MILL DESIGN & MILL OPERATION

BY
J.P. SRIVASTAVA
N.S.I, KANPUR

OBJECTIVE OF MILLING

- Maximum possible extraction of sucrose
- Minimum extraction of non sugars
- Minimum sucrose in final bagasse
- Optimum moisture in final bagasse
- Optimum power/ energy consumption

THRUST AREAS FOR EFFICIENT MILLING

1. CANE MANAGEMENT
2. PREPERATION OF CANE
3. SPECIFIC FIBRE LOADING
4. HYDRAULIC LOAD
5. PROPER SETTING OF MILLS
6. PRIMERY EXTRACTION
7. SECONDARY EXTRACTION
8. IMBIBITION
9. MILL SANITATION
10. MILL MAINTENANCE

CANE MANAGEMENT

- Quality cane supply
  - Fresh & clean cane
  - Minimum extraneous matter
- Uniform & adequate quantity of cane supply to maintain rated crush rate and avoid reduced crush rate

Thrust area

CANE PREPARATION

- Better cane preparation improves bulk density and has higher no of open juice cells and easy to extract free juice from prepared cane. Long fiberous preparation improves mill extraction and reducing the power consumption at mills. Prepared cane should long fibrous shrades to improve feedability to the mills

PREPERATION OF CANE

- Optimum cane preparatory Index between 85 to 90

- Avoid excess of cane preparatory devices

- Avoid dusting of cane

Thrust area

PREPARATORY INDEX

- With optimum preparatory index the permeability of bagasse increases & juice cells are opened holding free juice hence extraction become easier. As bagasse approach neutral plane the permeability of bagase reduces and density increases causing low juice extraction

JUICE DRAINAGE

- Drainage of juice start from gripping plane and is gradually increased. It is maximum before neutral plane. There is no drainage between neutral plane and axial plane. Thus the air and juice trapped are compressed in this zone due to extrusion. Trapped juice is carried along with bagasse causing re absorption.

SPECIFIC FIBRE LOADING

- ☆ Optimum loading range (Sp. Fibre loading)

With TRPF/GRPF 27 kg/m^3 to 30 kg/m^3
With UFR& D.chute 15kg/m3 to 20 kg/m3

- ☆ Specific fibre loading = Fibre loading /Diameter

where fiber loading = Af/60∏Dx n x L Kg / m² escribed surface

A crushing rate in kg/hr
f fibre per unit cane

Thrust area

REABSORPTION

- Speed of bagasse is lesser than roller surface speed when it comes in connect at roller gripping zone and reaches equal to roller speed at neutral plane. The speed of bagasse is higher than roller speed between neutral plane and axial plane. This phenomenon of excess speed causes the extrusion of bagasse which gives high volume of bagasse emerged than the escribed volume generated by rollers. The ratio of actual volume of bagasse to escribed volume at axial plane is called reabsorption factor

HYDRAULIC LOAD

a. To be decided by SHP
b. To curb excessive lift of top roller

Thrust area

SPECIFIC HYDRAULIC PRESSUR

SHP = F /0.1 LD

Where F Total load on top roller in tons

L Length of roller in mt.

D Dia. Of roller in mt.

MEAM VALUE OF SHP TONS/M2 (TONS/FT2)

	1ST	2ND	3RD	4TH	5TH
12ROLLER	2582	2367	2690	2958	--
	240	220	250	275	--
15 ROLLER	2582	2367	2475	2690	2958
	240	220	230	250	275

HYDRAULIC ACCUMULATOR

- Nitrogen gas pressure in accumulator should be in the range of 80 to 90% of the hydraulic oil pressure for efficient operation. Nitrogen gas pressure should never be higher than the oil pressure.

PROPER SETTING OF MILLS

- Relative positioning of three rollers (Top, Feed & Discharge)
- Trash plate properly drawn and positioned
- Setting of feeding devices
- Proper setting of scrapers knives etc.

Thrust area

MILL SETTING CALCULATIONS

- GIVEN :
- Crush rate - TCH
- Mill size – Diameter (D), Length (L)
- Mill speed – rpm
- Fibre% cane - fb
- PI factor - k (1.2)

- Assume Fibre%bagasse(q) as under:

	1st	2nd	3rd	4th	5th	6th
12 roller mill	33	42	47	52		
15 roller mill	32	41	47	52	55	
18 roller mill	32	40	47	53	50	60

- Wt of bagasse after each mill

$$w = \frac{TCH \times fb \times 1000}{q} \text{ kg}$$

- Assume bagasse density(d) after each mill

1200 1210 1220 1230 kg/m^3

- Discharge opening(operating), Dwo :

$$Dwo \times \prod \times D \times n \times L \times r \times 1.2 = \frac{w}{60\,d}\ m^3$$

$$Dwo = w / 60 \times d \times \prod \times D \times n \times L \times r \times 1.2\ m$$

Where' r ' is Reabsorption factor to be taken as under:

1st mill	1.33
2nd mill	1.33
3rd mill	1.33
4th mill	1.36

- Feed work opening:

	1st	2nd	3rd	4th
F/D conventional	2.0	1.9	1.85	1.8
TRPF/GRPF	1.75	1.7	1.65	1.60

Trash plate setting

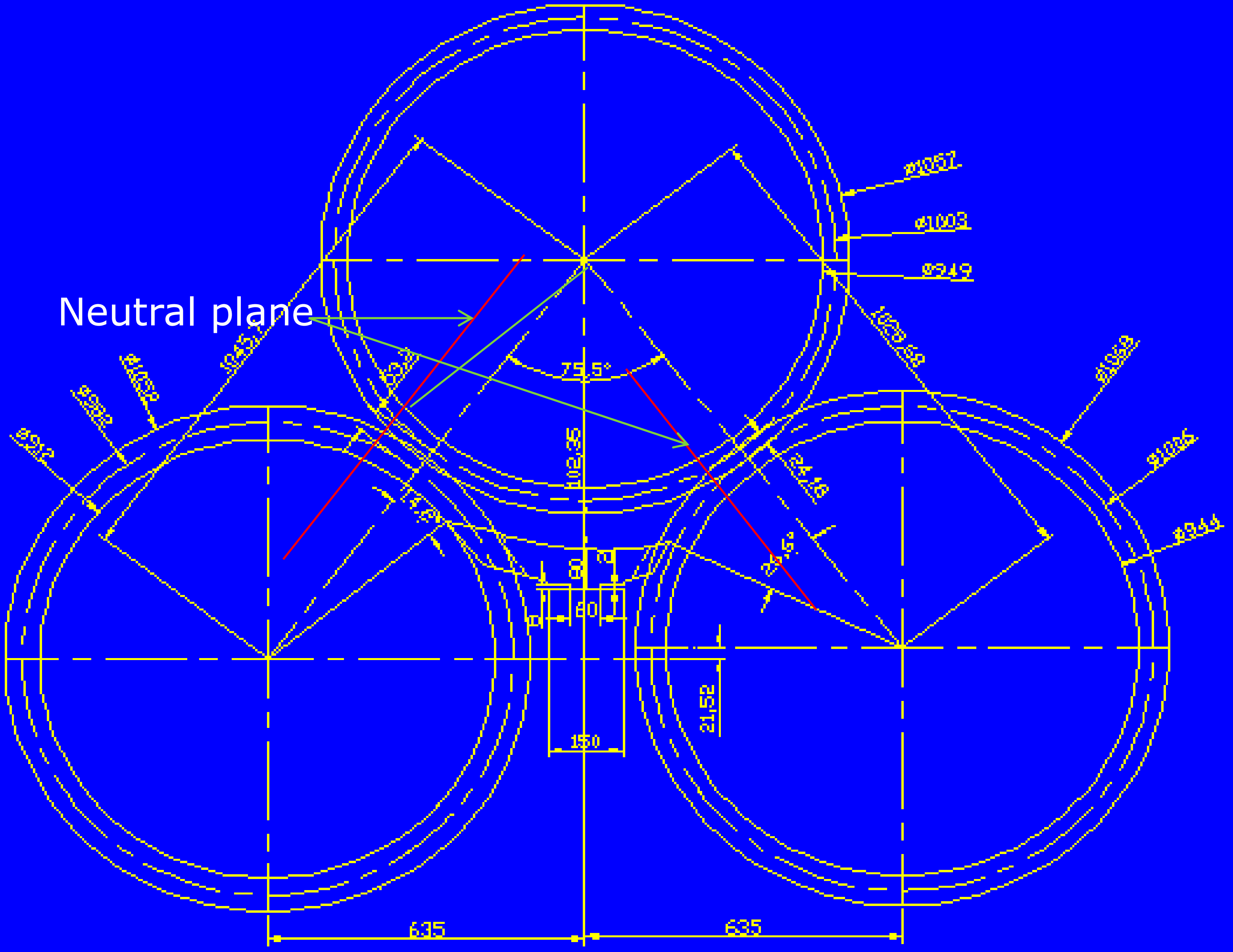
TP/F conventional	1.9	2.0	2.1	2.2
TRPF/GRPF	1.7	1.75	1.8	1.8

- Roller lift (mm)
- Following roller lift is taken

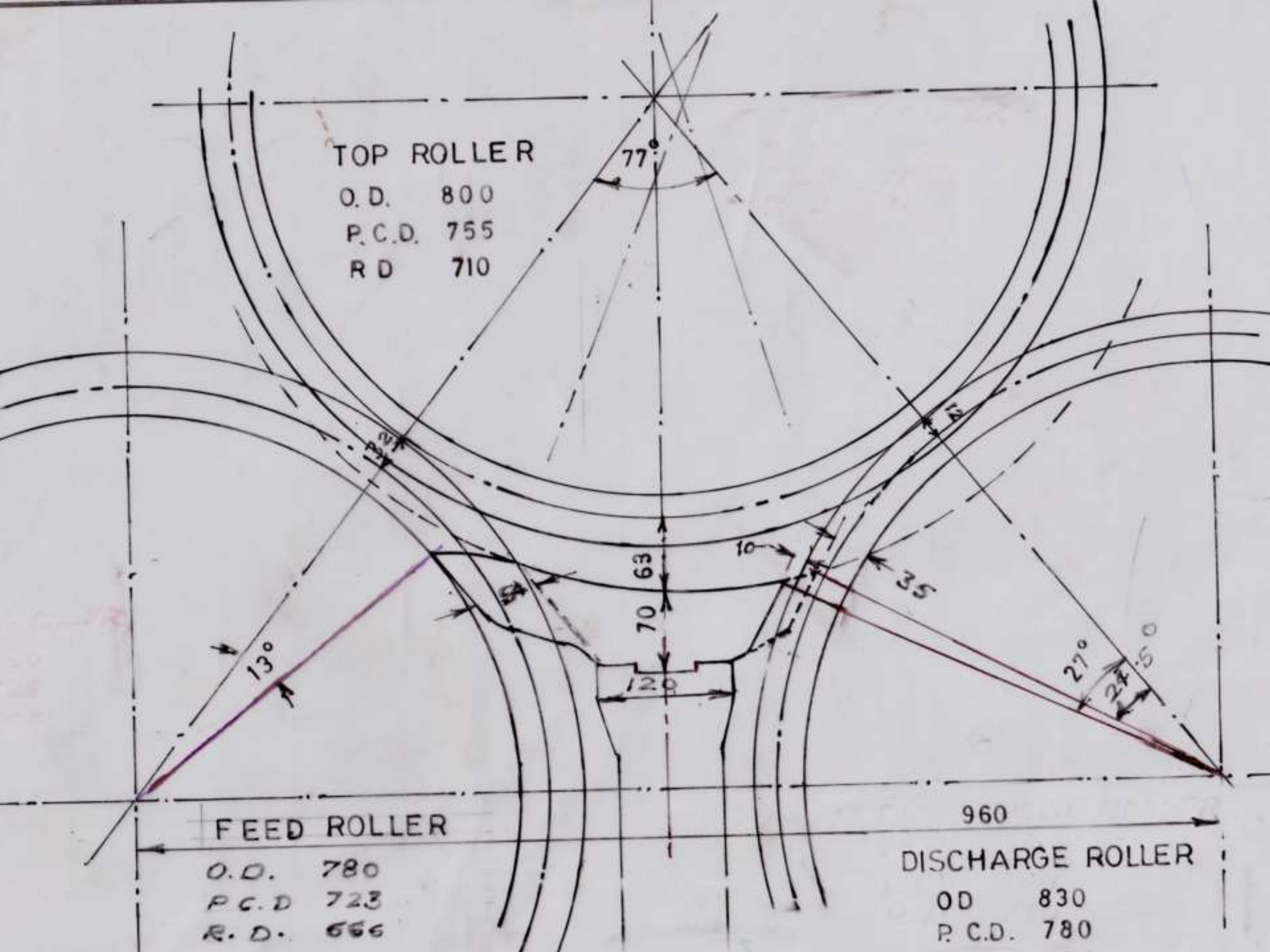
	1	2	3	4
F/D	10	10	8	8
TP	12	12	10	10

Mill setting at rest-

Subtract above lift of top roller from operating feed & discharge and TP setting


Neutral plane
ø1057
ø1003
ø949
75.5°
102.35
150
635
635
21.52
ø1058
ø1006
ø944

TRASH PLATE



TOP ROLLER
O. D. 800
P.C.D. 755
R D 710
77°
63
70
10
35
120
13°
27°
24
50
960
FEED ROLLER
O.D. 780
P.C.D 723
R.D. 666
DISCHARGE ROLLER
OD 830
P. C.D. 780

- Slope to trash plate profile towards discharge roller is given - 6%
- Toe point of trash plate is located on root circle of feed roller at an angle of 13° from centre line of feed and top roller
- Angle of heel point with centre line of discharge and top roller preferably should be maintained around 25°

MILL FEEDING DEVICES

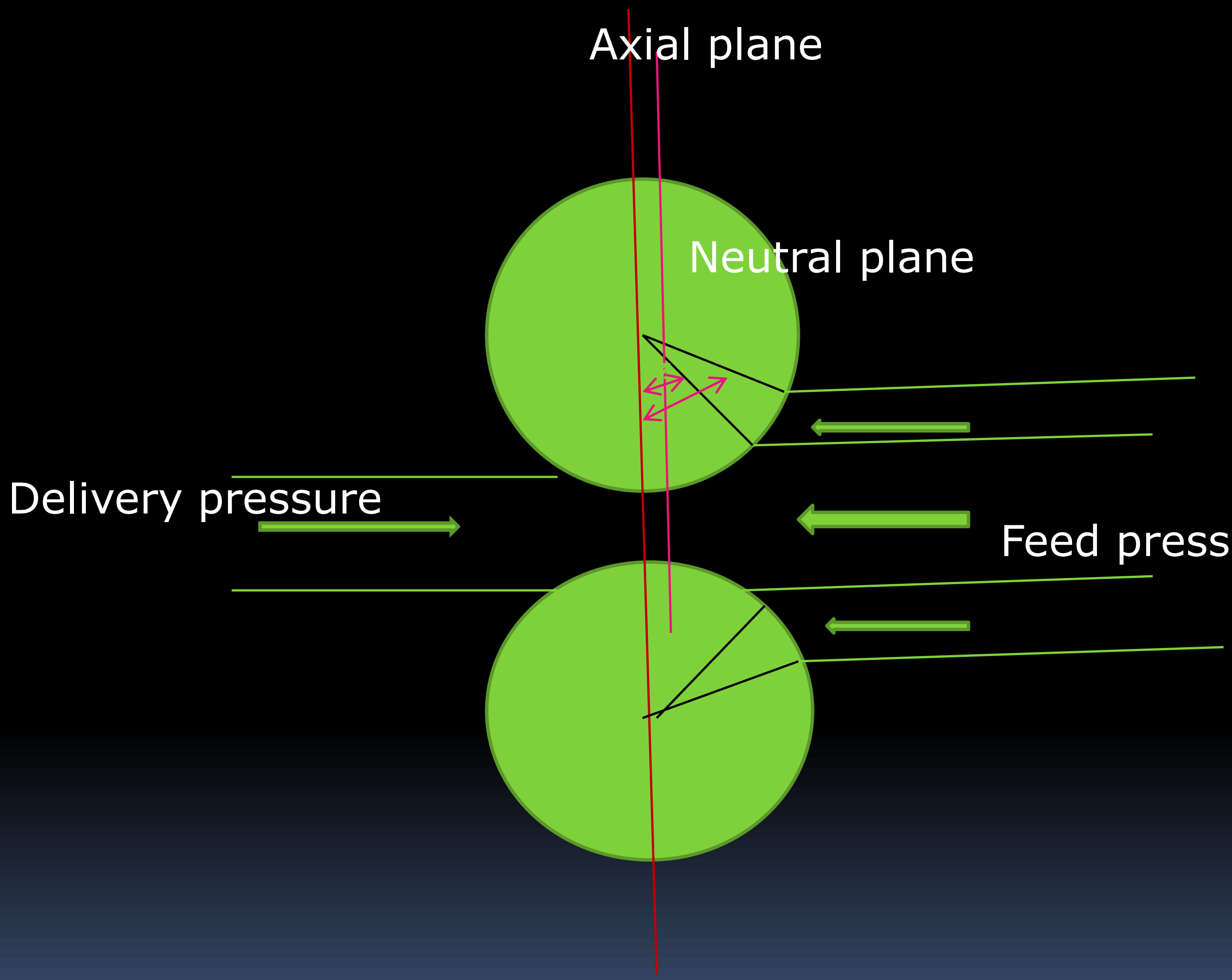
- In early age of sugar industry, feeding of cane and bagasse were made through open gravity chute and apron type cane carrier respectively
- The feeding force applicable during this type of feeding was only frictional force applied between Roll surface and material of feed i.e cane or bagasse

- The maximum angle of contact for Zero applied feed pressure (other than frictional force) would be angle β.
- Experiment shows that the maximum value of μ (frictional coefficient) does not often exceed to o.6. Hence
- $\tan^{-1} 0.6 = 31°$

- It is therefore clear that under frictional force only (no external feeding pressure) , the maximum contact angle would be 31° .
- For greater contact angle of the order of 50 or more the application of some external feed pressure by introduction of feeding devices be an essential component of a feeding theory.

- The external feed devices provided now a days are :

1. UFR
2. Donnelly Chute
3. TRPF
4. GRPF
5. TRF


Axial plane
Neutral plane
Delivery pressure
Feed pressure

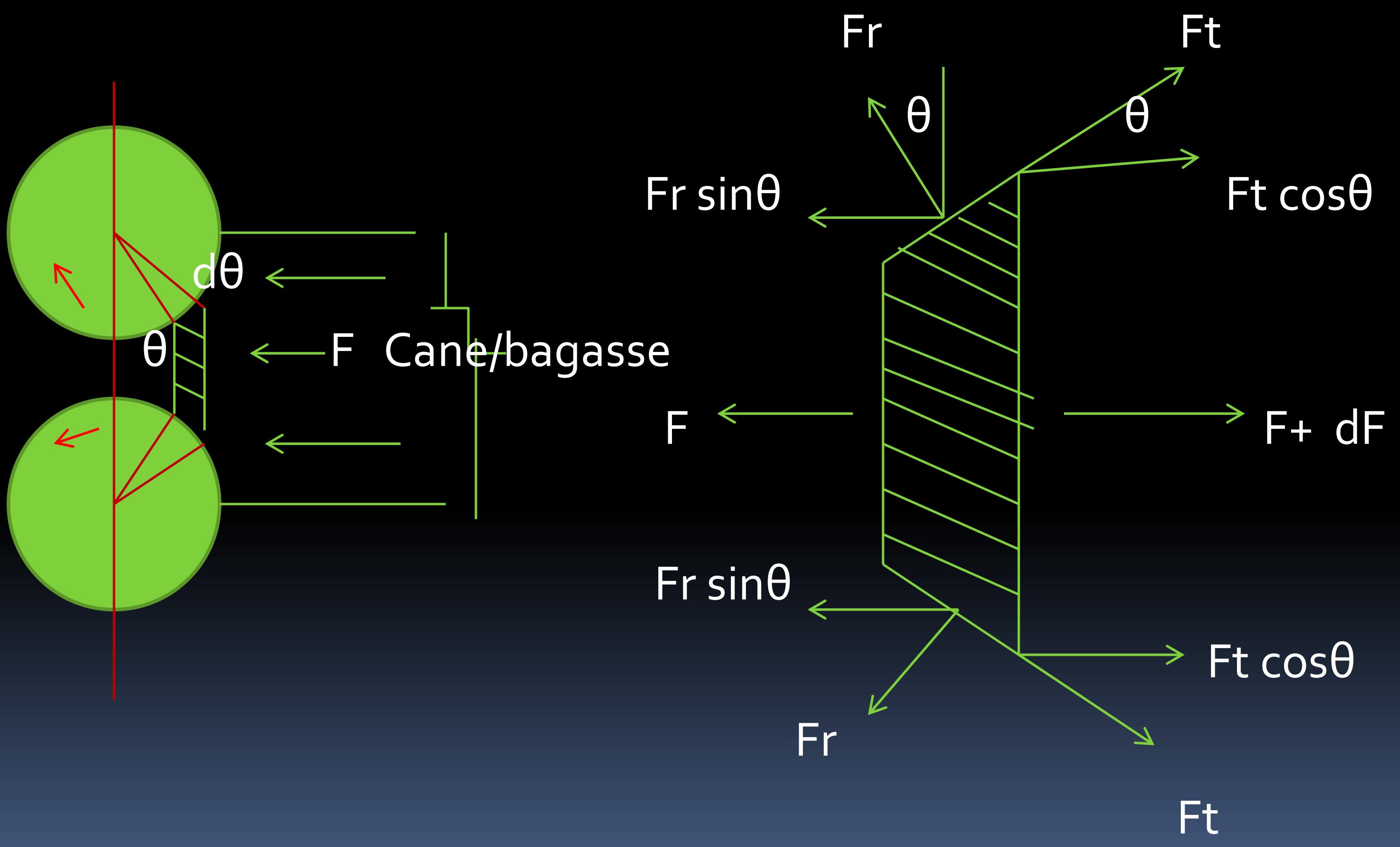
Frictional theory for cane feeding

- $dF/d\theta = PD\cos\theta(\tan\theta - \mu)$

This is the differential equation for forces on roll surface . This equation may be used to develop theories both for pressure required to feed the cane /bagasse to pass of rollers and for pressure build up by the feeding roll.

In above equation

- F is the horizontal force between elements of cane /bagasse per unit length of roller
- P = Normal force per unit area of roll surface
- μ = Ratio of tangential to the radial force on an element of the roll surface. It has a maximum value equal to coefficient of friction between the cane/bagasse material and the roll surface



Fr
Ft
θ
θ
Fr sinθ
Ft cosθ
dθ
θ
F
Cane/bagasse
F
F+ dF
Fr sinθ
Ft cosθ
Fr
Ft

- Net force on surrounding by the element

$$2(-F_r \sin\theta + F_t \cos\theta) + dF$$

Put $dF = \dfrac{dF}{d\theta} \, d\theta$

And $F_t = \mu F_r$, $F_r = P_s (D/2) \, d\theta$

Where P_s = normal pressure exerted by the solid material on roll surface

- $-2\, Ps\, (D/2)\, \sin\theta\, d\theta + 2\mu\, Ps\, (D/2)\, d\theta \cos\theta$

$$+ \frac{dF}{d\theta}\, d\theta$$

$$[\, dF/d\theta - PsD\cos\theta\, (\tan\theta - \mu)\,]\, d\theta \qquad \text{------1}$$

Put above equation equal to zero, Hence

$$dF/d\theta = Ps\, D \cos\theta\, (\tan\theta - \mu)$$

GRPF/TRPF SETTING

- Speed ratio: It is the ratio of surface speed of pressure feeder to surface speed of mill roller
- Speed ratio for TRPF 1 to 1.2
- Speed ratio for GRPF 1.2 to 1.5

- Volumetric ratio. It is the ratio of escribed volume of pressure feeder to escribed volume by mill roller

- Volumetric Ratio for TRPF = 2.5 to 3
- Volumatric Ratio for GRPF = 1.3 to 1.5

Calculation of TRPF/ GRPF setting

- Escribed Volume of Pressure Feeder
  = Volumatric Ratio x Escribed Volume of mills

  = VR x Lx v1x wf ---------- 1

  Where L = length of mill roller (m)

  v1 = Surface speed of mill roller (m/min)

  wf = Operating feed opening (m)

PRESSURE CHUTE SETTING

- Escribed volume of pressure feeder

$= L \times v2 \times W_{pf}$ ----------- 2

Where L = Length of pressure feeder (m)

v2 = Surface speed of pressure feeder

w_{pf} = pressure feeder opening

Equate equation 1 and 2, therefore

$L \times v2 \times Wpf = VR \times L \times v1 \times wf$

$Wpf = VR \times L \times v1 \times wf / L \times v2$

- Pressure Chute Inlet (d_1)
- $L \times v_1 \cos\theta_1 \times d_1 = K/\phi$ ---- 1

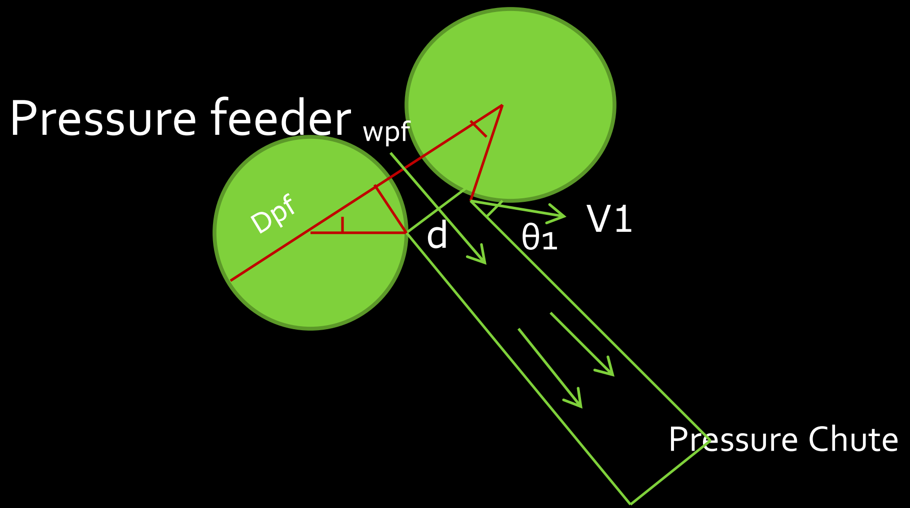
  where ϕ = Fibre compaction

  = 100 to 130 kg/m3

  K = Kg fibre /min

- $$\cos\theta_1 = \left(\frac{D_{pf} + W_{pf} - d_1}{D_{pf}}\right) \quad ---- \quad 2$$

Calculate d_1 ?



Pressure feeder
wpf
Dpf
d
θ1
V1
Pressure Chute

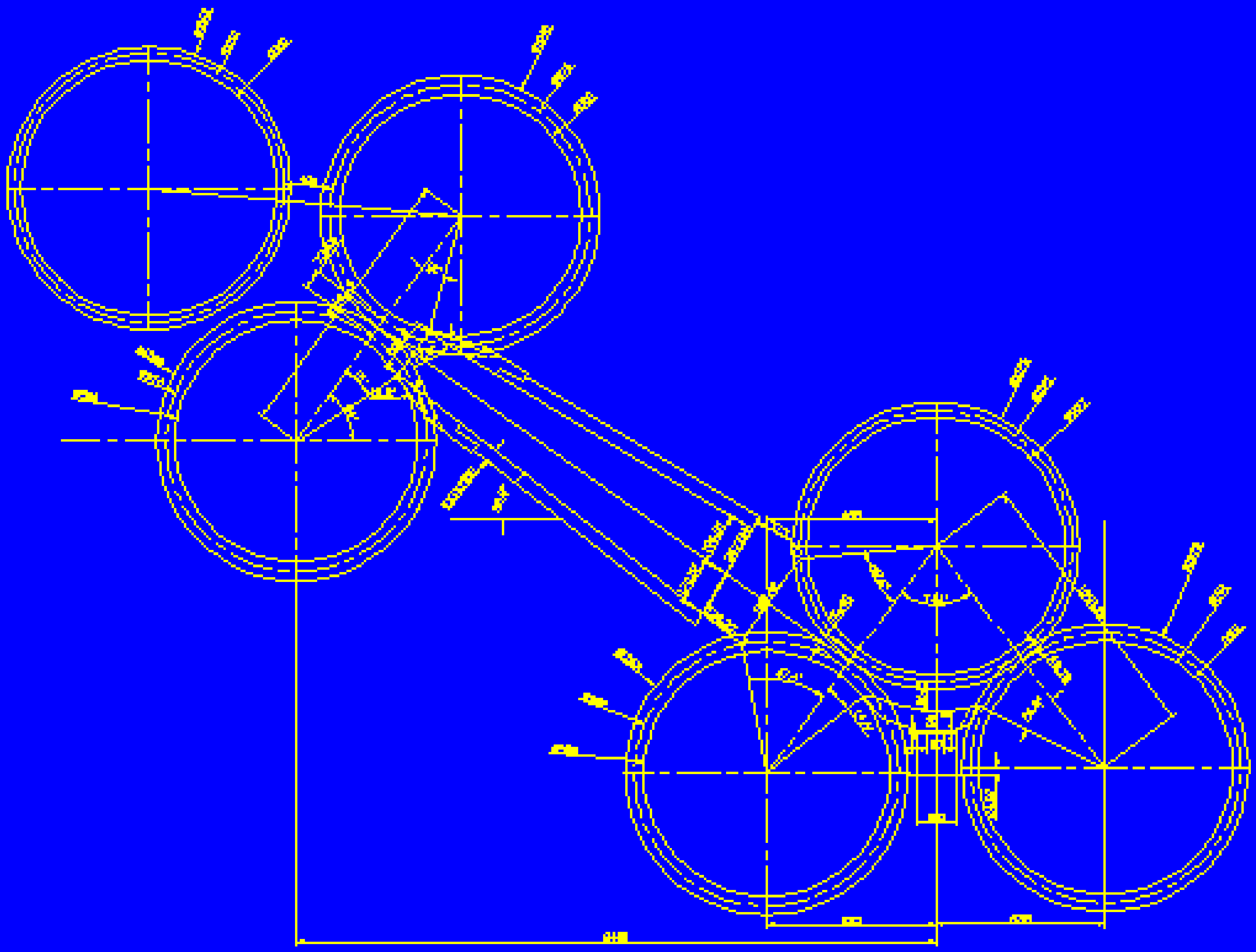
- Pressure Chute Outlet(d_2)
- $L \times V_2 \times \cos\theta_2 \times d_2 = K/\phi$ ---------- 1

  where k = Fibre/min

  ϕ = 80 to 125 kg/m3

$$\cos\theta_2 = \frac{(D + W_f - d_2)}{D} \qquad \text{----------} \quad 2$$

Calculate 'd_2' from equation 1& 2



G.R.P.F

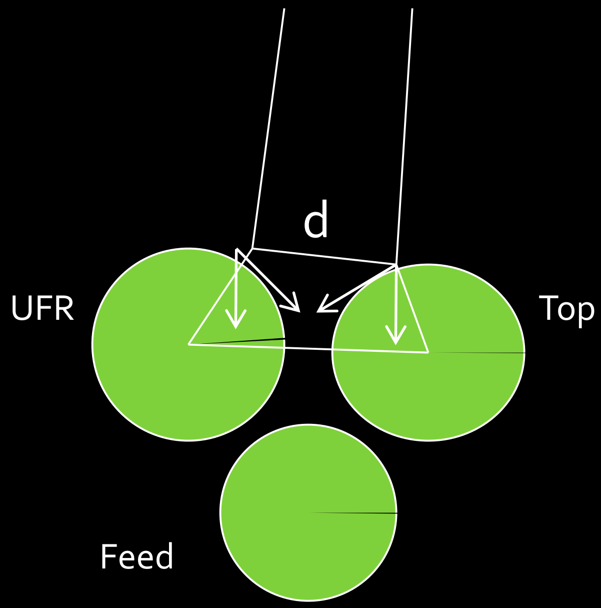
VALUE OF FIBRE COMPACTION(ϕ)

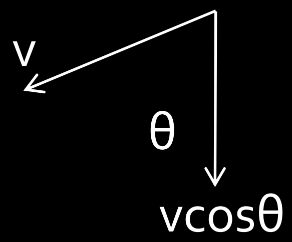
	ϕ (kg/ m^3)
D.Chute	50 to 80
UFR	80 to 90
Pressure feeder	100 to 130
Pressure chute inlet	100 to 130
Pressure chute outlet	80 to 125

UFR SETTING

- UFR rpm(n_1) = 1.1 x Mill rpm(n)
- Average roller speed(n_{av})=(n_1 + n)/2
- UFR length = L
- Average PCD of rollers= D
- Fibre Compaction (ϕ)= 80 to 90 kg/m^3
- UFR setting= $\dfrac{\text{Fibre/min} \times 1000}{\pi D n_{av} \times L \times \phi}$
-

DONNELLY CHUTE SETTING





v = Av.speed of rollers

θ = angle of contact

- $L \times v \cos\theta \times d =$ Fibre/min x 1000/ϕ

  $\cos\theta$ = Fibre/minx1000/ϕxLxvxd ---- 1

- Where ϕ = 50 to 80kg/m³

- $$\cos\theta = \frac{D_T + w_o - d}{D_T} \quad \text{------ 2}$$

Calculate ' d' from equation 1 & 2

PRIMERY EXTRACTION

- High purity extraction
- To be achieved maximum

Thrust area

SECONDARY EXTRACTION

- Low purity extraction
- Extraction based on imbibition efficiency
- Extraction of more non sugars
- High power consumption

Thrust area

IMBIBITION

- By cold water
- By hot water
- Optimum temperature of hot water 70°C to 75°C

Thrust area

JUICE DRAINAGE

- Efficient juice drainage leads to reduction in power consumption
- To improve juice drainage following are recommended

1. Higher pitch groove

1st	2nd	3rd	4th
50mm	50mm	35mm	35mm

2. Differential angle groove T- 50, F- 40, D- 45

- 3. Messchert groove in feed rollers
- 4. All top rollers are lotus roll
- 5. Flangeless top rollers with static collar
- Thin juice extraction by TRPF/GRPF which reduce load on mill

MILL SANITATION

- To avoid bacterial growth
- Rapid growth of Luconostres in acidic and Low Brix juice
- Regular steaming
- Regular chemical spray

Thrust area

NORMAL MILL PRACTICES

- Not to monitor lift of top roller
- It is assumed that top roller lifts only that value considered during mill setting calculations
- Normally actual lift of top roller during operation is higher than considered in mill setting calculation
- Higher thickness of cane/bagasse blanket passes through mills due to excessive lift of top roller
- This leads to poor extraction of sucrose and results in higher sugar loss in final bagasse
- Hydraulic load applies on top roller simply by assumption/experience
- It is seldom to consider the lift of top roller while deciding the hydraulic pressure
- To compromise with mill performance due to power constrain

PERFORMANCE OF INDIVIDUAL MILLS

- Plotting of Brix curve for feed and discharge side
- To monitor lift of top roller
- Analysis of bagasse leaving the mills for free pol and total pol
- Measurement of temperature of juice on feed and discharge
- Measurement of pol for bagasse leaving a mill and juice from back roller of same mill

OVER-ALL PERFORMANCE OF MILLS

- Pol percent final bagasse
- Brix of last expressed juice
- Primary extraction (PE)
- Reduced mill extraction (RME)

POINTS FOR IMPROVING EXTRACTION

- Proper hydraulic pressure by maintaining Nitrogen pressure in bladder i.e.80 to 90% of oil pressure
- Lift of top roller should be within limit and top roller should freely float
- Mill imbibition should be minimum 230 % on fibre and higher value is subjected to evaporater capacity

- Trash plate heel angle with discharge roller center line should be around 25°
- Trash plate heel clearance should be maintained carefully to have better drainage
- Scrapper and trash plate groove angle should be lesser than roller groove angle by 5° to 6°

- All mills should run under optimum loads
- Installation of ACFC (Auto cane feeding control) system to ensures:

1. Uniform feeding to mills
2. Reduce down time at preparatory devices
3. Uniform blanket thickness

4. Loading on motors is uniform, kick loads are avoided

MAINTENANCE FOR QUALITY PRODUCTION

AIM OF MAINTENANCE IS TO KEEP DOWN TIME MINIMUM AND TO ACHIEVE DESIRED CAPACITY UTILIZATION WITH EFFICIENCY AND QUALITY PRODUCTIVITY

PRESENT STATUS OF MAINTENANCE

- There is seldom preventive/predictive maintenance
- No records of individual equipments
- No records about repair of equipments
- No proper training programme
- No proper house keeping works
- No separate inspection cell
- Lack of motivation among staff

PROPER MAINTENANCE SYSTEM

- Complete repair and overhauling during off-season
- Preventive/ predictive maintenance during crushing season

STEPS FOR GOOD MAINTENANCE

- Right selection of equipments and their components
- Correct orientation of wrongly placed equipments
- Quality repair during off-season
- Planning and scheduling of various jobs
- Equipment cards
- Provision of stand by equipments

PREVENTIVE MAINTENANCE

CONSTANT MONITORING ON OPERATIONAL PARAMETERS THROUGH SYSTEMATIC INSPECTION SO AS TO TAKE TIMELY REPAIR/REPLACEMENT OF COMPONENTS UNDERGOING WEAR AND TEAR TO AVOID DOWNTIME DUE TO FAILURE

ELEMENTS OF PREVENTIVE MAINTENANCE

- Preventive maintenance cell with proper motivation
- Proper inventory to be maintained
- Categorization of plant and machinery
- Analysis of wear and tear and evaluation of service life

PREDICTIVE MAINTENANCE

IT IS MORE ADVANCE ON STREAM NON DESTRUCTIVE TESTING WITH A VIEW TO AVOID UNNECESSARY SHUT DOWNS BY TAKING FULL HELP OF TROUBLE PREDICTING AND TROUBLE SHOOTING TEST INSTRUMENTS

THANK YOU