REVIEW FOR FINAL EXAM

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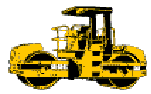

by

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Spring 2002

ENCE 420 - Construction Equipment and Methods

Department of Civil Engineering

University of Maryland

Finishing Equipment (Ch. 9)

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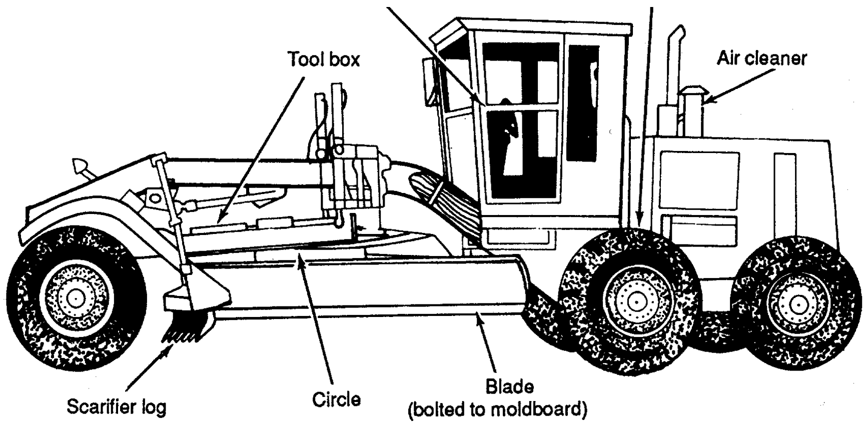
- **Finishing equipment include, but not limited to:**
  - ✓**Graders**
  - ✓**Gradalls**
  - ✓**trimmers**

GRADERS



Finishing Equipment (Ch. 9)

Estimating Production

✓ The following formula is used to estimate the total time

$$\text{Total Time} = \frac{P \times D}{S \times E} \qquad (1)$$

P = number of passes required
D = distance traveled in each pass, in miles or feet
S = speed of grader (mph or fps)
E = grader efficiency factor

Finishing Equipment (Ch. 9)

- The ***gradall*** is a utility machine which combines the operating features of the hoe, dragline, and motor grader.
- The full revolving superstructure of the unit can be mounted on either crawler tracks or wheels.

Finishing Equipment (Ch. 9)

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Finishing Equipment (Ch. 9)

- Trimmers are specialty machines to fine finishing for special jobs.
- The result is better accuracy and greater production compared to the fine-grading with a grader.

Finishing Equipment (Ch. 9)

Finishing Equipment (Ch. 9)

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- Production of a Trimmer
  - ✓A large full-width trimmer can have speeds of about **30** fpm.
  - ✓A small, single-lane trimmer, can be rated at **128** fpm.
  - ✓As operating speed is increased, there is usually a decrease in quality.

Trucks and Hauling Equipment (Ch. 10)

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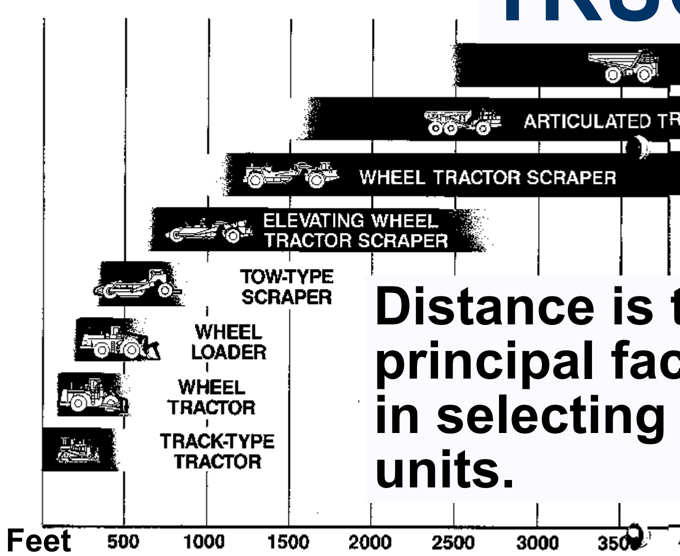
- Trucks are hauling units .
- Trucks have high travel speeds when operating on suitable roads, provide relatively low hauling costs.
- Trucks provide a high degree of flexibility permitting modifications in the total hauling capacity of a fleet and adjustments for changing haul distances.

TRUCKS

TRUCKS



Distance is the principal factor in selecting haul units.

Trucks and Hauling Equipment (Ch. 10)

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Tires are about 35% of a truck's operating cost. Overload a truck and you abuse the tires.

TIRES

Tires are designed for a wide range of applications.

Section 20 CAT Handbook

Trucks and Hauling Equipment (Ch. 10)

- **There are three methods of expressing the capacities of trucks and wagons:**
  1) **by the load which it will carry, expressed gravimetrically in tons.**
  2) **by its struck volume (cu yd).**
  3) **by its heaped volume (cu yd).**

Trucks and Hauling Equipment (Ch. 10)

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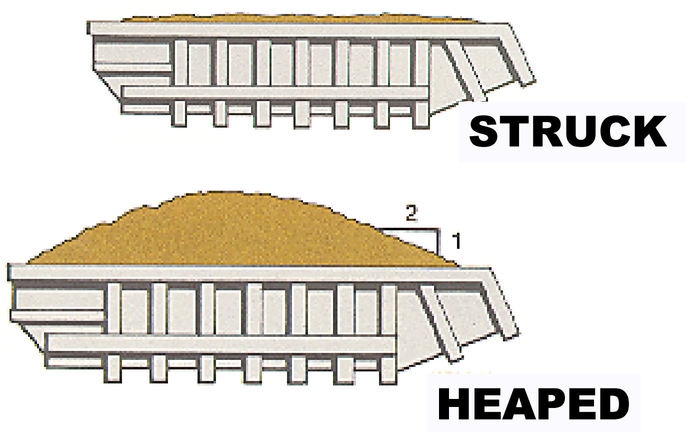
- The **struck capacity** of a truck is the volume of material which it will haul when it is filled level to the top of the sides of the body.
- The **heaped capacity** is the volume of material, which it will haul when the load is heaped above the sides.

Trucks and Hauling Equipment (Ch. 10)



Example 1

Determine the maximum speed for the truck, whose specifications are given below, when it is hauling a load of 22 tons up a 6% grade on a haul road having a rolling resistance of 60 lb per ton:

Engine: 239 fwhp

Capacity:

Struck, 14.7 cu yd

Heaped, 2:1, 18.3 cu yd

Net Weight (empty) = 36,860 lb

Payload = 44,000 lb

$$\text{Gross Vehicle Weight} = 36{,}860 + 44{,}000 = 80{,}860 \text{ lb}$$

$$\text{Total Resistance} = \text{rr} + \text{gr} = \frac{60}{20} + 6 = 9\%$$

$$\text{Maximum Speed} \approx 6.5 \text{ mph (from Figure 1, or Fig. 10-9 Text)}$$

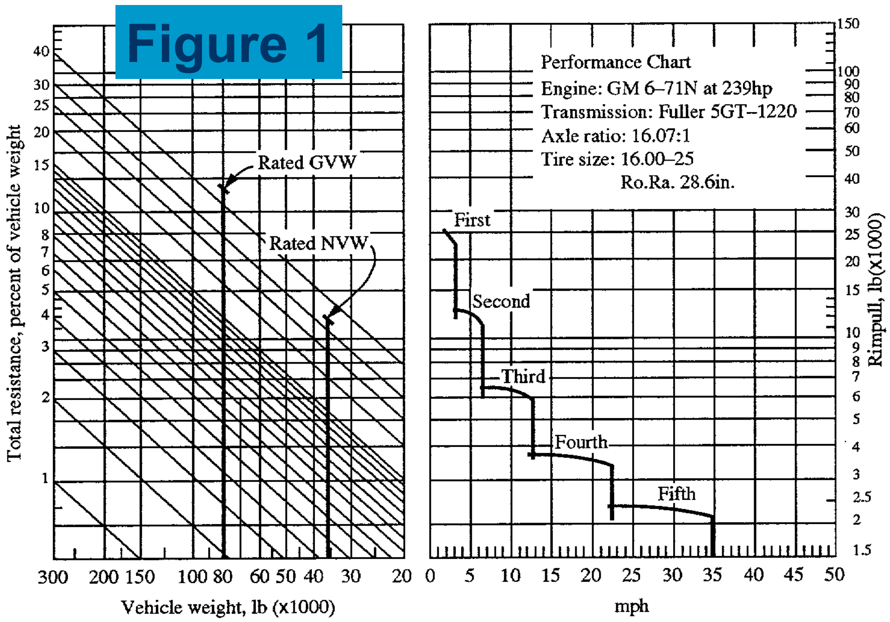
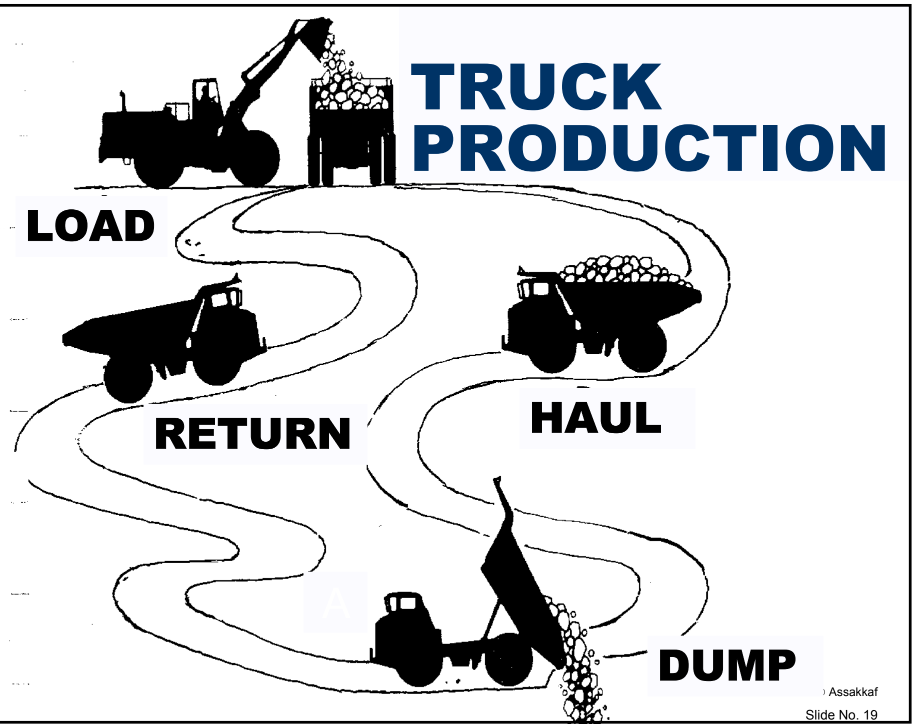


Figure 1
Total resistance, percent of vehicle weight
Rated GVW
Rated NVW
Vehicle weight, lb (x1000)
300 200 150 100 80 60 50 40 30 20
Performance Chart
Engine: GM 6–71N at 239hp
Transmission: Fuller 5GT–1220
Axle ratio: 16.07:1
Tire size: 16.00–25
Ro.Ra. 28.6in.
First
Second
Third
Fourth
Fifth
Rimpull, lb(x1000)
mph
0 5 10 15 20 25 30 35 40 45 50


TRUCK PRODUCTION
LOAD
RETURN
HAUL
DUMP

TRUCK PRODUCTION

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STEP 6: TRUCK CYCLE TIME

CYCLE TIME =

Load Time

+ Haul Time

+ Dump Time

+ Return Time

Compressed Air (Ch. 11)

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- Compressed air is used extensively on construction projects for:
  - ✓ Drilling rock
  - ✓ Loosening earth
  - ✓ Operating air motors
  - ✓ Hand tools
  - ✓ Pile drivers
  - ✓ Pumps
  - ✓ Mucking equipment
  - ✓ Cleaning.

Boyle's and Charles' Laws (Ch.11)

- Boyle's Law states that when a gas is subjected to a change in volume due to a change in pressure, at a *constant* temperature, the product of the pressure times the volume will remain constant

$$P_1V_1 = P_2V_2 = K$$

where
P_1 = initial absolute pressure
V_1 = initial volume
P_2 = final absolute pressure
V_2 = final volume
K = a constant

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \text{a constant}$$

- When a gas undergoes a change in volume or pressure with a change in temperature, Boyle's law will not apply
- Charles law states that the volume of a given weight of gas at <u>*constant pressure*</u> varies in direct proportion to its absolute temperature, that is

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = C$$

where
V_1 = initial volume
T_1 = initial absolute temperature
V_2 = final volume
T_2 = final absolute temperature
C = a constant

Example 1 (Ch. 11)

- Determine the final volume of 1,000 ft^3 of air when the gauge pressure is increased from 20 to 120 psi, with no change in temperature. The barometer indicates an atmospheric pressure of 14.7 psi.

P_1 = 20 + 14.7 = 34.7 psi
P_2 = 120 + 14.7 = 134.7 psi
V_1 = 1,000 ft^3

$$P_1V_1 = P_2V_2 = K$$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{34.7(1000)}{134.7} = \underline{257.6 \text{ ft}^3}$$

Example 5 (Ch. 11)

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Consider a 315-cfm two stage portable compressor with the following specifications as given by the manufacturer:

No. of low-pressure cylinders = 4
Diameter of low-pressure cylinders = 7 in
Length of stroke = 5 in
Revolution per minute (rpm) = 870

What is the efficiency of this compressor?

$$\text{Area of cylinder} = \frac{\pi\left(\frac{7}{2}\right)^2}{(144)} = 0.267\ \text{ft}^2$$

$$\text{Displacement per cylinder per stroke} = 0.267\left(\frac{5}{12}\right) = 0.111\ \text{ft}^3$$

$$\text{Displacement per minute} = 4 \times 0.111 \times 870 = 386.3\ \frac{\text{ft}^3}{\text{min}}$$

$$\text{Efficiency} = \frac{315}{386.3} \times 100 = 81.5\%$$

Loss of Air Pressure in Pipe due to Friction (Ch. 11)

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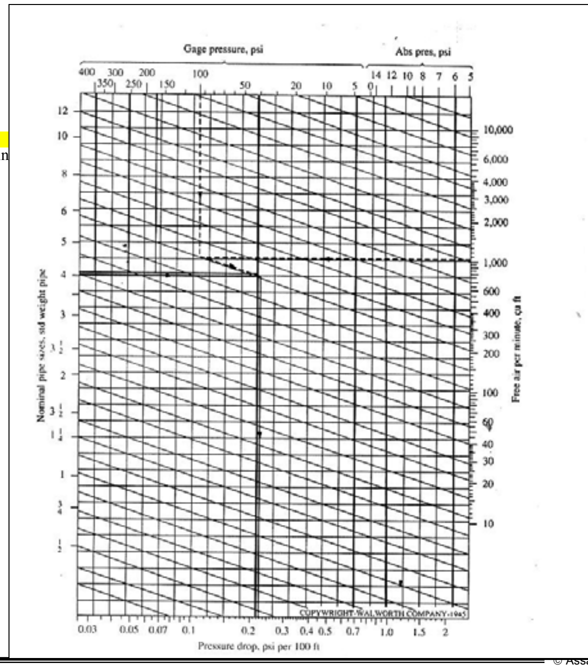
$$f = \frac{CL}{r} \times \frac{Q^2}{d^5} \qquad f = \frac{0.1025L}{r} \times \frac{Q^2}{d^{5.31}}$$

Where

f = pressure drop, psi
L = length of pipe, ft
Q = volume of free air, ft^3, per second
r = ratio of compression, based on absolute press.
d = actual ID of pipe, in
C = experimental coefficient ($0.1025/d^{0.31}$ for steel pipe)

Figure 2
Compressed-Air Flow Chart



Example 9 (Ch. 11)

A 4-in ordinary steel pipe with screwed fittings is used to transmit 1200 cfm of free air at an initial pressure of 90 psi gauge pressure. Determine the total loss of pressure in the pipline if the pipline includes the following items:

1450 ft of pipe,	6 standard on-run tees
4 gate valves,	3 angle Valves

Size of pipe = 4 in.
Length of pipe = 1450 ft
Q = 1200 cfm
P_1 = 90 psi gauge

Example 9 (continued) (Ch.11)

The equivalent length of the pipe will be:

Pipe		= 1450 ft
Gate valves:	4 X 2.4 (Table 3)	= 9.6 ft
on-run tees:	6 X 7.7 (Table 3)	= 46.2 ft
angle valves:	3 X 56.0 (Table 3)	= 168 ft
	Total	1673.8 ft

$$r = \frac{90 + 14.7}{14.7} = 7.122$$

$$f = \frac{0.1025L}{r} \times \frac{Q^2}{d^{5.31}} = \frac{0.1025(1673.8)}{7.122} \times \frac{\left(\frac{1200}{60}\right)^2}{(4)^{5.31}} = \underline{7.86\ \text{psi}}$$

Example 9 (continued) (Ch.11)

Table 3. Equivalent Length (ft) of Standard-weight Pipe Having the Same Pressure Losses as Screwed Fittings

Nominal pipe size (in.)	Gate valve	Globe valve	Angle valve	Long-radius ell or on run of standard tee	Standard ell or on run of tee	Tee through side outlet
$\frac{1}{2}$	0.4	17.3	8.6	0.6	1.6	3.1
$\frac{3}{4}$	0.5	22.9	11.4	0.8	2.1	4.1
1	0.6	29.1	14.6	1.1	2.6	5.2
$1\frac{1}{4}$	0.8	38.3	19.1	1.4	3.5	6.9
$1\frac{1}{2}$	0.9	44.7	22.4	1.6	4.0	8.0
2	1.2	57.4	28.7	2.1	5.2	10.3
$2\frac{1}{2}$	1.4	68.5	34.3	2.5	6.2	12.3
3	1.8	85.2	42.6	3.1	6.2	15.3
4	2.4	112.0	56.0	4.0	7.7	20.2
5	2.9	140.0	70.0	5.0	10.1	25.2
6	3.5	168.0	84.1	6.1	15.2	30.4
8	4.7	222.0	111.0	8.0	20.0	40.0
10	5.9	278.0	139.0	10.0	25.0	50.0
12	7.0	332.0	166.0	11.0	29.8	59.6

Effects of Altitude on the Consumption of Air by Rock Drills (Ch. 11)

Table 6. Factors to be Used in Determining the Capacities of Compressed air Required by Rock Drills at Different Altitudes

Altitude (ft)	Number of drills: 1	2	3	4	5	6	7	8	9	10
	Factor									
0	1.0	1.8	2.7	3.4	4.1	4.8	5.4	6.0	6.5	7.1
1,000	1.0	1.9	2.8	3.5	4.2	4.9	5.6	6.2	6.7	7.3
2,000	1.1	1.9	2.9	3.6	4.4	5.1	5.8	6.4	7.0	7.6
3,000	1.1	2.0	3.0	3.7	4.5	5.3	5.9	6.6	7.2	7.8
4,000	1.1	2.1	3.1	3.9	4.7	5.5	6.1	6.8	7.4	8.1
5,000	1.2	2.1	3.2	4.0	4.8	5.6	6.3	7.0	7.6	8.3
6,000	1.2	2.2	3.2	4.1	4.9	5.8	6.5	7.2	7.8	8.5
7,000	1.2	2.2	3.3	4.2	5.0	5.9	6.6	7.4	8.0	8.7
8,000	1.3	2.3	3.4	4.3	5.2	6.1	6.8	7.6	8.2	9.0
9,000	1.3	2.3	3.5	4.4	5.3	6.2	7.0	7.7	8.4	9.2
10,000	1.3	2.4	3.6	4.5	5.4	6.3	7.1	7.9	8.6	9.4
12,000	1.4	2.5	3.7	4.6	5.6	6.6	7.4	8.2	8.9	9.7
15,000	1.4	2.6	3.9	4.7	5.9	6.9	7.7	8.6	9.3	10.2

Source: Compressed Air and Gas Institute.

Example 11 (Ch. 11)

A single drill requires a capacity of 600 cfm of air at sea level. What would be the required capacities at altitudes of 5,000 ft and 15,000 ft?

Using Table 6 (Table 12-10, Text):

For an altitude of 5,000 ft:

Required Capacity = 600 X 1.2 = 720 cfm

For an altitude of 15,000 ft:

Required Capacity = 600 X 1.4 = 840 cfm

Drilling Rock and Earth (Ch. 12)

- Drilling equipment and methods are used by the construction and mining industries to drill holes in both rock and earth.
- Same or similar equipment may in some instances be used for drilling both materials.
- Purposes for which drilling are performed vary a great deal from general to highly specialized applications.

Selecting the Drilling Method and Equipment (Ch. 12)

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- Holes are drilled for various purposes, such as:
  - ✓To receive charges of explosives,
  - ✓For exploration, or
  - ✓For ground modification by the injection of grout.
- Within practical limits, the equipment which will produce the greatest overall economy for the particular project is the most satisfactory.

Selecting the Drilling Method and Equipment (Ch. 12)

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- Many factors affect the selection of equipment. Among these are:
  1. The nature of the terrain.
  2. The required depth of holes,
  3. The hardness of the rock.
  4. The extent to which the formation is broken or fractured.
  5. The size of the project.
  6. The extent to which the rock is to be broken for handling or crushing.

Estimating Drilling Production (Ch. 12)

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Figure 4. Format for Estimating Drilling Production

(1)	Depth of hole:	(a) ______ ft pull,	(b) ______ ft drill	
(2)	Penetration rate:	______ ft/min		
(3)	Drilling time:	______ min		(1b)/(2)
(4)	Change steel:	______ min		
(5)	Blow hole:	______ min		
(6)	Move to next hole:	______ min		
(7)	Align steel:	______ min		
(8)	Change bit:	______ min		
(9)	Total time:	______ min		
(10)	Operating Rate:	______ ft/min		(1b)/(9)
(11)	Production efficiency:	______ min/hr		
(12)	Hourly production:	______ ft/hr		(11)×(10)

Example 1 (Ch. 12)

A project utilizing experienced drillers will require the drilling and blasting of high silica, fine-grained sandstone rock. From field drilling tests it was determined that a direct drilling rate of 120 ft per hour could be achieved with a 3 1/2 HD bit on a rotary percussion drill @ 100 psi. The drills to be used take 10-ft steel. The blasting pattern will be a 10 X 10-ft grid with 2 ft of sub-drilling required. On the average the specified finish grade is 16 ft below the existing ground surface. Determine the drilling production.

Example 1 (continued) (Ch.12)

Using the format of Figure 4:

(1) Depth of hole	(a) 16-ft pull	(b) 18-ft drill (16 + 2)
(2) Penetration	2.00 ft/min	(120 ft ÷ 60)
(3) Drilling Time:	9.00 min	(18 ft ÷ 2 ft/min)
(4) Change Steel:	0.00 min	(d<20 ft)
(5) Blow Hole:	0.10 min	
(6) Move to Next Hole	0.45 min	(10 ft ÷ 0.25 mph)
(7) Align Steel:	1.00 min	
(8) Change Bit:	0.08 min	(4 X 18/850)
(9) Total Time	10.63 min	

Note: 850 was obtained from Table 5

Example 1 (continued) (Ch.12)

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Table 5 (Table 13-6c, Text)

Sedimentary rock: Average life, in feet, for drill bits and steel

Drill bits (in.)	Type	Sedimentary: High silica fine grain (Sandstone) (ft)	Medium silica coarse grain (Sandstone) (ft)	Low silica fine grain (Dolomite) (ft)	Low silica fine-med. grain (Shale) (ft)	Low silica coarse grain (Conglomerate) (ft)
3	B	800	1,200	1,300	2,000	1,800
3	STD	NR	850	900	1,500	1,200
$3\frac{1}{2}$	STD	NR	1,500	1,800	3,000	2,500
$3\frac{1}{2}$	HD	850	2,000	2,200	3,500	3,000
$3\frac{1}{2}$	B	2,000	3,100	3,500	4,500	4,000
4	B	2,500	3,500	2,000	5,000	4,800
Rotary bits						
5	ST	NR	1,000	NR	8,000	6,000
$5\frac{7}{8}$	ST	NR	2,500	NR	15,000	13,000
$6\frac{1}{4}$	ST	NR	4,000	4,000	18,000	14,000
$6\frac{3}{4}$	ST	500	6,000	8,000	20,000	15,000
$6\frac{3}{4}$	CB	2,000	8,000	10,000	25,000	20,000
$7\frac{7}{8}$	CB	3,000	10,000	15,000	25,000	20,000
Down hole bits						
$6\frac{1}{2}$	B	2,500	3,500	5,500	7,500	6,000
Drill steel						
Shanks		5,000	5,500	6,000	7,000	6,500
Couplings		1,000	1,200	1,500	2,000	1,750
Steel	10 ft	2,000	2,300	2,500	4,000	3,500
Steel	12 ft	4,500	5,000	6,000	7,500	7,000
5 in.	20 ft	65,000	250,000	200,000	300,000	250,000

B = button, CB = carbide button, HD = heavy duty, ST = steel tooth, STD = standard, NR = not recommended.

Example 1 (continued) (Ch.12)

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(10) Operating Rate:	1.69 ft/min	(18 ÷ 10.63)
(11) Production Efficiency.:	50 min/hr	
(12) Hourly Production	84.5 ft/hr	(50 X 1.55)

Example 2 (Ch. 12)

The drilling production of Example 1 must match that of hauling and loading for the project, which is 500 cu yd per hour. How many drill units will be required?

$$\text{Hole Production} = \frac{10\times10\times16}{27} = 59.26 \text{ cu yd/hole}$$

$$\frac{84.5 \text{ ft/hr}}{18 \text{ ft/hole}} = 4.69\frac{\text{hole}}{\text{hr}} \text{ per drill}$$

$$4.69\left(\frac{\text{hole}}{\text{hr}} \text{ per drill}\right)\times 59.26 \text{ cu yd / hole} = 278 \text{ cu yd}$$

$$2\times278 = 556 \text{ cu yd} > 500 \text{ cu yd}$$

$\therefore$ Two drills will be required

Blasting Rock (Ch. 13)

- ”Blasting" is performed to break rock so that it may be quarried for processing in an aggregate production operation, or to excavate a right-of-way.
- Blasting is accomplished by discharging an explosive that has either been placed in an unconfined manner, such as mud capping boulders, or is confined as in a borehole.

Commercial Explosives (Ch.13)

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- There are four main categories of commercial high explosives:
  1. Dynamite,
  2. Slurries,
  3. ANFO, and
  4. Two-component explosives.

Blasthole Dimensional Terminology (Ch.13)

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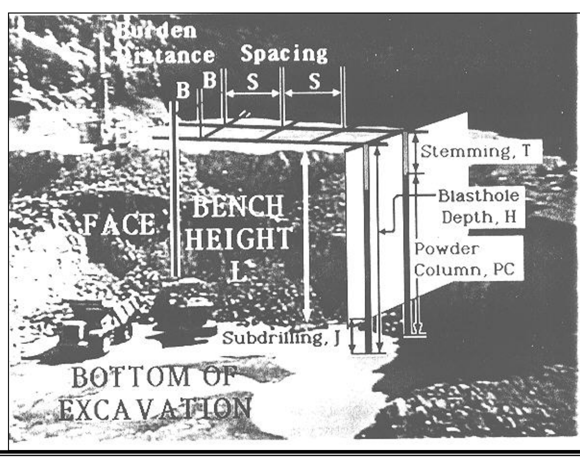
Figure 1. Blasthole Dimensional Terminology



Burden (Ch. 13)

- An empirical formula for approximating a burden distance to be used *on* a first trial shot is

$$B = \left(\frac{2SG_e}{SG_r} + 1.5\right)D_e$$

where

B = burden, ft
SG_e = specific gravity of the explosive
SG_r = specific gravity of the rock
D_e = diameter of the explosive, in.]

- The burden distance, *B*, based on relative bulk energy is given by

$$B = 0.67D_e\sqrt[3]{\frac{St_v}{SG_r}}$$

SG_r = specific gravity of the rock
D_e = diameter of the explosive, in.
St_v = relative bulk strength compared to ANFO

Problem (Ch. 13)

A material company is opening a new quarry in a limestone formation. Tests have shown that the specific gravity of this formation is 2.7. The initial mining plan envisions an average bench height of 24 ft based on the loading and hauling equipment capabilities. Bulk ANFO, specific gravity 0.8, and dynamite specific gravity 1.5, will be the explosives used. The contractor's equipment can drill 6-in diameter holes. Delayed initiation will be utilized. Develop a blasting plan for the first shot.

$$B = \left(\frac{2SG_e}{SG_r} + 1.5\right)D_e = \left(\frac{2(0.8)}{2.7} + 1.5\right)(6) = 12.6 \text{ ft}$$

Problem (Ch. 13)

SR= *L/B* = 24 ÷ 12.6 = 1.9 ----> Table 3: Fair

This might cause problem

Try drilling 4 in blasthole and loading 4 inches with ANFO:

$$B = \left(\frac{2SG_e}{SG_r} + 1.5\right) D_e = \left(\frac{2(0.8)}{2.7} + 1.5\right)(4) = 8.4 \text{ ft}$$

Use a burden distance of 8 ft

SR= *L/B* = 24 ÷ 8 = 3 ----> Table 3: Good

Stemming depth: *T* = 0.7 (8) = 5.6 ft ----> use 6 ft

Subdrilling depth: *J* = 0.3 (8) = 2.4 ft -----> use 2.5 ft

Problem (Ch. 13)

Table 3. Stiffness Ratio's Effect on Blasting Factors (Table 13-3, Text)

Stiffness Ratio (RS)	1	2	3	> 4*
Fragmentation	Poor	Fair	Good	Excellent
Air Blast	Severe	Fair	Good	Excellent
Flyrock	Severe	Fair	Good	Excellent
Ground Vibration	Severe	Fair	Good	Excellent

*Stiffness Ratios above 4 yield no increase in benefit

SR > 1 but < 4, and delayed initiation, hence

$$S = \frac{L + 7B}{8} = \frac{24 + 7(8)}{8} = 10 \text{ ft}$$

10 ± 0.15(10): The range for *S* is 8.5 to 11.5 ft

As a first try: Use a 8 X 10 Pattern

Aggregate Production (Ch. 14)

- The production of crushed-stone aggregate involves:
  - ✓Drilling
  - ✓Blasting
  - ✓Loading
  - ✓Transporting
  - ✓Crushing
  - ✓Screening
  - ✓Product handling and storage

Types of Crushers (Ch. 14)

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- Crushers are classified according to the stage of crushing which they accomplish, such as:
  - ✓Primary
  - ✓Secondary
  - ✓Tertiary
- A <u>primary crusher</u> receives the stone directly from a quarry after blasting, and produces the <u>first reduction in size</u>.

Major Types of Crushers (Ch. 14)

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Table 2

The major types of crushers

Crusher type	Reduction ratio range
Jaw	
a. Double toggle	
(1) Blake	4:1–9:1
(2) Overhead pivot	4:1–9:1
b. Single toggle: Overhead eccentric	4:1–9:1
Gyratory	
a. True	3:1–10:1
b. Cone	
(1) Standard	4:1–6:1
(2) Attrition	2:1–5:1
Roll	
a. Compression	
(1) Single roll	Maximum 7:1
(2) Double roll	Maximum 3:1
Impact	
a. Single rotor	to 15:1
b. Double rotor	to 15:1
c. Hammer mill	to 20:1
Specialty crushers	
a. Rod mill	
b. Ball mill	

Sizes of Stone Produced by Crushers

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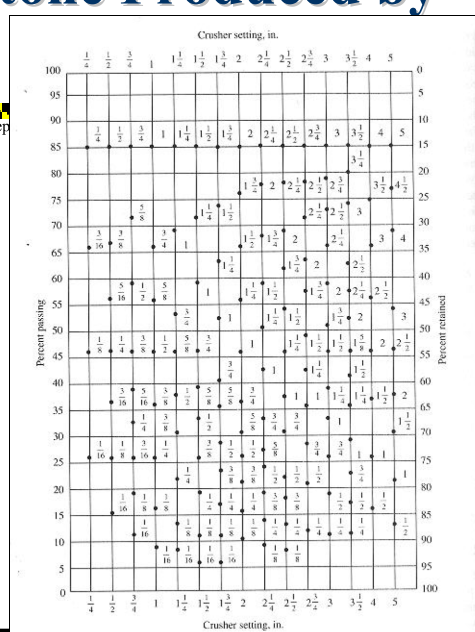
Figure 1 (Figure 14.4, Text)
Analysis of the Size of Aggregate Produced by Jaw and Roll Crushers



Example 1 (Ch. 14)

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- A jaw crusher with a closed setting of 3 in produces 50 tons per hour of crushed stone. Determine the amount of stone produced in tons per hour within the following size range: in excess of 2 in; between 2 and 1 in; between 1 and 1/4 in.

Example 1 (cont'd) (Ch. 14)

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- From Figure 1, the amount retained on a 2-in screen is 42% of 50, which is 21 tons per hr.
- Similarly, the amount in each of the size range is determined as shown in the following Table 3:

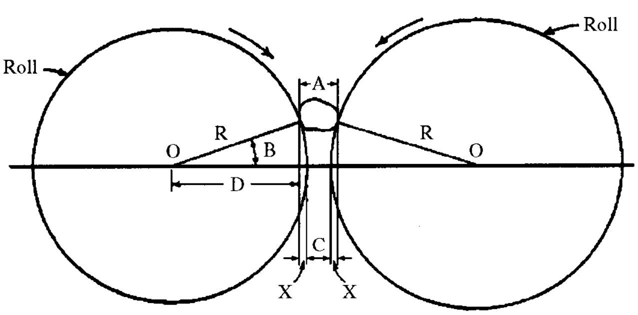
Example 1 (cont'd) (Ch. 14)

Table 3

Size Range (in)	% Passing Screen	Percent in Size Range	Total Output of Crusher (ton/hr)	Amount Produced in Size Range (ton/hr)
Over 2	100 – 58	42	50	21.0
2 – 1	58 – 33	25	50	12.5
1 – 1/4	33 – 11	22	50	11.0
¼ - 0	11 - 0	11	50	5.5
Total		**100 %**		**50.0 tph**

Feed Size (Ch. 14)

Figure 2



Crushing rock between two rolls.

Feed Size (Ch. 14)

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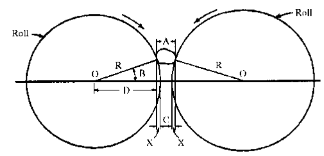
- The maximum-size particles that can be crushed is determined as follows:



Crushing rock between two rolls.

Let

R = radius of rolls

B = angle of nip

$D = R \cos B = R \cos(16.76) = 0.9575\ R$

A = maximum-size feed

C = roll setting = size of finished product

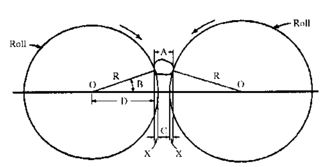
Feed Size (Ch. 14)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

$$X = R - D = R - 0.9575R = 0.0425R$$

$$A = 2X + C = 2(0.0425R) + C = 0.085R + C$$

$$\boxed{\therefore \text{Maximum-size Feed } (A) = 0.085R + C} \quad (1)$$



Crushing rock between two rolls.

Example 3 (Ch. 14)

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Determine the minimum-size single-deck screen, having 1.5-in-sq openings, for screening 120 tons per hour of dry crushed stone, weighing 100 lb per cu ft when crushed. A screening efficiency of 90% is satisfactory. An analysis of the aggregate indicates that approximately 30% of it will be less than 0.75 in. in size.

Example 3 (cont'd) (Ch. 14)

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The values of the factors to be used in Eq. 4 are as follows:

- Q = 120 ton/hr
- C = 3.3 ton/hr per sq ft (Figure 3)
- E = 1.25 (Table 6)
- D = 1.0 (Table 7)
- G = 0.8 (Table 8)

Substituting these values in Eq. 4, we get

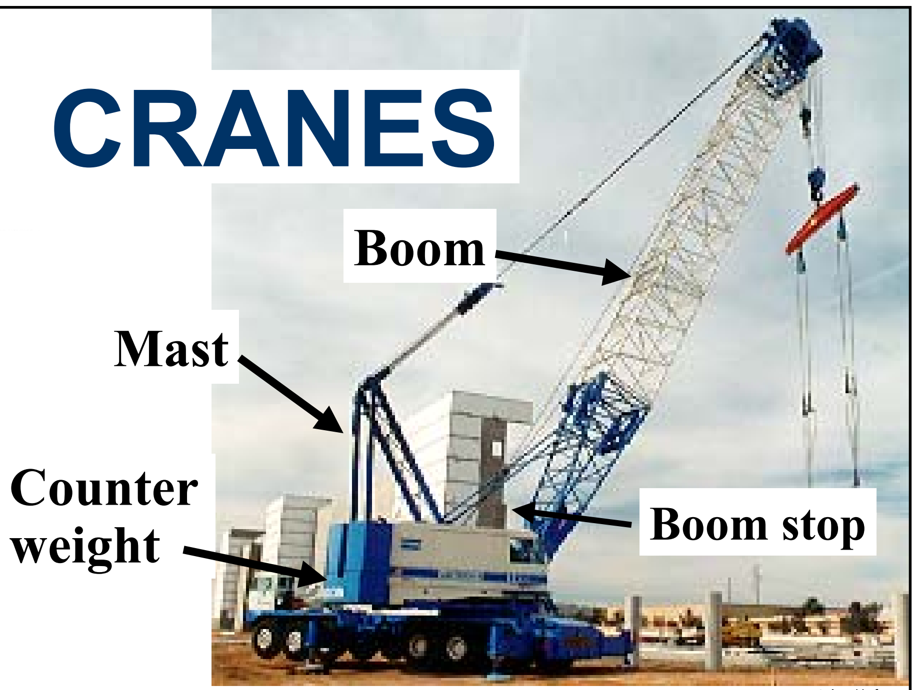
$$A = \frac{Q}{CEDG} = \frac{120}{3.3(1.25)(1.0)(0.8)} = \underline{36.4\ \text{sq ft}}$$

Cranes (Ch. 17)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

The crane is the primary machine used for the vertical movement of construction materials.

CRANES



Cranes (Ch. 17)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

- The most common types are:
  1. Crawler
  2. Hydraulic truck
  3. Lattice-boom truck
  4. Rough-terrain
  5. All-terrain
  6. Heavy lift
  7. Modified cranes for heavy lift
  8. Tower

Hydraulic Truck Cranes (Ch. 17)

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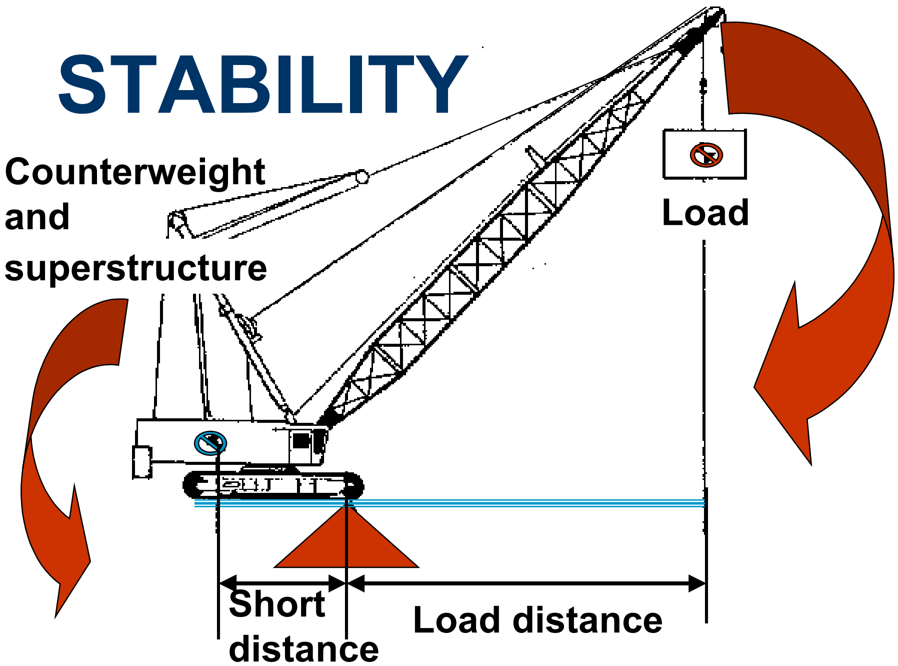
- **Remember:** All mobile cranes are stability-sensitive machines. Rated loads are based on ideal conditions, a level machine, calm air, and no dynamic effects.

STABILITY



Tower Cranes (Ch. 17)

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These are cranes that provide a high-lifting height with good working radius, and take up limited space.

Tower Cranes (Ch. 17)

- The three common configurations are:
  - (1) a special vertical boom arrangement on a mobile crane,
  - (2) a mobile crane superstructure mounted atop a tower, or
  - (3) a vertical tower (European type) with a jib and operator's cab atop.

Tower Cranes (Ch. 17)

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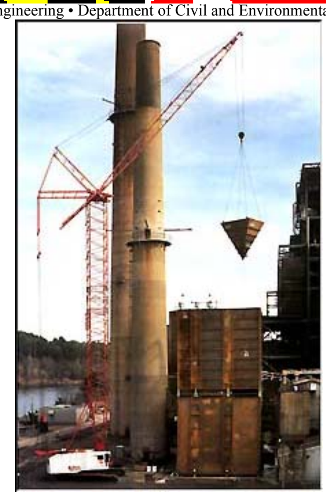

Example 1 (Ch. 17)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

Can the tower crane, whose load chart is given in Table 1(Table 17.3 of Textbook), lift a 15,000-lb load at a radius of 142 ft? The crane has a L7 jib and a two-part line hoist. The slings that will be used for the pick weigh 400 lb. Assume 5% margin be applied to computed weight.

Weight of Load = 15,000 lb

Weight of slings = 400 lb

Total Weight = 15,000 + 400 = 15,400 lb

Required Capacity = 15,400 X 1.05 = 16,170 lb

From Table 1, the maximum capacity at a 142-ft radius is 16,400 lb

16,400 lb > 16,170 lb

Therefore, the crane can safely make the lift

Example 1 (cont'd) (Ch. 17)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

Table 1. (Text 17.3) Lifting Capacities (lb) for a Tower Crane

Lifting capacities, in pounds, for a tower crane

Jib model	L1	L2	L3	L4	L5	L6	L7	Hook reach
Maximum hook reach	104'-0"	123'-0"	142'-0"	161'-0"	180'-0"	199'-0"	218'-0"	
	27,600	27,600	27,600	27,600	27,600	27,600	27,600	10'-3"
	27,600	27,600	27,600	27,600	27,600	27,600	27,600	88'-2"
	27,600	27,600	27,600	27,600	27,600	27,600	25,800	94'-6"
	27,600	27,600	27,600	27,600	27,600	25,800	24,200	101'-0"
	27,600	27,600	27,600	27,600	26,800	24,900	23,400	104'-0"
		27,600	27,600	27,600	25,200	23,600	22,200	109'-8"
		27,600	27,600	25,600	23,300	21,800	20,500	117'-8"
		27,000	27,000	25,100	22,800	21,300	20,100	120'-0"
		26,300	26,300	24,300	22,200	20,700	19,500	123'-0"
Lifting capacities in pounds, two-part line			24,800	22,800	20,800	19,300	18,300	130'-0"
			22,400	20,700	18,700	17,400	16,400	142'-0"
				19,500	17,600	16,300	15,400	150'-0"
				18,800	16,800	15,700	14,800	155'-0"
				17,900	16,200	15,100	14,200	161'-0"
					15,200	14,200	13,300	170'-0"
					14,200	13,200	12,400	180'-0"
						12,300	11,600	190'-0"
						11,700	10,800	199'-0"
							10,200	210'-0"
							9,700	218'-0"

Example 2 (Ch. 17)

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Determine the minimum boom length that will permit the crawler crane to lift a load which is 34 ft high to a position 114 ft above the surface on which the crane is operating. The length of the block, hook, and slings that are required to attach the hoist rope to the load is 26 ft. The location of the project will require the crane to pick up the load from a truck at a distance of 70 ft from the center of rotation of the crane. If the block, hook, and slings weigh 5,000 lb, determine the maximum net weight of the load that can be hoisted.

The operating radius = 70 ft
Total height of boom point = 114 + 34 + 26 = 174 ft
From Figure 1 (Figure 17.11 of Textbook), for a radius of 70 ft, the height of
of the boom point is 178 ft for 180-ft boom, which is high enough.
From Table 2 (Table 17.1 in Textbook),
for 180-ft boom and 70-ft radius, Maximum total load = 47,600 lb
Hence
Maximum Safe Weight = 47,600 - 5,000 = 42,600 lb

Example 2 (cont'd) (Ch. 17)

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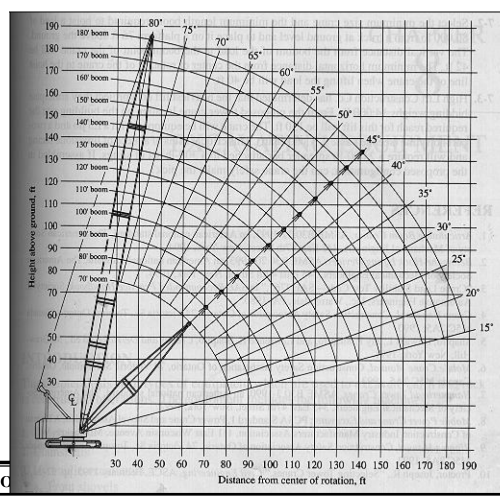
Figure 1. (Text 17.11) Working Ranges for a 200-ton Crawler Crane (Manitowoc Eng. Co)



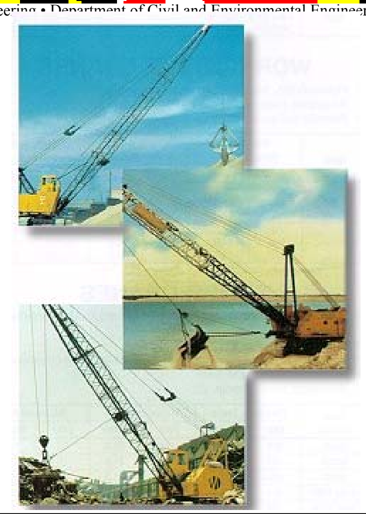
Example 2 (cont'd) (Ch. 17)

Table 2. (Text 17.1) Lifting Capacities (lb) for 200-ton Crawler Crane with 180 ft of Boom

Radius (ft)	Capacity (lb)	Radius (ft)	Capacity (lb)	Radius (ft)	Capacity (lb)
32	146,300	80	39,200	130	17,900
36	122,900	85	35,800	135	16,700
40	105,500	90	32,800	140	15,500
45	89,200	95	30,200	145	14,500
50	76,900	100	27,900	150	13,600
55	67,200	105	25,800	155	12,700
60	59,400	110	23,900	160	11,800
65	53,000	115	22,200	165	11,100
70	47,600	120	20,600	170	10,300
75	43,100	125	19,200	175	9,600

† Specified capacities based on 75% of tipping loads.
Source: Manitowoc Engineering Co.

Draglines and Clamshells (Ch. 18)



Draglines (Ch. 18)

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- Draglines are used to excavate material and to load it into hauling units, such as trucks or tractor-pulled wagons, or to deposit it in levees, dams, and spoil banks near the pits from which it is excavated.

Basic Components of Dragline (Ch. 18)

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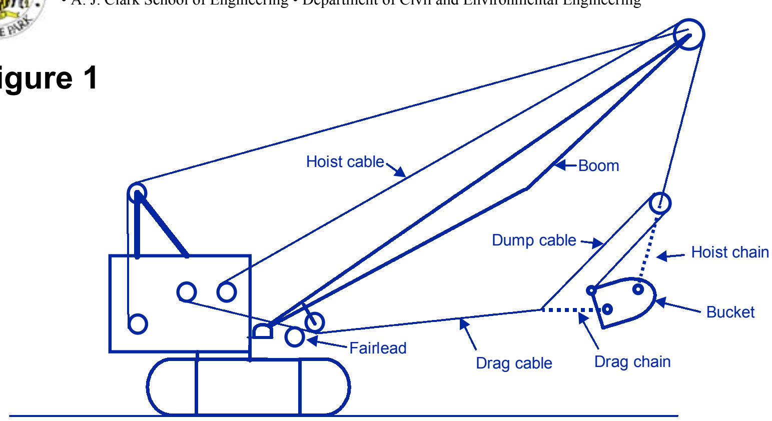
Figure 1



Types of Draglines (Ch. 18)

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- Draglines may be divided into three types:
  1. Crawler-mounted
  2. Wheel-mounted, self-propelled
  3. Truck-mounted

Operation of a Dragline (Ch. 18)

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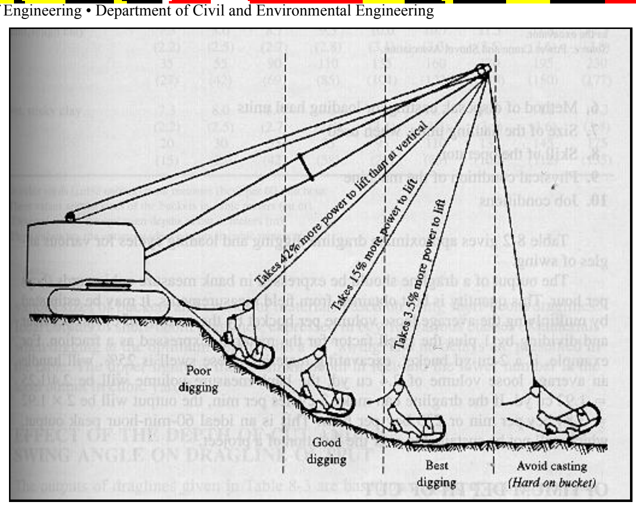
Figure 4
Dragline Digging Zones



Output of Draglines (Ch. 18)

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- The output of a dragline will vary with the following factors:
  1. Class of material
  2. Depth of cut
  3. Angle of swing
  4. Size and type of bucket
  5. Length of boom
  6. Method of disposal, casting, or loading haul units
  7. Size of the hauling units, when used
  8. Skill of the operator
  9. Physical condition of the machine
  10. Job conditions

Example 1 (Ch. 18)

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- A 2-cu-yd short-boom dragline is to be used to excavate hard, tough clay. The depth of cut will be 15.4 ft, and the swing angle will be 120^0. Compute the probable production of the dragline.

Example 1 (cont'd) (Ch. 18)

Optimum Depth of Cut = 11.8 ft ⇒ 195 cu-yd Ideal production (see Table 2)

$$\text{Percent of Optimum Depth} = \frac{15.4}{11.8} \times 100 = 130\%$$

The appropriate depth-swing factor = 0.89 (by interpolation in Table 3)

The Probable Production = 195 (0.89) = 173.6 bcy per 60-min hour

The production should be corrected for normal delays (i,e., 50-min hour)

$$\text{Production (corrected)} = 173.6\left(\frac{50}{60}\right) = 145\,\frac{\text{bcy}}{\text{hr}}$$

Effect of the Depth of Cut and Swing Angle on Dragline Output (Ch. 18)

Table 3. **Factors for Depth of Cut and Angle of Swing Effect on Dragline Production (Table 8-4 of Textbook)**

Percent of optimum depth	Angle of swing (degrees) 30	45	60	75	90	120	150	180
20	1.06	0.99	0.94	0.90	0.87	0.81	0.75	0.70
40	1.17	1.08	1.02	0.97	0.93	0.85	0.78	0.72
60	1.24	1.13	1.06	1.01	0.97	0.88	0.80	0.74
80	1.29	1.17	1.09	1.04	0.99	0.90	0.82	0.76
100	1.32	1.19	1.11	1.05	1.00	0.91	0.83	0.77
120	1.29	1.17	1.09	1.03	0.98	0.90	0.82	0.76
140	1.25	1.14	1.06	1.00	0.96	0.88	0.81	0.75
160	1.20	1.10	1.02	0.97	0.93	0.85	0.79	0.73
180	1.15	1.05	0.98	0.94	0.90	0.82	0.76	0.71
200	1.10	1.00	0.94	0.90	0.87	0.79	0.73	0.69

Clamshells (Ch. 18)

Clamshells are used to handle loose material such as sand, gravel, and crushed stone. They are specially suited for lifting material vertically.

Piles and Pile-Driving Equipment (Ch. 19)

- Load-bearing piles, are used primarily to transmit structural loads, through soil formations with poor supporting properties, into or onto soil strata that are capable of supporting the loads.
- If the load is transmitted to the soil through skin friction between the surface of the pile and the soil, the pile is called a *friction pile*.

Piles and Pile-Driving Equipment (Ch. 19)

- If the load is transmitted to the soil through the lower tip, the pile is called an *end-bearing pile*.
- Many piles depend on a combination of friction and end bearing for their supporting strengths.

Pile Driving Equations (Ch.19)

✓ For a drop hammer:

$$R = \frac{2WH}{S + 1.0}$$

where
R = safe load on a pile, lb
W = weight of a falling mass, lb
H = height of free fall for mass *W*, ft
E = total energy of ram at the bottom of its downward stroke, ft-lb
S = average penetration per blow for last 5 or 10 blows, in.

✓ For a single-acting steam hammer:

$$R = \frac{2WH}{S + 0.1}$$

✓ For a double- and differential-acting steam hammer:

$$R = \frac{2E}{S + 0.1}$$

Example 1 (Ch. 19)

The falling ram of a drop hammer used to drive a timber pile is 6,500 lb. The free-fall height during driving was 19 in, and the average penetration for the last eight blows was 0.5 in per blow. What is the safe rated load?

From Eq. 1:

$$\text{Safe Rated Load, } R = \frac{2WH}{S+1.0} = \frac{2(6{,}500)\left(\frac{20}{12}\right)}{0.5+1.0} = \underline{14{,}444 \text{ lb}}$$

Equipment for Pumping Water (Ch. 20)

- Pumps are used extensively on construction projects for:
  1. Removing water from pits, tunnels. and other excavations.
  2. Dewatering cofferdams.
  3. Furnishing water for jetting and sluicing.
  4. Furnishing water for many types of utility services.
  5. Lowering the water table for excavations.
  6. Foundation grouting.

Classification of Pumps (Ch.20)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

- The pumps commonly used on construction projects may be classified as:
  1. **Displacement**
     a. Reciprocating
     b. Diaphragm
  2. **Centrifugal**
     a. Conventional
     b. Self-priming
     c. Air-operated

ENCE 420 – REVIEW FOR THE FINAL EXAM

Slide No. 88

Simplex Double-Acting Pump (Ch. 20)

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- The volume pumped in gallons per minute (gpm) by a simplex double-acting pump will be

$$Q(\text{gpm}) = \frac{c(\text{area of cylinder} \times l \times n)}{231}$$

$$Q(\text{gpm}) = c\left[\left(\frac{\pi d^2}{4}\right) \times l \times n\right] \div 231 = c\frac{\pi d^2 l\, n}{924} \qquad (1)$$

where
Q= capacity of a pump, gpm
c = one-slip allowance; varies from 0.95 to 0.97
d = diameter of cylinder, in.
l = length of stroke, in.
n = number of strokes per min

ENCE 420 – REVIEW FOR THE FINAL EXAM

Slide No. 89

Multiplex Double-Acting Pump (Ch. 20)

- The volume pumped in gallons per minute (gpm) by a multiplex double-acting pump is given by

$$Q(\text{gpm}) = N\frac{c(\text{area of cylinder} \times l \times n)}{231}$$

$$Q(\text{gpm}) = Nc\left[\left(\frac{\pi d^2}{4}\right) \times l \times n\right] \div 231$$

$$\boxed{Q(\text{gpm}) = Nc\frac{\pi d^2 l\, n}{924}} \qquad (2)$$

where N = number of cylinders in a pump

Horsepower Required by a Pump (Ch. 20)

- The horsepower (hp) required by a pump is given by the following equation:

$$\boxed{P = \frac{W}{33{,}000} = \frac{wQh}{33{,}000e}} \qquad (4)$$

where

P = power, hp

W = energy, ft-lb per min

w = weight of one gallon of water, lb

h = total pumping head (ft), including friction loss in pipe

e = efficiency of the pump, expressed decimally

33,000 = ft-lb per minute for 1 hp

Example 1 (Ch. 20)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

How many gallons of freshwater will be pumped per minute by a duplex double-acting pump, size 6 X 12 in, driven by crankshaft making 90 rpm? If the total head is 160 ft and the efficiency of the pump is 60%, what is the minimum horsepower required to operate the pump? The weight of water is 8.34 lb per gallon.

Assume a water slippage of 4%, therefore, $c = 1.0 - 0.04 = 0.96$

$$Q(\text{gpm}) = Nc\frac{\pi d^2 l\, n}{924} = (2)(0.96)\frac{\pi\,(6)^2(12)(2\times 90)}{924} = \underline{508\text{ gpm}}$$

$$\therefore P = \frac{wQh}{33{,}000e} = \frac{8.34(508)(160)}{33{,}000(0.6)} = \underline{34.2\text{ HP}}$$

Centrifugal Pumps (Ch. 20)

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- **The Bernoulli Equation:**

$$z + \frac{v^2}{2g} + \frac{p}{\gamma} = \text{constant} \qquad (5)$$

where

z = elevation above datum

v = velocity of the fluid

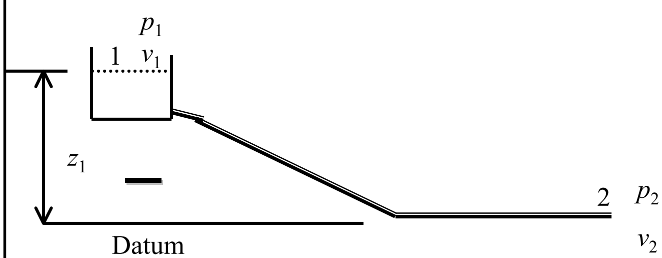
p = pressure of the fluid

Centrifugal Pumps (Ch. 20)

• A. J. Clark School of Engineering • Department of Civil and Environmental Engineering

Application of Bernoulli Equation:

$$z_1 + \frac{v_1^2}{2g} + \frac{p_1}{\gamma} = z_2 + \frac{v_2^2}{2g} + \frac{p_2}{\gamma} + \text{Losses}_{1\text{-}2} \qquad (6)$$



Example 3 (Ch. 20)

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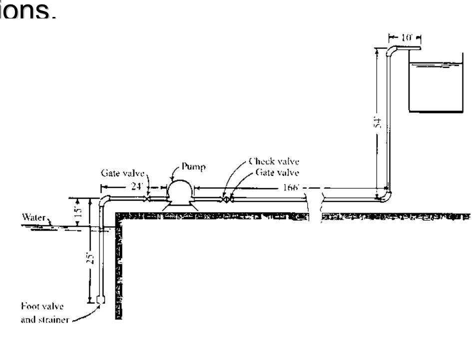
Select a self-priming centrifugal pump, with a capacity of 600 gpm, for the project illustrated as shown in the figure. All the pipe, fittings, and valves will be 6 in. with threaded connections.



Example 3 (continued) (Ch.20)

From Table 3 (Table 20-5 Text):

Length of pipe: 25 + 24 + 166 + 54 + 10		= 279 ft
One foot valve and strainer		= 76 ft
3 90^0-elbows:	3 X 16	= 48 ft
2 gate valves:	2 X 3.5	= 7 ft
1 check valve:	1 X 63	= 63 ft
Total equivalent length		= 473 ft

From Table 2 (Table 20-4,Text) the friction loss per 100 ft of 6-in pipe will be 3.10 ft

$$\text{Total Head} = \text{Lift Head} + \text{Head lost in Friction} = (15 + 54) + \left(\frac{473}{100} \times 3.1\right) = 83.7 \text{ ft}$$

<u>A model 90-M pump will deliver the required quantity of water (see Table 5 (Table 20-2c, Text)</u>

Example 3 (continued) (Ch.20)

Table 3. Length of Steel Pipe (ft) Equivalent to Fittings and Valves (Table 20-5, Text)

Length of steel pipe, in feet, equivalent to fittings and valves

	Nominal size (in.)											
Item	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**4**	**5**	**6**	**8**	**10**	**12**
90° elbow	2.8	3.7	4.3	5.5	6.4	8.2	11.0	13.5	16.0	21.0	26.0	32.0
45° elbow	1.3	1.7	2.0	2.6	3.0	3.8	5.0	6.2	7.5	10.0	13.0	15.0
Tee, side outlet	5.6	7.5	9.1	12.0	13.5	17.0	22.0	27.5	33.0	43.5	55.0	66.0
Close return bend	6.3	8.4	10.2	13.0	15.0	18.5	24.0	31.0	37.0	49.0	62.0	73.0
Gate valve	0.6	0.8	0.9	1.2	1.4	1.7	2.5	3.0	3.5	4.5	5.7	6.8
Globe valve	27.0	37.0	43.0	55.0	66.0	82.0	115.0	135.0	165.0	215.0	280.0	335.0
Check valve	10.5	13.2	15.8	21.1	26.4	31.7	42.3	52.8	63.0	81.0	105.0	125.0
Foot valve	24.0	33.0	38.0	46.0	55.0	64.0	75.0	76.0	76.0	76.0	76.0	76.0

Courtesy The Gorman-Rupp Company.

Example 3 (continued) (Ch.20)

Table 2 (Table 20-5 Text)
Water Friction Loss in Feet Per 100 ft for Clean Iron Steel Pipe.

Flow in U.S. (gpm)	Nominal diameter of pipe (in.) ½	¾	1	1¼	1½	2	2½	3	4	5	6	8	10	12
5	26.5	6.8	2.11	0.55										
10	95.8	24.7	7.61	1.98	0.93	0.31	0.11							
15		52.0	16.3	4.22	1.95	0.70	0.23							
20		88.0	27.3	7.21	3.38	1.18	0.40							
25			41.6	10.8	5.07	1.75	0.60	0.25						
30			57.8	15.3	7.15	2.45	0.84	0.35						
40				26.0	12.2	4.29	1.4	0.59						
50				39.0	18.5	6.43	2.2	0.9	0.22					
75					39.0	13.6	4.6	2.0	0.48	0.16				
100					66.3	23.3	7.8	3.2	0.79	0.27	0.09			
125						35.1	11.8	4.9	1.2	0.42	0.18			
150						49.4	16.6	6.8	1.7	0.57	0.21			
175						66.3	22.0	9.1	2.2	0.77	0.31			
200							28.0	11.6	2.9	0.96	0.40			
225							35.3	14.5	3.5	1.2	0.48			
250							43.0	17.7	4.4	1.5	0.60	0.15		
275								21.2	5.2	1.8	0.75	0.18		
300								24.7	6.1	2.0	0.84	0.21		
350								33.8	8.0	2.7	0.91	0.27		
400									10.4	3.5	1.4	0.35		
500									15.6	5.3	2.2	0.53	0.18	0.08
600									22.4	6.2	3.1	0.74	0.25	0.10
700									30.4	9.9	4.1	1.0	0.34	0.14
800											5.2	1.3	0.44	0.18
900											6.6	1.6	0.54	0.22
1,000											7.8	2.0	0.65	0.27
1,100											9.3	2.3	0.78	0.32
1,200											10.8	2.7	0.95	0.37
1,300											12.7	3.1	1.1	0.42
1,400											14.7	3.6	1.2	0.48
1,500											16.8	4.1	1.4	0.55
2,000												7.0	2.4	0.93
3,000													5.1	2.1
4,000														3.5
5,000														5.5

† For old or rough pipes, add 50% to friction values.
Courtesy Contractors Pump Bureau.

Example 3 (continued) (Ch.20)

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Table 5 (20-2c)

Minimum capacities for M-rated self-priming centrifugal pumps manufactured in accordance with standards of the Contractors Pump Bureau

Model 90-M (6-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
		Capacity [gpm (l/min)†]							
25	(7.6)	1,500	(5,678)						
30	(9.1)	1,480	(5,602)	1,280	(4,845)	1,050	(3,974)	790	(2,990)
40	(12.2)	1,430	(5,413)	1,230	(4,656)	1,020	(3,861)	780	(2,952)
50	(15.2)	1,350	(5,110)	1,160	(4,391)	970	(3,672)	735	(2,782)
60	(18.3)	1,225	(4,637)	1,050	(3,974)	900	(3,407)	690	(2,612)
70	(21.3)	1,050	(3,974)	900	(3,407)	775	(2,933)	610	(2,309)
80	(24.4)	800	(3,028)	680	(2,574)	600	(2,271)	490	(1,855)
90	(27.4)	450	(1,703)	400	(1,514)	365	(1,382)	300	(1,136)
100	(30.5)	100	(379)	100	(379)	100	(379)	100	(379)

Model 125-M (8-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
		Capacity [gpm (l/min)†]							
25	(7.6)	2,100	(7,949)	1,850	(7,002)	1,570	(5,943)		
30	(9.1)	2,060	(7,797)	1,820	(6,889)	1,560	(5,905)	1,200	(4,542)
40	(12.2)	1,960	(7,419)	1,740	(6,586)	1,520	(5,753)	1,170	(4,429)
50	(15.2)	1,800	(6,813)	1,620	(6,132)	1,450	(5,488)	1,140	(4,315)
60	(18.3)	1,640	(6,207)	1,500	(5,678)	1,360	(5,148)	1,090	(4,126)
70	(21.3)	1,460	(5,526)	1,340	(5,072)	1,250	(4,731)	1,015	(3,841)
80	(24.4)	1,250	(4,731)	1,170	(4,429)	1,110	(4,201)	950	(3,596)
90	(27.4)	1,020	(3,861)	980	(3,709)	940	(3,558)	840	(3,179)
100	(30.5)	800	(3,028)	760	(2,877)	710	(2,687)	680	(2,574)
110	(33.5)	570	(2,158)	540	(2,044)	500	(1,893)	470	(1,779)
120	(36.6)	275	(1,041)	245	(927)	240	(908)	240	(908)

† Liters per minute.
Courtesy Contractors Pump Bureau.

Wellpoint Systems (Ch. 20)

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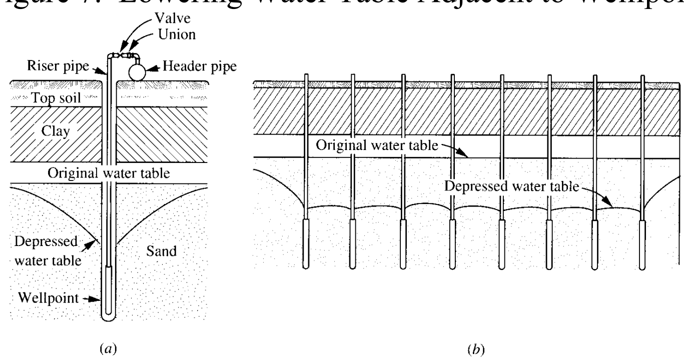
Figure 7. Lowering Water Table Adjacent to Welllpoints



Lowering the water table adjacent to wellpoints.

Capacity of a Wellpoint System (Ch.20)

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- The capacity of a wellpoint system depends on:
  - ✓number of point installed
  - ✓the permeability of soil
  - ✓the amount of water present
- The flow per wellpoint may vary from 3 or 4 gpm to as much as 30 or more gpm on some installations


Good Luck with Your Finals
☺