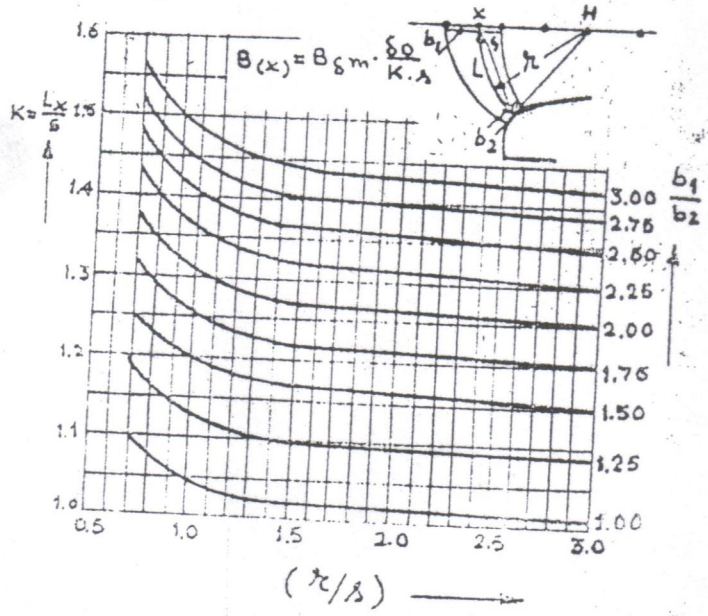


FIG. 16 CURVES FOR CONSTRUCTING FLUX DISTRIBUTION CURVES

(ENTWERFEN ELEKTRISCHER MASCHINEN 3 LEHRBRIEF P. 163)

For occ.

	40%	60%	80%	100%	120%	130%
$\phi_1 \Leftarrow \phi$						
$B_{\delta 1} \Leftarrow B_{\delta m}$						
B_{tt}						
B_{tm}						
B_{tb}						
at_{tt}						
at_{tm}						
at_{tb}						
at_{at}						
B_y						
at_y						
$\phi_{p\,(total)}$						
B_{pc}						
B_{py}						
at_{pc}						
at_{py}						
$AT_{2\delta}$						
AT_{2at}						
AT_y						
AT_{2pc}						
AT_{py}						
$AT_{pole\ pair}$						

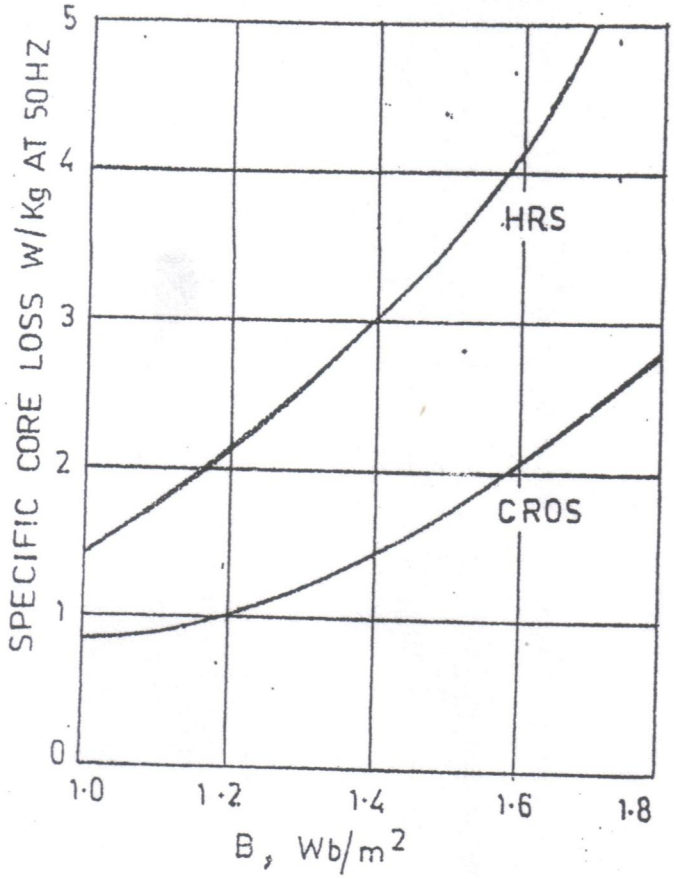


fig. 16(a) Specific core loss at 50 Hz (CRGO) Transformer : 0.35 mm thickness

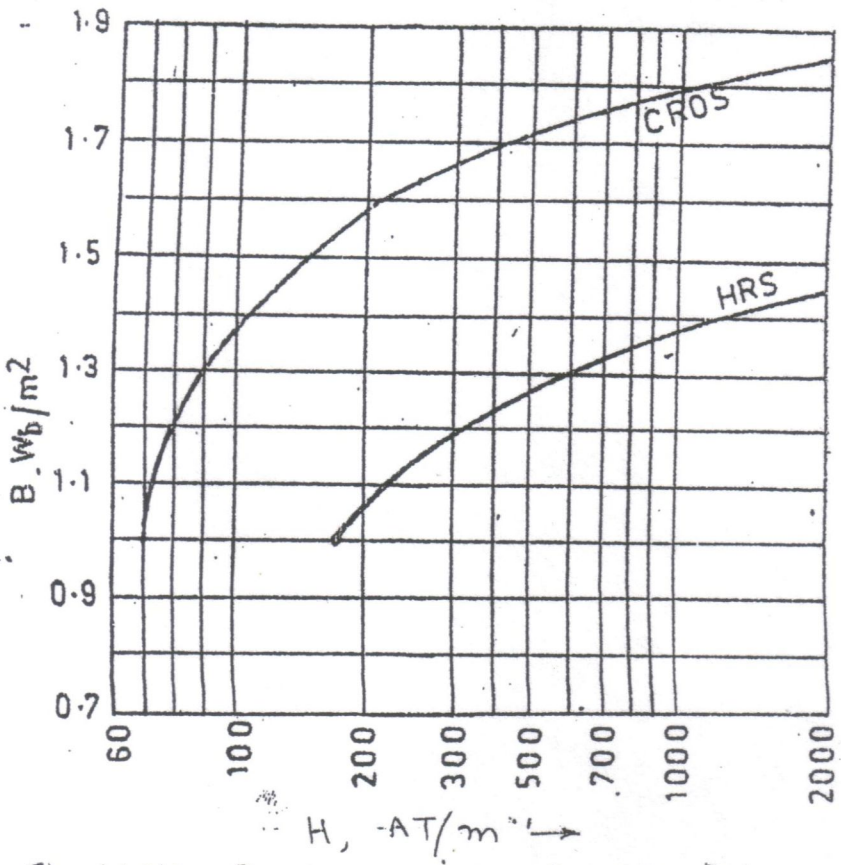
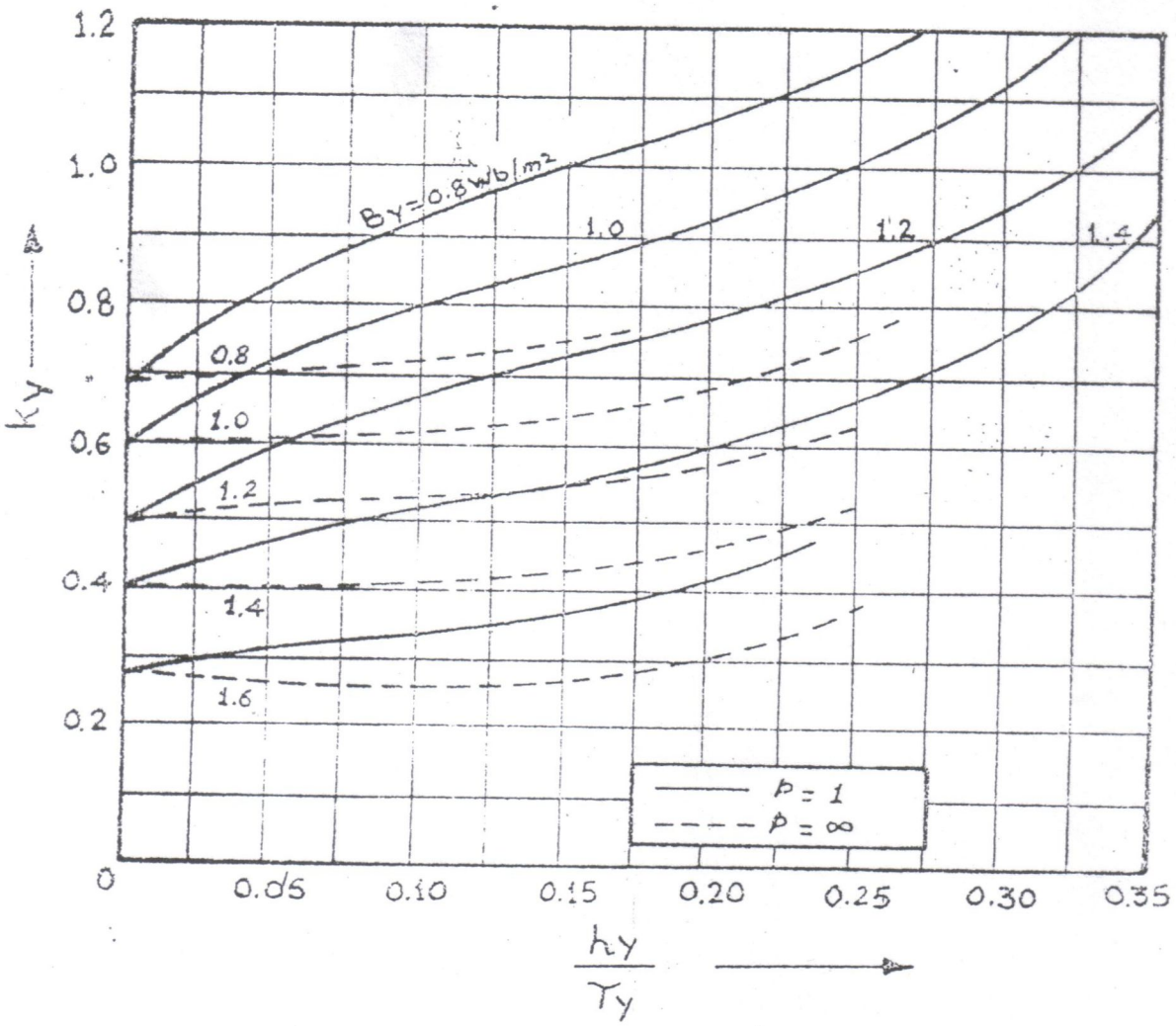


Fig 16(b) B-H curve (CRGO)

CURVES TO ESTIMATE THE M.M.F REQUIRED FOR ARMATURE YOKE



hy = THICKNESS OF YOKE

τ_y = YOKE MEAN POLE PITCH

By = AVERAGE FLUX DENSITY IN YOKE

FIG. 17

$$L = l + n_u b_u$$
$$l_e = L - n_u b_u'$$
$$b_u' = b_u \frac{5}{5 + b_u/\delta}$$
$$l_i = k_i l$$

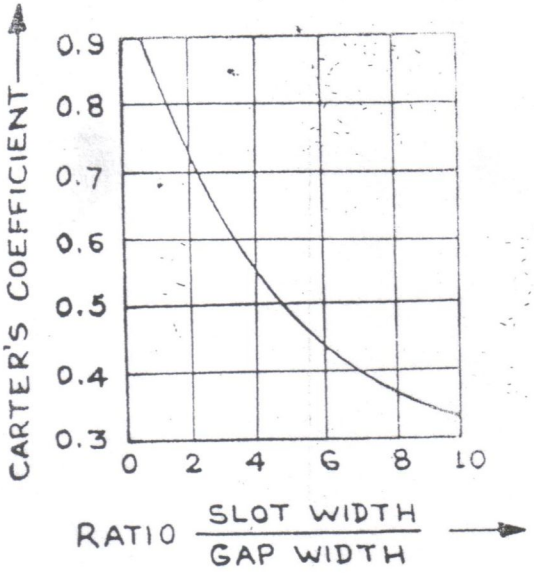


FIG.18. CARTER'S AIR GAP CONTRACTION COEFFICIENT.

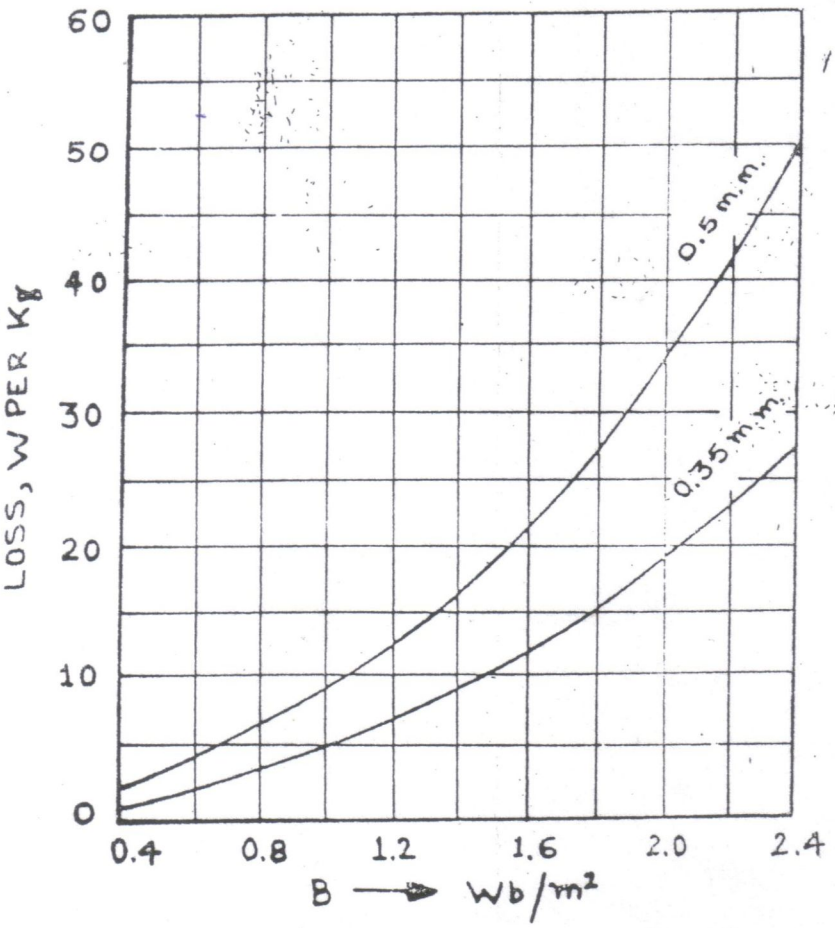


FIG. 19 CORE LOSSES AT 50 Hz FOR ROTATING MACHINES.

SYNCHRONOUS MACHINE

1) $B_{\delta_1} = 2\left[0.0431 u_1 + 0.0833 u_2 + 0.1179 u_3 + 0.1443 u_4 + 0.1610 u_5\right] + 0.1667 u_6$

2) $B_{\delta_3} = 2\left[0.1179 (u_1 + u_3 - u_5) + 0.1667 u_3\right] - 0.1667 u_6$

$K_\delta = \frac{B_{\delta 1}}{B_{\delta m}}$, $K_\phi = \frac{\phi_1}{\phi_{pole}}$

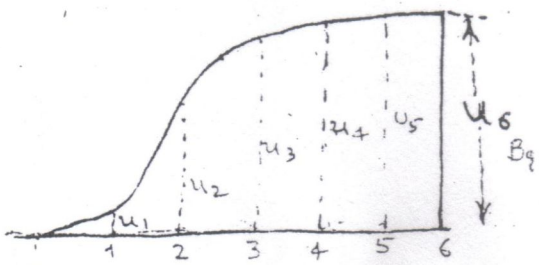


Fig 20

II Slot Insulation

a) Micanite Wall Insulation

kV	.4	1.1	3.3	6.6	11	15	22
mm	.5	.75	1.5	2.5	4	5.5	6.5

b) Semi-catherm Wall Insulation

kV	2	3	6	10	16	25
mm	1.1	1.4	1.8	2.8	4	6

Thickness $= 0.215\, x + .7$ mm
where x is voltage in kV

III Pole form arc of a circle

Air gap at any point x

$$\delta_x = \delta_0 + \frac{H}{2r}(H + r)\sin^2 \phi_x$$

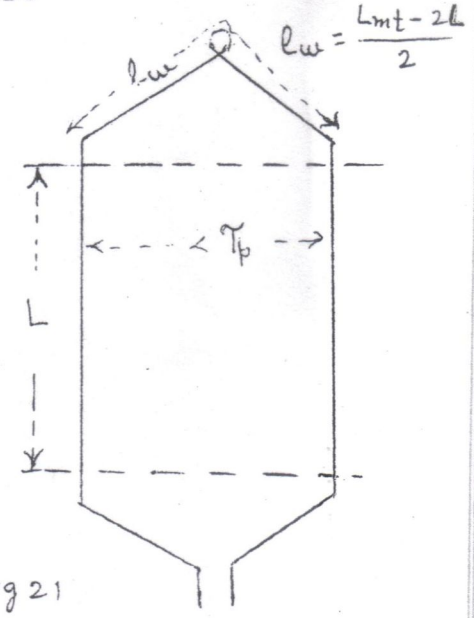


Fig 21

$$L_{mt} = 2\left[L + 1.25\,\tau_p + \frac{3kV + 1}{100}\right]$$

or

$$= 2\left[L + 1.5\,\tau_p\right]$$

IV a) Tooth top leakage Reactance X_{tl}

$$\lambda_{tl} = \frac{5\delta/b_0}{5 + 4\delta/b_0} \quad \text{(Cylindrical rotor)}$$

$$\lambda_{tl} = \frac{5\delta/b_0}{5 + 4\delta/b_0} \cdot \frac{b_p}{\tau_p} \quad \text{(salient pole)}$$

German Book
Richter Vol. II, p. 90

$$X_{tl} = 2\pi f L_{tl}$$

where $L_{tl} = \mu_0 \frac{N_{ph}^2}{pq} L \lambda_{tl}$

p = no. of poles

End winding leakage (End wdg leakage)

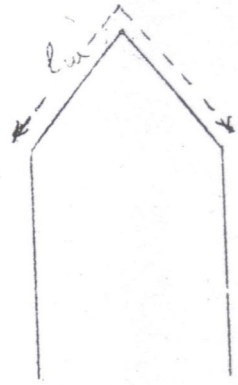


Fig 22

$X_{el} = 2\pi f L_{el} = X_{el}$

where $L_{el} = \mu_0 \frac{N_{ph}^2}{p} l_w \lambda_{el}$

and λ_{el}

		m = 3 Stator	m = 3 Rotor	m = 1 Stator
λ_{el}	1 layer	·3	·25	·12
	2 layer	·25	·20	·17

Ref: Handbook of Elec. Engg. Vol-II, Phillipnow (German) p. 182, Table 1.36

Losses ΣP in kW

Cu. loss : stator + field

Iron " : stator

Pole face loss : 25–70% of Iron loss

Stray load loss : ≈ 20% of total cu. loss due to harmonic fields when machine is loaded and also in overhang region.

F & W loss : 0.2–0.8% of m/c rating

: 0.2–0.4% with H_2 cooling

(for small m/cs about 1% & in fans 100%)

Cooling:

Quantity of cooling water reqd for cooling of air of enclosed machine. $= \frac{0.24\,\Sigma P}{\theta\ (\text{temp rise in } ^\circ C)}$ Li/sec (Loss in kW)

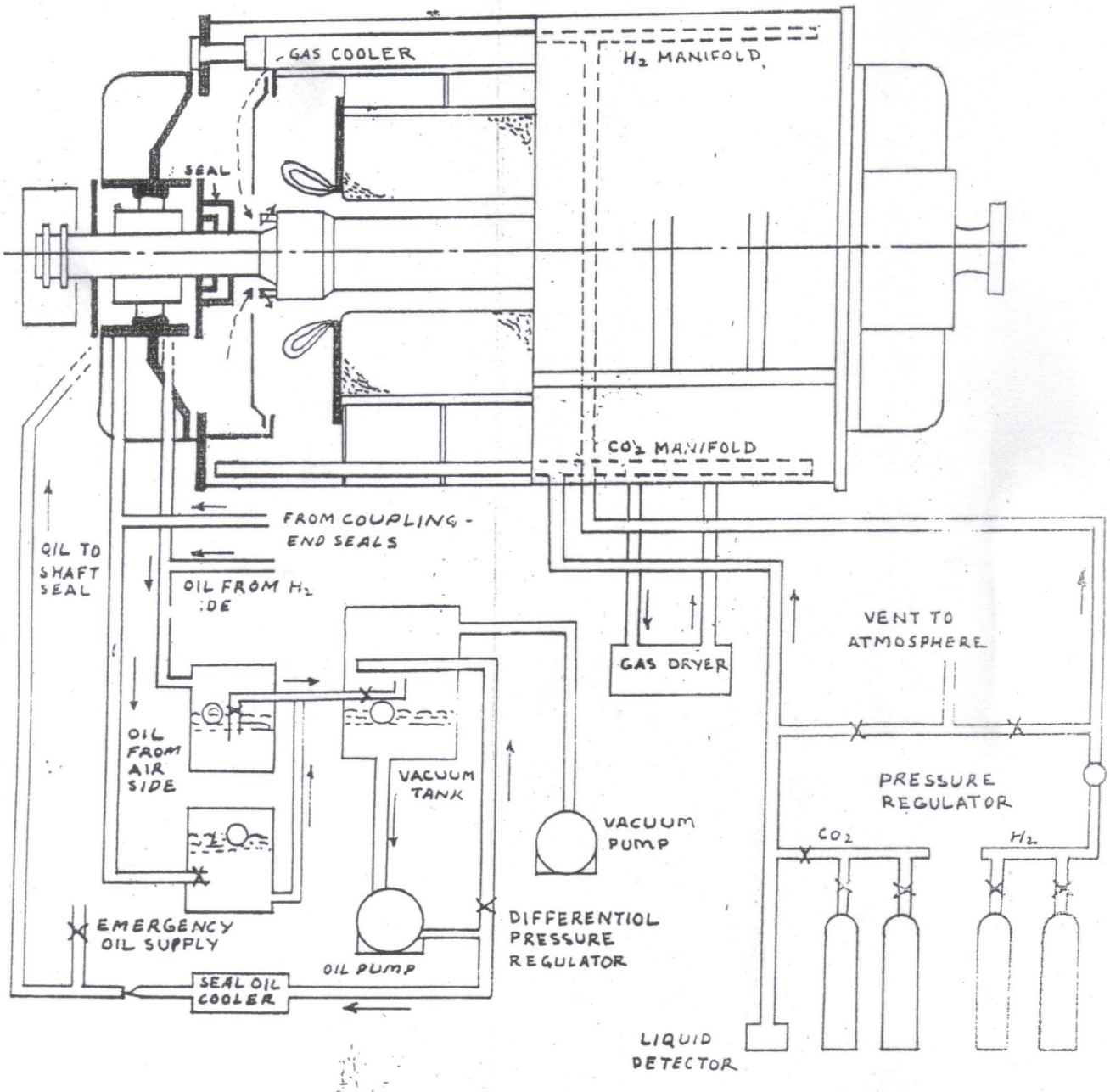


FIG. 23 ARRANGEMENT OF HYDROGEN-COOLING SYSTEM

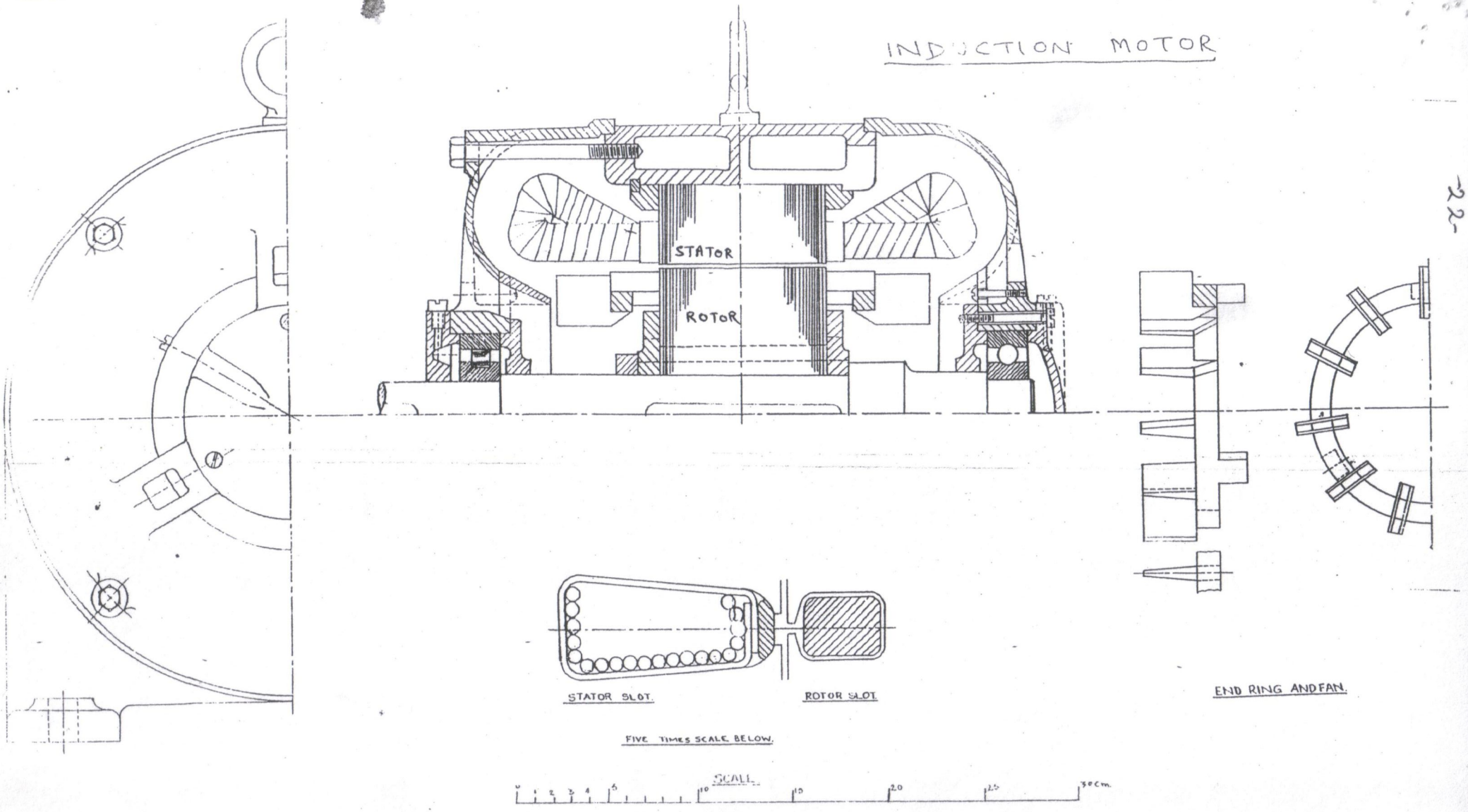


FIG 24: 5-H.P., 400 V., THREE-PHASE, 50-CYCLE, 4-POLE, CAGE INDUCTION MOTOR.

BY- J.P. SRIVASTAVA

rolling. For example, for machines with large diameter and large number of poles (as in water-wheel generator) variation of angle between the axis of one tooth and that of the next is not pronounced and use of CROS with segment core laminations and radial direction of grain orientation (Fig.) has proved

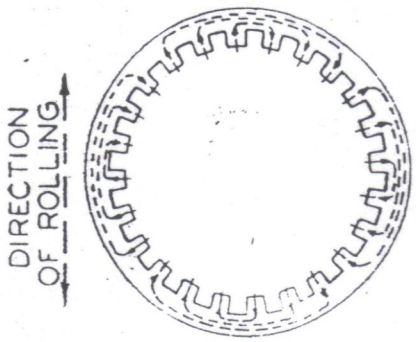


Fig. 25 : A complete stator lamination.

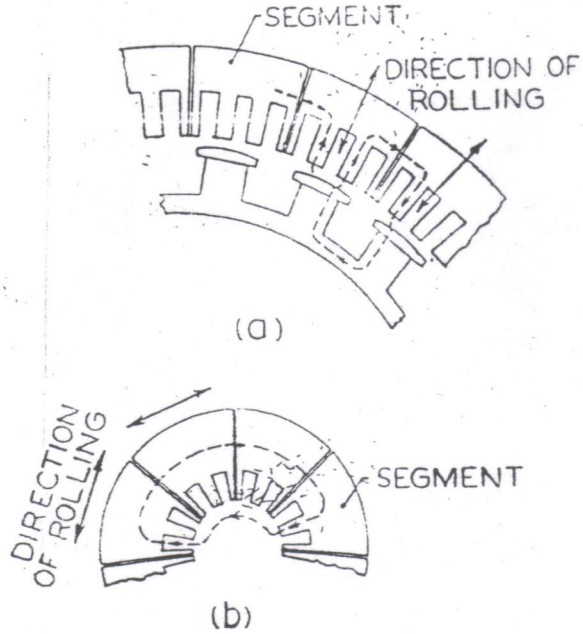


Fig. 26 : Segmental-core lamination-assembly.
(a) water-wheel generator,
(b) turbogenerator and induction motor.

to be of definite advantage*. On the other hand in large induction moto

Ref: M. G. Say,

Induction Motor

TYPICAL FRAME SIZES, 50-CYCLE MOTORS

Frame Designation		Outside Diameter of Stator Stampings, cm. D.	Gross Core-length, cm. L.	No. of Poles 2p	Stator Bore cm. D	D^2L cm.³
A	1	21·0	5·0	2	11·0	600
				4	13·0	845
	2		7·0	2	11·0	850
				4	13·0	1 180
B	1	24·0	6·5	2	13·0	1 100
				4	15·0	1 460
				6	18·5	1 760
	2		9·0	2	13·0	1 520
				4	15·0	2 020
				6	16·5	2 450
C	1	29·0	9·0	2	15·0	2 020
				4	18·5	3 080
				6	20·0	3 600
	2		12·0	2	15·0	2 700
				4	18·5	4 100
				6	20·0	4 800
D	1	34·5	10·5	2	18·6	3 800
				4	22·5	5 300
				6	24·5	6 300
	2		14·0	2	18·5	4 800
				4	22·5	7 100
				6	24·5	8 400
E	1	41·5	12·0	4	27·0	8 750
				6	29·0	10 000
	2		16·0	4	27·0	11 000
				6	29·0	12 000
F	1	48·5	13·0	4	31·5	11 900
				6	34·0	13 800
	2		18·0	4	31·5	15 900
				6	34·0	18 500
G	1	61·0	13·0	4, 6	35·0	16 800
				8	40·0	20 800
	2		18·0	4, 6	36·0	24 300
				8	40·0	29 000
H	1	68·0	16·0	4, 6	60·0	25 900
				8	65·0	32 000
	2		20·0	4, 6	60·0	32 000
				8	45·0	40 000

Magnetizing Current (I_μ)

$$I_\mu = (AT_{30}/\text{pole})\ \frac{p}{2} \cdot \frac{1}{1.17\ K_{d1}\ N_{ph1}} \quad (A)$$

p = No. of poles

Loss component of No Load current (I_c)

(i) Iron losses : stator teeth + stator core losses
Iron losses in cage rotor negligible, but in wound rotor at reduced speed to be considered.
Total iron losses = (1.75 – 2.2) Iron losses in stator teeth & core

(ii) F&W losses : 0.2 – 1.2 % (For small motors 3-5%)

Peripheral speed (m/s)	10	20	30	40	50
Losses % of Output	0.2	0.4	0.6	0.9	1.2

$$I_c/ph = \frac{\text{Total no load loss}}{3\ V_{ph1}}$$

No Load current (I_o)

$$I_o = \sqrt{I_\mu^2 + I_c^2}$$

($I_o \simeq 25-35\%$, for small motors 35 – 45%)

Leakage Reactance of Induction Motor

a) Stator slot leakage reactance (x_1)
b) Rotor slot " " (x_2)
c) Overhang or End turn leakage reactance (x_o)
d) Zigzag leakage reactance (x_3)
e) Differential, Belt or Harmonic leakage reactance (x_h)

Stator slot Leakage Reactance

$$x_1 = 2\pi f L_{sl1} \quad (\Omega)$$

$$L_{sl1\ (1\text{-layer})} \quad 4\mu_o \frac{N_{ph1}^2}{p\, q_1} L \left[\frac{h_1}{3b_s} + \frac{h_2}{b_s} + \frac{2h_3}{b_s + b_o} + \frac{h_4}{b_o} \right]$$

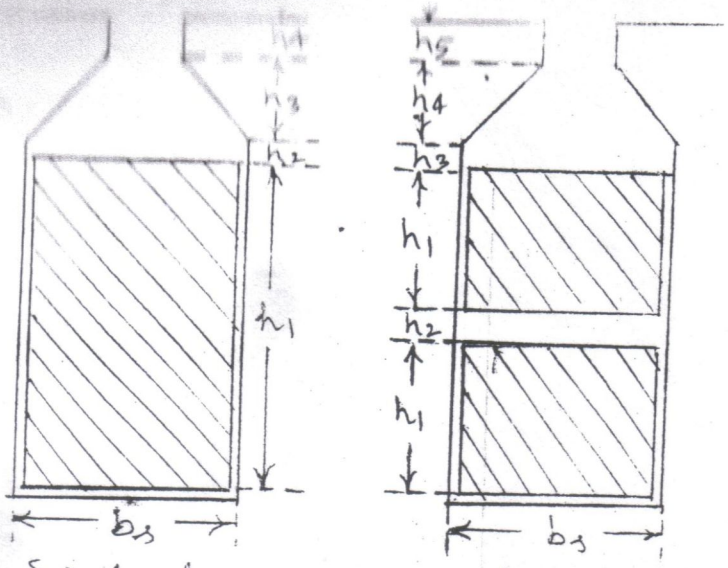
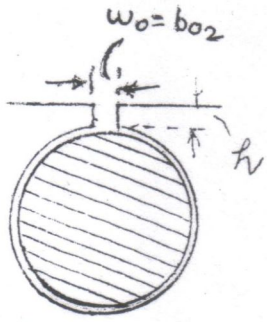


Fig. 27 a) Single-layer b) Double-layer



Cage rotor round slot

fig 28

$w_o = (0.2-0.4)\, d_{2bar}$

$h = 1-2$ mm

$$L_{sl_1\,(2\text{-layer})} = 4\mu_0 \frac{N_{ph_1}^2}{p q_1} L \left[\frac{2h_1}{3b_s} + \frac{h_4}{4b_s} + \frac{h_3}{b_s} + \frac{2h_4}{b_s+b_o} + \frac{h_5}{b_o} \right]$$

Rotor slot leakage reactance (x_2)

a) for wound rotor estimate in the above manner

b) for cage rotor:

$$x_2 = 8\pi f \frac{N_{ph_2}^2}{p q_2} L(\lambda_{RS}) \quad \Big\| \quad x_2' = \left[\frac{K_{d1} N_{ph_1}}{K_{d2} N_{ph_2}}\right]^2 x_2 \quad \Big\| \quad N_{ph_2} = \frac{S_2}{2\times 3}$$

λ_{RS} = Rotor specific slot permeance

$$= \mu_0 \left[0.623 + \frac{h}{w_o}\right]$$

Overhang Leakage Reactance (x_o)

See : p. 27, fig. 30,

Zig-zag Leakage Reactance (x_z)

$$x_z = \frac{5}{6} X_m \left[\frac{1}{S_{1p}^2} + \frac{1}{S_{2p}^2}\right] \quad \Omega/ph$$

$$S_{1p} = S_1/p, \quad S_{2p} = S_2/p$$

Differential, Belt or Harmonic Leakage (x_h)

See : p. 28, fig. 31,

Total leakage reactance referred to stator side

$$X_p = x_1 + x_2' + x_o + x_z + x_h.$$

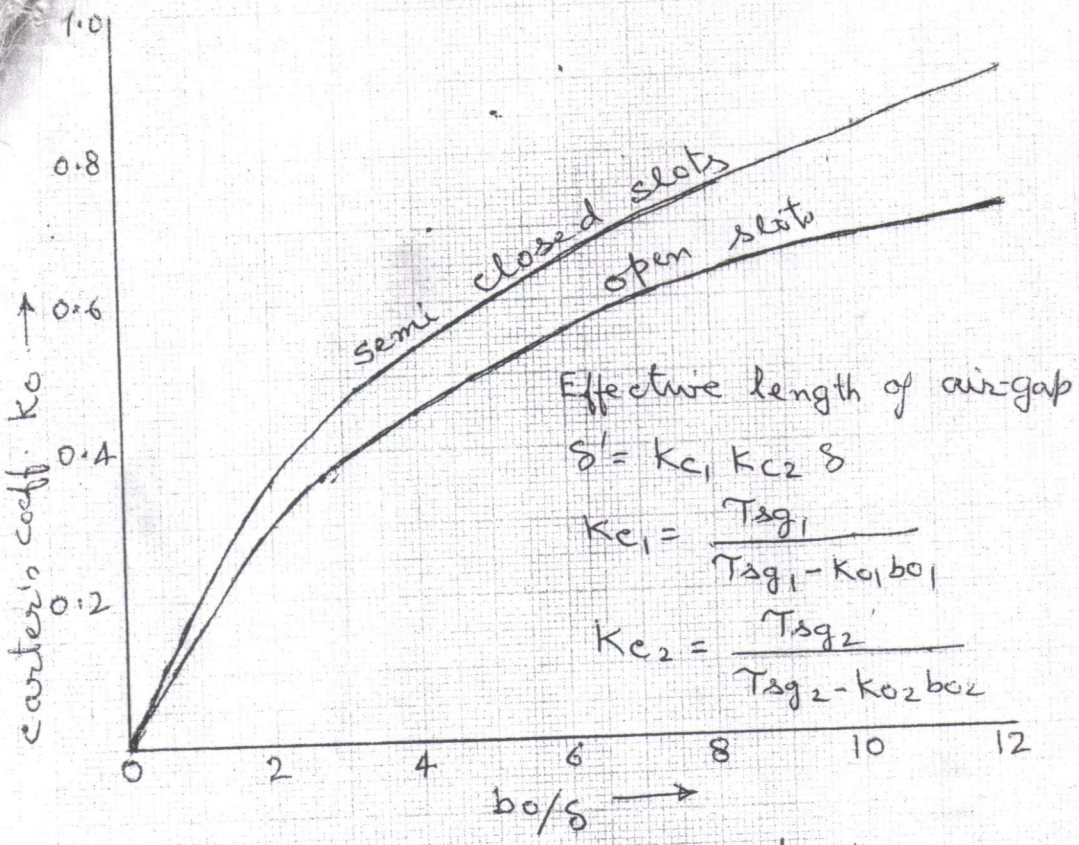


Fig 29. Carters Airgap coefficient.

Ref: A.K. Sawhney p.124 fig 4.9

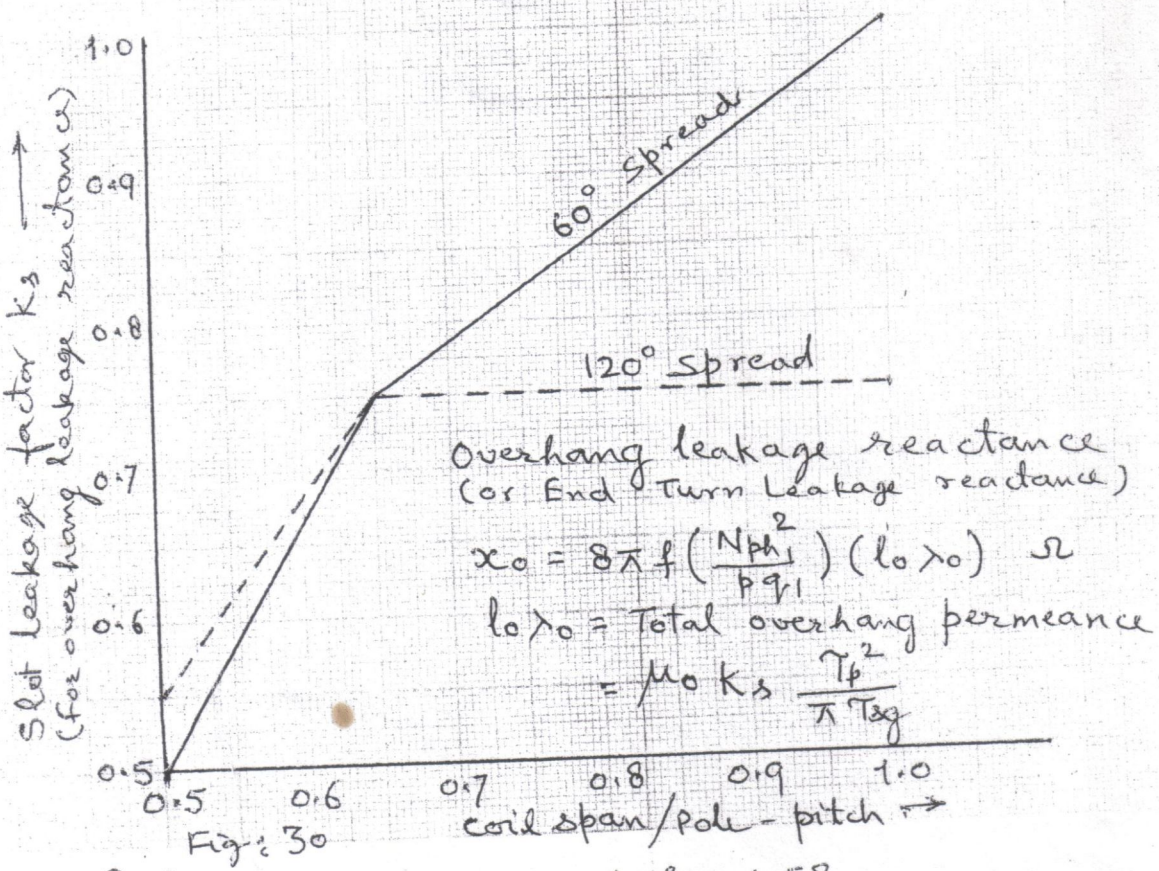


Fig: 30

Ref: A.K. Sawhney p.170 fig 4.58

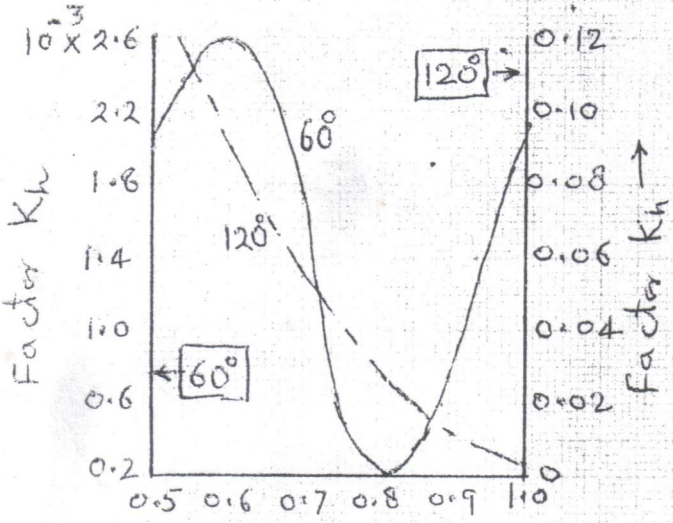


Fig 31

Ref: AK Sawhney p.643 fig 10.35
RK Agarwal p.137 fig 4.25

Differential, Belt or Harmonic leakage

$x_h = X_m (k_{h_1} + k_{h_2})$

Factor k_{h_1} for stator & k_{h_2} for rotor.

Note: This may be ignored for cage motors.

$$X_m = \frac{V_{1ph}}{I_\mu}$$

DR. R. C. GOEL