APPENDIX F

MATHEMATICS

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Section 1

IMPORTANT CONVERSION FACTORS

A mathematical constant is a number that represents the relationship between one value and another. Perhaps the best known of all constants is *pi*, often shown as the Greek letter π. Pi is the relationship between the diameter of a circle and the distance around the outside of the circle or its circumference. The circumference of a circle is approximately 3.14 times its diameter, so pi is equal to 3.14. It does not matter how the circle is measured, the relationship between the circumference and the diameter will always be 3.14:1. Thus, a circle with a diameter of 1 inch will have a circumference of about 3.14 inches, while a circle with a diameter of 1 kilometer will have a circumference of 3.14 kilometers.

Another common use of constants is to convert from one type of measurement system to another. Because there are 12 inches in 1 foot, it is easy to determine that 108 inches total 9 feet by dividing by the constant 12. Constants can also be used to convert from one system of measurement to another, such as converting between U.S. standard measurements and the metric system. For example, there are 39.37 inches in a meter. To convert 5.7 meters to inches, one need only multiply 5.7 by 39.37, while converting 144 inches to meters would require dividing 144 by 39.37. This value is the constant relationship between inches and meters.

The table below provides a number of useful constants that can be used to convert from one type of measurement to another, many of which have practical application for lease pumpers.

Multiply	**By**	**To Obtain**
Acres	43,560	Square feet
Acres	4047	Square meters
Acre feet	7758	Barrels
Acre feet	1233.5	Cubic meters
Atmospheres	33.94	Feet of water
Atmospheres	29.92	Inches of mercury
Atmospheres	760	Inches of mercury
Atmospheres	14.7	Pounds per square inch
Barrels	5.6146	Cubic feet
Barrels	0.15898	Cubic meters
Barrels	42	Gallons
Barrels	158.9	Liters
Barrels per hour	0.0936	Cubic feet per minute
Barrels per hour	0.700	Gallons per minute
Barrels per hour	2.695	Cubic inches per second

Barrels per day	0.02917	Gallons per minute
Centimeters	0.03281	Feet
Centimeters	0.3937	Inches
Centimeters of mercury	0.1934	Pounds per square inch
Cubic centimeters	0.06102	Cubic inches
Cubic feet	0.1781	Barrels
Cubic feet	7.4805	Gallons (U.S.)
Cubic feet	28.32	Liters
Cubic feet	1728	Cubic inches
Cubic feet	0.02832	Cubic meters
Cubic feet	0.03704	Cubic yards
Cubic feet per minute	10.686	Barrels per hour
Cubic inches per second	28.8	Cubic inches per second
Cubic feet per minute	7.481	Gallons per minute
Cubic inches	0.00433	Gallons
Cubic inches	0.0164	Liters
Cubic meters	6.2897	Barrels
Cubic meters	35.314	Cubic feet
Cubic meters	1.308	Cubic yards
Cubic yards	4.8089	Barrels
Cubic yards	27	Cubic feet
Cubic yards	0.7646	Cubic meters
Feet	30.48	Centimeters
Feet	0.3048	Meters
Feet of water @ 60° F	0.4331	Pounds per square inch
Feet per second	0.68182	Miles per hour
Foot pounds per second	0.001818	Horsepower
Gallons (U.S.)	0.02381	Barrels
Gallons (U.S.)	0.1337	Cubic feet
Gallons (U.S.)	231	Cubic inches
Gallons (U.S.)	3.785	Liters
Gallons (U.S.)	0.8327	Gallons (Imperial)
Gallons per minute	1.429	Barrels per hour
Gallons per minute	0.1337	Cubic feet per minute
Gallons per minute	34.286	Barrels per day
Grain (Avoirdupois)	0.0648	Grams
Grains per gallon	17.118	Parts per million
Grains per gallon	142.86	Pounds per million gallons
Grains per gallon	0.01714	Grams per liter
Grams	15.432	Grains
Grams	0.03527	Ounces
Hectare	2.471	Acres
Horsepower	550	Foot pounds per second
Horsepower	1.014	Horsepower (Metric)

Horsepower	0.7457	Kilowatts
Inches	2.54	Centimeters
Inches	0.08333	Feet
Inches of mercury	1.134	Feet of water
Inches of mercury	0.4912	Pounds per square inch
Inches of water @ 60°F	0.0361	Pounds per square inch
Kilograms	1000	Grams
Kilometers	0.6214	Miles
Kilowatt	1.341	Horsepower
Liters	1000	Cubic centimeters
Liters	61.02	Cubic Inches
Liters	0.2642	Gallons
Liters	1.0567	Quarts
Meters	3.281	Feet
Meters	1.094	Yards
Miles	5280	Feet
Miles	1.609	Kilometers
Miles per hour	1.4667	Feet per second
Ounces (Avoirdupois)	437.5	Grains
Ounces (Avoirdupois)	28.3495	Grams
Parts per million	0.05835	Grains per gallon
Pounds	7000	Grains
Pounds per gallon	453.6	Gram
Pounds per gallon	0.052	Pounds/sq. in/ft of depth
Pounds per square inch	2.309	Feet of water at 60°F
Pounds per square inch	2.0353	Inches of mercury
Pounds per square inch	0.0703	Kilograms per square cm
Pounds per square inch	6.8947	Kilopascals
Quarts	0.946	Liters
Square centimeters	0.1550	Square inches
Square feet	0.0929	Square meters
Square kilometer	0.3861	Square miles
Square meters	10.76	Square feet
Square meters	1.196	Square yards
Square miles	640	Acres
Square miles	2.590	Square kilometers
Tons (Long)	2240	Pounds
Tons (Metric)	2205	Pounds
Tons (Short or Net)	2000	Pounds

Temperature conversions

Temperature Centigrade = 5/9 (Temp. °F - 32)

Temperature Fahrenheit = 9/5 (Temp. °C) + 32

Volume Capacity of Pipe

Gallons per 1000 feet = 40.8 x $(\text{I.D. in inches})^2$

Barrels per 1000 feet = 0.9714 x $(\text{I.D. in inches})^2$

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Section 2

LEASE PUMPER SAMPLE MATH PROBLEMS

A lease pumper is frequently required to use mathematics in performing various duties associated with the job. Some of these calculations include:

- Gauge tanks.
- Daily production.
- Oil sold.
- Liquids hauled by transport.
- Gas produced and sold.
- Water produced and injected.
- Rod strings pulled and run.
- Tubing strings pulled and run.
- Quantity of chemicals needed and injected.
- Pipe transfers.
- Production for well tests.
- Percentages, ratios, and proportions in production and waste.
- Convert fractions, decimals, and percentages.
- Fill in time forms and other records.

Rules of Thumb

From the conversion constants given in Section 1, we find that multiplying the pounds per gallon by the constant 0.052 gives the pressure in pounds per square inch for each foot of depth. These values can be use to compute the bottom hole pressure based on various columns of liquid.

1. One foot of oil weighs approximately 1/3 pound. If the oil well has a standing column of oil 3,000 feet high, bottom hole pressure holding the standing valve closed is 1,000 pounds.

   Example Problem # 1: 35 API gravity oil
   0.052 x 7.08 pounds per gallon x 3,000 feet = Bottom Hole Pressure of 1,104 pounds.
   This is 0.368 pounds per foot, which is close to .333 or 1/3 pounds per foot.

2. One foot of saturated salt water weighs approximately ½ pound. If the oil well has a standing column of salt water 3,000 feet high, the bottom hole pressure is 1,500 pounds.

Example Problem # 2: 10 API gravity fresh water
0.052 x 8.33 pounds per gallon x 3,000 feet = Bottom Hole Pressure of 1,300 pounds.
Fresh water has a weight of 0.433 pounds per foot, a little under ½ pound per foot.

Example Problem # 3: Nearly saturated salt water weighing 9.4 pounds per gallon
0.052 x 9.5 pounds per gallon x 3,000 feet = Bottom Hole Pressure of 1,482 pounds.
This salt water has a bottom hole pressure of 0.494 or almost ½ pound per foot.

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Section 3

BELTS AND SHEAVES

ABBREVIATIONS

D	=	Diameter of Pump Sheave
d	=	Diameter of Prime Mover Sheave
L	=	Belt Length
SPM	=	Strokes Per Minute
RPM	=	Revolutions Per Minute (of Prime Mover for these calculations)
R	=	Pumping Unit Gear Box Ratio
C	=	Shaft Center Distance (Prime Mover to Shaft Center of Driven Equipment)

CALCULATIONS.

Use the appropriate formula to determine the unknown value. For example, use the formula

$$SPM = \frac{RPM \times d}{R \times D}$$

to determine the number of strokes per minute if the diameters, center distance, and gear box ratio are known. The same formula can be used to determine how SPM will be affected if the pump sheave diameter (D) is changed.

1. Calculating Belt Length, Full Formula

$$L = 2C + 1.57\,(D + d) + \frac{(D - d)2}{4\,C}$$

2. Calculating Belt Length, Short Formula (Note: This method is generally satisfactory for oilfield work.)

$$L = 2C + 1.57\,(D + d)$$

3. To determine the required diameter of the pump sheave to the effect of changing the pump sheave diameter

$$D = \frac{RPM \times d}{SPM \times R}$$

4. To determine the required diameter of the pump sheave to the effect of changing the pump sheave diameter

$$d = \frac{SPM \times R \times D}{RPM}$$

5. To determine the stokes per minute or the effect on strokes per minute if the RPM, diameters, or gear ratio is changed

$$SPM = \frac{RPM \times d}{R \times D}$$

6. To determine the revolutions per minute or the effect on revolutions per minute if the SPM, diameters, or gear ratio is changed

$$RPM = \frac{SPM \times R \times D}{d}$$

7. To determine the gear ratio or the effect on gear ratio if the RPM, diameters, or SPM is changed

$$R = \frac{RPM \times d}{SPM \times D}$$

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Section 3

Multiplication Table

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	1	2	3	4	5	6	7	8	9	10	11	12
2	2	4	6	8	10	12	14	16	18	20	22	24
3	3	6	9	12	15	18	21	24	27	30	33	36
4	4	8	12	16	20	24	28	32	36	40	44	48
5	5	10	15	20	25	30	35	40	45	50	55	60
6	6	12	18	24	30	36	42	48	54	60	66	72
7	7	14	21	28	35	42	49	56	63	70	77	84
8	8	16	24	32	40	48	56	64	72	80	88	96
9	9	18	27	36	45	54	63	72	81	90	99	108
10	10	20	30	40	50	60	70	80	90	100	110	120
11	11	22	33	44	55	66	77	88	99	110	121	132
12	12	24	36	48	60	72	84	96	108	120	132	144