bucket fill factor of 0.95.
  - Estimated cycle time is 40 s.
  - Job efficiency is estimated at 50 min/h.

**Solution**

Production = $\frac{3600}{40} \times 0.75 \times 0.95 \times \frac{50}{60} = 53$ LCM/h
Job Management

• The maximum allowable load (bucket weight plus soil weight) on a clamshell should be obtained from the manufacturer's clamshell loading chart for continuous operation.

• Limit the load to 80% of the safe lifting capacity given by the crane capacity chart for rubber-tired equipment or 90% for crawler-mounted equipment.

• Use of the lightest bucket capable of digging the material will enable a larger bucket to be used and will usually increase production.
Job Management

• Cycle time is reduced by organizing the job so that the dumping radius is the same as the digging radius (fixed boom angle).

• Keep the machine level to avoid swinging uphill or downhill.

• Non level swinging is hard on the machine and usually increases cycle time.
3-6 TRENCHING AND TRENCHLESS TECHNOLOGY

• There is a growing demand for methods of installing utility systems below the ground with minimum open excavation.

• Some methods available for achieving this goal include:
  – 1. Specialized trenching machines
  – 2. Plows
  – 3. Trenchless technology (trenchless excavation).
1. Trenching Machines

• **A. Chain trenchers**, Figure 3-16 shows a large chain trencher capable of digging 356-911-mm wide vertical-sided trenches to a depth of 3.1 m.

• **B. Ladder trencher**, are similar to chain trencher, but are larger. They are capable of digging trenches up to 10-ft (3.1 m) wide and 25-ft (7.6-m) deep.

• **C. Bucket wheel** trenchers use a revolving bucket wheel to cut a trench up to 5-ft (1.5 m) wide and 9-ft (2.7-m) deep.
Chain trencher
https://www.youtube.com/watch?v=sdthb4YU1Rk
Bucket wheel trencher
https://www.youtube.com/watch?v=cY9O0NBKZ3E
Ladder Trencher

https://www.youtube.com/watch?v=-JD3vrSs5Tw
2. Plows

- Plows can be used to cut a narrow trench and simultaneously insert a small diameter cable or pipeline in most soil.
- Vibratory plows, deliver a more powerful cutting action than static plows and can be used to insert utility lines in hard soil or soft rock.

- [https://www.youtube.com/watch?v=4Vb7-ZEW5vE](https://www.youtube.com/watch?v=4Vb7-ZEW5vE)
Figure 3-17  Hydrostatic vibratory plow. (Courtesy of Vermeer Manufacturing Co.)
3. Trenchless Technology

• The principal categories of trenchless technology include:
  – 1. pipe jacking,
  – 2. horizontal earth boring, and
  – 3. microtunneling.
1. Pipe Jacking

- The process of *pipe jacking* involves forcing pipe horizontally through the soil.
- Working from a vertical shaft, a section or pipe is carefully aligned and advanced through the soil by hydraulic jacks braced against the shaft sides.
- As the pipe advances, spoil is removed through the inside of the pipe.
- After the pipe section has advanced far enough, the hydraulic rams are retracted and another section of pipe is placed into position for installation.
- The process often requires workers to enter the pipe during the pipe jacking operation.
Figure 3-18 Installing a utility line by pipe jacking.
2. Horizontal earth boring

- In *horizontal earth boring* a horizontal hole is created mechanically or hydraulically with the pipe to be installed serving as the casing for the hole.
- Some of the many installation methods used include auger boring, rod pushing (thrust boring), rotational compaction boring, impact piercing, horizontal directional drilling, and fluid boring.
- Many of these technologies utilize lasers and television cameras for hole alignment and boring control.
Figure 3-20 Installing a utility line by horizontal earth boring.
Placing pipe into the borehole.

- In one method, pipe is pulled through the bore using the tool's air hose or a steel cable pulled by the air hose.
- Another method uses the piercing tool to push the pipe through the borehole.
- A third method uses a pipe pulling adapter attached to the piercing tool to advance the pipe at the same time as the piercing tool advances the bore.
Microtunneling or Utility Tunneling

- *Microtunneling* or *utility tunneling* is similar to the conventional tunneling except for the tunnel size and use.
  - Since the tunnels are used for utility systems rather than for vehicle passage, they are normally smaller than road or rail tunnels.
  - They differ from other trenchless methods in their use of a conventional tunnel liner instead of using the pipe itself as a liner. Small moles are frequently used in creating such tunnels.
Repair and Rehabilitation of Pipelines

• The repair and rehabilitation of existing pipelines without excavation is another form of trenchless technology.
• most repair and rehabilitation methods involve the
  – relining of the existing pipeline or
  – the bursting of the existing pipe while inserting a new pipe.
• Relining of a pipeline is accomplished by

– pulling a new plastic pipe into the existing pipe, the resulting pipe must be slightly smaller than the original pipe.

– by inserting a liner into the existing pipe which involves pulling a folded liner into the existing pipe, expanding the liner, treating the liner with an epoxy, and curing it in place.
Pipe bursting

- *Pipe bursting* uses a high-powered hydraulic or pneumatic piercing tool equipped with a special bursting head to shatter the existing pipe and enlarge the opening. A new, often larger, pipe is then pulled into the opening by the piercing head.

- https://www.youtube.com/watch?v=HX5beh0ubGY
- https://www.youtube.com/watch?v=qTMZLfjzHDk
Figure 3-21  Schematic of pipe bursting. (Courtesy of Vermeer Manufacturing Co.)