AGRICULTURAL ENGINEERING FORMULA

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Iloilo City, Philippines**

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About the Author

Alexis T. Belonio is a Professional Agricultural Engineer. Presently, he is an Associate Professor and Chairman of the Department of Agricultural Engineering and Environmental Management, College of Agriculture, Central Philippine University, Iloilo City. He finished his Bachelor of Science in Agricultural Engineering and Master of Science degrees from Central Luzon State University, Muñoz, Nueva Ecija. He has been deeply involved in teaching, research, project development, and entrepreneurial activity on various agricultural engineering projects since 1983.

He was awarded by the Philippine Society of Agricultural Engineers (PSAE) as Most Outstanding Agricultural Engineer in the Field of Farm Power and Machinery and by the Professional Regulation Commission (PRC) as Outstanding Professional in the Field of Agricultural Engineering in 1993. In 1997, he was awarded by the TOYM Foundation and the Jerry Roxas Foundation as the Outstanding Young Filipinos (TOYF) in the Field of Agricultural Engineering. He is presently a PSAE Fellow Member.

As a dedicated professional, he serves as technical consultant to various agricultural machinery manufacturers in Region VI. He also serves as a Reviewer of the TGIM Foundation Review Center on the field of Agricultural Machinery and Allied Subjects, and Agricultural Processing and Allied Subjects since 1998. He has written and published several research and technical papers.

Other Books Available:

Dictionary of Agricultural Engineering
Agricultural Engineering Design Data Hanbook
Problems and Solutions in Agricultural Engineering
Agricultural Engineering Reviewer: Volume I
Agricultural Engineering Reviewer: Volume II
Rice Husk Gas Stove Handbook
Small Farm Irrigation Windpump Handbook
Axial Flow Biomass Shredder Handbook

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Revised Edition

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The author is very much thankful to the Lord God Almighty who inspired him to prepare this material for the benefit of those who are called to serve in the agricultural engineering profession.

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To his friends in the Philippine Society of Agricultural Engineers in the Regional and National Chapters who also encouraged me to collect all the information and materials needed in the preparation of this Handbook.

To Salve and their children: Mike, Happy, Humble, Jireh, Justly, Tenderly, and Wisdom, for their prayer and inspiration.

PREFACE

This book is a compilation of the various formula that are commonly used in agricultural engineering curriculum. Students who are taking the course as well as those who are preparing for the Professional Agricultural Engineer Board Examination may find this book useful. Practicing Agricultural Engineers and those other Engineers working in the field of agriculture will find this book as a handy reference material for design, estimate, testing, and evaluation activities.

The presentation of the formula in this book covers the different subject matter as follows: agricultural power and energy, agricultural machinery and equipment, agricultural processing and food engineering, farm electrification and instrumentation, agricultural buildings and infrastructures, agricultural waste utilization and environmental pollution, and soil and water engineering. The subject areas are arranged in alphabetical manner for ease of finding the formula needed. The parameters and units for each formula are specified in the book and can be converted to either English, Metric, or SI system using the conversion constants given at the end of the book.

This book is still in draft form. Additional subject matter and formula will be included in the future to make this material more comprehensive. Comments and suggestions are welcome for the future improvement of this book.

God bless and may this book become useful to you!

ALEXIS T. BELONIO

TABLE OF CONTENTS

AIR MOVING DEVICES

Specific Speed $N_s = [N \; Q^{0.5}] / [Ps^{0.75}]$	N_s – specific speed, dmls N - speed of air moving unit, rpm Q - airflow, cfm P_s – pressure requirement, in. H_2O
Impeller Diameter $D = \sqrt{\dfrac{(2.35)\,108\,P_s}{\psi \; N^2}}$	D - diameter of impeller, in. P_s – pressure requirement, in. H_2O ψ - pressure coefficient, 0.05 to 2.0 N - speed of impeller, rpm
Pitch Angle for Axial Fan $\alpha = \text{Sin}^{-1} \dfrac{350 \; Q}{\phi \; N \, D^3}$	α - pitch angle, deg Q - airflow, cfm N - speed of impeller, rpm D - diameter of impeller, in. ϕ - flow coefficient, 0.01 to 0.80
Impeller Width (centrifugal and mixed flow blower) $W = \dfrac{175 \; Q}{\phi \; N \, D^2}$	W – width of impeller, in. Q - airflow, cfm N - speed of impeller, rpm D - diameter of impeller, in. ϕ - flow coefficient, 0.01 to 0.80
Impeller Width (traverse flow) $W = \dfrac{550 \; Q}{\phi \; N \, D^2}$ for $0.5 \leq W/D \leq 10$	W – width of impeller, in. Q - airflow, cfm N - speed of impeller, rpm D - diameter of impeller, in. ϕ - flow coefficient, 0.01 to 0.80

AIR MOVING DEVICES

Casing Dimension (Forward Curved Centrifugal) H_c = 1.7 D B_c = 1.5 D W_c = 1.25 W + 0.1 D	H_c – height of casing, in. B_c - breath of casing, in W_c – width of casing, in. D – diameter of impeller, in W - width of impeller, in
Casing Dimension (Narrow Backward Curved Centrifugal) H_c = 1.4 D B_c = 1.35 D W_c = W + 0.1 D	H_c – height of casing, in. B_c - breath of casing, in W_c – width of casing, in. D – diameter of impeller, in W - width of impeller, in
Casing Dimension (Wide Backward Curved Centrifugal) H_c = 2.0 D B_c = 1.6 D W_c = W + 0.16 D	H_c – height of casing, in. B_c - breath of casing, in W_c – width of casing, in. D – diameter of impeller, in W - width of impeller, in
Casing Dimension (Mixed Flow) H_c = 2.0 D B_c = 2.0 D W_c = 0.46 D	H_c – height of casing, in. B_c - breath of casing, in W_c – width of casing, in. D – diameter of impeller, in
Casing Dimension (Traverse Flow) H_c = 2.2 D B_c = 2.2 D W_c = W + [D/4]	H_c – height of casing, in. B_c - breath of casing, in W_c – width of casing, in. D – diameter of impeller, in
Casing Dimension (Vane Axial Flow) W_c = 1.2 D	W_c – width of casing, in. D – diameter of impeller, in
Casing Dimension (Tube Axial Flow) W_c = 1.0 D	W_c – width of casing, in. D – diameter of impeller, in
Casing Dimension (Partially Cased Fan) W_c = 0.5 D	W_c – width of casing, in. D – diameter of impeller, in

AIR MOVING DEVICES

Air Horsepower $$AHP = \frac{Q\ V\ H}{33{,}000}$$	AHP - air horsepower, hp Q - airflow rate, cfm V - specific weight of air, lb/ft^3 H - total head, ft
Brake Horsepower $$BHP = \frac{Q\ P_a}{6360\ \xi_f}$$	BHP - brake horsepower, hp Q - airflow rate, cfm P_a - static pressure, in. water ξ_f - fan efficiency, decimal
Mechanical Efficiency $\xi_f = AHP / BHP$	ξ_f - fan efficiency, decimal AHP - air horsepower, hp BHP - brake horsepower, hp
Propeller Fan Pitch $P = 2\ \pi\ r\ \tan\ \alpha$	P - pitch in. r - fan radius, in. α - angle of fan blade twist, deg
Fan Laws $$D_2 = D_1 \frac{H_1^{1/4}}{Q_1^{1/2}} \frac{Q_2^{1/2}}{H_2^{1/4}}$$	D – impeller diameter, in. H - fan head, in. H_20 Q - air flow rate, cfm
Fan Laws $$N_2 = N_1 \frac{Q_1^{1/2}}{H_1^{3/4}} \frac{H_2^{3/4}}{Q_2^{1/2}}$$	N – impeller speed, rpm H - fan head, in. H_20 Q - air flow rate, cfm
Fan Laws $$HP_2 = HP_1 \frac{D_2^{5}}{D_1^{5}} \frac{N_2^{3}}{N_1^{3}}$$	HP – fan horsepower, hp D - fan diameter, in. N - speed of impeller, rpm

AGRICULTURAL BUILDING CONSTRUCTION

Volume of Cement/Sand/Gravel (1:2:3) $V_c = 10.5\ V_{co}$ $V_s = 0.42\ V_{co}$ $V_g = 0.84\ V_{co}$	V_c - volume of cement, bags V_s - volume of sand, m^3 V_g - volume of gravel, m^3 V_{co} – volume of concrete, m^3
Volume of Cement/Sand/Gravel (1:2:4) $V_c = 7.84\ V_{co}$ $V_s = 0.44\ V_{co}$ $V_g = 0.88\ V_{co}$	V_c - volume of cement, bags V_s - volume of sand, m^3 V_g - volume of gravel, m^3 V_{co} – volume of concrete, m^3
Volume of Cement/Sand/Gravel (1:3:6) $V_c = 5.48\ V_{co}$ $V_s = 0.44\ V_{co}$ $V_g = 0.88\ V_{co}$	V_c - volume of cement, bags V_s - volume of sand, m^3 V_g - volume of gravel, m^3 V_{co} – volume of concrete, m^3
Volume of Cement/Sand/Gravel (1:3.5:7) $V_c = 5.00\ V_{co}$ $V_s = 0.45\ V_{co}$ $V_g = 0.90\ V_{co}$	V_c - volume of cement, bags V_s - volume of sand, m^3 V_g - volume of gravel, m^3 V_{co} – volume of concrete, m^3
Number of Hallow Blocks per m^2 Wall Area (8 in. x 16 in.) $N_{HB} = 13\ A_w$	N_{HB} - number of hallow blocks, pieces A_w – area of wall, m^2

AGRICULTURAL BUILDING CONSTRUCTION

Volume of Cement and Sand for Mortar and Plaster per m^3 of Mixture (1:2) $V_c = 14.5\ V_m$ $V_s = 1.0\ V_m$	V_c - volume of cement, bags V_m – volume of mixture, m^3 V_s - volume of sand, m^3
Volume of Cement and Sand for Mortar and Plaster per m^3 of Mixture (1:3) $V_c = 9.5\ V_m$ $V_s = 1.0\ V_m$	V_c - volume of cement, bags V_m – volume of mixture, m^3 V_s - volume of sand, m^3
Volume of Cement and Sand for Mortar and Plaster per m^3 Mixture (1:4) $V_c = 7.0\ V_m$ $V_s = 1.0\ V_m$	V_c - volume of cement, bags V_m – volume of mixture, m^3 V_s - volume of sand, m^3
Volume of Cement and Sand for Mortar and Plaster per m^3 Mixture (1:5) $V_c = 6.0\ V_m$ $V_s = 1.0\ V_m$	V_c - volume of cement, bags V_m – volume of mixture, m^3 V_s - volume of sand, m^3
Quantity of Cement and Sand for Plastering per Face (50kg Cement-Class B) $V_c = 0.238\ A_w$ $V_s = 0.025\ A_w$	V_c - volume of cement, bags V_s - volume of sand, m^3 A_w – area of wall, m^2

Quantity of Cement and Sand for Plastering per Face (50kg Cement-Class C) $V_c = 0.170\ A_w$ $V_s = 0.025\ A_w$	V_c - volume of cement, bags V_s - volume of sand, m^3 A_w – area of wall, m^2
Quantity of Cement and Sand for Plastering per Face (50kg Cement-Class D) $V_c = 0.150\ A_w$ $V_s = 0.025\ A_w$	V_c - volume of cement, bags V_s - volume of sand, m^3 A_w – area of wall, m^2
Quantity of Cement and Sand per 100 - 4 in. CHB Mortar (50kg Cement-Class B) $V_c = 3.328\ N_{HB}/100$ $V_s = 0.350\ N_{HB}/100$	V_c - volume of cement, bags V_s - volume of sand, m^3 N_{HB} – number of hallow blocks
Quantity of Cement and Sand per 100 - 6 in. CHB Mortar (50kg Cement-Class B) $V_c = 6.418\ N_{HB}/100$ $V_s = 0.675\ N_{HB}/100$	V_c - volume of cement, bags V_s - volume of sand, m^3 N_{HB} – number of hallow blocks
Quantity of Cement and Sand per 100 - 8 in. CHB Mortar (50kg Cement-Class B) $V_c = 9.504\ N_{HB}/100$ $V_s = 1.000\ N_{HB}/100$	V_c - volume of cement, bags V_s - volume of sand, m^3 N_{HB} – number of hallow blocks

AGRICULTURAL BUILDING CONSTRUCTION

Quantity of Cement and Sand per 100 - 8 in. CHB Mortar (50kg Cement-Class B) $V_c = 9.504\ N_{HB}/100$ $V_s = 1.000\ N_{HB}/100$	V_c - volume of cement, bags V_s - volume of sand, m^3 N_{HB} – number of hallow blocks
Weight of Tie Wire (No. 16 GI wire) $W_{tw} = 20\ W_{rb}$	W_{tw} – weight of tie wire, kg W_{rb} - weight of reinforcement bar, tons
Vertical Reinforcement Bar Requirement $L_b = 3.0\ A_w$ (0.4 m spacing) $L_b = 2.1\ A_w$ (0.6 m spacing) $L_b = 1.5\ A_w$ (0.8 m spacing)	L_b - length of vertical bar needed, m A_w - area of wall, m^2
Horizontal Reinforcement Bar Requirement $L_b = 2.7\ A_w$ (every 2 layers) $L_b = 1.9\ A_w$ (every 3 layers) $L_b = 1.7\ A_w$ (every 4 layers)	L_b - length of vertical bar needed, m A_w - area of wall, m^2

AGRICULTURAL BUILDING CONSTRUCTION

Board Feet of Lumber $$BF = \frac{T\ W\ L}{12}$$	BF - number of board foot, bd-ft T – thickness of wood, in. W - width of wood, in. L - length of wood, ft
Number of Board Foot that can be Obtained from Log $$BF = \frac{(D-4)^2\ L}{16}$$	BF - number of board foot, bd-ft D – small diameter of log, in. L - length of log, ft
Volume of Paint Needed for Wood $P_v = 3.78\ A_w / 20$ (1st coating) $P_v = 3.78\ A_w / 25$ (2nd coating)	P_v - volume of paints needed, liters A_w - area of wall, m^2
Nails Requirement $W_n = 20\ BF_w / 1000$	W_n - weight of nail needed, kg BF_w – number of board foot of wood, bd-ft
Wood Preservation $V_p = A_s / 9.3$	V_p - volume of preservatives, gal A_s - area of surface, m^2

AGRICULTURAL ECONOMICS

Elasticity $$E = \frac{\%\ \Delta Qd}{\%\ \Delta P}$$	E – elasticity Qd – quantity of demand P - Price
Point Elasticity $$\acute{E}pa = \left(\frac{\frac{\Delta Q}{Q + Q_2 / 2}}{\frac{\Delta P}{P_1 + P_2 / 2}} \right)$$	Q – quantity P - price ΔQ – change in quantity ΔP – change in price
Simple Interest $I = P\ i\ N$ $F = P + I$	I – total interest earned for N period i – interest rate N – number of interest period P – principal or the present value F – future value or the total amount to be repaid
Compound Interest $F = P(1 + i)^n$	F – future value or the total amount to be repaid P – principal or the present value i – interest rate n – number of interest period
Effective Interest Rte $EIR = \frac{F - P}{P}$ $EIR = (1 + i)^n - 1$	EIR – effective interest rate F – future value or the total amount to be repaid P – principal or the present value i – nominal interest rate n – interest period

Perpetuity 1. To find for P given A: $P = \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right]$ 2. T find for A given P: $A = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$ 3. To find for F given A: $A = P \left[\frac{(1+i)^n - 1}{i} \right]$ 4. To find for A given F: $A = F \left[\frac{i}{(1+i)^n - 1} \right]$	P – principal or present value A – annuity i – interest rate n – interest period F – Future value or the total amount to be repaid

AGRICULTURAL ECONOMICS

Perpetuity and Capitalized Cost $P = \frac{x}{i}\left[\frac{i}{(1+i)^n - 1}\right]$	P – capitalized value of A x – amount needed to provide for replacement or maintenance for K period
Arithmetic Gradient $A = G\left[\frac{1}{i} - \frac{n}{(1 = i)^n - 1}\right]$ $P = \frac{1}{i} - \frac{(1+i)^n}{i} - \frac{n}{(1+i)^n}$ $P = \frac{G}{i}\left[\frac{(1+i)^n - 1}{i} - \frac{n}{(1+i)^n}\right]$ $F = \frac{G}{i}\left[\frac{(1+i)^n - 1}{i} - n\right]$	A – uniform periodic amount equivalent to the arithmetic gradient series. G – arithmetic gradient change in periodic amounts t the end of each period. P – present with of G F – future worth of accommodated G
Depreciation Cost $d = \frac{C_o - C_n}{n}$ $D_m = m \times d$ $C_m = C_o - C_m$	d – annual depreciation C_o – original cost n – useful life; years C_n – salvage value or the scrap value D_m – accrued total depreciation up to "m" years m – age of property at any time less than "n" C_m – book value t the end of "m" years

AGRICULTURAL ECONOMICS

Sinking Fund Method $d = (C_o - C_n)\left[\dfrac{i}{\dfrac{(1+i)^n - 1}{i}}\right]$	d – annual depreciation C_o – original cost n – useful life; years C_n – salvage value or the scrap value i – interest rate
$D_m = (C_o - C_n)\left[\dfrac{\dfrac{(1+i)^m - 1}{i}}{\dfrac{(1+i)^n - 1}{i}}\right]$	d – annual depreciation C_o – original cost n – useful life; years C_n – salvage value or the scrap value D_m – accrued total depreciation up to "m" years
Declining Balance Method (Matheson Formula) $K = 1 - \sqrt[n]{C_n / C_o}$ $d_m = K\ C_m - 1$ $C_m = C_o (1 - K)^m$ $C_n = C_o (1 - K)^n$	d – annual depreciation C_o – original cost n – useful life; years C_n – salvage value or the scrap value m – age of property at any time less than "n" C_m – book value t the end of "m" years
Sum of the Years – Digits (SYD) Method $\sum \text{Years} = n / 2\ (n + 1)$ Annual Depreciation = $(C_o - C_n)\ [n / \sum \text{years}]$	C_o – original cost n – useful life; years C_n – salvage value or the scrap value

AGRICULTURAL ECONOMICS

Double Rate Declining Balance $C_m = C_o (1 – 2 / n)^m$	C_o – original cost n – useful life; years m – age of property at any time less than "n" C_m – book value t the end of "m" years
Service Output Method $d_1 = \frac{C_o - C_n}{T}$ $D_m = O_m d$ or $D_m = \frac{(C_o – C_n)}{T} Q_m$ $C_m = C_o - D_m$	T – total units of output produced during the life of property Q_m – total units of output during year "m" d_1 – depreciation per unit of output
Fixed Cost $C_t = C_p + C_v$ $Cv = vD$ $C_T = C_F + vD$	C_F – fixed cost v – variable cost / unit D – units produced C_T – total cost
Profit $P = TR – TC$	P – profit TR – total revenue TC – total cost

ALGEBRA

Laws of Exponents $a^m . a^n = a^{m+n}$ $a^m \div a^n = a^{m-n}$ $= a^o$ $(a^m)^n = a^{mn}$ $(ab)^m = a^m b^m$ $(a/b)^m = a^m / b^m$	If m > n m = n; a ≠ 0
Rational Exponents $a^{1/n} = {}^n\sqrt{a}$ $a^{m/n} = {}^n\sqrt{a^m}$ or $({}^n\sqrt{a})^m$	
Negative Exponents $a^{-m} = 1/ a^m$ $(a^{-m} / b) = (b /a)^m$ $1 = \frac{a^m}{a^{-m}}$	
Radicals $a^{1/n} = {}^n\sqrt{a}$ $a^{m/n} = {}^n\sqrt{a^m}$ or $({}^n\sqrt{a})^m$	A – is called the radicand m, n index (root)

ALGEBRA

<table>
<tr><td colspan="2">Law of Radicals
$\sqrt[n]{a^n} = a$
$\sqrt[m]{\ }\ \sqrt[n]{\ } = \sqrt[mn]{a}$
$\sqrt[m]{a} \,.\, \sqrt[m]{b} = \sqrt[m]{ab}$
$\dfrac{\sqrt[m]{a}}{\sqrt[m]{b}} = \sqrt[m]{a/b}$</td></tr>
<tr><td>Complex Number
$i = \sqrt{-1} = i^2 = -1$
$\sqrt[n]{a} = \sqrt[n]{a}\ (i)$</td><td>n is even</td></tr>
<tr><td colspan="2">Power of i
$(i = \sqrt{-1})^2$
$i^2 = -1$</td></tr>
<tr><td>Linear Equation in One Variable
$ax + b = 0$</td><td>$a \neq 0$</td></tr>
</table>

ALGEBRA

Special Products

Factor Types

1. Common factor

$a (x + y + z) = ax + ay + az$

2. Square of binomial

$(a \pm b)^2 = a^2 \pm 2ab + b^2$

3. Sum or difference of two numbers

$(a + b) (a – b) = a^2 – b^2$

4. Difference of two cubes

$(x – y) (x^2 + xy + y^2) = x^3 – y^3$

5. Sum of two cubes

$(x + y) (x^2 – xy + y^2) = x^3 + y^3$

6. Product of two similar numbers

$(x + b) (x + d) = x^2 + (b + d) x + bd$

$(ax + b) (cx + d) = acx^2 + (bc + ad)x + bd$

Quadratic Trinomial

$x^2 + (b +d)x + bd = (x + b) (x +d)$

$acx^2 + (bc + ad)x + bd = (ax+b)(ax+d$

ALGEBRA

Factoring of Polynomial Functions with Rational Roots

Form:

$a_n x^n + a_{n-1} x^{n-1} + a_{n-2} x^{n-2} + \ldots ax + a_0$

Possible roots:

$$(r) = \pm \frac{\text{factor of } a_0}{\text{factor of } a_n}$$

Quadratic Equation in One Variable

Form:

$Ax^2 + bx + c = 0$

Method of Solutions:

If $b = 0$, $x = \pm\sqrt{-c/a}$

If factorable, use the theorem:

If $ab = 0$, $a = 0$ or $b = 0$

Note:

Avoid dividing an equation by variable so as not to loose roots.

ALGEBRA

Quadratic Formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	
The Discriminant: $D = b^2 - 4ac$	$D = 0$ Two identical and real roots $D > 0$ Two distinct and real roots $D < 0$ Two complex conjugates roots
Sum and Products of Roots The sum $(X_s) = -b/a$ The product $(X_p) = c/a$	 $X_1 + X_2$ X_1X_2
Linear Equation in Two Variables Forms: $a_1 x + b_1 y + c_1 = 0$ $a_2 x + b_2 y + c_2 = 0$ Method of Solution: 1. by elimination 2. by determinants	

ALGEBRA

Linear Equation of Three Variables

$a_1 x + b_1 y + c_1 z + d_1 = 0$

$a_2 x + b_2 y + c_2 z + d_2 = 0$

$a_3 x + b_3 y + c_3 z + d_3 = 0$

Method of Solution:

1. by elimination
2. by determinants

Quadratic Equations in Two Variable One Linear and One Quadratic:

$a_1 x + b_1 y = c_1$

$a_1 x^{-2} + b_1 y^2 = c_2$

Two Formulas Used in Solving a Problem in Arithmetic Progression:

Last term (nth term)

$a_n = a_1 + (n - 1)\, d$

Sum of all terms

$S = n/2\ (a_1 + a_n)$

or

$S = n/2 \left[2a_1 + (n-1)\, d \right]$

ANIMAL SPACE REQUIREMENT (Minimum)

Lairage $SR = 2.23\ N_a$: large/loose type $SR = 3.30\ N_a$: large/tie-up type $SR = 0.70\ N_a$: swine less than 100kg $SR = 0.60\ N_a$: swine more than100kg $SR = 0.56\ N_a$: small animals	SR - space requirement, m^2 N_a - number of animals
Goat and Sheep (Solid Floor) $SR = 0.80\ N_a$: 35 kg animal $SR = 1.10\ N_a$: 50 kg animal $SR = 1.40\ N_a$: 70 kg animal $SR = 0.45\ N_a$: kid/lamb $SR = 3.00\ N_a$: buck/ram	SR - space requirement, m^2 N_a - number of animals
Goat and Sheep (Slatted Floor) $SR = 0.70\ N_a$: 35 kg animal $SR = 0.90\ N_a$: 50 kg animal $SR = 1.10\ N_a$: 70 kg animal $SR = 0.35\ N_a$: kid/lamb $SR = 2.60\ N_a$: buck/ram	SR - space requirement, m^2 N_a - number of animals

ANIMAL SPACE REQUIREMENT (Minimum)

Goat and Sheep (Open Yard) $SR = 2.00\ N_a$: 35 kg animal $SR = 2.50\ N_a$: 50 kg animal $SR = 3.00\ N_a$: 70 kg animal	SR - space requirement, m^2 N_a - number of animals
Goat and Sheep (Lactating) $SR = 1.30\ N_a$: 50-70 kg pregnant $SR = 1.60\ N_a$: over 70 kg pregnant $SR = 2.00\ N_a$: 50-70 kg lactating $SR = 2.30\ N_a$: over 70 kg lactating	SR - space requirement, m^2 N_a - number of animals
Cattle Feed Lot $SR = 4.00\ N_a$: shed space $SR = 5.00\ N_a$: loafing area	SR - space requirement, m^2 N_a - number of animals
Cattle Ranch (Holding Pen) $SR = 1.30\ N_a$: up to 270 kg $SR = 1.60\ N_a$: 270-540 kg $SR = 1.90\ N_a$: over 540 kg	SR - space requirement, m^2 N_a - number of animals

ANIMAL SPACE REQUIREMENT (Minimum)

Cattle Shed or Barn SR = 1.00 N_a : calves up to 3 mo SR = 2.00 N_a : calves 2-3 mo SR = 3.00 N_a : calves 7 mo-1 yr SR = 4.00 N_a : yearling 1-2 yr SR = 5.00 N_a : heifer/steer 2-3 yr SR = 6.00 N_a : milking and dry cow SR = 10.00 N_a : cows in maternity stall	SR - space requirement, m^2 N_a - number of animals
Carabao Feedlot SR = 4.00 N_a	SR - space requirement, m^2 N_a - number of animals
Laying Hens (Growing 7-22 Weeks) SR = 0.14 N_a : litter floor SR = 0.06 N_a : slotted floor SR = 0.07 N_a : slot-litter floor	SR - space requirement, m^2 N_a - number of birds
Laying Hens (Laying Beyond 22 Weeks) SR = 0.17 N_a : litter floor SR = 0.09 N_a : slotted floor SR = 0.14 N_a : slot-litter floor	SR - space requirement, m^2 N_a - number of birds

ANIMAL SPACE REQUIREMENT (Minimum)

Broiler SR = 0.0625 N_a : 4 week and below SR = 0.1250 N_a : above 4 weeks	SR - space requirement, m^2 N_a - number of birds
Swine (Group of Growing Swine) SR = 0.11 N_a : up to 10 kg SR = 0.20 N_a : 11 to 30 kg SR = 0.35 N_a : 21 to 40 kg SR = 0.50 N_a : 41 to 60 kg SR = 0.70 N_a : 61 to 80 kg SR = 0.85 N_a : 81 to 100 kg	SR - space requirement, m^2 N_a - number of animals
Swine SR = 1.00 N_a : Gilts up to mating SR = 2.50 N_a : Adult pigs in group SR = 1.20 N_a : Gestating sows SR = 7.50 N_a : Boar in pens SR = 7.40 N_a : Lactating sows and liters – individual pen SR = 5.60 N_a : Lactating sows and liters - multi-suckling groups SR = 1.80 N_a : Dry sows	SR - space requirement, m^2 N_a - number of animals

BEARINGS

Bearing Life $$L = \left[\frac{C}{F} \right]^n$$	L – bearing life, million revolution C – basic dynamic capacity, N F – actual radial load, N n – 3 for ball bearing, and 3.33 for roller bearing
Radial Load Acting on Shaft $$F = \frac{19.1 \times 10^6 \; P \; K}{D_p \; N}$$	F – radial force on the shaft, N P – power transmitted, kW K – drive tension factor, 1 for chain drive and gears; and 1.5 for v-belt drive D_p – pitch diameter of sheave, sprocket, etc, mm N – shaft speed, rpm
Bearing Load in Belt $$F_t = \frac{974\,000 \; H}{N \; r}$$	F_t – effective force transmitted by belt or chain, kgf-mm H – power transmitted, kW N – speed, rpm r – effective radius of pulley or sprocket, mm

BEARINGS

Actual Load Applied to Pulley shaft $L_a = f_b \; F_t$	L_a – actual load applied to pulley shaft, kgf f_b – belt factor, 2 to 2.5 for v-belt and 2.5 to 5 for flat belt; 1.25 to 1.5 for chain drive F_t – effective force transmitted by belt or chain, kgf-mm
Rating Life of Ball Bearing in Hours $L_h = 500 \left(\left(\dfrac{10^6}{3 \times 10^4 N} \right)^{0.33} \dfrac{C}{P} \right)^3$	L_h – rating life of ball bearing, hours N - speed, rpm C - basic load rating, kgf P – bearing load, kgf
Rating Life of Roller Bearing in Hours $L_h = 500 \left(\left(\dfrac{10^6}{3 \times 10^4 N} \right)^{0.3} \dfrac{C}{P} \right)^{3.33}$	L_h – rating life of roller bearing, hours N - speed, rpm C - basic load rating, kgf P – bearing load kgf

BIOGAS

Manure Production (Pig) $W_m = 2.20\ N_a\ N_d$: 3-8 mos $W_m = 2.55\ N_a\ N_d$: 18-36 kg $W_m = 5.22\ N_a\ N_d$: 36-55 kg $W_m = 6.67\ N_a\ N_d$: 55-73 kg $W_m = 8.00\ N_a\ N_d$: 73-91 kg	W_m – weight of manure produced, kg N_a - number of animals N_d - number of days
Manure Production (Cow) $W_m = 14.0\ N_a\ N_d$: Feedlot $W_m = 13.0\ N_a\ N_d$: Breeding $W_m = 7.5\ N_a\ N_d$: Work	W_m – weight of manure produced, kg N_a - number of animals N_d - number of days
Manure Production (Buffalo) $W_m = 14.00\ N_a\ N_d$: Breeding $W_m = 8.00\ N_a\ N_d$: Work	W_m – weight of manure produced, kg N_a - number of animals N_d - number of days
Manure Production (Horse) $W_m = 13.50\ N_a\ N_d$: Breeding $W_m = 7.75\ N_a\ N_d$: Work	W_m – weight of manure produced, kg N_a - number of animals N_d - number of days
Manure Production (Chicken) $W_m = 0.075\ N_a\ N_d$: Layer $W_m = 0.025\ N_a\ N_d$: Broiler	W_m – weight of manure produced, kg N_a - number of birds N_d - number of days

BIOGAS

Volume of Mixing Tank (15% Freeboard) $V_{mt} = w_m N_a T_m MR$	V_{mt} - volume of mixing tank, m^3 w_m - daily manure production, kg/day-animal N_a - number of animals T_m – mixing time, day MR – mixing ratio, 1 for 1:1 and 2 for 1:2
Volume of Digester Tank (15% Freeboard) $V_{dt} = w_m N_a T_r MR$	V_{dt} - volume of digester tank, m^3 w_m - daily manure production, kg/day-animal N_a - number of animals T_r – retention time, day MR – mixing ratio, 1 for 1:1 and 2 for 1:2
Digester Dimension (Floating Type-Cylindrical) $D_d = [(4.6 \text{ x } V_d) / (\pi \text{ x } r)]^{1/3}$ $H_d = r D_d$	D_d - inner diameter, m V_d - effective digester volume, m^3 r – height to diameter ratio H_d - digester height, m
Digester Dimension (Floating Type-Square) $S_d = [(1.15 \text{ x } V_d) / (r)]^{1/3}$ $H_d = r Sd$	S_d - inner side, m V_d - effective digester volume, m^3 r – height to side ratio H_d - digester height, m

BIOGAS

Digester Dimension (Floating Type-Rectangular) $W_d = [(1.15\ V_d) / (r\ p^2)]^{1/3}$ $H_d = r\ L_d$	W_d - inner width, m V_d - effective digester volume, m^3 r – height to width ratio p - desired width and length proportion H_d - digester height, m
Gas Chamber (Floating-Type Cylindrical) $D_g = (45\ D_d - w) / 50$: inner diameter $h = D_g \text{ Tan } 9.5 / 2$: height of pyramidal roof $H_s = 1.15[\{4\ V_s / \pi\ D_s) + H_p]$: height of gas chamber	D_g - inner diameter of gas chamber, m D_d – inner diameter of digester, m V_s - effective gas chamber volume, m^3 w – gas chamber wall thickness, cm h – height of pyramidal roof, m H_s - height of gas chamber, m H_p - desired pressure head, m
Gas Chamber (Floating-Type Square/Rectangular) $L_g = (45\ L_d - w) / 50$: inner length $W_g = (45\ L_d - w) / 50$: inner width $h = W_g \text{ Tan } 9.5 / 2$: height of pyramidal roof $H_g = 1.15[\{V_g/L_g W_g) + H_p]$: height of gas chamber	L_g - inner length of gas chamber, m W_g - inner width of gas chamber, m L_d – inner length of digester, m W_d – inner width of digester,m V_s - effective gas chamber volume, m^3 w – gas chamber wall thickness, cm h – height of pyramidal roof, m H_g - height of gas chamber, m H_p - desired prressure head, m

BIOMASS COOKSTOVE

Design Power $P_d = 0.7\,(P_c + P_v)$	P_d - design power, KCal/hr P_c - chracoal power, KCal/hr P_v - max volatile, KCal/hr
Power Output $P_o = F_c H_f / T_b$	P_o - power output, KCal/hr F_c - Fuel charges, kg H_f - heating value of fuel; KCal/kg T_b - total burning time, hr
Burning Rate $BR = P_o / H_f$	BR - burning rate, kg/hr P_o - power output, KCal/hr H_f - heating value of fuel; KCal/kg
Fuel Consumption Rate $FCR = W_{fc} / T_o$	FCR - fuel consumption rate, kg/hr W_{fc} - Weight of fuel consumed, kg T_o – operating time, hr
Power Density $PD = FCR / A_g$	PD - power density, kg/hr-m^2 FCR - fuel consumption rate, kg/hr A_g - area of grate, m^2
Height of Fuel Bed $H_{fb} = F_c / (p\,\rho_f\,A_b)$	H_{fb} - height of the fuel bed, m F_c - fuel charges, kg p - packing density, decimal ρ_f - density of fuel, kg/h^3 A_b - area of fuel bed, m^2
Area of the Fuel Bed $A_{fb} = P_d / PD$	A_{fb} - area of the fuel bed, m^2 P_d - design power, KCal/hr PD - power density, KCal/hr-m^2

BIOMASS COOKSTOVE

Flame Height $FH = C\ P^{2/5}$	FH – flame height, mm C – grate constant, 76 mm/KW for fire with grate, and 110 mm/KW for fire without grate P – power output, KCal/hr
Cooking Time $CT = 550\ M_f^{\ 0.38}$	CT - cooking time, sec M_f - mass of food, kg
Maximum Power $P_{max} = \dfrac{M_f\ C_p\ (T_f - T_i)}{T_c\ \xi_t}$	P_{max} - maximum power, KCal/hr M_f - mass of food, kg C_p - specific heat of food, KCal/kg-C T_f - final temperature of food, C T_i - initial temperature of food, C T_c - cooking time, hr ξ - thermal efficiency of the stove, decimal
Thermal Efficiency $\xi_t = \dfrac{M_w\ C_p\ (T_f - T_i) + W_e\ H_v}{W_{FC}\ \ H_{VF}} \times 100$	ξ_t - thermal efficiency, % M_w – mass of water, kg C_p - specific heat of water, 1 KCal/kg-C T_f - final temperature of water, C T_i - initial temperature of water, C W_e - weight of water evaporated, kg H_v – heat of vaporization of water, 540 KCal/kg W_{FC} – weight of fuel consumed, kg H_{VF} – heating value of fuel, KkCal/kg

BIOMASS FURNACE

Sensible Heat $Q_s = M\ C_p\ (T_f - T_i)$	Q_s - sensible heat, KCal M - mass of material, kg C_p – specific heat of material, KCal/kg-C T_f – final temperature of material, C T_i - initial temperature of material, C
Latent Heat of Vaporization $Q_l = m\ H_{fg}$	Q_l - latent heat of vaporization, KCal/hr m - mass of material, kg H_{fg} - heat of vaporization of material, KCal/kg
Design Fuel Consumption Rate $FCR_d = Q_r\ /\ (HVF\ \xi_t)$	FCR_d - design fuel consumption rate, kg/hr Q_r - heat required for the system, KCal/hr HVF – heating value of fuel, KCal/kg ξ_t - thermal efficiency of the furnace, decimal
Actual Fuel Consumption Rate $FCR_a = W_{fc}\ /\ T_o$	FCR_a - fuel consumption rate, kg/hr W_{fc} - Weight of fuel consumed, kg T_o – operating time, hr
Fuel Consumption Rate for Rice Husk Fueled Inclined Grate Furnace with Heat Exchanger $FCR = (1000\ BR \times Ag) / (\xi f \times \xi he)$	FCR – fuel consumption rate, kg/hr BR – burning rate, 40-50 kg/hr-m2 Ag – grate area, m2 ξf – furnace efficiency, 50 to 70% ξhe – heat exchanger efficiency, 70-80%
Fuel Consumption Rate for Rice Husk Fueled Inclined Grate Furnace without Heat Exchanger $FCR = (100\ BR \times Ag) / \xi f$	FCR – fuel consumption rate, kg/hr BR – burning rate, 40-50 kg/hr-m2 Ag – grate area, m2 ξf – furnace efficiency, 50 to 70%

BIOMASS FURNACE

Burning Rate $BR = FCR / A_g$	BR - burning rate, kg/hr-m^2 FCR – fuel consumption rate, kg/hr A_g - area of grate; m^2
Power Density $PD = FCR / A_g$	PD - power density, kg/hr-m^2 FCR - fuel consumption rate, kg/hr A_g - area of grate, m^2
Area of the Fuel Bed $A_{fb} = P_d / BR$	A_{fb} - area of the fuel bed, m^2 P_d - design power, KCal/hr BR - burning rate, KCal/hr-m^2
Air Flow Rate Requirement $AFR = FCR\ S_a$	AFR - airflow rate, kg/hr FCR - fuel consumption rate, kg/hr S_a - stoichiometric air requirement, kg air per kg fuel
Thermal Efficiency $\xi_t = \dfrac{Q_s}{F_{CR}\ H_{VF}} \times 100$	ξ_t - thermal efficiency, % Q_s – heat supplied, KCal/hr F_{CR} – fuel consumption rate, kg/hr H_{VF} – heating value of fuel, KCal/kg
Burning Efficiency $\xi_b = \dfrac{H_v - H_r}{H_v} \times 100$	ξ_b - burning efficiency, % H_v - heating value of fuel, KCal/kg H_r - heating value of ash residue, KCal/kg

BOARDER IRRIGATION

Maximum Stream Size per Foot Width of Boarder Strip $Q_{max} = 0.06\ S^{0.75}$	Q_{max} - maximum stream size per foot of width of the boarder strip, cfs S - slope, %
Minimum Stream size per Foot Width of Boarder Strip $Q_{min} = 0.004\ S^{0.5}$	Q_{min} - minimum stream size per foot of width of the boarder strip, cfs S - slope, %

CHAIN TRANSMISSION

Speed and Number of Teeth $N_r T_r = N_n T_n$	N_r – speed of driver sprocket, rpm N_n – speed of driven sprocket, rpm T_r – no. of teeth of driver sprocket T_n – no. of teeth of driven sprocket
Length of Chain $L = 2C + \left(\frac{T_2 + T_1}{2}\right) + \left(\frac{T_2 - T_1}{4\pi^2 C}\right)$	L – chain length, pitches C – center distance between sprockets, pitches T_2 – no. of teeth on larger sprocket T_1 – no. of teeth on smaller sprocket
Length of Driving Chain $L = 2C_p + \frac{T}{2} + \frac{t}{2} + \left(\frac{T - t}{2\pi}\right)\left(\frac{1}{C_p}\right)$	L – length of chain in pitches C_p - center to center distances in pitches T - no. of teeth on larger sprocket t - no. of teeth on smaller sprocket

CHAIN TRANSMISSION

Pitch Diameter of Sprocket $PD = \dfrac{P}{\sin(180/N_t)}$	PD – pitch diameter of sprocket, inches P – pitch, inch N_t – number of teeth of sprockets
Chain Pull $CP = 1000\ (P / V)$	CP – chain pull, kg P – chain power, watts V – chain velocity, m/s
Chain Speed $V = p\ T\ N / 376$	V – chain speed, m/s p – chain pitch, in T – number of teeth of sprocket N – sprocket speed, rpm
Speed Ratio $R_s = T_n / T_r$	R_s – speed ratio T_n – driven sprocket, inches T_r – driver sprocket, inches
Design Power $DP = P_t\ S / MSF$	DP - design power, Watts P_t - power to be transmitted, Watts S - service factor, 1.0 to 1.7 MSF – multiple strand factor, 1.7 to 3.3 @ 2 to 4 strands

CHAIN TRANSMISSION

Power Rating Required $PR = \frac{DP \quad DL}{15,000}$	PR - Power rating required, Watts DP - design power, Watts DL - design life, hours
Horsepower Capacity (At Lower Speed) $HP = 0.004\, T_1^{1.08}\, N_1^{0.9}\, P^3 - 0.007\, P$	HP – horsepower capacity, hp T_1 – number of teeth of smaller sprocket N_1 - speed of smaller sprocket, rpm P – chain pitch, inches
Horsepower Capacity (At Higher Speed) $HP = \frac{1700\, T_1^{1.5}\, P^{0.8}}{N_1^{1.5}}$	HP – horsepower capacity, hp T_1 – number of teeth of smaller sprocket N_1 - speed of smaller sprocket, rpm P – chain pitch, inches
Center Distance $C = \frac{P}{8} [\; 2L_p - T - t + \sqrt{(2L_p - T - t)^2 - 0.810\,(T-t)^2}\;]$	C - center distance in mm P - pitch of chain in mm L_p - length of chain in pitches T - number of teeth in large sprocket t - number of teeth in small sprocket

CONSERVATION STRUCTURES, DAMS AND RESREVIOR

Capacity of drop spillway $q = 0.55\ C\ L\ h^{3/2}$	q – discharge, cubic meter per second C – weir coefficient L – weir length, meter h – depth of flow over the crest, meter
Total width of the dam $W = 0.4\ H + 1$	W – top width, meters H – maximum height of embankment, meters
Wave height $H = 0.014\ (D_f)^{1/2}$	h – height of the wave from through to crest under ,maximum wind velocity, meters D_f – fetch or exposure, meters
Compaction and settlement $V = V_s + V_o$	V = total in-place volume, m^3 V_s = volume of solid particles, m^3 V_o = volume of voids, either air or water, m^3

CONVEYANCE CHANNEL

Continuity Equation $Q = A V$	Q - discharge, m^3/sec A – cross-sectional area of the channel, m^2 V – velocity of water, m/sec
Manning Equation $V = (1.00 / n)\ R^{2/3}\ S^{1/2}$	V – velocity, m/sec n – Manning's coefficient, 0.010 to 0.035 R – hydraulic radius, m S – slope of water surface
Chezy Equation $V = C\ (R S)^{1/2}$	V – flow velocity C - coefficient of roughness, 50 to 180 R – hydraulic radius, m S – slope of water surface, decimal
Hydraulic Radius $R = A / P$	R – hydraulic radius, m A – cross-sectional area of flow, m^2 P – wetted perimeter, m
Best Hydraulic Cross-Section $b = 2\ d\ \tan(\theta / 2)$	b - bottom width of channel, m d – depth of water in the canal, m θ - angle between the side slope and the horizontal

CONVEYANCE CHANNEL

Cross-Sectional Area of Channel $A = b\,d + z\,d^2$: Trapezoidal $A = z\,d^2$: Triangular $A = 2/3 + t\,d$: Parabolic	A - cross sectional area, m^2 b – base width of the channel, m d – depth of water, m z - canal slope h/d, decimal t - top width, m
Wetted Perimeter of Channel $WP = b + 2d\,(z^2 + 1)^{½}$: Trapezoidal $WP = 2d\,(z^2 + 1)^{½}$: Triangular $WP = t + (8\,d^2 / 3t)$: Parabolic	WP - wetted perimeter, m b – base width of the channel, m d – depth of water, m z - canal slope h/d, decimal t - top width, m
Top Width $t = b + 2\,d\,z$: Trapezoidal $t = 2\,d\,z$: Triangular $t = A/(0.67\,d)$: Parabolic	t - top width, m b – base width of the channel, m d – depth of water, m z - canal slope h/d, decimal A - cross sectional area, m^2
Discharge (Float Method) $Q = C\,A\,V_{max}$	Q - discharge, m^3/s C – coefficient, 2/3 A - cross-sectional area of the stream, m^2 V_{max} - average maximum velocity of stream, m/s

CORN SHELLER

Kernel-Ear Corn Ratio $R = (W_k / W_{ec})$	R – grain ratio, decimal W_k – weight of kernel, grams W_{ec} – weight of ear corn, grams
Actual Capacity $C_a = W_s / T_o$	C_a – actual capacity, kg/hr W_s -weight of shelled kernel, kg T_o – operating time, hr
Corrected Capacity $C_c = \dfrac{100 - MC_o}{100 - MC_r} \times P\, C_a$	C_c – corrected capacity, kg/hr MC_o – observed moisture content, % MC_r – reference MC, 20% P – kernel purity, % C_a – actual capacity, kg/hr
Purity $P = (W_c / W_u) 100$	P – purity, % W_u – weight of uncleaned kernel, grams W_c – weight of cleaned kernel, grams
Total Losses $L_t = L_b + L_s + L_u + L_{sc}$	L_t – total losses, kg L_b – blower loss, kg L_s – separation loss, kg L_{sc} – scattering loss, kg L_u – unthreshed loss, kg

CORN SHELLER

Shelling Efficiency $\xi_s = \dfrac{W_c + L_b + L_s + L_{sc}}{W_c + L_b + L_s + L_u + L_s} \times 100$	ξ_s – shelling efficiency,% W_c – weight of clean shelled kernel, kg L_b – blower loss, kg L_s – separation loss, kg L_{sc} – scattering loss, kg L_u – unthreshed loss, kg
Fuel Consumption $F_c = F_u / t_o$	F_c – fuel consumption, Lph F_u - amount of fuel used, liters T_o – operating time, hrs
Shelling Recovery $S_r = \dfrac{W_c}{W_c + L_b + L_s + L_u + L_s} \times 100$	S_r – threshing recovery, % W_c – weight of clean shelled kernels, kg L_b – blower loss, kg L_s – separation loss, kg L_{sc} – scattering loss, kg L_u – unthreshed loss, kg
Cracked Kernels $C_k = N_{ck}\ 100\ /\ 100$ kernel sample	C_k – percentage cracked kernel, % N_{ck} – number of cracked kernels
Mechnically Damaged Kernel $D_k = N_{dk}\ 100 / 100$ kernel sample	D_k – percentage damage kernel, % N_{dk} – number of damaged kernels

COST-RETURN ANALYSIS

Investment Cost $IC = MC + PMC$	IC - investment cost, P EC - equipment cost, P PMC – prime mover cost, P
Total Fixed Cost $FC_t = D + I + RM + i$	FC – total fixed cost, P/day D - depreciation, P/day I - interest on investment, P/day RM - repair and maintenance, P/day i - insurance, P/day
Total Variable Cost $VC_t = L + F + E$	VC_t - total variable cost, P/day L - labor cost, P/day F – fuel cost, P/day E – electricity, P/day
Total Cost $TC = FC_t + VC_t$	TC – total cost, P/day FC_t – total fixed cost, P/day VC_t - total variable cost, P/day
Operating Cost $OC = TC / C$	OC - operating cost, P/ha or P/kg TC - total cost, P/day C - capacity, Ha/day or Kg/day

COST-RETURN ANALYSIS

Depreciation (Staight Line) $$D = \frac{IC - 0.1\ IC}{365\ LS}$$	D - depreciation, P/day IC - investment cost, P LS – life span, years
Interest on Investment $I = R_i\ IC / 365$	I - interest on investment, P/day R_i - interest rate, 0.24/year IC – investment cost, P
Repair and Maintenance $RM = R_{rm}\ IC / 365$	RM – repair and maintenance, P/day R_{rm} - repair and maintenance rate, 0.1/year IC - investment cost, P
Insurance $i = R_i\ IC / 365$	i - insurance, P/day R_i - insurance rate, 0.03/year IC - investment cost, P
Labor Cost $L = NL\ S_a$	L - labor cost, P/day NL – number of laborers S_a – salary, P/day
Fuel Cost $F = W_f\ C_f$	F - fuel cost, P/day W_f - weight of fuel used, kg C_f - cost of fuel, P/kg

COST-RETURN ANALYSIS

Electricity $E = E_c C_e$	E – cost of electricity, P/day E_c - electrical consumption, KW-hr C_e – cost of electricity, P/KW-hr
Net Income NI = (CR - OC) C OP	NI - net income, P/yr CR – custom rate, P/ha or P/kg OC – operating cost, P/ha or P/kg C - capacity, Ha/day or Kg/day OP – operating period, days/year
Payback Period PBP = IC / NI	PBP – payback period, years IC - investment cost, P NI - net income, P/yr
Benefit Cost Ratio BCR = NI / (TC OP)	BCR - benefit cost ratio, decimal NI - net income, P/year TC – total cost, P/day OP – operating period, days per year
Return on Investment ROI = (TC / NI) 100	ROI - return on investment, % TC - total cost, P/year NI - net income, P/year

CYCLONE SEPARATOR

Diameter of Cyclone Separator $D_c = (Q / 0.1 V_t)^{0.5}$	D_c - diameter of cyclone separator, m Q – airflow, m^3/hr V_t – velocity of air entering the cyclone, m/s
Pressure Draft of the Cyclone $P_d = \dfrac{6.5 D_a V_t^2 A_d}{D_s}$	P_d - pressure drop, mm D_a – air density, 1.25 kg/m^3 V_t – velocity of air entering the cyclone, m/s A_d – inlet area of the duct, m^2 D_s - diameter of separator, m
Cyclone Cylinder Height (High Efficiency) $H_{cy} = 1.5 D_c$	H_{cy} – cylinder height, m D_c - cyclone diameter, m
Inverted Cone Height (High Efficiency) $H_{co} = 2.5 D_c$	H_{co} - cone height, m D_c - cyclone diameter, m
Air Duct Outlet Diameter (High Efficiency) $D_o = 0.5 D_c$	D_o - air duct outlet diameter, m D_c - cyclone diameter, m

CYCLONE SEPARATOR

Air Duct Outlet Lower Height (High Efficiency) $HDO_l = 1.5\ D_c$	HDO_l - lower height of air duct outlet, m D_c - cyclone diameter, m
Air Duct Outlet Upper Height (High Efficiency) $HDO_u = 0.5\ D_c$	HDO_u - upper height of air duct outlet, m D_c - cyclone diameter, m
Width of the Inlet Rectangular Square Duct (High Efficiency) $WD = 0.2\ D_c$	WD – width of the inlet duct, m D_c – cyclone diameter, m
Height of the Inlet Rectangular Square Duct (High Efficiency) $HD = 0.5\ D_c$	HD – height of the inlet duct, m D_c – cyclone diameter, m
Cylinder Height (Medium Efficiency) $H_{cy} = 1.5\ D_c$	H_{cy} – cylinder height, m D_c - cyclone diameter, m
Inverted Cone Height (Medium Efficiency) $H_{co} = 2.5\ D_c$	H_{co} - cone height, m D_c - cyclone diameter, m

CYCLONE SEPARATOR

Air Duct Outlet Diameter (Medium Efficiency) $D_o = 0.75\ D_c$	D_o - air duct outlet diameter, m D_c - cyclone diameter, m
Air Duct Outlet Lower Height (Medium Efficiency) $HDO_l = 0.875\ D_c$	HDO_l - lower height of air duct outlet, m D_c - cyclone diameter, m
Air Duct Outlet Upper Height (Medium Efficiency) $HDO_u = 0.5\ D_c$	HDO_u - upper height of air duct outlet, m D_c - cyclone diameter, m
Width of the Inlet Rectangular Square Duct (Medium Efficiency) $WD = 0.375\ D_c$	WD – width of the inlet duct, m D_c – cyclone diameter, m
Height of the Inlet Rectangular Square Duct and Upper Cyclone Cylinder (Medium Efficiency) $HD = 0.75\ D_c$	HD – height of the inlet duct, m D_c – cyclone diameter, m

DIFFERENTIAL CALCULUS

$$\frac{d}{dx}(u + v) = \frac{du}{dx} + \frac{dv}{dx}$$

$$\frac{d}{dx}\,u/v = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$$

$$\frac{d}{dx}(x^n) = nx^{n-1}$$

$$\frac{d}{dx}\,u.v = v\frac{du}{dx} + u\frac{dv}{dx}$$

$$\frac{d}{dx}(u^n) = nu^{n-1}\frac{du}{dx}$$

$$\frac{d}{dx}(\ln u) = \frac{du/dx}{u}$$

$$\frac{d}{dx}(a^u) = a^u \,.\, \ln a \,.\, du/dx$$

$$\frac{d}{dx}(e^u) = e^u \cdot du/dx$$

$$e^{\ln u} = u$$

$$e^0 = 1$$

$$\frac{d}{dx}(\log 10^u) = 0.4343 \,.\, \frac{du/dx}{u} = \frac{du/dx}{u} \,.\, \log 10^e$$

$$\frac{d}{dx}(\sqrt{u}) = \frac{du/dx}{2\sqrt{u}}$$

$$\frac{d}{dx}(\sin u) = \cos u.du/dx$$

$$\frac{d}{dx}(\cos u) = -\sin u.du/dx$$

$$\frac{d}{dx}(\tan u) = \sec^2 u.du/dx$$

$$\frac{d}{dx}(\csc u) = -\csc u.\cot u.du/dx$$

$$\frac{d}{dx}(\sec u) = \sec u.\tan u.du/dx$$

$$\frac{d}{dx}(\cot u) = \csc^2 u.du/dx$$

$$\frac{d}{dx}(\arcsin u) = \frac{du/dx}{\sqrt{1-u^2}}$$

DIFFERENTIAL CALCULUS

$\frac{d}{dx}(\arctan u) = \frac{du/dx}{1 + u^2}$

$\frac{d}{dx}(\text{arcsec } u) = \frac{du/dx}{u\sqrt{u^2-1}}$

$\frac{d}{dx}(\text{arccsc } u) = \frac{-du/dx}{u\sqrt{u^2-1}}$

$\frac{d}{dx}(\text{arccot } u) = \frac{-du/dx}{1 + u^2}$

$\frac{d}{dx}(\log a^u) = \frac{du/dx}{du} \cdot \log a^e$

$\frac{d}{dx}(\csc h\, u) = -\csc h\, u \cot h\, u . du/dx$

$\frac{d}{dx}(\sec h\, u) = -\sec h\, u\ \text{tn}\ h\, u . du/dx$

$\frac{d}{dx}(\cot h\, u) = -\csc h^2\, u . du/dx$

$\frac{d}{dx}(\arccos u) = \frac{-du/dx}{\sqrt{1-u^2}}$

$x^{m/n} = ({}^n\sqrt{x})^m$

$\frac{d}{dx}(\sin h\, u) = \cos h\, u . du/dx$

$\frac{d}{dx}(\cos h\, u) = \sin h\, u . du/dx$

$\frac{d}{dx}(\tan h\, u) = \sec h^2\, u . du/dx$

DRIP IRRIGATION

Maximum Depth of Irrigation $I_{dn} = D_s [(F_c - W_p) / 100] D_d \; P$	I_{dn} - maximum net depth of each irrigation application, mm D_s - depth of soil, m F_c - field capacity, % W_p - wilting point, % D_d - portion of the available moisture allowed to deplete, mm P - area wetted, % of total area
Irrigation Interval $I_i = [I_d \; TR \; EU] / 100T$ $T = ET$ (min of PS/85)	I_i - irrigation interval, days I_d - gross depth of irrigation, mm TR - ratio of transpiration to application, 0.9 EU - emission uniformity, % ET - conventionally accepted consumptive use rate of crop, mm/day PS - area of the crop as percentage of the area, %
Gross Depth of Irrigation $I_d = 100 \; I_{dn} \; / \; [TR \; EU]$	I_d - gross depth of irrigation, mm I_{dn} - maximum net depth of each irrigation application, mm TR - ratio of transpiration to application, 0.9 EU - emission uniformity, %

DRIP IRRIGATION

Average Emitter Discharge $Q_a = k [I_d \; S_e \; S_l] / I_t$	Q_a - emitter discharge, m^3/hr k - constant, 1 for metric unit I_d - gross depth irrigation, m S_e - emitter spacing on line, m S_l - average spacing between lines, m I_t - operational unit during each of irrigation cycle, hrs
Lateral Flow Rate $Q_l = 3600 \; N_e \; Q_a$	Q_l - lateral flow rate, lps N_e - number of emitters on laterals Q_a - emitter discharge, m^3/hr

ELECTRICITY

Power (DC) $P = V I$	P – power, Watts V – voltage, volt I – current, Ampere
Power (AC) $P = V I$	P – power, volt-ampere V – voltage, volt I – current, Ampere
Power (AC) $P = V I p_f$	P – power, Watts V – voltage, volt I – current, Ampere p_f – power factor
Ohms Law (DC) $I = V / R$	I – current, Ampere V– voltage, volt R – resistance, ohms
Ohms Law (AC) $I = V / Z$	I – current, Ampere V – voltage Z – impedance
Power $P = I^2 R$	P – power, Watts I – current, Ampere R – resistance, ohms
Power $P = V^2 / R$	P – power, Watts V – voltage, volts R – resistance, ohms

ELECTRICITY

Resistance $R = P / I^2$	P – power, Watts I – current, Ampere R – resistance, ohms
Resistance $R = V^2 / P$	P – power, Watts V – voltage, volts R – resistance, ohms
Voltage $V = P / I$	V – voltage, volt P – power, Watts I – current, Ampere
Voltage (Series) $V_t = V_1 + V_2 + V_3 \ldots$	V_t – total voltage, volt V_1 – voltage 1, volt V_2 – voltage 2, volt V_3 – voltage 3, volt
Resistance (Series) $R_t = R_1 + R_2 + R_3 \ldots$	R_t – total resistance, ohms R_1 – resistance 1, ohms R_2 – resistance 2, ohms R_3 – resistance 3, ohms
Current (Series) $I_t = I_1 = I_2 = I_3$	I_t – total current, ampere I_1 – current 1, Ampere I_2 – current 2, Ampere I_3 – current 3, Ampere

ELECTRICITY

Voltage (Parallel) $V_t = V_1 = V_2 = V_3$	V_t – total voltage, volt V_1 – voltage 1, volt V_2 – voltage 2, volt V_3 – voltage 3, volt
Resistance (Parallel) $R_t = \dfrac{1}{1/R_1 + 1/R_2 + 1/R_3}$	R_t – total resistance, ohms R_1 – resistance 1, ohms R_2 – resistance 2, ohms R_3 – resistance 3, ohms
Current (Parallel) $I_t = I_1 + I_2 + I_3$	I_t – total current, Ampere I_1 – current 1, Ampere I_2 – current 2, Ampere I_3 – current 3, Ampere
Energy $E = P\ T$	E – energy, Watt-hour P – power, Watts T – time, hour

ELECTRICITY

Current (Parallel) $I_t = I_1 + I_2 + I_3$	I_t – total current, Ampere I_1 – current 1, Ampere I_2 – current 2, Ampere I_3 – current 3, Ampere
Energy $E = P\,T$	E – energy, Watt-hour P – power, Watts T – time, hour
Power Factor $p_f = \dfrac{P_r}{P_a} = \dfrac{E\,I\,\cos\theta}{E\,I}$ $= \cos R/Z$	p_f – power factor E – voltage, volt I – current, ampere P_r – real power, watts P_a – apparent power, watts R – resistance, ohms Z – impedance, ohms
KVA (Single Phase Circuit) $KVA = \dfrac{E\ I}{1000}$	KVA – kilovolt ampere E – voltage, volt I – current, ampere
KVA (Three-Phase Circuit) $KVA = \dfrac{1.732\,E\,I}{1000}$	KVA – kilovolt ampere E – voltage, volt I – current, ampere
Horsepower Output (Single-Phase) $HP = \dfrac{\eta\ I\ E\ p_f}{746}$	HP – power output, hp E – voltage, volt I – current, amperes η - efficiency, decimal p_f – power factor, decimal

ELECTRIC MOTOR

Horsepower Output (Three-Phase) $HP = \sqrt{3}\,\dfrac{\eta\ I\ E\ p_f}{746}$	HP – power output, hp E – voltage, volt I – current, amperes η - efficiency, decimal p_f – power factor, decimal
Power in Circuit (Single-Phase) $P = E\,I$	P – power, watts E – voltage, volts I – current, ampere
Power in Circuit (Three Phase) $P = \sqrt{3}\ E\ I$	P – power, watts E – voltage, volts I – current, ampere
KVA (Single-Phase Circuit) $KVA = \dfrac{E\ I}{1000}$	KVA – kilovolt ampere E – voltage, volt I – current, ampere
KVA (Three-Phase Circuit) $KVA = \dfrac{1.732\ E\ I}{1000}$	KVA – kilovolt ampere E – voltage, volt I – current, Ampere
Horsepower Output (Single-phase) $HP = \dfrac{\eta\ I\ E\ p_f}{746}$	HP – power output, hp E – voltage, volt I – current, amperes η - efficiency, decimal p_f– power factor, decimal

ELECTRIC MOTOR

Horsepower Output (Three-phase) $HP = \sqrt{3}\,\frac{\eta \; I \; E \; p_f}{746}$	HP – power output, hp E – voltage, volt I – current, amperes η - efficiency, decimal p_f – power factor, decimal
Slip (Three-Phase Motor) S = [Ns – N] / Ns	S - slip, decimal Ns – motor synchronus speed, rpm N – actual motor speed, rpm
Power in Circuit (Single-Phase) P = E I	P – power, Watts E – voltage, volts I – current, Ampere
Power in Circuit (Three-Phase) $P = \sqrt{3}\; E \; I$	P – power, Watts E – voltage, volts I – current, Ampere
Rotr Speed (Synchronous Motor) Ns = 120 [f / P]	Ns – rotor speed, rpm F - frequency of stator volatge, hertz P – n umber of pole
Motor Size to Replace Engine MHP = EHP 2/3	MHP - motor power, hp EHP - engine power, hp
Motor Size to Replace Human $MHP = N_H \; 1/4$	MHP - motor power, hp N_H - number of human

ELECTRIFICATION

Energy Loss in Lines $L_e = \dfrac{V_l \; I \; T_o}{1000}$	L_e – energy loss, KW-hr V_l - voltage loss in line, volt I - current flowing, Amp T_o - operating time, hr
Area Circular Mill $A_{cm} = D^2$	A_{cm} - area, circular mill D - diameter, mill or 1/1000 of an inch
Energy Consumption (Disk Meter) $EC = \dfrac{60 \; K_h \; D_{rev}}{1000 \; t_c}$	EC = electrical consumption, KW-hr K_h - meter disk factor, 2.5 D_{rev} – number of revolutions, rev T_c - counting period, min
Minimum Number of Convenience Outlet $N_{co} = P_f / 20$	N_{co} - minimum number of convenience outlet, pieces of duplex receptacle P_f - floor perimeter, ft
No. of Branch Circuit (15-amp) $N_{bc} = A_f / 500$ $N_{bc} = NO_{gp} / 10$	N_{bc} - number of branch circuit A_f - floor area, ft^2 NO_{gp} - number of general outlet

ELECTRIFICATION

No. of Branch Circuit (20 Amp) $N_{bc} = NO_{sa} / 8$	N_{bc} - number of branch circuit NO_{sa} - number of small appliance outlet
Resistance of Copper Wire $R = \dfrac{10.8\ L}{A}$	R - resistance in wire, ohms L – length of wire, ft A - cross sectional area of wire, cir mil
Wire Size Selection $A = \dfrac{10.8\ N_w\ L\ I}{V_d\ E}$	A - area of wire, circular mill N_w - number of wires L - length of wire, ft I - current flowing, amp V_d - allowable voltage drop, decimal equal to 0.02 adequate for all conditions E – voltage, volt
Lamp Lumen Required $L_l = \dfrac{L_i\ A_f}{CU\ SF}$	L_l - lamp lumen required, lumen L_i - light intensity, foot candle A_f - floor area, ft^2 CU - coefficient of utilization, 0.04 to 0.72 SF - service factor, 0.7
Maximum Lamp Spacing (Florescent Lamp) $M_S = C_i\ M_H$	M_S - maximum lamp spacing, ft C_i - lamp coefficient, 0.9 for RLM standard-dome frosted lamp and 1.0 for RLM standard silvered-bowl lamp M_H – Lamp height, ft
Maximum Lamp Spacing (Incandescent Lamp) $M_S = C_f\ M_H$	M_S - maximum lamp spacing, ft C_f - lamp coefficient, 0.9 for Direct RLM with louvers, 1.0 for direct RLM 2-40 watts, and 1.2 for indirect-glass, plastic, metal M_H - lamp height, ft

ENGINE

Indicated Horsepower $$IHP = \frac{P\,L\,A\,N\,n}{33000\;c}$$	IHP – indicated horsepower, hp P – mean effective pressure, psi L – length of stroke, ft A – area of bore, in^2 N – crankshaft speed, rpm n – number of cylinder c - 2 for four stroke engine and 1 for two stroke engine
Piston Displacement $$PD = \frac{\pi D^2}{4} L\;n$$	PD – piston displacement, cm^3 Dp – piston diameter, cm L – length of stroke, cm n – number of cylinders
Piston Displacement Rate $$PDR = 2\,\pi\;PD\,N$$	PDR – piston displacement rate, cm^3/min PD – piston displacement, cm^3 N – crankshaft speed, rpm
Compression Ratio $$CR = \frac{PD + CV}{CV}$$	CR – compression ratio PD – piston displacement, cm^3 CV – clearance volume, cm^3
Brake Horsepower $$BHP = IHP\,\xi_m \quad \text{or}$$ $$= IHP - FHP$$	BHP – brake horsepower, hp IHP – indicated horsepower, hp ξ_m – engine mechanical efficiency, decimal FHP – friction horsepower, hp

ENGINE

Mechanical Efficiency $\xi_m = \dfrac{BHP}{IHP} \times 100$	BHP – brake horsepower, hp IHP – indicated horsepower, hp ξ_m – engine mechanical efficiency, decimal
Rate of Explosion $ER = \dfrac{N}{c}$	ER – explosion rate, explosion per minute N – crankshaft speed, rpm C – 2 for four stroke engine
Thermal Efficiency, Theoritical $\xi_{theo} = \dfrac{C\ W_t}{Q_t} \times 100$	ξ_{theo} –theoretical thermal efficiency, % W_t – theoretical work, kg-m Q_t – supplied heat quantity, Kcal/hr C – conversion constant
Thermal Efficiency, Effective $\xi_{eff} = \dfrac{C\ N_e}{H_u\ B} \times 100$	ξ_{eff} – effective thermal efficiency, % N_e – Effective output, watt H_u – calorific value of fuel, kCal/kg B - indicated work, kg/hr C – conversion constant

ENGINE

Specific Fuel Consumption $$SFC = \frac{V}{N_e \quad t} S$$	SFC – specific fuel consumption, kg/W-sec V – fuel consumption, m^3 N_e – Brake output T – time, sec S – specific gravity of fuel, kg/m^3
Break Mean Effective Pressure $$BMEP = \frac{(75)\ 50\ BHP}{L\ A\ N\ n}$$	BMEP – brake mean effective pressure, kg/cm^2 BHP – brake horsepower, hp L – piston stroke, m A – piston area, cm^2 N – number of power stroke per minute N – number of cylinders
Number of Times Intake Valve Open $$TO = \frac{N}{c}$$	TO – number of time intake valve open N – crankshaft speed, rpm C – 2 for four stroke engine - 0 for two stroke engine
Piston Area $$A_p = \frac{\pi\ D^2}{4}$$	A_p - piston area, cm^2 D – piston diameter, cm

ENGINE

Stroke to Bore Ratio $R = \dfrac{S}{B}$	R – stroke to bore ratio S – piston stroke, cm B – piston diameter, cm
BHP Correction Factor (Gasoline Engine-Carburator or Injection) $K_g = \left(\dfrac{1013}{Pb}\right) \times \left(\dfrac{T + 273}{293}\right)^{0.5}$	K_g – BHP correction factor. Dmls T – ambient air temperature, C P_b – total atmospheric pressure, mb
BHP Correction Factor (Diesel Engine-4 Stroke Naturally Aspirated) $K_d = \left(\dfrac{1013}{P_b}\right)^{0.65} \times \left(\dfrac{T + 273}{293}\right)^{0.5}$	K_d – BHP correction factor. Dmls T – ambient air temperature, C P_b – total atmospheric pressure, mb
Output Power $P_o = \dfrac{T\ N}{974}$	P_o – power output, KW T – shaft torque, kg-m N – shaft speed, rpm

ENGINE

Fuel Consumption $F_c = F_u / T_o$	F_c – fuel consumption, lph F_u – fuel used, liters T_o – total operating time, hrs
Specific Fuel Consumption $SFC = F_c \rho_f / P_s$	SFC – specific fuel consumption, g/KW-hr F_c – fuel consumption, lph ρ_f - fuel density, kg/liter P_s – shaft power, KW
Fuel Equivalent Power $P_{fe} = [H_f\ m_f] / 3600$	P_{fe} - fuel equivalent power, kW H_f - heating value of fuel, kJ/kg m_f - rate of fuel consumption, kg/hr
Air Fuel Ratio $A/F = \dfrac{137.3 [x + y/4 - z/2]}{\phi [12 x + y + 16 z]}$	A/F - mass of air required per unit mass of fuel x, y, z – number of carbon, hydrogen, and oxygen atoms in the fuel molecule ϕ - equivalence ratio
Air Handling Capacity $m_a = 0.03\ V_e N_e \rho_a\ \eta_v$	m_a – air handling capacity, kg/hr V_e – engine displacement, liters N_e – engine speed, rpm ρ_a - density of air, 1.19 kg/m3 η_v - air delviery ratio0.85 for CI, 2.0 turbocharge engine
Engine Air Density $\rho_a = p / 0.287\ \Theta$: inlet $\rho_{ex} = p / 0.277\ \Theta$: exhaust	ρ_a - density of inlet air, kg/m^3 ρ_{ex} - density of engine exhaust, kg/m^3 p – gas pressure, kPa Θ - gas temperature, K

ENGINE FOUNDATION

Weight of Foundation $W_f = \varepsilon\ W_e\ [N]^{0.5}$	W_f - weight of foundation, kg ε - empirical coefficient, 0.11 W_e - weight of engine and base frame, kg N - maximum engine speed, rpm
Volume of Foundation $V_f = W_f / \rho_c$	V_f - volume of foundation, m^3 W_f - weight of foundation, kg ρ_c - density of concrete, 2,4006 kg/m^3
Depth of Foundation $D_f = V_f / [w_e + L_e]$	D_f - depth of foundation, m V_f - volume of foundation, m^3 w_e - width of engine plus allowance, m L_e - length of engine plus allowance, m
Exerted Soil Pressure at the Foundation $P_s = [W_e + W_f] / A_f$	P_s - soil pressure exerted at the based of foundation, kg/m^2 W_e - weight of engine, kg W_f - weight of foundation, kg A_f - area of foundation , kg
Factor of Safety $FS = BC_s / P_s$	FS - factor of safety, dmls BC_s - safe soil bearing capacity, 12,225 kg/m^2 P_s - soil pressure exerted at the based of foundation, kg/m^2

FLAT AND V-BELT TRANSMISSION

Width of Flat belt $$W = \frac{R\ M}{K\ P}$$	W – width of flat belt, in. R – nameplate horsepower rating of motor, hp K – theoretical belt capacity factor, 1.1 to 19.3 P – pulley correction factor, 0.5 to 0.1
Width of Belt $$W = \frac{H\ S}{K\ C}$$	W - width of belt, mm H - power transmitted, Watts S - service factor, 1.0 to 2.0 K - power rating of belt, watts/mm C - arc correction factor, 0.69 at 90 deg and 1.00 at 180 deg
Horespower Rating of Belt $$H = \frac{W\ K\ P}{M}$$	H – horsepower rating of belt, hp W – width of belt, in M – motor correction factor, 1.5 to 2.5 P – pulley correction factor, 0.5 to 1.0 K – theoretical belt capacity factor, 1.1 to 19.3

FLAT AND V-BELT TRANSMISSION

Speed and Diameter $N_r D_r = N_n D_n$	N_r – speed of driver pulley, rpm N_n – speed of driven pulley, rpm D_r – diameter of driver pulley, inches D_n – diameter of driven pulley, inches
Length of Belt (Open drive) $L = 2C + 1.57(D_r + D_n) + \dfrac{(D_r - D_n)^2}{4C}$	L – length of belt, inches C – center distance between pulleys, inches D_r – diameter of driver pulley, inches D_n – diameter of driven pulley, inches
Length of Belt (Cross drive) $L = 2C + 1.57(D_r + D_n) + \dfrac{(D_r + D_n)^2}{4C}$	L – length of belt, inches C – center distance between pulleys, inches D_r – diameter of driver pulley, inches D_n – diameter of driven pulley, inches

FLAT AND V-BELT TRANSMISSION

Length of Belt (Quarter-Turn drive) $L = 1.57(D_r+D_n) + \sqrt{C^2+D_r^2} + \sqrt{C^2+D_n^2}$	L – length of belt, inches C – center distance between pulleys, inches D_r – diameter of driver pulley, inches D_n – diameter of driven pulley, inches
Belt Speed $V = 0.262\ N_p\ D_p$	V – belt speed, fpm N_p – pulley speed, rpm D_p – pulley diameter, inches
Speed Ratio $R_s = N_n / N_r$	R_s – speed ratio N_n – driven pulley, inches N_d – driver pulley, inches
Arc of Contact $Arc = 180° - 57.3 \dfrac{(D_l - D_s)}{C}$	Arc – arc of contact, degrees D_l – diameter of larger pulley, inches D_s – diameter of smaller pulley, inches C – center distance between pulleys, inches

FLAT AND V-BELT TRANSMISSION

Effective Pull $$(T_1 - T_2) = \frac{1000\ P}{V}$$	$(T_1\text{-}T_2)$ - effective pull, N P – power, KW V – belt speed, m/s
Center Distance $$C = \frac{b + \sqrt{b^2 - 32\,(D_l - D_s)^2}}{16}$$ $b = 4L_s - 6.28\,(D_l + D_s)$	C – distance between centers of pulley, mm L_s – available belts standard length, mm D_l – diameter of larger pulley, mm D_s – diameter of small pulley, mm
Length of Arc $$L_a = \frac{D\ A}{115}$$	L_a – length of arc, mm D – diameter of pulley, mm A – angle in degrees subtended by the arc of belt contact on pulley, deg

FLUID MECHANICS

Density, ρ $\rho = m/v$	m – mass, kg, slug v – volume, m^3, ft^3
Specific volume, υ $\upsilon = v/m$	v – volume, m^3, ft^3 m – mss, kg, slug
Specific weight, γ, ω $\gamma = \omega = \rho g$	ρ – density, kg/m^3, $slug/ft^3$ g – gravitational acceleration, ft/sec^2, m/sec^2
Specific gravity, s $s_{subs} = \frac{\rho_{subs}}{\rho_{std\ subs}} = \frac{\gamma_{subs}}{\gamma_{std\ subs}}$	subs – substance std subs – standard substance
Vapor Pressure, Pv $P_v \ \alpha \ T_s$	Pv – vapor pressure Ts – saturation or boiling Temperature
Viscosity $v = \mu/\rho$	v – kinematic viscosity, m^2/sec μ – absolute viscosity, Pasec ρ – density, kg/m^3
Ideal Gas Equation of State: $Pv = mRT$	P – absolute pressure, kPaa v – total or absolute volume, m^3 R – gas constant, 8.3143 kJ/M kg K, 1545.32 ft lb/M lb °R M – molecular weight of gas T – absolute temperature, K
Gas constant and specific heat $R = C_p - C_v$ $k = C_p/C_v > 1.0$	Cp – specific heat at constant pressure Cv – specific heat at constant volume R – gas constant k – specific heat ratio
Gay – Lussac's Law $\left[\frac{Pv}{mT}\right]_1 = \left[\frac{Pv}{mT}\right]_2$ $m_1 \neq m_2$ $\frac{P_1 v_1}{m_1 T_1} = \frac{P_2 v_2}{m_2 T_2}$ $m_1 = m_2$ $\frac{P_1 v_1}{T_1} = \frac{P_2 v_2}{T_2}$	P_1 – initial absolute pressure, kPaa,psia P_2 – final absolute pressure, kPaa, psia T_1 - initial absolute temperature, K, °R T_2 – final absolute temperature, K, °R v_1 – absolute initial volume, m^3, ft^3 v_2 - absolute final volume, m^3, ft^3 m_1 – initial mass, kg, lb m_2 – final mass, kg, lb

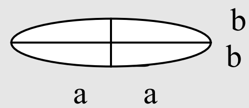
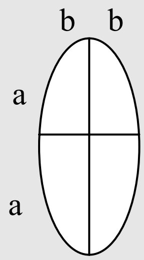
FLUID MECHANICS

Boyle's Law $T_1 = T_2$ $$\frac{P_1 v1}{m_1} = \frac{P_2 v_2}{m_2}$$ $$P_1\upsilon_1 = P_2\upsilon_2$$	$\boldsymbol{\upsilon_1}$ **–** initial specific volume, m^3/kg υ_2 – final specific volume, m^3/kg
Charles Law Case I: @ $v_1 = v_2$, $m_1 \neq m_2$ $$\frac{P_1}{m_1T_1} = \frac{P_2}{m_2T_2}$$ @ $m_1 = m_2$ $$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$ Case II: @ $P_1 = P_2$ $$\frac{v1}{m_1T_1} = \frac{v_2}{m_2T_2}$$ or $$\frac{v1}{T_1} = \frac{v_2}{T_2}$$ @ $m_1 = m_2$ $$\frac{v1}{T_1} = \frac{v_2}{T_2}$$	

FLUID MECHANICS

Bulk Modulus of Elasticity $E_v = \dfrac{-\ \upsilon_1\, dP}{d\upsilon}$	E_v – bulk modulus of elasticity or volume modulus of elasticity υ_1 – initial specific volume υ_2 – final specific volume dP – change in pressure $d\upsilon$ – change in volume
Pressure Measurements $P_{abs} = P_g + P_b$	P_{abs} – absolute pressure P_g – vacuum pressure gage or tensile pressure P_b – pressure of atmospheric air measured by the use of barometer
sForces on Plane Areas $F = \gamma h_c A$ $h_p = h_c + e$ $e = \dfrac{I_{NA}}{h_c\, A}$ Common I_{NA}	F – volume of pressure diagram h_c – vertical height from fluid surface to neutral axis, m A – plane area, m^2 h_p – vertical height from vertical point of application of F to fluid surface, m e – eccentricity, m I_{NA} – centroidal moment of inertia
Rectangle $I_{NA} = \dfrac{BH^3}{12}$	B – base of the rectangle H – height of the rectangle
Triangle $I_{NA} = \dfrac{BH^3}{36}$	B – base of the triangle H – height of the triangle
Circle $I_{NA} = \dfrac{\pi D^4}{64} = \dfrac{\pi R^4}{4}$	D – diameter R – radius

FLUID MECHANICS

Semi-circle $I_{NA} = 0.1098\ R^4$	 R – radius
Ellipse  $I_{NA} = \dfrac{\pi}{4}\ ab^3$	a – horizontal distance from neutral axis to end of ellipse b – vertical distance from neutral axis to the end of ellipse
 $I_{NA} = \dfrac{\pi}{4}\ ba^3$	a – vertical distance from the neutral axis to the end of ellipse b – horizontal distance from the neutral axis to the end of ellipse
Archimedes Law $BF = V\gamma$	BF – buoyant force V – volume displaced γ – specific weight

FLUID MECHANICS

Vertical Motions of Liquids For upward motion: $P_B = \gamma h\ (1 + a/g)$ For downward motion: $P_B = \gamma h\ (a - a/g)$	a – vertical acceleration g – 9.81 m/s^2 - 32.2 ft/s^2 h – height of fluid γ – specific weight of fluid P_B – pressure exerted by fluid at tank's bottom
For horizontal motion of liquids $\tan\theta = a/g$	θ – angle of inclination of fluids surface where subjected to horizontal motion a – acceleration g – 9.81 m/s^2, 32.2 m/s^2
Inclined plane motion Upward motion: $\tan\theta = \dfrac{ax}{g + ay}$ Downward motion: $\tan\theta = \dfrac{ax}{g - ay}$	ax - a cos β ay – a sin β

FURROW IRRIGATION

Size of Stream $Q_s = 10 / S$	Q_s - maximum non-erosive furrow stream, gpm S - slope of land, %
Safe Length of Furrow $L_s = 1000 / [(I - F) W S]$	L_s - safe length of furrow, ft I - rainfall intensity, iph F - infiltration rate of soil, iph W - furrow spacing, ft S - slope of furrow, %

GAS CLEANING

Minimum Particle Size Diameter for Horizontal Settling Chamber (Particles smaller than 200 micron) $d_{min} = \sqrt{\dfrac{18\ H\ V\ \mu}{\rho_p\ g\ L}}$	d_{min} - particle size that can be retained, m H - height of chamber, m V - gas velocity, m/s μ - viscosity, 220x10-7 kg/m-s for producer gas ρ_p - particle density, 1000-1500 kg/m^3 g - gravitational acceleration, 9.81 m/sec^2 L - length of chamber, m
Diameter of Particles too be Collected from Cyclone Separator at 50% Collection Efficiency $d_{50} = 58.4\ [\ 0.2\ D\ /\ V\ ]$	D_{50} - diameters of particles collected with 50% efficiency, micron D - cyclone separator diameter, m V - inlet gas velocity, m/s

GASIFIER

Heat Energy Demand to Replace Fuel For Diesel Qd = Vfr x 0.845 x 10917 For kerosene Qd = Vfr x 0.7923 x 11,000 For LPG Qd = Mfr x 11767	Qd = heat energy demand, kcal/hr Vfr – mass flow rate, liters/hr Mfr – mass flow rate, kg/hr HVF – heating value of fuel
Weight of Fuel $FCR = Q_a / [\xi_g \ HVf]$	FCR - weight of fuel, kg/hr Q_a – actual heat required, kCal/hr ξ_g - efficiency of gasifier, decimal HVf - heating value of fuel, kCal/kg
Air Required for Gasification AFR = FCR SA e	AFR – air flow rate, kg/hr FCR – fuel consumption rate, kg/hr SA – stoichiometric air, kg air/kg fuel e - equivalence ratio, 0.3 to 0.4
Inner Reactor Diameter (Double Core Down Draft-Type) $D_i = [1.27 \ FCR / SGR]^{0.5}$	D_i - reactor diameter , m FCR - fuel consumption rate, kg/hr SGR - specific gasification rate, kg fuel/m^2-hr
Outer Reactor Diameter (Double Core Down Draft Type) $D_o = 1.414 \ D_i$	D_o - outer core diameter of reactor, m D_i - inner core diameter of reactor, m

GASIFIER

Height of Reactor for Batch Type Gasifier $H_r = FZR\ T_o$	H_r - reactor height, m FZR - fire zone rate, m/hr T_o – operating time
Static Pressure Requirement $P_s = H_r\ \delta_s$	P_s - static pressure requirement in fuel bed, cm H_2O H_r - reactor height, m δ_s - specific draft, cm H_2O/m depth of fuel
Char Discharge Rate $Q_c = FCR\ \ \zeta_c$	Q_c – char discharge rate, kg/hr FCR – fuel consumption rate, kg/hr ζ_c – percentage char produced, decimal
Power Output $Po = 0.0012 \times FCR \times \xi g / HVF$	Po – power output, kw FCR – fuel consumption rate, kg/hr ξg – gasifier efficiency, % HVF – heating value of fuel, kcal/kg
Power Output Rice Husk Gasifier based on Gas Produced $Po = Vfr \times 1400$	Po – power output, kcal/hr Vfr – volumetric flow rate of gas produced, m3/hr
Efficiency of Rice Husk Gasifier $\xi g = Po\ 100 / (Mfr x3000)$	ξg – gasifier efficiency, % Vfr – volumetric flow rate of gas, m3/hr Mfr – mass flow rate of fuel, kg/hr

GEARS

Gear Ratio $GR = T_n / T_r$	GR - gear ratio T_n - number of teeth of driven gear T_r - number of teeth of driver gear
Design Power (Helical and Spur Gears) $P_d = P_t \ (SF_{lo} + SF_{lu})$	Pd - design power, kW Pt - power to be transmitted, kw SF_{lo} - service factor for the type of load, 1.0 -1.8 SF_{lu} - service factor for type of lubrication, 0.1-0.7
Center Distance $CD = \dfrac{M \ (t_1 + t_2)}{2}$	CD - center distance M - module t_1 - number of teeth of the driven gear t_2 - number of teeth of the driver gear
Design Power (Straight Bevel Gear) $P_d = P_t \ SF \ / \ LDF$	P_d - design power, KW P_t - power to be transmitted, KW SF – service factor, 1 to 2.5 LDF – load distribution factor, 1.0 to 1.4
Driver Gear Pitch Angle (Straight Bevel Gear) $\gamma = \tan^{-1} t_1 / t_2$	γ - pitch angle for the driver gear, deg t_1 – number of teeth of the driver gear t_2 – number of teeth of the driven gear
Driven Gear Pitch Angle (Straight Bevel) $\Gamma = 90° - \gamma$	Γ - pitch angle for the driven gear, deg γ - pitch angle for the driver gear, deg

GRAIN DRYER

Drying Capacity $C_d = (W_i / T_d)$	C_d – drying capacity, kg/hr W_i – initial weight of material, kg T_d – drying time, hr
Final Weight of Dried Material $W_f = \dfrac{W_i\,(100 - M_{ci})}{(100 - MC_f)}$	W_f – final weight of dried material, kg W_i – initial weight of material, kg M_{ci} – initial moisture content, % MC_f – final moisture content, %
Moisture Reduction per Hour $MRR = \dfrac{W_i - W_f}{T_d}$	MRR – moisture reduction rate, kg/hr W_i – initial weight, kg W_f – final weight, kg T_d – drying time, hr
Heat Supplied to the Dryer $Q_{sd} = \dfrac{60\,(h_2 - h_1)\,AR}{\gamma}$	Q_{sd} – heat supplied to the dryer, KJ/hr H_2 – enthalpy of drying air, KJ/kg da H_1 – enthalpy of ambient air, KJ/kg da AR – airflow rate, m^3/min γ - specific volume, m^3/kg da
Heat Available in the Fuel $Q_{af} = FCR\ \ HV_f$	Q_{af} – heat available in the fuel, KJ/hr FCR – fuel consumption rate, kg/hr HV_f – heating value of fuel, KJ/hr

GRAIN DRYER

Heat System Efficiency $\xi_{hs} = (Q_{sd} / Q_{af})\ 100$	ξ_{hs} – heating system efficiency, % Q_{sd} – heat supplied to the dryer, KJ/hr Q_{af} – heat available in the fuel, KJ/hr
Heat Utilization $HU = (Q_{sd} \times T_d / MR)\ 100$	HU – heat utilization, KJ/kg Q_{sd} – heat supplied to the dryer, KJ/hr T_d – drying time, hr MR – amount of moisture removed, kg
Heat Utilization Efficiency $\xi_{hu} = \frac{THU}{Q_{sd}} \times 100$	ξ_{hu} – heat utilization efficiency, % THU – total heat utilized, KJ/hr Q_{sd} – heat supplied to the dryer, KJ/hr
Volume of Grain to be Dried $V_g = 1000\ W_i / D_g$	V_g – volume of grain to be dried, m^3 W_i – initial weight of grain, tons D_g – grain density, kg/m^3
Drying Floor Area $A_f = V_g / D_g$	A_f – floor area of bin, m^2 V_g – volume of grain in bin, m^3 D_g – depth of grain in bin, m

GRAIN DRYER

Airflow Requirement $A_f = C \;\; SAF$	A_f – air flow rate, m^3/min C – dryer capacity, tons SAF – specific air flow rate, m^3/min-ton
Apparent Air Velocity in Grain Bed $V_{app} = AF / A_f$	V_{app} – apparent air velocity, m/min AF – total airflow, m^3/min A_f – dryer floor area, m^2
Blower Pressure Draft Requirement $P_d = P_s \;\; D_g$	P_d – blower pressure draft, cm of water P_s – specific pressure draft, cm water per meter depth of grain D_g – depth of grain in bed, m
Theoretical Heat Required $Q_r = \dfrac{H_n \;\; AF}{V_s}$	Q_r – theoretical heat required, KJ/min H_n – net enthalpy, KJ/kg V_s – specific volume of air, m^3/kg
Theoretical Weight of Fuel $WF = Q_r / HVF$	WF – theoretical weight of fuel, kg/min Q_r – total heat required, KJ/min HVF – heating value of fuel, KJ/kg

GRAIN DRYER

Theoretical Volume of Fuel $V_f = WF / D_f$	W_f – theoretical volume of fuel, lpm WF – total weight of fuel, kg/min D_f – density of fuel, kg/liter
Actual Volume of Fuel $FV_a = V_f / \xi_t$	FV_a – actual volume of fuel, lph V_f – theoretical volume of fuel, lph ξ_t –thermal efficiency, decimal
Weight of Moisture Removed $WMR = W_i \left(1 - \dfrac{1 - Mc_i}{1 - MC_f}\right)$	WMR – weight of moisture removed, kg W_i – initial weight of grain to be dried, kg MC_i – initial moisture content, decimal MC_f – final moisture content, decimal
Drying Time $DT = \dfrac{WMR}{AF\ \ V_s\ \ HR}$	DT – drying time, min WMR – weight of moisture to be removed, kg AF – airflow rate mg/min V_s – air density, kg/m^3 HR – humidity ratio, kg moisture/kg da

GRAIN ENGINEERING PROPERTIES

Paddy Porosity P_m = 69.05 - 0.885 M P_l = 65.55 - 0.475 M	P_m – porosity for medium paddy, % P_l – porosity for long paddy, %t M – moisture content wet basis, %
Thermal Conductivity of Paddy Grains K = 0.0500135 + 0.000767 M	K – thermal conductivity, BTU/hr-ft-°F M – moisture content, % wet basis
Specific Heat of Paddy C = 0.22008 + 0.01301 M	C – specific heat, BTU/lb-°F M – moisture content, % wet basis
Length of Paddy (Short Grain) **11.21%<M<21.89%** L = 0.7318 + 0.00122 M	L - length of paddy, cm M – moisutre content of paddy, %
Width of Paddy (Short Grain) **11.21%<M<21.89%** W = 0.3358 + 0.00089 M	W - width of paddy, cm M – moisutre content of paddy, %
Thickness of Paddy (Short Grain) **10.40%<M<22.59%** T = 0.2187 + 0.000089 M	T - thickness of paddy, cm M – moisutre content of paddy, %

GRAIN ENGINEERING PROPERTIES

Coefficient of Thermal Expansion of Milled Rice (For Temp Below 53 °C) C_k = 0.0002403 per C	C_k – coefficient of thermal expansion at storage moisture over a temperature of 30-70 °C
Coefficient of Thermal Expansion of Milled Rice (For Temp Equal and Above 53 °C) C_k = 0.0003364 per C	C_k – coefficient of thermal expansion at storage moisture over a temperature of 30-70 °C
Latent Heat of Vaporization of Paddy HV = 2.32 [1094-1.026 x (T+17.78)] x [1 + 2..4962 Exp (-21.73M)]	HV – latent heat of vaporization, KJ/kg T – air temperature, °C M – moisture content, decimal dry basis
Equilibrium Moisture Content $M_d = E - F \ln [-R (T + C) \ln RH]$	Md – moisture content, decimal dry basis E – constant, 0.0183212 to 0.480920 F – constant, 0.026383 to 0.066826 R – universal gas constant, 1.987 T – temperature, °C C – constant, 12.354 to 120.098 RH – relative humidity, decimal

GRAIN ENGINEERING PROPERTIES

Mass Transfer Coefficient of Paddy K_g = 0.008489-0.000225T +0.000236 RH – 0.00042 Q	K_g – mass transfer coefficient, moisture decimal drybasi-cm^2/h-m^2-kg T – temperature of drying air, °C RH – relative humidity, % Q – airflow rate of drying air, m^3/min
Equilibrium Moisture Content M_d = E – F ln [-R (T + C) ln RH]	Md – moisture content, decimal dry basis E – constant, 0.0183212 to 0.480920 F – constant, 0.026383 to 0.066826 R – universal gas constant, 1.987 T – temperature, °C C – constant, 12.354 to 120.098 RH – relative humidity, decimal
Mass Transfer Coefficient of Paddy K_g = 0.008489-0.000225T +0.000236 RH – 0.00042 Q	K_g – mass transfer coefficient, moisture decimal drybasi-cm^2/h-m^2-kg T – temperature of drying air, °C RH – relative humidity, % Q – airflow rate of drying air, m^3/min

GRAIN SEEDER

Nominal Working Width $W = n \; d$	W - working width, m n - number of rows d - row spacing, m
Effective Diameter of Ground Wheel $D_e = \dfrac{d}{\pi \; N}$	D_e - effective diameter of ground wheel under load, m d - distance for a given N, m N - number of revolution, rpm
Delivery Rate $Q = \dfrac{L \;\; 10{,}000}{\pi \; D_e \; N \; W}$	Q - delivery rate, kg/ha L - delivery for a given N, kg D_e - effective diameter of ground wheel under load, m N – number of revolution, rpm W - working with, m
Delivery Rate (PTO-Driven Machine) $Q = \dfrac{L \;\; 10{,}000}{v \; t \; W}$	Q - delivery rate, kg/ha L - delivery for a given N, kg v - tractor speed, m/s t – time for measuring delivery, s W - working with, m
Effective Field Capacity $e_{fc} = A \; / \; t$	e_{fc} - effective field capacity, m^2/h A - area covered, m^2 t – time used during operation, hr

GRAIN SEEDER

Theoretical Field Capacity $t_{fc} = 0.36\ w\ v$	t_{fc} - theoretical field capacity, m^2/hr w - working width, m v - speed of operation, m/s
Field Efficiency $F_e = (e_{fc} / t_{fc})\ 100$	F_e - field efficiency, % e_{fc} - effective field capacity, m^2/hr t_{fc} – theoretical field capacity, m^2/hr
Fuel Consumption Rate $FC = V / t$	FC - fuel consumption, lph V - volume of fuel consumed, l t - total operating time, hr
No. of Hills Planted $H_n = \frac{A\ 10,000}{S_r\ S_h}$	H_n - number of hills A - area planted, hectares S_r - row spacing, m S_h - hill spacing, m
Wheel Slip $W_s = \frac{N_o - N_l}{N_o} \times 100$	W_s - wheel slip, % N_o - sum of the revolutions of the driving wheel without load, rev N_l - sum of the revolutions of all driving wheel with load, rev
Distance per Hill $D_{ph} = S_r\ \pi\ D_g / Nc$	D_{ph} - distance per hill, mm S_r - speed ratio of ground wheel and seed plate D_g - diameter of the ground wheel, mm N_c - number of cells in the seed plate

GRAIN SEEDER

Speed Ratio of Ground Wheel and Metering Device $$R = \frac{N_c \quad H_s}{C_{gw}}$$	R - speed ratio N_c - number of cells H_s - hill spacing, m C_{gw} - circumference of ground wheel, m
Total Weight of Seeds $$TW_s = \frac{N_h \quad N_{sh} \quad S_w}{1000 \quad E}$$	TW_s - total weight of seeds needed, kg N_h - number of hills N_{sh} – number of seeds per hill S_w - specific weight of seeds, g/seeds E - emergence, decimal

GRAIN STORAGE LOSS

Loss Due to Respiration (Medium Grain) $L_{res} = W_p \times DML$ $DML = 1\text{-}\exp[[-At^C \exp[D(T-60)]$ $\text{Exp}\ [E\ (W-0.14)]]$	L_{res} – weight loss due to respiration, kg W_g – weight of grain stored, kg DML – dry mater loss, decimal t – storage time, hr/1000 T – temperature, °F W – moisture content, decimal wb A – constant, 0.000914 C – constant, 0.6540 D – constant, 0.03756 E – constant, 33.61
Loss Due to Microorganism $Lm = \left(\frac{W_i(100-M_i)}{100} + 0.68 \times 10^{0.44Mi-11.08} \right) D$	L_m - weight loss due to microorganism, kg W_i - weight of incoming stock, tons M_i - moisture content of incoming stock, % w.b. D - storage period, days
Loss Due to Insect $L_i = 0.003\ I_d$	L_i - weight loss due to insects, kg I_d - percent insect damaged kernels at the end of the storage period, %

GRAIN STORAGE LOSS

Loss Due to Rodents $L_r = C\ D$	L_r - weight loss due to rodents, kg C – coefficient, 0.0036, 0.020, 0.035 kg/day for mice, small rats, and big rats respectively D - storage period, days
Loss Due to Birds $L_b = 0.005\ D\ P$	L_b - weight loss due to birds, kg D - storage period, days P - bird population
Loss Due to Spillage $L_s = 0.005\ W_g\ H_f$	L_s - weight loss due to spillage, kg W_g - weight of grain handled, kg H_f – number of times of handling
Total Weight Loss $L_t = L_r + L_m + L_i + L_r + L_b + L_s$	L_t - total weight loss, kg L_r - weight loss due to respiration, kg L_m - weight loss due to microorganism, kg L_i - weight loss due to insect, kg L_r - weight loss due to rodents, kg L_b - weight loss due to birds, kg L_s – weight loss due to spillage, kg

GRAIN STORAGE STRUCTURE

Volumetric Capacity of Cylindrical Grain Bins (Level Full Volume) $$V = \frac{\pi D^2}{4} EH$$	V - bin capacity, m^3 D - bind diameter, m EH - eave height of bin, m
Volumetric Capacity of Cylindrical Grain Bins (Peaked Storage Capacity) $$V = \left(\frac{\pi D^2}{4}\right) EH + \left(\frac{\pi D^2}{4}\right)\left(\frac{(D/2)\tan\phi}{3}\right)$$	V - bin capacity, m^3 D - bind diameter, m EH - eave height of bin, m ϕ - maximum angle of fill, deg
Volumetric Capacity of Cylindrical Grain Bins (Hopper Bottom Bin) $$V = \left(\frac{\pi D^2}{4}\right) EH + \left(\frac{\pi D^2}{4}\right)\left(\frac{(D/2)\tan\phi}{3}\right) + \left(\frac{\pi D^2}{4}\right)\left(\frac{(D/2)\tan\delta}{3}\right)$$	V - bin capacity, m^3 D - bind diameter, m EH - eave height of bin, m ϕ - maximum angle of fill, deg δ - slope of the hopper measured in deg from horizontal

GRAIN STORAGE STRUCTURE

Airflow Resistance $$\Delta P = \frac{a\ Q^2}{\log_e (1+ bQ)} L$$	ΔP - airflow resistance, Pa L - bed depth, m a - constant, 2.57×10^4 for rice; 2.104 for shelled corn Q - airflow, $m^3/s\text{-}m^2$ B - constant, 13.2 for rice and 30.4 for shelled corn
Flow of Grain through Horizontal Orifice $Q_h = 0.028\ A\ D^{0.62}$ (corn 12-15%wb)	Q_h - volume flow, m^3/hr A - area of the orifice, cm^2 D - hydraulic diameter, cm
Flow of Grain through Vertical Orifice $Q_h = 0.016\ A\ D^{0.79}$ (corn 13-165%wb) $Q_h = 0.024\ A\ D^{0.62}$ (sorghum 12-18%wb) $Q_h = 0.018\ A\ D^{0.72}$ (soybean 12%wb)	Q_h - volume flow, m^3/hr A - area of the orifice, cm^2 D - hydraulic diameter, cm
Moisture Content, Wet Basis $$MC = \frac{W_i - W_o}{W_i} \times 100$$	MC - moisture content, % wb W_i - initial weight of sample, g W_o - oven dry weight of the sample, g

GRAIN STORAGE STRUCTURE

Moisture Content, Dry Basis $$MC = \frac{W_i - W_o}{W_o} \times 100$$	MC - moisture content, % wb W_i - initial weight of sample, g W_o - oven dry weight of the sample, g
MC Wet to Dry Basis $$MC_d = \frac{MC_w}{100 - MC_w}$$	MC_d - moisture content dry basis, % MC_w – moisture content wet basis, %
MC Dry to Wet Basis $$MC_w = \frac{MC_d}{100 + MC_d}$$	MC_w – moisture content wet basis, % MC_d - moisture content dry basis, %
Warehouse Capacity (Height of Sack in Pile = 0.225 m) C_{wh} = 15 (L W H) : Rice C_{wh} = 10 (L W H) : Palay C_{wh} = 12 (L W H) : Corn	C_{wh} - estimated warehouse capacity, bags L - effective length of warehouse, m W – effective width of warehouse, m H - effective height of warehouse, m

HEAT TRANSFER

Conduction (Homogenous Wall) $Q_k = k\ A\ (T_o - T_i)\ /\ x$	Q_k - heat transfer rate, W k - thermal conductivity, W / °K-m A - surface area, m^2 T_o - outside wall temperature, °K T_i - inside wall temperature, °K x - wall thickness, m
Conduction (Composite Wall) $Q_k = \dfrac{A\ (T_1 - T_4)}{x_{12}/k_{12} + x_{23}/k_{23} + x_{34}/k^{34}}$	Q_k - heat transfer rate, W k - thermal conductivity, W / °K-m A - surface area, m^2 T_4 - outside wall temperature, °K T_1 - inside wall temperature, °K x - wall thickness, m 1,2,3,4 - represent wall surfaces

HEAT TRANSFER

Conduction (Homogenous Cylindrical Wall) $$Q_k = \frac{2\ \pi\ k\ L\ (T_i\ - T_o)}{L_n\ ro/ri}$$	Q_k - heat transfer rate, W K - thermal conductivity, W / °K-m A - surface area, m^2 L - length of cylinder, m T_o - outside wall temperature, °K T_i - inside wall temperature, K r - radius of wall, m o, i – outside and inside wall surfaces
Convection $Q_h = h\ A\ (T_o - T_i)$	Q_h - heat transfer rate, W h - heat transfer coefficient, W-m^2-°K A - surface area, m^2 T_f - fluid temperature, °K T_s - surface temperature, °K
Radiation $Q_r = \varepsilon\ \lambda\ A\ T^4$	Qr - heat trabsfer rate, W ε - emmisivity λ - Stefan-Boltzman constant, 5.7x104 W/m^2-°K^4 A - surface area, m^2 T - temperature of the surface of the material, °K

HUMAN AND ANIMAL POWER

Human Power $P_g = 0.35 - 0.092 \log t$	P_g – power generated, hp t – time, minutes
Required Human Rest Period $Tr = 60 \; [1 - 250/P\,]$	Tr - required rest period, min/hr of work P - actual rate of energy consumption, watts
Animal Pull $P = \dfrac{W L_1 \mu}{(L + h_2\mu)\cos\alpha + L_2 \mu \sin\alpha}$	P – pull, kg W – animal weight, kg L_1 - horizontal distance between front foot and center of gravity of the animal, m μ - coefficient of friction between hoof and ground surface L – horizontal distance between front and rear feet, m L_2 - horizontal distance of the neck load point from the front foot, m h_2 - height of neck load point from the ground, m α - angle of line of pull from horizontal, deg
Draft Force of Ox $F = [300\,E/D\,] - 0.6\,M$	F - averge draft force, N E - energy available for work, MJ D - distance travelled, km M - weight of ox, kg

HUMAN AND ANIMAL POWER

Drawbar Horsepower DHP = F V	DHP – draw bar horsepower, hp F – load, kg V – speed of animal, m/sec
Total Draft $D_t = NA\ D_s\ f$	D_t – total draft, kg NA – number of animals D_s – draft per animal F – factor, 0.63 for 6 animals and 0.95 for 2 animals
Animal Energy Used for Work E = A F M + B F L + W/C + [9.81 H M] / D C = work done/energy used D = work done in raising body wieght / energy used	E - extra energy used for work, kJ A - energy used to move 1 kg of body weight 1 m horizontally, J F – distance travelled, km M - liveweight, kg L - load carried, kg B - energy used to move 1 kg of applied load 1 m horizontally, J W – work done in pulling load, kJ C – efficiency of doing mechanical work, decimal H – distance move vertically upwards, km D - efficiency of raising body weight, decimal

HYDRAULIC OF WELL

Rate of Flow (Gravity Well) $q = \dfrac{\pi K (H^2 - h^2)}{\log_e R/r}$	q - rate of flow, m^3/s K - hydraulic conductivity, m/s H - height of the static water level above the bottom of the water-bearing formation, m h - height of the water level at the well measured from the bottom of the water bearing formation, m R - radius of influence, m r - radius of well, m
Rate of Flow (Artesian Well) $q = \dfrac{2 \pi Kd (H - h)}{\log_e R/r}$	q - rate of flow, m^3/s K - hydraulic conductivity, m/s d - thickness of the confined layer, m H - height of the static piezometric surface above the top of the water-bearing formation, m h - height of the water in the well above the top of the water bearing formation, m R - radius of influence, m r - radius of well, m

HYDRAULICS

Static Pressure $P = W H$	P - intensity of pressure, kg/m^2 W - unit weight of liquid, 1000 kg/m^3 H - depth of water, m
Continuity Equation $Q = A V$	Q - discharge, m^3/sec A - cross sectional area of pipe, m^2 V - average velocity of water, m/s
Velocity of Flow $V = [2 g H]^{1/2}$	V - velocity of flow, m/s g - gravitational acceleration, m/s^2 H - height of water, m
Friction Loss in Pipe $H_f = [f L V^2] / [2 g D]$	H_f - pressure loss in pipe, m f - friction factor L - length of pipe, m V - average velocity of water in pipe, m/s g - gravitational acceleration, 9.8 m/s^2 D - pipe diameter, m

HYDRO POWER

Water Power $P = 9810\ K\ Q\ H$	P – power output, watts K – turbine efficiency, 0.25 to 0.9 Q – water flow rate, m^3/sec H – head, m
Turbine Specific Speed $N_s = \dfrac{N_t\ P_o^{0.5}}{H^{1.25}}$	N_s – turbine specific speed, dmls N_t – turbine speed, rpm P_o – shaft Power, kW H – pressure head across turbine, m
Jet Speed $V_j = C_v\ (2\ g\ H)^{0.5}$	V_j – jet speed, m/s C_v – nozzle coefficient of velocity, 0.9-0.97 g – gravitational acceleration, 9 m/sec^2 H – head, m
Bucket Speed $V_b = 0.46\ V_j$	V_b – bucket speed, m/s V_j – jet speed, m/s
Runner Diameter $D_{run} = 39 \dfrac{H^{0.5}}{N_t}$	D_{run} – runner diameter, m H – head, m N_t – shaft speed, rpm
Nozzle Diameter $D_n = 0.54 \dfrac{Q^{0.5}}{H^{0.25}}$	D_n – nozzle diameter, m Q – water flow rate, m^3/s H – head, m
Number of Buckets $N_b = 0.5 \dfrac{D_{run}}{D_n} + 15$	H_b – number of buckets D_{run} – runner diameter, m D_n – nozzle diameter, m
Bucket Width $W_b = 3\ D_n$	W_b – bucket width, m D_n – nozzle diameter, m

INFILTRATION, EVAPORATION AND TRANSPIRATION

Infiltration Through Saturated Homogenous Soil $q = K h A / L$	q - flow rate, m^3/s K - hydraulic conductivity of flow, m/s h - head, m A – cross-sectional area of flow, m^2 L - length of flow, m
Evaporation of Water (Pans and Shallow Ponds) $E = (15 + 0.93\ W)\ (C_s - C_d)$	E - rate of evaporation, mm/day W - average wind velocity at 0.15 m, kph C_s – saturated vapor pressure at the temperature of the water surface, mm Hg C_d - actual vapor pressure of the air (Cs x relative humidity, mm Hg

INFILTRATION, EVAPORATION AND TRANSPIRATION

Evaporation of Water (Small Lakes and Reservoirs) $E = (11 + 0.68\ W)\ (C_s - C_d)$	E - rate of evaporation, mm/day W - average wind velocity at 0.15 m, kph C_s – saturated vapor pressure at the temperature of the water surface, mm Hg C_d - actual vapor pressure of the air (Cs x relative humidity, mm Hg
Evapotranspiration (Rice Crops – Wet Season) $ET = 0.8\ E + 0.3$: vegetative stage $E\ T = 0.9\ E + 0.2$: reproductive stage	ET - evapotranspiration rate, mm/day E - pan evaporation, mm/day
Evapotranspiration (Rice Crops – Dry Season) $ET = 0.8\ E + 0.5$: vegetative stage $E\ T = 0.9\ E + 0.5$: reproductive stage	ET - evapotranspiration rate, mm/day E - pan evaporation, mm/day

INTEGRAL CALCULUS

Indefinite Integral $\int f(x)dx = F(x) + C$	$\int$ = integral sign x = integrand C = constant integration
Properties of Indefinite Integral A. definition of integral $\int du = u + C$ B. $\int(du + dv + dw + \ldots) = \int du + \int dv + \int du + \ldots$ C. $\int Cdu = C\int du$	u – is any function C – constant factor
Fundamental Integration Formulas A. Power formula $\int u^n\, du = \frac{u^{n+1}}{n+1} + C$ B. Logarithm $\int \frac{du}{u} = \ln u + C$ C. Exponential Function $\int a^u\, du = \frac{a^u}{\ln a} + C$ D. Trigonometric function $\int \cos u\, du = \sin u + C$ $\int \sin u\, du = -\cos u + C$ $\int \sec^2 u\, du = \tan u + C$ $\int \csc^2 u\, du = -\cot u + C$ $\int \sec u \tan u\, du = \sec u + C$ $\int \csc u \cot u\, du = -\csc u + C$	a – constant u – any function
Integral of tan u, cot u, sec u and csc u: $\int \tan u\, du = -\ln \cos u + C$ $\int \cot u\, du = \ln \sin u + C$ $\int \sec u\, du = \ln(\sec + \tan u) + C$ $\int \csc u\, du = \ln(\csc u - \cot u) + C$ or $\int \csc u\, du = -\ln(\csc u + \cot u) + C$	

INTEGRAL CALCULUS

Transformation Using Trigonometric Formulas	
Type I	
$\int \sin^m u \cos^n u\, du$	m or n – positive odd integer
$\int \sin^m u \cos^{n-1} \cos u\, du$	if m = positive odd integer $\cos^2 u = 1-\sin^2 u$
$\int \cos^n u \sin^{m-1} \sin u\, du$	if m = positive odd integer $\sin^2 u = 1-\cos^2 u$
Type II	
$\int \tan^m u\, du$ or $\int \cot^m u\, du$	m = is positive even integer
$\int \tan^{m-2} u \tan^2 u\, du$	$\sec^2 u = 1 + \tan^2 u$
$\int \cot^n u \csc^{m-2} u \csc^2 u\, du$	$\csc^2 u = 1 + \cot^2 u$
Type IV	
$\int \sin^m u \cos^n u\, du$	m and n = positive even integer
if m = n $\int (\sin u \cos u)^n\, du$	$\sin u \cos u = ½ \sin 2u$
$\int \sin^m u\, du$ $\int (\sin^2 u)^{m/2}\, du$	$\sin^2 u = ½ (1-\cos 2u)$
$\int \cos^n u\, du$	$\cos^2 u = ½ (1+\cos 2u)$
Walli's Formula $\int_0^{\pi/2} \sin^m x \cos^n x\, dx = \dfrac{[(m-1)(m-3)(m-5)\ldots, \text{ or } {}^{2}_{1}][(n-1)(n-3)]}{[(m+n)(m+n-2)(m+n-4)\ldots \text{ or } {}^{2}_{1}]}$	
Inverse Trigonometric Functions	
$\int du / a^2 + u^2 = 1/a \arctan u/a + C$	
$\int du / \sqrt{a^2 - u^2} = \arcsin u/a + C$	
Integration by Parts	
$\int u\, dv = uv - \int v\, du$	

INTEGRAL CALCULUS

Partial Fractions A. Linear and Distinct Factors $\frac{A}{ax + b}$ B. Linear and Repeated Factors $\frac{A}{ax + b} + \frac{B}{(ax + b)^2} + \frac{C}{(ax + b)^3} + \ldots \frac{Z}{(ax + b)^n}$ C. Quadratic and Distinct Factor $\frac{A(2ax + b) + B}{ax^2 + bx + c}$	ax + b – factor of the denomination $(ax + b)^n$ – factor of the denominator $ax^2 + bx + c$ – factor of the denominator - cannot be - factored
Volume of Solids of Revolution Volume of circular disk = $\pi r^2 t$ $dv = \pi r^2 t$ $v = \pi \int r^2 t$ If using vertical element: $v = \pi \int_{x_1}^{x_2} (y_h - y_l)^2\, dx$ If using horizontal element: $v = \pi \int_{y_1}^{y_2} (x_R - x_L)^2\, dy$	r – radius t - time

INTEGRAL CALCULUS

Volume Element: Circular Ring Vol. of circular ring = $\pi r_0^2 t - \pi r_i^2 t$ $dv = \pi (r_0^2 - r_i^2)t$ $v = \pi \int(r_0^2 - r_i^2)t$ Vol. of cylindrical shell = $2\pi rht$ $d v = 2\pi rht$ $v = 2\pi \int rht$	r_0 – the distance from axis of revolution to other end of the area element r_i – the distance from axis of revolution to the nearest end of area element t – dx (if using vertical element) t – dy (if using horizontal element) r – distance from area element to axis of revolution If using vertical element; $t= dx$ $h = y_h\ y_L$ If using horizontal element; $t = dy$ $h = x_R - x_L$
Pappu's Theorem Volume = area ($2\pi R$) If y-axis the axis of revolution; Volume = $2\pi \overline{x}$ (area) If y = b is the axis of revolution; Volume = $2\pi (\overline{y} - b)$ (area) If x = a is the axis of revolution; Volume = $2\pi (a - \overline{x})$ (area)	R – distance from centroid to axis of revolution

IRRIGATION EFFICIENCY

Water Conveyance Efficiency $\xi_c = 100\ W_d / W_i$	ξ_c - water conveyance efficiency, % W_d - water delivered to distribution system, m^3 W_i - water introduced to the distribution system, m^3
Water Application Efficiency $\xi_a = 100\ W_s / W_d$	ξ_a - water application efficiency, % W_s - water stored in the soil root zone, m^3 W_d - water delivered to the area being irrigated, m^3
Water Use Efficiency $\xi_u = 100\ W_u / W_d$	ξ_u - water use efficiency, % W_u - water beneficially used, m^3 W_d - water delivered to the area being irrigated, m^3
Water Storage Efficiency $\xi_s = 100\ W_s / W_n$	ξ_s - water storage efficiency, % W_s - water stored in the root zone during irrigation, m^3 W_n - water needed in the root zone prior to irrigation, m^3

IRRIGATION EFFICIENCY

Water Distribution Efficiency $\xi_d = 100 (1 - y/d)$	ξ_d - water distribution efficiency, % y - average numerical deviation in depth of water stored from the average stored during irrigation, mm d - average depth of water stored during irrigation, mm
Consumptive Use Efficiency $\xi_{cu} = 100 W_{cu} / W_{drz}$	ξ_s - consumptive use efficiency, % W_{cu} - normal consumptive use of water, m^3 W_{drz} – net amount of water depleted from the root zoon, m^3
Uniformity Coefficient $UC = 1 - (y/d)$	UC - uniformity coefficient y - average of the absolute values of the deviation in depth of water infiltrated or caught, m d - average depth of water infiltrated or caught, m

IRRIGATION REQUIREMENT

Water Applied $Q = 27.8\ A\,D\,/\,T$	Q - size of stream, lps A - area irrigated, hectares D - depth of water applied, cm T - time required to irrigate, hours
Time of Application $T = \dfrac{P_w\ A_s\ D\ A}{100\ C\ Q}$	T - time of application, hours P_w - soil moisture in dry weight, % A_s – apparent specific gravity, decimal D - depth of root zone, cm A – area irrigated, hectares Q - size of stream, cubic m per hour C - constant equal to 100
Evapotranspiration $ET = E + T$	ET – evapotranspiration, mm/day E – evaporation, mm/day T - transpiration, mm/day
Water Requirement $WR = ET + P$	WR – water requirement, mm/day ET - evapotranspiration. mm/day P - percolation, mm/day

IRRIGATION REQUIREMENT

Irrigation Requirement IR = WR + FW - ER	IR – irrigation requirement, mm/day WR – water requirement, mm/day FW - farm waste, mm/day ER - effective rainfall, mm/day
Farm Turnout Requirement FTR = IR + FDL	FTR – farm turnout requirement, mm/day IR - irrigation requirement, mm/day FDL – farm ditch loss, mm/day
Diversion Requirement DR = FTR + CL	DR – diversion requirement, mm/day FTR – farm turnout requirement, mm/day CL – conveyance loss, mm/day

MATERIAL HANDLING

Belt Capacity $C = 1710\,A\,S$	C – capacity, bu/hr A – Area of cross-section of belt, m^2 S – Belt speed, m/min
Horsepower to Drive Empty Belt Conveyor $HP_e = \frac{S}{0.3048} + \frac{A+B\,(3.28L)}{100}$	HP_e – horsepower (empty), hp S – belt speed, m/min A – constant, 0.20 to 0.48 @ 36-76 belt width B – constant, 0.00140 to 0.00298 @ 36-76 belt width L – belt length, m
Horsepower to Convey Materials in Belt Conveyor on Level Position $HP_l = C \times \frac{0.48 + 0.01\,L}{100}$	HP_l – horsepower to drive belt conveyor on level position, hp C – belt capacity, tph L – belt length, m
Horsepower to Lift Materials in Belt Conveyor $HP_h = \frac{h}{0.3048} \times 1.015 \times \frac{C}{1000}$	HP_h – horsepower to lift materials, hp h – lift, m C – capacity, tph

MATERIAL HANDLING

Total Horsepower of Belt Conveyor $HP_t = HP_e + HP_l + HP_h$	HP_t – total horsepower, hp HP_e – power to drive empty, hp HP_l – power to drive in level, hp HP_h – power to lift materials, hp
Capacity of Screw Conveyor $C = \dfrac{(D^2 - d^2)}{36.6} \times P \times N$	C – capacity of screw conveyor, ft^3/hr D – screw diameter, in. D – shaft diameter, in P – screw pitch, in (normally equal to D) N – shaft speed, rpm
Power Requirement of Screw Conveyor $HP = \dfrac{L (D S + Q K)}{1,000,000}$	HP – horsepower requirement, hp L – overall length, ft D – bearing factor, 10 to 106 for ball bearing @ conveyor diameter of 7.5 to 40 cm S – Speed, rpm Q – quantity of materials, lbs/hr K –material factor, 0.4 to 0.7
Motor Horsepower of Screw Conveyor $MHP = \dfrac{HP \ P}{0.85}$	MHP – motor horsepower, hp HP – power requirement, hp P – 2 when HP is less than 1; 1.5 when HP is between 1 and 2

MATERIAL HANDLING

Horsepower Requirement when Screw is Inclined Position $HP_i = HP_h \sin \alpha$	HP_i – power requirement when screw is in inclined position, hp HP_h – power requirement in horizontal position, hp α - inclination of the screw, deg
Bucket Elevator Speed $N = \dfrac{54.19}{R^{0.5}}$	N – speed of the head pulley, rpm R – radius of wheel plus ½ the projection of bucket, ft
Bucket Velocity $V_b = \pi D N$	V_b - velocity of bucket, fpm D - pulley diameter, feet N - pulley speed, rpm
Bucket Capacity $C = 60\ Q_b\ n_b\ S_b$	C – elevator capacity, m^3/hr Q_b – bucket capacity, $m^3/1{,}000{,}000$ n_b – number of buckets per meter of belt S_b – belt speed, m/min
Horsepower Requirement of Bucket Elevator $HP = \dfrac{Q\ H\ F}{4562}$	HP – power requirement, hp Q – bucket elevator capacity, kg/min H – lift, m F – 1.5 for elevator loaded in down side; 1.2 for elevator loaded in up side

PIPE FLOW

Flow from Vertical Pipe (50-200 mm Pipe Diameter with H = 0.075 to 0.1m) $$Q = \frac{0.87\ D^2\ H^{1/2}}{287}$$	Q - pipe discharge, lps D - pipe diameter, mm H - vertical rise of water jet, m
Flow from Vertical Pipe (50-200 mm Pipe Diameter with H = 0.3 to 0.6m) $$Q = \frac{0.97\ D^2\ H^{1/2}}{287}$$	Q - pipe discharge, lps D - pipe diameter, mm H - vertical rise of water jet, m
Flow from Horizontal Pipe $$Q = 3.6\ \frac{A\ X}{y^{1/2}}$$	Q - discharge, gpm A - cross sectional area of water at the end of the pipe, in2 X - coordinate of the point on the surface measured parallel to the pipe, in y - vertical coordinate, in

POWER TILLER

Belt Slip $$\%BS = \frac{N_0 - N_1}{N_0} \times 100$$	BS – belt slip, % N_0 – revolution per minute of the driven pulley without slip, rpm N_1 – revolution per minute of the driven pulley under load, rpm
Wheel Slip $$\%\ WS = \frac{Nw_1 - Nw_0}{Nw_1} \times 100$$	Nw_1 – sum of the revolutions of all driving wheels for a given distance with slip, rpm Nw_0 – sum of the revolutions of all driving wheels for the same distance without slip, rpm
Average Swath or Width of Cut $$S = \frac{W}{2n}$$	S – average swath, m W – is the width of plot, m n – is the number of rounds 2 – is the number of trips per round
Total Distance Traveled $$D = \frac{A}{S} = 2nL$$	D – distance traveled, m A – is the area of plot, m^2 L – is the length of the plot, m S – average swath, m n – is the number of rounds

POWER TILLER

Effective Area Accomplished $A_e = wD = 2nLw$ The width of swath is less than the plow's or rotary tiller's width $A_0 = A_e - A$ The width of swath is greater than the plow's or rotary tiller's width $A_u = A - A_e$	A_e – effective area accomplished, m^2 w – width of plow or rotary tiller, m D – distance traveled, m L – is the length of the plot, m n – is the number of rounds A_0 – overlap (area which is plowed or rototilled twice), m^2 A_u – unplowed or rototilled area (area missed), m^2 A – area of the field, m^2
Effective Field Capacity $EFC = \dfrac{60A_e}{t}$	EFC – effective field capacity, m^2/hr A_e – effective area accomplished, m^2 t – time used during the operation, min
Theoretical Field Capacity $TFC = w_e\ v$	TFC – theoretical field capacity, m^2/hr w_e – effective or theoretical width of tillage, m v – speed of operation, m/h

POWER TILLER

Field Efficiency $$F_{eff} = \frac{EFC}{TFC} \times 100$$	F_{eff} – field efficiency, % EFC – effective field capacity, ha/hr TFC – theoretical field capacity, ha/hr
Fuel Consumption $$FC = \frac{V}{t}$$	FC – fuel consumption, lph V – volume of fuel consumed, L t – total operating time, h
Axle/Rotary Shaft Torque $$T = F\ \ L$$	T – shaft torque, kg-m F – axle or rotary shaft load, kg L – length of pony brake arm, m
Axle/Rotary Shaft Power $$P = \frac{F_t\ \ N}{1340}$$	P – shaft power, KW F_t – total axle or rotary shaft load, kg N – speed of axle or rotary shaft, rpm
Specified Fuel Consumption $$SFC = \frac{F_c\ \ P_f}{P}$$	SFC – specific fuel consumption, (g/KW-h) F_c – fuel consumption, L/h P_f – density of fuel, g/h P – axle or rotary shaft power, KW

PUMP

Fluid Horsepower $$Fhp = \frac{q\,\gamma\,H}{550}$$	Fhp – fluid horsepower, hp q – flow rate, cfs γ – fluid specific weight, lb per cu ft H – total head, ft
Hydraulic Efficiency $$\xi_h = \frac{H\ \ Q}{P\ \ 33000} \times 100$$	ξh – hydraulic efficiency, % H – head, ft Q – mass flow rate, lb/min P – power input, hp
Pump Discharge Requirement $$Q = 183.4\ \frac{A\ \ D}{F\ \ H}$$	Q – pump discharge requirement, gpm A – design irrigable area, hectares D – depth of irrigation, inches F – number of days permitted for irrigation, days H – average number of hours of operation, hours per day
Water Horsepower $$P_w = \frac{Q\,H}{102}$$	P_w – water horsepower, hp Q – discharge, lps H – total head, m

PUMP

Pump Brake Horsepower $BHP = P_w / \xi_p$	BHP – pump brake horsepower, hp P_w – water horsepower, hp ξ_p - pump efficiency, decimal
Pump Motor Horsepower $MHP = BHP / \xi_m$	MHP – motor horsepower, hp BHP – pump brake horsepower, hp ξ_m - motor efficiency, decimal
Engine Horsepower $EHP = BHP / \xi_m$	EHP – engine horsepower, hp BHP – pump brake horsepower, hp ξ_m - engine efficiency, decimal 80% for diesel and 70% for gasoline
Overall System Efficiency $\xi_s = (P_w / MHP)\ 100$	ξ_s - overall system efficiency, % P_w – water horsepower, hp MHP – motor horsepower, hp
Total Pump Head $H_t = H_s + (HL_{sp} + HL_f)$	H_t – total head loss, ft H_s – head loss due to elevation, ft HL_{sp} – friction loss on straight pipe, ft HL_f – head loss on fittings, ft
Input Power Delivered to Pump $P_i = 9.8\ q\ h\ /\ \xi_p$	P_i - power input delivered to pump, KW q - discharge rate, m_3/s h - total heat, m ξ_p - pump efficiency, 0.20 to 0.75
Pump Specific Speed $N_s = C\ N\ q^{½}\ /\ h^{¾}$	N_s - specific speed C - 51.65 N – impeller speed, rpm q - flow rate, m^3/s h - head, m

PUMP LAWS

Speed vs Capacity $N_1/N_2 = q_1/q_2$	N_1 – pump speed, rpm N_2 – pump speed, rpm q_1 – pump capacity, gpm q_2 – pump capacity, gpm
Speed vs Head $N_1^2 / N_2^2 = H_1 / H_2$	N_1 – pump speed, rpm N_2 – pump speed, rpm H_1 – pump head, ft H_2 – pump head, ft
Speed vs Power $N_1^3 / N_2^3 = Hp_1 / Hp_2$	N_1 – pump speed, rpm N_2 – pump speed, rpm Hp_1 – pump head, ft Hp_2 – pump head, ft
Impeller Diameter vs Capacity $D_1^3 / D_2^3 = q_1 / q_2$	D_1 – pump diameter, inches D_2 – pump diameter, inches q_1 – pump capacity, gpm q_2 – pump capacity, gpm
Impeller Diameter vs Head $D_1^2 / D_2^2 = H_1 / H_2$	D_1 – pump diameter, inches D_2 – pump diameter, inches H_1 – pump head, ft H_2 – pump head, ft
Impeller Diameter vs Horsepower $D_1^5 / D_2^5 = Hp_1 / Hp_2$	D_1 – pump diameter, inches D_2 – pump diameter, inches Hp_1 – pump power, hp Hp_2 – pump power, hp

PUMP LAWS

Capacity vs Speed and Diameter $q_1 / q_2 = (N_1 / N_2)(D_1^3 / D_2^3)$	q_1 – pump capacity, gpm q_2 – pump capacity, gpm N_1 – pump speed, rpm N_2 – pump speed, rpm D_1 – pump diameter, inches D_2 – pump diameter, inches
Head vs Speed and Diameter $H_1 / H_2 = (N_1^2 / N_2^2)(D_1^2 / D_2^2)$	H_1 – pump head, ft H_2 – pump head, ft N_1 – pump speed, rpm N_2 – pump speed, rpm D_1 – pump diameter, inches D_2 – pump diameter, inches
Horsepower vs Speed and Diameter $Hp_1 / Hp_2 = (N_1^3 / N_2^3)(D_1^5 / D_2^5)$	Hp_1 – pump power, hp Hp_2 – pump power, hp N_1 – pump speed, rpm N_2 – pump speed, rpm D_1 – pump diameter, inches D_2 – pump diameter, inches

RAINFALL AND RUNOFF

Rainfall Intensity $I = (a\ T^{b}) / d^{c}$	I - rainfall intensity, mm/hr T – return period, years d – storm duration, min a, b, and c - constant for a given location
Point Rainfall Analysis (Simple Arithmetic Method) $R_{ave} = \Sigma R / n$	R_{ave} – average rainfall, mm R - rainfall record, mm n - number of rainfall stations
Point Rainfall Analysis (Thiessen Method) $R_{ave} = \dfrac{A_1R_1 + A_2R_2 + \ldots + A_nR_n}{A_t}$	R_{ave} – average rainfall, mm R - rainfall depth, mm $A_{1\text{-}n}$ - area within the polygon, m^2 A_t – entire area of the basin, m^2
Runoff (Rational Method) $Q = C\ I\ A / 360$	Q - peak discharge, m^3/sec C - runoff constant, 0.05 to 0.95 I - rainfall intensity, mm/hr A – drainage area, hectare
Time of Concentration $T_c = 0.0196\ L^{1.15}\ H^{-0.385}$	T_c - time of concentration, min L – length of channel, m H - difference in elevation, m

REAPER HARVESTER

Star Wheel Velocity $V_w = V_f / \cos \alpha$	V_w - average star wheel velocity, m/s V_f - machine forward velocity, m/s α - angle of inclination of star wheel, 22 deg
Flat Belt Conveyor Velocity $V_b = V_{wo} \; P \; N / \pi$ $V_b = 1.4 \, V_f$	V_b - flat belt conveyor velocity, m/s V_{wo} - velocity of outer tip of star wheel lugs, m/s P - pitch of the flat belt lugs, m N – number of star wheel lugs V_f - machine forward velocity, m/s
Pitch of the Flat belt Lugs $P < D \sin (\pi / N)$	P - pitch of the flat belt lugs, m D - diameter of star wheel, m N - Number of star wheels
Velocity Ratio $K = V_k / V_f$ k falls 1.3 to 1.4	K - velocity ratio V_k - average knife velocity, m/s V_f - average forward velocity, m/s

REFRIGERATION

Heat Gain on Walls $Q_w = A\ R_t\ (T_o - T_i)$	Q_w - heat gain from walls, W A - wall surface area, m^2 R_t - thermal transmittance, W/m-°C T_o – wall outside temperature, °C T_i - wall inside temperature, ° C
Air Infiltration Load $Q_{ai} = \dfrac{V_r\ H_f\ AC}{86400}$	Q_{ai} - air infiltration loss, W V_r - room volume, m^3 H_f - heat factor, J AC - Air changes, KJ/m^3
Product Load $Q_p = W_p\ C_p\ (T_i - T_f) / 86400$	Q_p - product load, W W_p - weight of the product, kg C_p - specific heat of the product, J/kg-°C T_i – product initial temperature, °C T_f – product final temperature, °C
Heat of Respiration Load $Q_r = W_p\ HR_p / 86400$	Q_r - heat of respiration load, W W_p – weight of the product, kg HR_p – product heat of respiration, J/kg-day

REFRIGERATION

Light Load $Q_l = L_r$	Q_l - light load, W L_r - lamp rating, W
Human Heat Load $Q_h = N_h\ HR_h\ / 86400$	Q_h - human heat load, W N_h - number of human HR_h - heat of respiration of human, J/man-day
Tons of Refrigeration $TR = TL / 12{,}000$	TR - refrigeration capacity, tons of ref TL – total load, BTU/hr
Latent Heat of Freezing $Q_{lf} = M_w\ LHF$	Q_{lf} - latent heat of freezing water, KJ M_w - mass of water, kg LHF - Latent heat of freezing, 336 KJ/kg

RICE MILLING

Hulling Coefficient $C_h = W_{br} / W_p$	C_h – hulling coefficient, decimal W_{br} – weight of brown rice, grams W_p – weight of paddy, grams
Wholeness Coefficient $C_w = W_{wbr} / W_{br}$	C_w – wholeness coefficient, decimal W_{wbr} – weight of whole brown rice, grams W_{br} – weight of brown rice, grams
Hulling Efficiency $\xi_h = C_h C_w$	ξ_h – hulling efficiency, decimal C_h – hulling coefficient, decimal C_w – wholeness coefficient, decimal
Percentage Brown Rice Recovery $\% BRR = (W_{brr} / W_p) \times 100$	%BRR – percentage brown rice recovery, % W_{brr} – weight of brown rice, kg W_p – weight of paddy, kg
Percentage Broken Milled Rice $\%BR = (W_{br} / W_{mr})\ 100$	%BR – percentage broken rice, % W_{br} – weight of broken rice, kg W_{mr} – weight of milled rice, kg
Throughput Capacity $C_t = 0.2\ W_p / T_o$: brown rice $C_t = [W_p\ MR]/T_o$: milled rice	C_t - throughput capacity, kg/hr W_p – weigh t paddy input, kg T_o - operating time, hr MR – milling recovery, decimal 0.60 to 0.69

RICE MILLING

Percentage Brewer's Rice $\%BrR = (W_{brr} / W_{mr})\, 100$	%BrR – percentage brewer's rice, % W_{brr} – weight of brewer's rice, kg W_{mr} – weight of milled rice, kg
Hear Rice Recovery $\%HR = (W_{hr} / W_{mr})\, 100$	%HR – head rice recovery, % W_{hr} – weight of head rice, kg W_{mr} – weight of milled rice
Milling Recovery $\%\, MR = (W_{mr} / W_p)\, 100$	% MR – milling recovery, % W_{mr} – weight of milled rice, % W_p – weight of paddy, kg
Speed of Low Speed Rubber Roller $N_s = N_h - [0.25 / N_h]$	N_s - speed of slower rubber roller, rpm N_h - speed of faster rubber rollre, rpm
Number of Compartments for Paddy Separator $N_C = C_b / 40$: long grain $N_C = C_b / 60$: short grain	N_C - number of compartments C_b - throughput capacity, kg brown rice per hour
Number of Brake for Vertical Abbrassive Whitener $N_B = [D / 100]$: Germany $N_B = [D / 100]$: Itally	N_B – number of brakes, units D - cone diameter, mm

RICE THRESHER

Grain Ratio $R = (W_g / W_{gs})$	R – grain ratio, decimal W_g – weight of grain, grams W_{gs} – weight of grain and straw, grams
Actual Capacity $C_a = W_c / T_o$	C_a – actual thresher capacity, kg/hr W_c -weight of threshed clean grain, kg T_o – operating time, hr
Corrected Capacity $C_c = \frac{100 - MC_o}{100 - MC_r} \times \frac{R_m}{R_o} \times C_a$	C_c – corrected capacity, kg/hr MC_o – observed moisture content, % MC_r – reference MC, 20% R_m – reference grain-straw ratio, 0.55 R_o – observed grain-straw ratio, decimal C_a – actual capacity, kg/hr
Purity $P = [\, 1 - \frac{W_u - W_c}{W_c} \,]\ 100$	P – purity, % W_u – weight of uncleaned grain, grams W_c – weight of cleaned grains, grams

RICE THRESHER

Total Losses $L_t = L_b + L_s + L_u + L_{sc}$	L_t – total losses, kg L_b– blower loss, kg L_s– separation loss, kg L_{sc} – scattering loss, kg L_u– unthreshed loss, kg
Threshing Efficiency $\xi_t = \dfrac{W_c + L_b + L_s + L_{sc}}{W_c + L_b + L_s + L_u + L_s} \times 100$	ξ_t – threshing efficiency, W_c – weight of clean threshed grain, kg L_b – blower loss, kg L_s – separation loss, kg L_{sc} – scattering loss, kg L_u – unthreshed loss, kg
Threshing Recovery $T_r = \dfrac{W_c}{W_c + L_b + L_s + L_u + L_s} \times 100$	T_r – threshing recovery, % W_c – weight of clean threshed grain, kg L_b – blower loss, kg L_s – separation loss, kg L_{sc} – scattering loss, kg L_u – unthreshed loss, kg

RICE THRESHER

Cracked Grains $C_g = N_{cg}\ 100\ /\ (N_{cg} + N_{ucg})$	C_g – percentage cracked grains, % N_{cg} – number of cracked grains N_{ucg} – number of uncracked grains
Damaged Grain $D_g = N_{dg}\ 100\ /\ (N_{dg} + N_{udg})$	D_g – percentage damage grains, % N_{dg} – number of damaged grains N_{udg} – number of undamaged grains
Fuel Consumption $F_c = F_u\ /\ T_o$	F_c – fuel consumption, Lph F_u - amount of fuel used, liters T_o – operating time, hrs

SHAFT, KEY, AND KEWAYS

Horsepower Transmitted $HP = T N / 63025$ or $HP = F V / 33000$	HP – horsepower transmitted, hp T – torque, in-lb N – shaft speed, rpm
Torque (Solid Shaft) $T = \dfrac{\pi S_d D^3}{16}$	T – torque, in-lb D – shaft diameter, inches S_d – design stress, 6000 psi
Torque (Hollow Shaft) $T = \dfrac{\pi S_d (D_o^4 - D_i^4)}{16 D_o}$	T – torque, in-lb D – shaft diameter, inches S_d – design stress, 6000 psi

SHAFT, KEY, AND KEWAYS

Shaft Diameter (Solid Shaft) $D = \sqrt[3]{\dfrac{16\ T}{\pi\ S_d}}$	D – shaft diameter, inches T – torque, in-lb S_d – design stress, 6000 psi
Shaft Force $F = T / r$	F – force at shaft forces, lb T – torque, in-lb r – radius of shaft, in
Length of Key $L = \dfrac{F}{\sigma_{allow}\ W}$	L – length of key, in F – force, lb σ_{allow} - bearing stress, 25,000 psi W – width of key, in
Length of Key (In Shear) $L = \dfrac{3\ F}{\tau_{all}\ W}$	L – length of key, in F – force, lb τ_{all} – allowable shear, 25,000 psi W – width of key, in

SOIL, WATER, PLANT RELATIONS

Porosity $P = V_v\ 100\ /\ V$	P - porosity, % V_v - volume of voids, cm^3 V - total volume of soil column, cm^3
Void Ratio $VR = V_v\ /\ V_s$	VR - void ratio V_v - volume of voids, cm^3 V_s - volume of solid, cm^3
Degree of Saturation $DS = V_w / V_v$	DS - degree of saturation V_w - volume of water, cm^3 V_v - volume of voids, cm^3
Specific Gravity $\gamma_s = W_{sc}\ /\ W_w$	γ_s - specific gravity of entire soil column W_{sc} - unit weight of entire soil column, g/cc W_w - unit weight of water, g/cc
Soil Moisture Content by Volume Basis $P_v = V_w\ 100\ /\ Vt$	P_v - moisture content by volume, % V_w - volume of water, cm^3 V_t - total volume of soil sample, cm^3
Soil Moisture Content by Volume Basis $P_v = P_w\ A_s$	P_v - moisture content volume basis, % P_w – moisture content weight basis, % A_s - apparent specific gravity

SOIL, WATER, PLANT RELATIONS

Depth of Water $d = P_v \; D_{rz} / 100$	d - depth of water, mm P_v – moisture content by volume, % D_{rz} - depth of root zone, mm
Depth of Water $d = P_w \; A_s \; D_{rz} / 100$	d - depth of water, mm P_w - moisture content by weight, % A_s – apparent specific gravity, decimal D_{rz} – depth of root zone, mm
Total Available Moisture TAM = FC - PWP	TAM - total available moisture, % FC - moisture content at filed capacity, % PWP - moisture content at permanent wilting point, %
Moisture Range MR = RAM – TAM	MR - moisture range, % RAM – readily available moisture, % TAM – total available moisture, %

SOIL AND WATER CONSERVATION ENGINEERING

General formula for water yields of wells $Q = \dfrac{\pi K (H^2 - h^2)}{Log_e R/r}$	Q – rate of flow, ft^3/day K – hydraulic conductivity H – height of the static water level above the bottom of water bearing formation, ft h – height of water level at the ell measured from the water bearing formation, ft R – radius of influence, ft R – radius of the well
Water yield of a confined and unconfined well $Q = \dfrac{2 (\pi) k t(h_c - h_w)}{2.3 \log_{10} (T_e/T_w)}$	
Flow measurement $Q = AV$	Q – discharge, m^3/sec A – cross sectional area of water, m^2 V – mean velocity of water, m/sec
Average stream discharge $Q_{ave} = 2/3 (A_{ave}) (V_{ave})$	Q_{ave} - average discharge, m^3/sec A_{ave} - average stream cross-sectional area, m^2 V_{ave} – maximum stream velocity, m/sec
Weirs and orifices $Q = C L h^m$	Q – discharge C – coefficient dependent on the nature of the crest and approach condition L – length of crest h^m – head of the crest, and the exponent "m" is dependent upon the shape of the weir opening

SOIL AND WATER CONSERVATION ENGINEERING

Orifice under head $Q = CA\sqrt{2gh}$	Q – discharge, m^3/sec A – cross-sectional area of the orifice g – 32.2 ft/sec^2 h – height (depth) of water from surface down to the orifice area
Submerged orifice $q = 0.61\ A\sqrt{2gh}$	q – discharge, m^3/sec A – cross-sectional area of the orifice g – 32.2 ft/sec^2 h – depth of water
Rectangular weir $Q = 2CLh\sqrt{2gh}$ $Q = 2CLh^{3/2}gh$	Q – discharge, m^3/sec C – coefficient of roughness L – h – depth of water g – 32.2 ft/sec^2
Partly-filled orifice $Q = 2hL$	Q – discharge, m^3/sec h – depth of water
Trapezoidal weir $Q = 2.49\ H^{5/2}$	
Triangular notch weir $Q = 2.49\ H^{5/2}$	
Velocity formula $V = \sqrt{2gh}$	V – average velocity, ft/sec g – acceleration due to gravity h – depth of water (feet) or pressure head

SOIL AND WATER CONSERVATION ENGINEERING

Manning velocity equation $V = 1.486/n\ R^{2/3}\ S^{1/2}$	V – velocity, ft/sec n – roughness coefficient R – hydraulic radius of the channel, m S – slope/gradient of the channel
Chezy velocity formula $V = C \sqrt{R \times S}$	C – coefficient of roughness R – hydraulic radius S – slope of water surface, gradient or piezometric head line
Best hydraulic radius croo-section $b = 2\ d\ \tan \theta/2$	b – bottom width of the channel d – depth of water flow θ – side slope of the channel
Water floe for vertical pipe $Q = \frac{K\ D^2\ H^{1/2}}{287}$	Q – discharge, li/sec D – inside pipe diameter, mm H – vertical rise of water jet, m k – discharge coefficient varying from: 0.87 for height of 75 mm to 100 mm, 0.97 for height of 0.3 m to 0.6 m in pipe of 50 to 200 mm in diameter
Flow of water in a horizontally-installed pipe $Q = \frac{[\ 3.6 \times A \times X]}{\sqrt{Y}}$	Q – discharge, gal/min A – cross-sectional area at the end of the pipe, in^2 D – pipe diameter, ft X – coordinates of the point on the surface measures in inches parallel to the pipe Y – vertical coordinate, ft

SOIL AND WATER CONSERVATION ENGINEERING

Water flow in siphon tubes and pipes $Q = 0.65\ A \sqrt{2gh}$	Q – siphon discharge, gal/min A – cross-sectional area of the siphon tube, ft^2 h – suction head, ft
Maximum discharge/flow in furrows $Q = 10/S$	Q – maximum non-erosive stream, gal/min S – slope/gradient of the land/furrow, %
Length of furrows $L = \frac{1,000}{(I-A)WS}$	L – safe length of furrow, ft I – rainfall intensity, in/hr A – absorption or infiltration rate of soil, in/hr W – furrow spacing, ft S – slope/gradient of furrow, %
Intake rate of soil $I = K\ t\ n$	I – intake rate of soil t – time rate that water is on the surface of the soil K – intake rate intercept at unit time n – slope of the line (vertical scaled distance divided by the horizontal scaled distance
Design parameters/formulas in border irrigation a) volume of water $V_t = \frac{W\ [\ C_1 D_0 + E_1\ ]}{X_1}$	V_t – volume of water on the surface of the soil t time t_1 W –width of the border check D_0 – depth of water t the upper end C_1 – shape factor E – depth correction factor E_1 – distance leading to edge in time t_1

SOIL AND WATER CONSERVATION ENGINEERING

Advance distance $$x = \frac{qt}{[k_1 D_0 + k_2\, y_0]}$$	x – distance to the leading edge q – unit stream size or flow per unit width of border strip t – total time of flow D_0 – depth of water at upper end y_0 – cumulative intake at the upper end k_1 – surface storage coefficient varying from 0.5 to less than 1.0
Percolation losses $$P = \frac{(R + 1)^{n+1} - R^{n+1}}{(R + 1)^{n+1} + R^{n+1}} \times 100$$	P – percent water intake which is lost by deep percolation below root zone R – a time ratio n – the exponent of **t** in the intake equation
Unit border stream size $Q_u = 1/E_a\, [\, t_{cr}/(t_{tcr} - t_r)\,]\, [\, D/7.2\, t_{cr}\,]$	Q_u - unit stream, ft^3/sec E_a – water application efficiency expressed as a decimal , 1.0 – P where P is the percolation loss in decimal t_{cr} – time in minutes required for infiltration of D inches of water t_r - recession lag time in minutes (from the time the stream is cut of average area irrigated per set)
Maximum-stream size per foot width of border strip $q_{mx} = 0.06\, S^{0.75}$	q_{mx} – maximum stream in cubic feet per second per foot width of border strip S – lope/gradient, %
Minimum stream size per foot width of strip $Q_{min} = 0.004\, S^{0.5}$	q_{min} – maximum stream in cubic feet per second per foot width of border strip S – slope/gradient, %

SOIL AND WATER CONSERVATION ENGINEERING

Water conveyance efficiency $$E_c = \frac{W_f}{W_e} \times 100$$	E_c - water conveyance efficiency W_t – water delivered to the farm W_e – water delivered from the river or reservoir
Water application efficiency $$E_a = \frac{W_s}{W_f} \times 100$$	E_u – water application efficiency W_s - water stored in the soil root zone during irrigation W_f – water delivered to the farm
Water use efficiency $$E_u = \frac{W_u}{W_d} \times 100$$	E_u – water use efficiency W_u – water beneficially used W_d – water delivered
Water storage efficiency $$E_a = \frac{W_s}{W_n} \times 100$$	E_a - water use efficiency W_s – water stored in the root zone during irrigation W_n – water needed in the root zone prior to irrigation
Water distribution efficiency $E_d = 100 [1 – (y/d)]$	E_d – water distribution efficiency y – average numerical deviation in depth of water stored from average depth stored during irrigation d – average depth of water stored during irrigation

SOIL AND WATER CONSERVATION ENGINEERING

Consumptive use efficiency $E_{cu} = \frac{W_{cu}}{W_d} \times 100$	E_{cu} - consumptive use efficiency W_{cu} – normal consumptive use of water W_d - net amount of water depleted from root-zone soil
Rainfall intensity $I = \frac{KT^x}{t^n}$	I – rainfall intensity K, x and n – constants for a given geographic location t – duration of storm in minute T – return period
Return period and probability of occurrence $T = \frac{100}{P}$	t – return period in years P- probability in percent that an observed event in a given year is equal to or greater than a given event
Thiesen method of rainfall determination $P = \frac{A_1P_1 + A_2P_2 + A_3P_3 + \ldots A_nP_n}{A}$	P – representative average rainfall in a watershed of area A P_1, P_2, P_3 = rainfall depth I the polygon having areas A_1, A_2, A_3 within the watershed
Runoff rates-Rational method q = 0.0028 C I A	q – the design peak runoff rate, m^3/sec C – runoff coefficient i – rainfall intensity in mm/hour for the design return period and for a duration equal to the "time of concentration" of the watershed A – watershed area, ha

SOIL AND WATER CONSERVATION ENGINEERING

Time of concentration $T_c = 0.0195\ L\ 0.77\ S_g^{0.385}$	Tc - time of concentration, min L – maximum length of flow, m S_g –the watershed gradient in m/m or the difference in elevation between outlet and the most remote point divided by the length, L
Flood runoff (Chow method) $q = KA^x$	q – magnitude of the peak runoff (L^3/T) k – coefficient depended on various characteristics of the watershed A – watershed area, L^2
Runoff volume (US/SCS method) $Q = \frac{(I - 0.2S)^2}{1 + 0.8\ S}$	Q – direct runoff depth, mm I – storm rainfall, mm S – maximum potential between rainfall and runoff in mm, starting at the time the storm begins
Required pump capacity for irrigation $Q = 453\ \frac{Ad}{FH}$	Q – discharge, gpm A – design area, acres D – gross depth of irrigation, in. H – average umber of hours of operation per day F – number of days permitted for irrigation, days
Return period (General formula) T = 100/P	T – return period in years P – probability in percent that n observed event in a given year is equal to or greater than a given event

SOIL AND WATER CONSERVATION ENGINEERING

Return period (Gumbel's formula) $$T = \frac{N + 1}{m}$$	T – return period in years N – total number of statistical events m – rank of events arranged in descending order of magnitude
Dimensional flow of water (Darcy equation) $$q = KhA / L$$	q – flow rte (L^3/T) K – hydraulic conductivity f the flow of medium (L/T) h – head or potential causing flow (L) A – cross-sectional area of flow (L^2) L – length of the flow path (L)
Terrace spacing $$V.I. = Xs + Y$$	V.I. – vertical interval between corresponding points of consecutive terraces or from the top of the slope to the bottom of first terrace, m X – constant for geographical location Y – constant for soil erodability and cover condition during critical erosion periods - 0.3, 0.6, or 1.2 with the low value for highly erodable soils with no surface residue and the high value for erosion-resistant soils with conservation tillage s – average land slope above the terrace in percent

SOIL AND WATER CONSERVATION ENGINEERING

Terrace cross section $c + f = h + sW$	c – cut (L) f – fill (L) h – depth of channel including freeboard (L) s – original land slope (L/L) W – width of side slope (L)
Drop spillway capacity (free flow/ no submerged) $q = 0.55\ C\ L\ h^{3/2}$	q – discharge in m^3/s C – weir coefficient L – weir length, m h – depth of flow over the crest, m
Culvert capacity (flowing full condition) $Q = \dfrac{a \sqrt{2gH}}{\sqrt{1 + K_e + K_c L}}$	q – flow capacity (L^3/T) a – conduit cross-sectional area (L^2) H – head causing flow (L) K_e – entrance loss coefficient K_b – loss coefficient for bends in culvert
Top width of dams (those exceeding 3.5 meters) $W = 0.4\ H + 1$	W – top width of dam, m H – maximum height of embankment, m
Wave height in dams $h = 0.014\ (D_f)^{1/2}$	h – height of the wave from trough to crest under maximum wind velocity, m D_f – fetch or exposure, m
Compaction and settlement – volume relationship $V = V_s + V_e$	V – total in-place volume (L^3) V_s – volume of solids particles (L^3) V_e – volume of voids, either air or water (L^3)

SOIL AND WATER CONSERVATION ENGINEERING

Tractive force (on the bottom of open channel) $T = wdsK$	T – tractive force (F/L^2) w – unit weight of water (9800 N/m^3) (F/L^3) d – depth of flow (L) s – slope (hydraulic gradient) (L/L) K – ratio of the tractive force for noncohesive material necessary to start motion of sloping side of a channel to that required to start motion for the same on a level suface
Drainage ditches design capacity $q = 0.013\ CM^{0.833}$	q – runoff, m^3 C - constnt M – watershed area, km^2
Drainage and seepage discharge (from irigted lands in rid regions) – ASAE 1988 $Dc = \frac{I\ (P + S)}{1007}$	D – drainage coefficient lands in rid regions, mm/day P – deep percolation from percolation and bsed on the maximum area to be irrigated at the same time in percent of irrigation application S – field canal seepage los in percent I – irrigation depth of application, days
Discharge equation in pipe drains (Pillsbury, 1985) $Q = 1.56\ A^{0.75}$	Q – maximum flow, L/s A – drained area, ha
Drain size $d = 52.2\ (D_c \times A \times n)^{0.375}\ s^{-0.1875}$	d – inside diameter, mm D_c – drainage coefficient, mm/day A – drainage area, ha n – roughness coefficient s – drain slope, m/m

SOIL AND WATER CONSERVATION ENGINEERING

Load formula for ditch conduits (drainage pipes) $W_c = C_d w B_d^2$	W_c - total load on the conduit per unit length (F/L) C_d – load coefficient for ditch conduits w – unit weight of fill material, (F/L^3) B_d – width of ditch t top of conduit (L)
Conduit formula (for wide ditches) $W_c = C_c w B_w^2$	C_c – load coefficient for projecting conduits B_c – outside diameter of the conduit (L)
Soils loads on flexible pipes $W_c = C_d w B_c B_d$	W_c – total load on the conduit per unit length (F/L) C_d – load coefficient for ditch conduits w – unit weight of fill material, (F/L^3) B_c – outside diameter of the conduit (L) B_d – width of ditch at the top of conduit (L)
Volume storage of reservoir $V = d/2\ (A_1 + A_2)$	V – volume of storage, (L^3) d – distance between end areas (L) A_1 and A_2 – end area (L^2)
Earthwork volumes $V_c = \dfrac{L^2 (\sum C)^2}{4 (\sum C + \sum F)}$	V_c – volume of cut (L^3) L – grid spacing (L) C – cut on the grid corners(L) F – fill on the grid corners (L)

SOIL AND WATER CONSERVATION ENGINEERING

Prismoidal formula $V = d/6\ (A_1 + 4A_m + A_2)$	A_m – middle are halfway between the end areas
Storage volume (when slopes in the reservoir area is given) $V = A_0 d + \dfrac{177\ d^2\ A_0^{1/2}}{S}$	A_0 – area at spillway crest (L^2) d – depth of water above spillway crest (L) S – average slope of reservoir sides and banks, through range of **d**, %
Sprinkler capacity $\text{Capacity} = \dfrac{S_1 S_m \text{ x application rate}}{96.3}$	S_1 – spacing along lateral , ft S_m – spacing between laterals along main in feet
Application rate $I = \dfrac{V_g}{T_{sp}} = \dfrac{1000 \text{ x } q}{S_m \text{ x } S_e}$	I – application rate, mm/hr V_g – gross amount of water applied per irrigation, mm T_{sp} – time of sprinkling, hours q – sprinkler discharge, m^3/hr S_m – spacing between adjacent laterals, m S_e – sprinkler spacing along laterals, m
Irrigation interval $T = \dfrac{V}{C_u}$	T – irrigation interval, day V – net amount of water in single irrigation not to exceed the oil's water holding capacity, mm C_u – consumptive use, mm/day

SOIL AND WATER CONSERVATION ENGINEERING

Number of irrigation days (within irrigation interval) $T = T_k \times T_e$	T – number of irrigation days within the irrigation interval, days T_e – number of days moving the systems and no ater applied
Gross amount of water per application $V_g = V/E_a$	V_g – gros amount of water applied per irrigation V – net amount of water in single irrigation not to exceed the holding capacity of soil E_a – irrigation efficiency
Sprinkler (nozzle) discharge $q = 29.85 \times C \times d_n^2 \times P^{1/2}$	q – sprinkler or nozzle discharge, gpm d_n – diameter of the nozzle orifice, in P – pressure at the nozzle, psi C – coefficient of discharge - 0.95 to 0.98 for well-designed nozzles - 0.80 for larger nozzles
Average area irrigated daily $A_d = A/T_n$	A_d - average area irrigated daily, ha A – total area of the field, ha T_n – number of irrigation days within the irrigation interval, days
Number of times the system is moved per day x = integer [24_{Tsp}]	x – number of times the system is moved per day T_{sp} – time of sprinkling, hrs

Average areas irrigated per set $A_s = A_d/x$	A_s – average area irrigated per set, ha A_d – average areas irrigated dily, ha x – number of times the system is moved per ady
Area irrigated by a single lateral $A_1 = \frac{L_e \times S_m}{1000}$	A_1 – area irrigated by a single lateral, ha L_e – effective length of lateral, m S_m– spacing between adjacent laterals,m
Effective length of lateral $L_1 = N_{sl} \times S_l$	L_1- effective length of laterals, m N_{sl} – number of sprinkler along lateral S_l – spacing of sprinkler long lateral, m
Sprinkler system capacity $Q = A_s \times I$	Q – system capacity A_s – average area irrigated per set I – application rate
Density of sprinkler per hectare $N_{sp} = \frac{10,000}{S_m \times S_l}$	N_{sp} – density of sprinkler per hectare S_m– spacing between adjacent laterals,m S_l – sprinkler spacing along laterals, m

SOIL AND WATER CONSERVATION ENGINEERING

Number of sprinkler per set $N_{set} = A_s \times N_{sp}$	N_{sp} – number of sprinkler per set A_s - average area irrigated per set N_{sp} – density of sprinklers per hectare
Number of lines in a single set $N_{ls} = A_s/A_l$	N_{ls} – number of lines/set A_s – average area irrigated per set A_l – area irrigated by a single lateral
Uniformity of distribution $C_u = 100\left[1 - \dfrac{\sum l \times m - m \times l}{m \times n}\right]$	$\sum$lm – ml – sum of the obsolete deviation of individual collector reading from the mean m – mean of all collector values m_l – individual reading of each collector n – number of collectors

SOLAR THERMAL SYSTEM

Direct Solar Radiation in an Inclined Surface $Q_i = Q_o D A \cos \alpha$	Q_i – Direct solar radiation, kW Q_o – solar constant, kW/m^2 A – absorber surface area, m^2 D – transmission factor, 0.06 – 0.82 α - angle between a line perpendicular to the surface and the direction of radiation
Energy Requirement for Water Space Heating $Q_n = m C_p (T_2 - T_1)$	Q_n – energy needed, kJ/hr m – mass of water needed to be heated per hour, kg C_p – specific heat of water, 4.18 kJ/kg-C T_2 – final temperature of warm water, C T_1 – initial temperature of water, C
Collector Area $A_c = \frac{m C_p}{\eta Q_o \cos \alpha} (T_2 - T_1)$	A_c –collector area, m^2 m – mass of water ,kg C_p – specific heat of water, 4.18 kJ/kg-C T_2 – final temperature of warm water, C T_1 – initial temperature of water, C η - overall efficiency of the solar plant Q_o – average global radiation density α - angle between a line perpendicular to the surface and the direction

SOLAR THERMAL SYSTEM

Heat Gain in the Solar Collector $Q_g = \eta\ IR$	Q_g – heat gain from the solar collector, W/m^2 η - collector efficiency, % IR – Insulation rate, W/m^2
Thermal Efficiency of flat Plate Collector $TE = \alpha\ \tau \cos\beta - \mu \dfrac{T_a - T_u}{Q_g}$	TE – thermal efficiency, % α - heat transfer coefficient of the absorber material τ - transmissivity of the covering surface β - angel between a line perpendicular to the surface and the direction of radiation, deg μ - coefficient for losses through convention, conduction, and insulation T_a – average temp of the absober, C T_u – ambient air temperature, C Q_g – Global radiation intensity, kW/m^2

SOLID GEOMETRY

Area of Square $A_s = S^2$	A_s - area of square, m^2 S - side, m
Area of Rectangle $A_r = W\ L$	A_r - area of rectangle, m^2 W - width, m L - length, m
Area of Triangle $A_t = [B\ H] / 2$	A_t - area of triangle, m^2 B - base, m H - height, m
Area of Parallelogram $A_p = B\ H$	A_p - area of parallelogram, m^2 B - base, m H - height, m
Area of Rhombus $A_{rm} = B\ H$	A_{rm} - area of rhombus, m^2 B - base, m H - height, m
Area of Trapezoid $A_{tr} = [B_1 + B_2]\ H / 2$	A_{tr} - area of trapezoid, m^2 B_1 - upper base, m B_2 - lower base, m H - height, m
Area of Circle $A_c = [\pi /4]\ D^2$	A_c - area of circle, m^2 D - diameter, m
Surface Area of Cone $SA = \pi RS\ [R^2 + H^2]^{0.5}$	SA – surface area, m R – radius, m H – height, m
Surface Area of Conical Frustum $SA = \pi (R+R2)\ [(R1-R2)^2 + H^2]^{0.5}$	SA – surface area, m R1 – top radius, m R2 – bottom radius, m H – height, m
Surface Area of Sphere $SA = 4 \pi R^2$	SA – surface area, m R – radius, m

SOLID GEOMETRY

Area of Ellipse $A_e = \pi R_1 R_2$	A_e - area of ellipse, m^2 R_1 - smaller radius, m R_2 - bigger radius, m
Volume of Cube $V_c = S^3$	V_c - volume of cube, m^3 S - side, m
Volume of Rectangular Parallelepiped $V_p = L W H$	V_p - volume of parallelepiped, m^3 L - length, m W - width, m H - height, m
Volume of Circular Cylinder $V_c = [\pi D^2 H] / 4$	V_c - volume of circular cylinder, m^3 D - diameter of cylinder, m H - height of cylinder, m
Volume of Cone $V_{cn} = [\pi R^2 H] / 3$	V_{cn} - volume of cone, m^3 R - radius of cone, m H - height of cone, m
Volume of Frustum of Right Circular Cone $V_{fc} = [\pi H/2] [r^2 + R^2 + rR]$	V_{fc} - volume of frustum of cone, m^3 R - larger radius of frustum, m r - smaller radius of frustum, m H - height of frustum, m
Volume of Pyramid $Vp = 1/3 L W H$	Vp – volume of pyramid, m^3 L – length of base, m W – width of base, m H – height, m
Volume of Sphere $V_s = 4/3 \pi R^3$	V_s – volume of sphere, m^3 R – radius, m

SPRAYER

Application Rate $$AR = \frac{10000\ Q}{S\ V}$$	AR – application rate, liters per hectare Q – delivery, lpm S – swath, m V – travel speed, m/min
Sprayer Field Capacity $$FC_s = \frac{S\ \ V}{10}$$	FC_s – theoretical field capacity, ha/hr S – swath, m V – travel speed, kph
Actual Sprayer Field Capacity $FC_a = A_s / T_s$	FC_a – actual field capacity, ha/hr A_s – area sprayed, hectares T_s – time spent, hr
Boom Discharge per Minute $Q_b = Q_n\ N_n$	Q_b – boom discharge, lpm Q_n – nozzle discharge, lpm N_n – number of nozzle
Piston Displacement $$D_p = \frac{\pi\ d^2\ L}{4\ (1000)}$$	D_p – piston displacement, liters d – diameter of the cylinder, cm L – length of actual piston travel, cm

SPRAYER

Volumetric Efficiency $\xi_v = (V_a / D_p)\ 100$	ξ_v – volumetric efficiency, % V_a – actual volume discharge, liters D_p – piston displacement, liters
Spraying Speed $V = \dfrac{167\ Q_d}{S\ Q}$	V – travelling speed, m/s Q_d – total discharge quantity of boom sprayer, lpm S – spraying width, m Q – spraying quantity, liters per hectare
Number of Sprayer Load per Hectare $L = Q / C_t$	L - number of loads per hectare Q - application rate, liters per hectare C_t - tank capacity, liters per load

SPRINKLER IRRIGATION

Irrigation Interval $I_i = V / CU$ $I_i = T_{ii} \;\; T_{ms}$	I_i - irrigation interval, days V - net amount of water in single irrigation not to exceed the soil water holding capacity, mm CU - consumptive use, mm/day T_{ii} - number of irrigation days within the irrigation interval, days T_{ms} - number of days of moving the system and no water applied, days
Gross Amount of Water Per Irrigation $V_g = V / \xi_i$	V_g - gross amount of water applied per irrigation, mm/day V - net amount of water applied in single irrigation not to exceed the soil's water holding capacity, mm/day ξ_I - irrigation efficiency, decimal
Application Rate $I = V_g / T_{sp}$ $I = 1000 [Q /(S_m S_l)]$	I - application rate, mm/hr V_g - gross amount of water applied per irrigation, mm T_{sp} - time of sprinkling, hrs Q - sprinkler discharge, m^3/hr S_m - sprinkler spacing between adjacent lateral, m S_l - sprinkler spacing along laterals, m
Area Irrigated by a single Lateral $A_l = [L_e \;\; S_m] / 10000$	A_l - area irrigated by a single lateral, ha L_e - effective length of lateral, m S_m - spacing between adjacent laterals, m

SPRINKLER IRRIGATION

Sprinkler Discharge $Q_s = 30\ C\ D_n^2\ P_n^{0.5}$	Q_s - sprinkler nozzle discharge, gpm C - coefficient of discharge, 0.95 to 0.98 for well designed small nozzle and 0.80 for larger nozzzle D_n - diameter of nozzle orifice, in. P_n - nozzle pressure, psi
Effective Length of Lateral $L_e = N_{sl}\ S_l$	L_e - effective length of lateral, m N_{sl} - number of sprinkler along lateral S_l - spacing of sprinkler along lateral, m
System Capacity $Q_s = A_s\ I$ $Q_s = [453\ A\ d] / [F\ H]$	Q_s - system capacity, ha-mm/day A_s - average area irrigated per set, ha I - application rate, mm/day Q_s - system capacity, gpm A - design area, acre d - gross depth of application, in F - time allowed for completion of one irrigation, days H - actual operating time, hr/day
Density of Sprinklers per Hectare $N_{sp} = 10000 / [S_m\ S_l]$	N_{sp} - density of sprinklers per hectare, units of sprinklers S_m - spacing between adjacent laterals, m S_l - spacing along laterals, m

STATISTICS

Arithmetic mean ($\bar{x}$) For small n: $\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n}$ for large n: $\bar{x} = \frac{\sum fx}{n}$ $\bar{x} = \bar{w} + c\,\bar{d}$ $\bar{d} = \frac{\sum fd}{n}$	$\bar{x}$ - arithmetic mean n– number of observations $\bar{\omega}$ – guess mean or the value estimated to the nearest c – class size n – number of observations
Median $x = L + \frac{n/2 - f_1}{f_2} - C$	c - class size L – lower value of the class range where the median class is located n – number of observations f_1 – cumulative frequency of the premedian class f_2 – frequency of the median class
Mode $x = L = \frac{F - f_{pr}}{2f - f_{pr} - f_{po}}$	L – lower limit of the modal class F – frequency of the modal class f_{pr} - frequency of the premodal class f_{po} – frequency of the post modal class c – class size
Standard deviation For small n: $s = \frac{\sqrt{\sum (x_i - \bar{x})^2}}{n-1}$ For large n: $s = \frac{\sqrt{\sum fx^2 - (\sum fx)^2/n}}{n-1}$	s – standard deviation n – number of observations

STATISTICS

Variance Biased: $s^2 = \dfrac{\sum(x_i - x)^2}{n}$ Unbiased: $s^2 = \dfrac{\sum (x_i - x)^2}{n - 1}$ for small n: $s^2 = \dfrac{\sum(x_i - x)^2}{n-1}$ direct computation: $s^2 = \dfrac{\sum x_i^2 - (\sum x_i)^2/n}{n-1}$ for large n: machine form: $s^2 = \dfrac{\sum fx^2 - (\sum fx)^2/n}{n-1}$ coded data: $s^2 = c^2 \left[\dfrac{\sum fd^2 - (\sum fd)^2/n}{n-1} \right]$	S^2 - variance n – number of observations
Permutation $nPr = \dfrac{n!}{(n-r)!}$	note: 0! = 1 n – number of objects P – number of permutation r - number of objects taken at a time nPr – number of permutation of n objects taken r at a time

STATISTICS

Combination $$nCr = \frac{n!}{(n-r)!\ r!}$$	n – number of objects C – number of combination r – number of objects taken at a time nCr – number of combination of n objects taken r at a time
Sampling and Sampling Designs Sample size: $$n = \frac{N \times z^2 \times (p \times q)}{N \times (Te)^2 + (z^2 + pq)}$$	n – sample size N – population size z – z value of the corresponding confined level adopted Te – tolerable or permissible error for the corresponding confidence level p – the proportion of the population decided to be the included portion q – the proportion of the population decided to be the included portion
Two Ways of Solving a Sample Size 1. Sample size which can satisfy prescribed margin of error of the plot mean. $$n = \frac{(z_\alpha^2)\ (v_s)}{d^2(x^2)}$$ 2. Sample size which can satisfy a prescribed margin of error of the treatment mean. $$n = \frac{(z_\alpha^2)(v_s)}{r(D^2)\ (x^2) - (z_\alpha^2)\ v_p}$$	n – sample size z_α – value of the standardized normal variate corresponding to the level of significance α v_s – sampling variance x – arithmetic mean d – margin or error expressed as a fraction of the plot mean z_α – value of the standardized normal variate corresponding to the level of significance α v_s – sampling variance x – arithmetic mean r – number of replications D – prescribed margin of error expressed of the treatment mean v_p – size of the experimental error

TEMPERATURE

Centigrade to Farenheight $F = (9/5)\ C + 32$	F - farenheight, deg F C - centigrade, deg C
Farenheight to Centigrade $C = (5/9)\ F - 32$	C - centigrade, deg C F - farenheight, deg F
Rankine to Centigrade $C = (5/4)\ R$	C - centigrade, deg C R - rankine, deg R
Centigrade to Rankine $R = (4/5)\ C$	R - rankine, deg R C - centigrade, deg C
Rankine to Farenheight $F = (9/4)\ R + 32$	R - rankine, deg R F - farenheight, deg F
Farenheight to Rankine $R = (4/9)\ F - 32$	F - farenheight, deg F R - rankine, deg R
Centigrade to Kelvin $K = C + 273$	K - Kelvin, deg K C - centigrade, deg C
Farenheight to Kelvin $K = 1.8\ F$	K - Kelvin, deg K F - farenheight, deg F

TILLAGE

Plow Area of Cut $A_c = W_c \; D_c$	A_c – area of cut of plow, m^2 W_c – width of cut, m D_c – depth of cut, m
Draft of Plow $F = A_c \; \delta_s$	F – draft of plow, kg A_c – area of cut, m^2 δ_s – specific resistance of soil, kg/m^2
Drawbar Horsepower $DHP = \dfrac{F \; V}{76.2}$	DHP – drawbar horsepower F – draft of implement, kg V – velocity of implement, m/s
Theoretical Field Capacity $C_t = 0.1 \; W_i \; V_i$	C_t – theoretical field capacity, ha/hr W_i – width of implement, m V_i – implement speed, kph
Effective Field Capacity $C_e = C_t \; \xi_f$	C_e – effective field capacity, ha/hr C_t – theoretical field capacity, ha/hr ξ_f – field efficiency, decimal
Field Efficiency $\xi_f = \dfrac{C_e}{C_t} \times 100$	ξ_f – field efficiency, % C_e – effective field capacity, ha/hr C_t – theoretical field capacity, ha/hr

TILLAGE

Number of Implement Unit $$N_I = \frac{A_f}{T_o\ C_e}$$	N_I – number of implement units A_f – area of the farm, hectares T_o – total operating time to finish operation, hours Ce – effective field capacity of implement, ha/hr
Time to Finish Tillage Operation $$T_o = \frac{A_f}{C_e\ N_I}$$	T_o – time required to finish tillage operation, hr A_f – area of the farm, hectares C_e – effective field capacity, ha/hr N_I – number of tillage implement
Width of Cut of Disc Plow $$W = \frac{0.95\ N\ S + D}{1000}$$	W - width of cut, m N - number of disk S - disk spacing, mm D - diameter of disk, mm
Width of Cut of Disc Harrow (Single Action) $$W = \frac{0.95\ N\ S + 0.3\ D}{1000}$$	W - width of cut, m N - number of disk S - disk spacing, mm D - diameter of disk, mm

TILLAGE

Width of Cut of Disc Harrow (Tandem Type) $$W = \frac{0.95\ N\ S + 1.2\ D}{1000}$$	W - width of cut, m N - number of disk S - disk spacing, mm D - diameter of disk, mm
Width of Cut of Disc Harrow (Offset Type) $$W = \frac{0.95\ N\ S + 0.6\ D}{1000}$$	W - width of cut, m N - number of disk S - disk spacing, mm D - diameter of disk, mm
Draft of Moldboard Plow $D = 7.0 + 0.049\ S^2$: silty clay $D = 6.0 + 0.053\ S^2$: clay loam $D = 3.0 + 0.021\ S^2$: loam $D = 3.0 + 0.056\ S^2$: sandy silt $D = 2.8 + 0.013\ S^2$: sandy loam $D = 2.0 + 0.013\ S^2$: sand	D - unit draft of implement, N/cm^2 S - implement speed, kph

TRACTOR

Engine Speed $V_e = \dfrac{0.333\ R\ N_e}{I}$	V_e – engine speed, km/hr R – diameter of wheel, m N_e – engine speed. Rpm I – reduction ratio, 1st gear equal to 4.48 and 4th gear equal to 1.45
Engine Power $P_w = \eta\ P_e$	P_w – wheel power, kw P_e – engine power, kw η -mechanical efficiency, 0.75 to 0.95
PTO Power $P_{pto} = \eta\ P_e$	P_{pto} – PTO horsepower, kw P_e – engine power, kw η -mechanical efficiency, 0.75 to 0.95
Wheel Axle Torque $T = \dfrac{1000\ N}{2\ \pi\ n}$	T – wheel axle torque, N-m N – wheel axle power, kw n – speed of the wheel axle, rpm

TRACTOR

Wheel Axle Power $P_d = P_w - P_l$ or $= P_w - (P_s + P_r)$	P_d – drawbar power or effective power, kW P_w – wheel axle power, kw P_l – lost power, kw P_s – lost power by slip of wheel, kw P_r – lost power by rolling resistance, kw
Traction Efficiency $\eta_d = P_d / P_w$	η_d – traction efficiency, % P_d – drawbar power, kw P_w – wheel power , kw
Running Resistance $R = C_r W$	R – rolling resistance, kgf C_r – coefficient of rolling resistance0.01 to 0.4 for wheel type and 0.05 to 0.12 for track type W - trator weight, kg
Drive Wheel or Track Slippage $\% \text{ Slip} = 100 \dfrac{R - r}{r}$	% Slip – percent wheel slip, % R – total drive wheel revolution count to traverse the drawbar runway under no load, rev r – total drive wheel revolution count to traverse the drawbar runway under load, rev

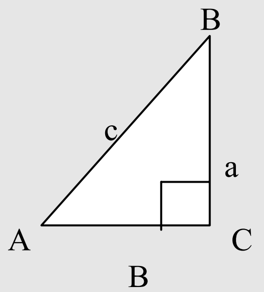
TRACTOR

Travel Reduction or Slip $$S = 100 \frac{A_n - A_l}{A_l}$$	S – slip, % A_n – tract revolution under no load condition, m A_l – tract revolution under load condition, m
Stability Factor $$K = \frac{F_w \; W_b}{P \; h}$$	K – stability factor, 1.25 min F_w – static front end weight, kg W_b – wheel base, P – maximum drawbar pull parallel to ground, kg h – height of static line of pull perpendicular to ground
Drawbar Power $DHP = (F \; S) \; / \; 3.6$	DHP - drawbar power, kW F - force measured, kN S - forward speed, km/hr
PTO Power $PTOP = 2 \; \pi \; F \; R \, N \; / \; 60$ $PTOP = 2 \; \pi \; T \, N \; / \; 60$	PTOP - power take-off power, kW F - tangential force, kN R - radius of force rotation, m N - shaft speed, rpm T - torque, N-m
Hydraulic Power $HyP = P_g \; Q \; / \; 1000$	Hy P – hydraulic power, kW P_g - gage pressure, kPa Q - flow rate, lps

TRACTOR

Drawbar Horsepower $DHP = \xi_m \times NEP$	DHP - drawbar power, hp NEP - net engine power, hp ξ_m - mechanical efficiency, 0.75 to 0.81
PTO Power $PTOP = \xi_m \times NEP$	PTOP - power take-off power, hp NEP - net engine power, hp ξ_m - mechanical efficiency, 0.87 to 0.90
Axle Power $AXP = \xi_m \times NEP$	AXP - axle power, hp NEP - net engine power, hp ξ_m - mechanical efficiency, 0.82 to 0.87
Drawbar Horsepower $DHP = \xi_m \times PTOP$	DHP - drawbar power, hp PTOP – power take-off power, hp ξ_m - mechanical efficiency, 0.86 to 0.89

TRIGONOMETRY



A + B + C = 180°

A + B = 90°

C = 90°

sin θ = opp / hyp

cos θ = adj / hyp

tan θ = opp / hyp

Given $\angle$ is α	Given $\angle$ is β
sin α = a / c	sin β = b / c
cos α = b / c	cos β = a / c
tan α = a / b	tan β = b / a

a - opposite
b – adjacent
c – hypotenuse

Reciprocal terms:
sin θ = csc θ
cos θ = sec θ
tan θ = cot θ
sin 30 = cos (90° - 30°)

co – function:

sin α = cos (90° – α)
cos α = sin (90° - α)
tan α = cot (90° - α)
sec α = csc (90° - α)

Identities: Reciprocal

sin θ = 1 / cos θ; sin θ csc θ = 1

cos θ = 1 / sec θ; cos θ sec θ = 1

tan θ = 1 / cot θ; tan θ cot θ = 1

csc θ = 1 / sin θ
sec θ = 1 / cos θ
cot θ = 1 / tan θ

TRIGONOMETRY

Pythagorean:

$\sin^2\theta + \cos^2\theta = 1$; $\sin^2\theta = 1 - \cos^2\theta$;
$\cos^2\theta = 1 - \sin^2\theta$
$1 + \tan^2\theta = \sec^2\theta$; $1 = \sec^2\theta - \tan^2\theta$;
$\tan^2\theta = \sec^2\theta - 1$

$1 + \cot^2\theta = \csc^2\theta$; $1 = \csc^2\theta - \cot^2\theta$;
$\cot^2\theta = \csc^2\theta - 1$

Ratio:

$\tan\theta = \sin\theta / \cos\theta$; $\tan\theta \cos\theta = \sin\theta$

$\cot\theta = \cos\theta / \sin\theta$; $\cot\theta \sin\theta = \cos\theta$

Half Angle Formulas

$$\sin x/2 = \pm \frac{\sqrt{1 - \cos x}}{2}$$

$$\cos x/2 = \pm \frac{\sqrt{1 + \cos x}}{2}$$

$$\tan x/2 = \frac{1 - \cos x}{\sin x} = \frac{\sin x}{1 + \cos x}$$

Double Angle Formula

$\sin 2x = 2 \sin x \cos x$
$\frac{1}{2} \sin 2x = \sin x \cos x$
$\cos 2x = \cos^2 x - \sin^2 x$
$= \cos^2 x - (1 - \cos^2 x)$
$= 2\cos^2 x - 1$
$= 1 - 2\sin^2 x$

$$\tan 2x = \frac{2\tan x}{1 - \tan^2 x}$$

TRIGONOMETRY

Sum and Difference of Two Angles $\sin(A \pm B) = \sin A \cos B + \cos A \sin B$ $\cos(A \pm B) = \cos A \cos B \pm \sin A \sin B$ $\tan(A \pm B) = \dfrac{\tan A \pm \tan B}{1 \pm \tan A \tan B}$	
Area of Triangle Given three sides a, b and c: Hero's Formula: $A = \sqrt{s(s-a)(s-b)(s-c)}$ $s = \frac{1}{2}(a + b + c)$	

WATER TREATMENT

Settling Velocity $V_s = H / T$	V_s - settling velocity, m/hr H - depth of settling tank, m T - detention time, hour
Volume of Settling Tank $V_t = Q / T$	V_t - volume of settling tank, m^3 Q - throughput, m^3/hr T - detention time, hrs
Filter Surface Area $A = Q / (a\ v)$	A - filter area, m^2 Q - throughput of water, m^3/hr a - operating time, hr/day v - filtration rate, m^3/m^2-hr
Amount of Active Chlorine per Hour $Q_{ac} = D_c\ Q_t$	Q_{ac} - amount of active chlorine per hour, g/hr D_c - chlorine demand, g/m^3 Q_t - amount of water to be treated, m^3/hr
Chlorine Demand $D_c = C_c + R_d$	D_c - chlorine demand, mg/l C_c - chlorine consumption, mg/l R_d - desired residual, 0.1 to 0.3 mg/l

WEIR, FLUMES, AND ORIFICE

Rectangular Weir Without Contraction $Q = 0.0184\ L\ H^{3/2}$	Q – discharge, lps L - length of weir crest, cm H - total head, cm
Rectangular Weir With Contraction $Q = 3.33\ (L - 0.2\ H)\ H^{3/2}$	Q – discharge, lps L - length of weir crest, cm H - total head, cm
Trapezoidal Weir (4h:1l) $Q = 0.0186\ L\ H^{3/2}$	Q – discharge, lps L - length of weir crest, cm H - total head, cm
Triangular Weir (90 deg) $Q = 0.0138\ H^{5/2}$	Q – discharge, lps H - total head, cm
Parshall Flume (1 to 8 ft Throat Width) $Q = 4\ W\ H_a^{1.522\ W^{0.026}}$	Q - discharge, lps W - throat width, cm H_a – head on the crest, cm
Orifice $Q = 0.61 \times 10^{-3}\ A\ (2gh)^{0.5}$	Q – discharge, lps A – area of orifice, cm^2 g – gravitational acceleration, 9.8 cm/sec^2 h – head, cm

WEIR, FLUMES, AND ORIFICE

Submerged Orifice $Q = 0.027\ A\ g\ (h)^{1/2}$	Q – discharge, lps A – area of orifice, cm^2 g – gravitational acceleration, 9.8 cm/sec^2 h – head, cm

WIND ENERGY

Wind Power $P_w = ½ \rho A_r V^3$	P_w – wind power, watts ρ - air density, 1.25 kg/m^3 A_r – rotor area, m^2 V – velocity of the wind, m/s
Performance Coefficient $P_{shaft} = C_p ½ \rho A V^3$	P_{shaft} – power at the rotor shaft, watts C_p – power coefficient, 0.17 to 0.47 ρ - air density, 1.25 kg/m^3 A – rotor area, m^2 V – wind velocity, m/s
Tip-Speed Ratio $\lambda = 2 \pi R N / V$	λ - tips-speed ratio, decimal R – rotor radius, m N – rotor speed, rps V – wind velocity, m/s
Hydraulic Power $P_h = \rho_w g Q H$	P_h – hydraulic power, watts ρ_w – water density, 1000 kg/m^3 g – gravitational acceleration, 9.8 m/s Q – water flow rate, m^3/s H – lifting head, m
Overall System Efficiency $\xi = P_h/P_w$ or $\xi = P_e/P_w$	ξ - overall system efficiency, % P_h – hydraulic power, watts P_e – electrical power, watts P_w – wind power, watts

WIND ENERGY

Windpump Rotor Diameter $D_r = (8\ P_h\ /\ \pi\ \rho_w\ \xi\ V^3)^{1/2}$	D_r – rotor diameter, m P_h – hydraulic power, watts ρ_w – density of water, 1000 kg/m^3 ξ - overall system efficiency, 0.1 V – wind velocity, m/s
Windturbine Rotor Diameter $D_r = (8\ P_e\ /\ \pi\ \rho\ \xi\ V^3)^{1/2}$	D_r – rotor diameter, m P_e – electrical power, watts ρ - air density, 1.25 kg/m^3 ξ - overall system efficiency, 0.2 V – wind velocity, m/s

CONVERSION CONSTANTS

Length	1 ft	= 12 inches
	1 yard	= 3 feet
	1 mi	= 5280 feet
	1 cm	= 0.3937 inch
	1 inch	= 2.54 cm
	1 m	= 3.28 feet
	1 cm	= 10^4 microns
	1 mi	= 1.609 km
Area	1 acre	= 0.4047 hectare
	1 ha	= 2.47 acre
	1 ft^2	= 144 $in.^2$
	1 acre	= 43,560 ft^2
	1 mi^2	= 650 acres
	1 m^2	= 10.76 ft^2
	1 ft^2	= 929 cm^2
	1 $in.^2$	= 6.452 cm^2
Volume	1 liter	= 1000 cc
		= 0.2642 gal
		= 61.025 $in.^3$
		= 10^3 cm^3
	1 ft^3	= 144 $in.^3$
		= 7.482 gal
		= 28.317 liter
		= 28,317 cm^3
	1 acre-ft	= 43,560 ft^3
	1 gal	= 3.7854 liter
		= 231 in^3
		= 8 pint

	1 m^3	= 35.31 ft^3
		= 10^3 liter
Density	1 lb/in.^{3}	= 1728 lb/ft^3
	1 slug/ft^3	= 32.174 lb/ft^3
		= 0.51538 gm/cm^3
	1 lb/ ft^3	= 16.018 kg/m^3
	1 gm/cm^3	= 1000 kg/m^3
Angular	2π	= 6.2832 radian
	1 rad	= 57.3 deg
	1 rev	= 2π
	1 rpm	= 2π rad/min
	1 rad/sec	= 9.549 rpm
Time	1 min	= 60 seconds
	1 hour	= 3600 seconds
		= 60 min
	1 day	= 24 hours
Speed	1 mph	= 88 fpm
		= 0.44704 m/s
		= 1.467 fps
	1 fps	= 0.6818 mph
		= 0.3048 m/s
	1 knot	= 0.5144 m/s
		= 1.152 mph
	1 m/s	= 3.6 kph
		= 2.24 mph
		= 3.28 fps

Force, Mass	1 lb	=	16 oz
		=	444,820 dynes
		=	32.174 poundals
		=	4.4482 N
		=	7000 grains
		=	453.6 g
	1 slug	=	32.174 lb
		=	14.594 kg
		=	14.594 kg
	1 kg	=	2.205 lb
		=	9.80665 N
		=	1 kilopond
	1 kip	=	1000 lb
	1 g	=	980.665 dynes
	1 ton	=	2000 lb
		=	907.18 kg
	1 oz	=	28.35 gm
	1 metric ton	=	1000 kg
	1 Newton	=	9.8 kgf
		=	0.225 lbf
Pressure	1 atm	=	1.033 bar
		=	33.90 ft of water (at 4°C)
		=	10.33 m of water (at 4°C
		=	14.7 psi
		=	101,325 N/m^2
		=	29.921 in. Hg (0°C)
		=	33.934 ft H_2O (60°F)
		=	760 mm Hg (O°C)
		=	406.79 in. H_2O (39.2°F)
		=	1.0332 kg/cm^2

	1 bar	=	10 m of water
	1 mm Hg (0°C)	=	13.6 kg
	1 psi	=	27.684 inches of water
		=	2.036 inches mercury
		=	51.715 mm Hg (0 C)
		=	0.0731 kg/cm^2
	1 psf	=	47.88 N/m^3
	1 in. Hg (60°F)	=	13.57 in. H_2O (60°F)
		=	0.4898 psi
	1 N/m^2	=	0.1 $dyne/cm^2$
	1 in H_20	=	0.0361 psi
		=	0.0736 inches mercury
Energy	1 Btu	=	778.16 ft-lb
		=	251.98 cal
		=	1.055 kJ
	1 hp-hr	=	2544.4 Btu
	1 J	=	1 wt-s
		=	1 N-m
		=	0.01 bar-dm^3
	1 hp-s	=	550 ft-lb
	1 hp-min	=	42.4 Btu
		=	33,000 ft-lb
	1 kw-hr	=	3412.2 Btu
		=	3600 kJ
	1 kJ	=	1 kw-s
		=	101.92 kg-m
	kcal/gmole	=	1800 Btu/pmole

1 wt-s	=	1 V-amp
1 kw-s	=	737.562 ft-lb
1 kw-min	=	56.87 Btu
1 atm-ft^3	=	2.7194 Btu
1 J	=	10^7 ergs
1 ft-lb	=	1.3558 J
1 kcal	=	4.1668 kJ
1 hp	=	0.746 kw
1 kW	=	1.34 hp
	=	1.32 cv metric horsepower in French
1 PS	=	0.986 Hp
1 wt-hr	=	860 cal

Entropy, Specific Heat, Gas Constant

1 cal/g-°K	=	1 Btu/lb-°R
1 kcal/kg-°K	=	1 kcal/kg-°R
1 Btu/lb-°R	=	4.187 kJ/kg-°K

Universal Gas Constant

1 pmole-°R	=	1545.32 ft-lb
	=	0.7302 atm-ft^3
	=	1.9859 Btu
	=	10.731 psi-ft^3
1 kgmole-°K	=	8.3143 kJ
	=	0.08206 atm-m^3
1 gmole-°K	=	82.057 atm-cm^3
	=	1.9859 cal
	=	83.143 bar-cm^3
	=	8.3143 J
	=	8.3149 x 10^7 erg
	=	0.083143 bar-liter

Standard Gravity g, (as conversion unit)

1 slug	=	32.174 fps^2-lb
1 psin	=	388.1 ips^2-lb
1 s^2-kg	=	9.80665 N-m
1 s^2-gm	=	980.665 cm-dynes

REFERENCES

AMTEC. Philippine Agricultural Engineering Standards. Volume I. Agricultural Machinery Testing and Evaluation Center. College of Engineering and Agro-Industrial Technology. University of the Philippines, Los Banos, College Laguna.

AMTEC. Philippine Agricultural Engineering Standards. Volume II. Agricultural Machinery Testing and Evaluation Center. College of Engineering and Agro-Industrial Technology. University of the Philippines, Los Banos, College Laguna.

Andreas, J. C. 1982. Energy-Efficient Electric Motors. Selection and Application. Marcel Dekker, Inc. 270 Madison Avenue, New York, New York 10016 USA. 200pp.

Aprovecho Institute. 1984. Fuel Saving Cookstove. GATE/GTZ, Postbox 5180, D-6236 Eschborn 1, Federal Republic of Germany. 128pp.

ASAE. ASAE Standards 1997. Standard Engineering Practices Data. The Society for Engineering in Agricultural, Food and Biological Systems. 2950 Niles Road, St. Joseph, MI 49085-9659 U.S.A. 978pp.

Boost, M. 1992. Refrigeration. CBS Publishers and Distributors. 485 Jain Bhawan BholaNath Nagar, Delhi. 450 pp.

Brown, R. H. 1956. Farm Electrification. Mc-Graw-Hill Book Company. New York. U.S.A. 367pp.

Butlig, F. and R. Branzuela. 1988. Handbook of Applied Engineering. Formulas: Irrigation and soil and Water Conservation. National Book Store. Metro Manila. 90pp.

Campbell, J.K. 1990. Dibble Sticks, Donkeys and Diesel. International Rice Research Institute. Los Baños, Laguna, Philippines. 329pp.

Cardenas. E. 1989. Fundamentals of Electricity. National Bookstore. Quad alpha Centrum Bldg. 125 Pioneer St. Mandaluyong City.. 141pp.

CLSU. Training Course Manual on Design, Installation, and Evaluation of Drip/Sprinkler Irrigation Systems. Training Course Manual. Central Luzon State University, Munoz, Nueva Ecija. October 1995.

Creamer, R. H. 1984. Machine Design. Third Edition. Addison-Wesley Publishing Co., Inc. Reading, Mass. USA. 654pp.

Eldridge, Frank R. Wind Machines. The MITRE Energy Resources and Environment Series. New York: Van Nostrand Reinhold Co. 2nd edition. 1980. 215pp.

Fajardo, M. 2001. Simplified Methods on Building Construction. Second Edition. 5138 Merchandizing. 10-A Pangilinan Street, Congressional Avenue. Project 6 diliman, quezon City. 389pp.

GATE/GTZ. 1986. Solar Energy: Status Report. GATE//GTZ. Postbox 5180. D-6236 Eschborn 1. Federal Republic of Germany. 54pp.

GATE/GTZ. Wind Energy. Postbox 5180, D-6236 Eschborn 1, Federal Republic of Germany. 1985. 54pp.

Herber, G. 1985. Simple Methods for the Treatment of Drinking Water. GATE/GTZ. Postbox 5180, D-6236 Eschborn 1, Federal Republic of Germany. 77pp.

Hunt, D. 1983. Farm Power and Machinery Management. Eight Edition. Iowa State University Press. Ames, Iowa. 352pp.

IRRI. Small Farm Equipment for Developing Countries. Proceedings of the International Conference on Small Farm Equipment for Developing Countries: Past Experiences and Future Priorities 2-6 September 1985. The International Rice Research Institute. P.O. Box 933, Manila, Philippines. 629pp.

Jacob, M. and G. Hawkins. 1957. Element of Heat Transfer. 3rd Edition. John Wiley and Sons. New York. 317pp.

Kaupp, A. 1984. Gasification of Rice Hulls. GATE/GTZ, Postbox 5180, D-6236 Eschborn 1, Federal Republic of Germany. 303pp.

Krutz, G., Thompson, L., and P. Claar. 1984. Design of Agricultural Machines. John Wiley and Sons, Inc. New York, USA. 472pp.

Levinson, I. J. 1978. Machine Design. Reston Publishing Company, Inc. Reston, Virginia. A Prentice-Hall Company. Reston Virginia. 512pp.

Miller, R and M. R. Miller. 1984. Small Gasoline Engines. Theodore Audel and Company. Boston. 632pp.

PCARRD. The Philippine Recommends for Irrigation Water Management. Philippine Council for Agricultural and Natural Resources Research and Development. Los Banos, Laguna. 120pp.

RNAM. Agricultural Machinery Design and Data handbook. (Seeders and Planters). Regional Network for Agricultural Machinery. Economic and Social Commission for Asia and the Pacific. United Nation Bldg., Rajadamnem Avenue, Bangkok, Thailand. October 1991. 137pp.

Sasse, Ludwig. 1984. Biogas Plants: Design and Details of Simple Biogas Plants GATE/GTZPostbox 5180. D-6236 Eschborn 1. Federal Republic of Germany. 85pp.

Smith, H.P. and L.H. Wilkes. 1977. Farm Machinery and Equipment. Sixth Edition. Tata Mc-Graw Hill Publishing Company LTD. New Delhi, India. 487pp.

Stephenson, G. E. 1984. Small Gasoline Engines. Fourth Edition. Delmar Publishers Inc. Canada. 279pp.

Schwab, G., Barnes, K., Frevert, R., and T. Edminster. Elementary. 1971. Soil and Water Engineering. Second Edition. John Wiley and Sons. New York. 316pp.

Schwab, G., Fangmeier, D., Elliot, W., and R. Frevert. 1993. Soil and Water Conservation Engineering. Fourth Edition. John Wiley and Sons, Inc. New York. 507pp.

Starkey, P. Harnessing and Impelemtns for Animal Traction. GATE/GTZ, Postbox 5180, D-6236 Eschborn 1, Federal Republic of Germany. 245pp.

Tanaka, T. Farm Tractor. Handout Sheet. JICA Agricultural Machinery Management Course. Japan. 45pp.

Velasco, R. 1997. Handbook of Construction Estimate. Loacan Publishing House. Metro Manila. 147pp.

Wimberly, J.E. 1983. Technical Handbook for the Paddy Rice Postharvest Industry in Developing Countries. The International Rice Research Institute. Los Baños, Laguna. Philippines. 188pp.