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Solid Particles

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* 29/9

* The Three important characteristics of an individual particle :-
1] Composition مكونات المادة

→ Density

→ Porous (المسامية)

① يتم في نقاء المادة وكذلك في وجود فجوات او فراغات

2] Size حجم الجسيمات

→ affects properties

→ Surface per unit volume ③ منة - الحايون عنده حبة كبيرة وادخلها الفرن براح تحتاج وقت اطول من الحبة الصغيرة

3] Shape

→ irregular

لا يمكن ان يكون له شكل مختلف في المظهر
لهم نفس شكل الحبة

Can't define it

Refer to regular shape

→ regular (Spherical / Cubic) or Precise definition By math. eg
[حالة شكل محدد لذلك استطيع ان احس كل شيء لها بالحارة الرياضية]

Industrial Scale

1] Handling large quantities

2] Need to Specify the system as a whole

3] Defining a mean particle size

* Storage → hoppers (Silo)

* Metering → flow

* Mixing

* Separation

→ Important Operation of Particles.

ask & believe & recieve

Five Apple

*** Partical Size

→ Physical Boundary

* The upper limit $\rightarrow$ difficult to define

BS 2955 $\rightarrow$ Definition (Shall consist of discrete particles
 $\hookrightarrow$ British Standard & any material with a max of
less than $1000 \mu\text{m}$ (micro meter)
 $= 1 \text{ mm}$)

* lower limit

*** Shapes :- (1) Acicular (Needle shaped)

مثل الابرة او مثل الرز

(2) Angular (Sharp edged) $\rightarrow$ (يكون ترتيب الزوايا في الداخل مختلف)

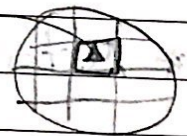
(3) Flaky (Plate like) $\rightarrow$ على شكل صفيحة

(4) Modular (Rounded, irregular shape) $\rightarrow$ مدورة تشبه الكرة لكنها ليست
كروية

*** Characteristics [Size of equivalent Spheres]

1] The Sphere which will just pass through the Same Size
of Square aperture as the Partical. (Screen)

2] The Sphere with the Same Settling Velocity as the Partical
in a Specified fluid



3] The Sphere of the Same Volume as the Partical

4] Surface Area

5] Surface Area / Unit Volume

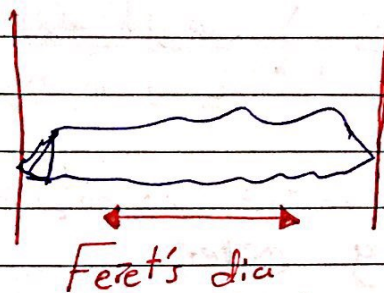
recieve
Five Apple

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* $\psi_{\text{sphericity}} = \frac{\text{Surface Area of Sphere}}{\text{Surface Area of Particle}}$

* $\psi_{\text{sphere}} = 1$

* Feret's diameter



هذا للشكل المختلف
يفضل اني اتيت القطر

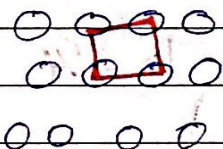
* نأخذ Tangent من ابعدي نقطتين وكسافة بين هذه النقطتين تكون هي القطر

* هناك طريقة اخرى مثل نضع الجسيم على الطاولة ونرسمها بعدد من نأخذ القطر من اكثر
من مكان واحد ذلك نأخذ ال avg لهم

** Properties of Particle &

1) Crystalline / Amorphous → مادة حبيبية

لودرسنا الى مادة راح تكون مكونة من حبيبات مادة حبيبية
اذا كانت الحبيبات مرتبة والستطوعنا ان نرسم
بينهم ايه شكل هندسي فيانه رجليه على Crystalline



وتكون اكثر حبيبية من ال Amorphous

من ال Amorphous الحبيبات الحبيبة / الزجاج ← Crystalline

Long range order



A Simple Cubic (SC) (atoms)

عند كل زاوية في الحبيبات الية الذرة
في كل زاوية موجود $\frac{1}{8}$ منها

* Atomic Packing Factor → يعني الى كم ذرة في

(APF)

B) Body Center Cubic (BCC) $\rightarrow$ عنده وحدة $\rightarrow$ (2 atoms)
حاملة في الوسط

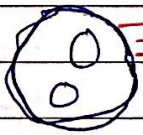
يعني هنا ال $APF = 2$ لان عنده وحدة بكل الزوايا ووحدة بالوسط

C) Face Centered Cubic (FCC) $\rightarrow$ (4 atoms)

الفتحة هنا يوجد عنده (SC) تكون لا يوجد (BCC) يوجد بداله
نصف ذرة في كل وجه يعني 8 وجوه في 8 ذرات

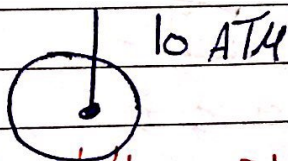
اما بالسبي لل Amorphous جاذبة لا يوجد عنده long يوجد بداله
Short range order

يعني ال Cubes الى عنده موجبة منتشرة بطرته 3D موجبة منتشرة لمسافات بعيدة
ولهذا السبي فان الذرات منه هذا النوع تتكسر وتنفقت بسرعة

2) whether it is porous  اذا كانت الحبة فيها مخوفة
او فراغ يعني لها اكس الحبيبة موجبة

Composition/Density هذه الخاصية تلعب دور كبير في ال

3) Hardness (الصلابة) $\rightarrow$ Exo-Brinell Hardness No
اشهر التجارب الى بقيت الصلابة



* الفترة في هذه التجربة احيب قطعة من المعدن ولجيب الجهاز هذا الى هو
عبارة عن ابرة صلبة لحظ ضغط معين من 1000g وبعدها على سطح المعدن
بعد ذلك سيقوم ال ابرة كم اختراق المعدن ومن خلال حبه اول سيقوم ال
Brinell Hardness No

* هناك طريقة اخرى اسمها (Vickers) نفس الفترة لكن
بدل ما ياخذ ال ابرة ياخذ صامة الدائرة الى فتحتها الدبرة

ask : Date : & recieve

Five Apple

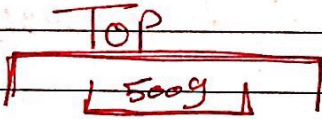
4) Surface → Rough

→ Smooth

السطح الخشن ليس عليه الـ Adorption
أقل بكثير من السطح الناعم

* Measure the size of the particles

تغيير Sieving (Screening)



400µm

300µm

200µm

100µm

Bottom

Bottom

Shake
15-20 min

Pass 100 / retained Bottom

100 + Bottom → Bottom

يعاد ارتجاج وحركة حتى تسقط الجسيمات من الفتحات

* أكبر Aperture يكون ثقل بعد ذلك يبلت أيضا كلما تنزل تحت والفرد
سبب كل Aperture هو $\sqrt{2}$

** Particle Passes through aperture depends On

1 Size → يعني إذا الجسيم أكبر من الفتحة ما حتم

2 Orientation → يعني هذه الجسيم ما حتمت من الفتحة إلا إذا حركتها
و كذلك الـ Orientation يلعب دور كبير في هذا الجسيم

* lower limit of size & Screen

① The proportion of free space on the Screen becomes very small as the
size of aperture is reduced

② the attractive forces between particles become larger at small particle sizes (stick together)

(1) يعني كما الحبيبة تنزل على فتحة اصغر راح اصير الحافه اليه تتحرك صغرا اصغر
خال free space راح اصبح صغيره في الحيات ~~في~~ ساقه

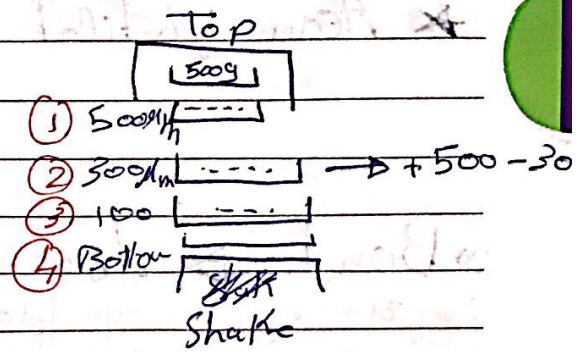
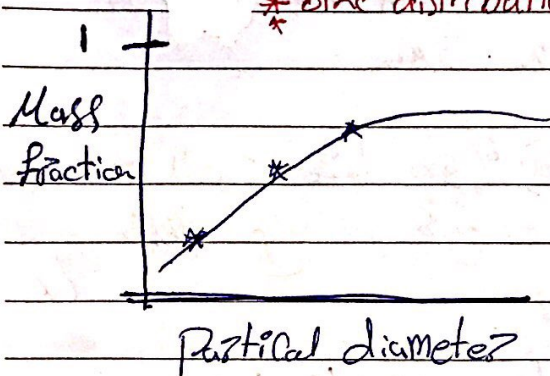
٥) كما الحبيبات تتصادم مع بعضها البعض راجع $attractive$ بينهم وراجع $attractive$ لتلقف مع بعضها البعض فراجع $attractive$ العجيب ولاحظ نقطة وكذلك في الحببة الخشنة يكون الـ $attractive$ أكبر من الحببة الناعمة

* Types of Screening :- (1) Dry
(2) Wet $\Rightarrow$ Particulate very Clean

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* Partical Size distributions

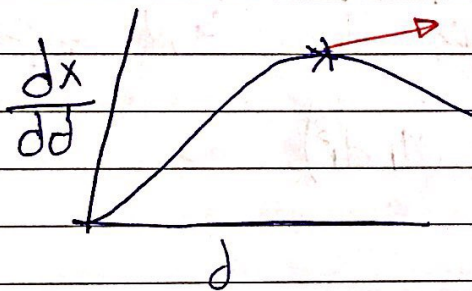
* Size distribution Curve *



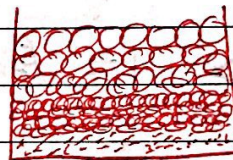
Mass Fraction ← وزن النسبة

500

$$\frac{\text{وزن النسبة 1 + وزن النسبة 2 + وزن النسبة 3}}{500} \quad \text{وزن النسبة 1 + وزن النسبة 2 + وزن النسبة 3} \quad \text{وزن النسبة 1 + وزن النسبة 2 + وزن النسبة 3}$$



الكمية Size موجود في هذه النسبة

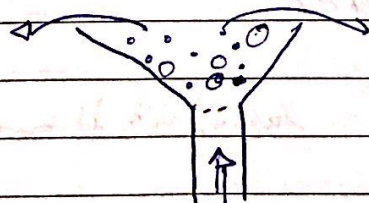


B Microscopic analysis (1 - 100 µm)

يكونوا في حبيبات على شرايات زجاجية وسنوف الحبيبات
الكسبة حبة اي Circles ويكون هذا هو حجم الكسبة

C Coulter Counter (1 - 100 µm)

هذا الجهاز يستعمل على الاستناد السحابة



D Elutration

Flow of air

Settling velocity

في حال الكسبة تباعد عن بعضها
وتنقل

سوف الكسبة الصغيرة التأثير على الحبيبات
الحجم حبيبات الحبيبات من قطع من فوق

كل ما نزيد 9.17 كم نأخذ حبيبات ركم
Apple & recieve
ask the
recovery

* Mean Partical Size

جميع الجسيمات (Product)
80% 1μm
15% 2μm
5% 3μm

* Bond $\Rightarrow d_{80} = 1\mu m \rightarrow (1\mu m) \% 80$
هذا اذا الجسيم منها 80% (يعني راج اقربها)
راج الاستطبع ان اعتبر الجسيم كلها 1μm

$\Rightarrow$ Unit Mass of Partical Consisting $n_i / d_i / \rho$

$$X_i \text{ (mass fraction)} = \rho * d_i^3 * K_i * n_i$$

Constant depends on shape $\square$ No. of partical

$$\sum X_i = 1 \Rightarrow 1 = \rho * K_i * \sum (n_i d_i^3)$$

* Volume Mean Diameter

** weight Mean Diameter (d_v)

$$\rightarrow d_v = \frac{\sum n_i d_i^4}{\sum n_i d_i^3} \rightarrow (\text{هو No. of partical})$$

$$\rightarrow \sum X_i * d_i \rightarrow \text{لو عنده mass. fraction}$$

* Mean Volume diameter

$$1] d_v = \sqrt[3]{\frac{1}{\sum \frac{X_i}{d_i^3}}} \quad \text{Mass. fraction}$$

$$2] d_v = \sqrt[3]{\frac{\sum n_i d_i^3}{\sum n_i}} \quad \text{No of partical}$$

ask, believe & recieve

Five Apple

* Surface mean diameter &
 ** Sauter mean diameter

$$\rightarrow d_s = \frac{1}{\sum \frac{x_i}{d_i}} \quad (\text{mass fraction})$$

$$\rightarrow d_s = \frac{\sum n_i \cdot d_i^3}{\sum n_i \cdot d_i^2} \quad (\text{no. of particle})$$

* Mean Surface diameter

$$\rightarrow d'_s = \sqrt{\frac{\sum x_i \cdot d_i}{\sum \frac{x_i}{d_i^3}}}$$

μm	d	n_i	x_i
10-8	9	-	-
8-6	8	-	-
...	...	-	-
2-Bottom	...	-	-

من 8 إلى 10
الباقي

$$\rightarrow d'_s = \sqrt{\frac{\sum n_i \cdot d_i^3}{\sum n_i}}$$

* length mean (dl):

$$d_L = \frac{\sum \frac{x_i}{d_i}}{\sum \frac{x_i}{d_i^2}}$$

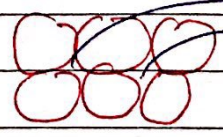
** Mean length diameter

$$d'_L = \frac{\sum \frac{x_i}{d_i^2}}{\sum \frac{x_i}{d_i^3}}$$

$$d_L = \frac{\sum n_i \cdot d_i^2}{\sum n_i \cdot d_i}$$

$$d'_L = \frac{\sum n_i \cdot d_i^2}{\sum n_i}$$

* Solids in Bulk &

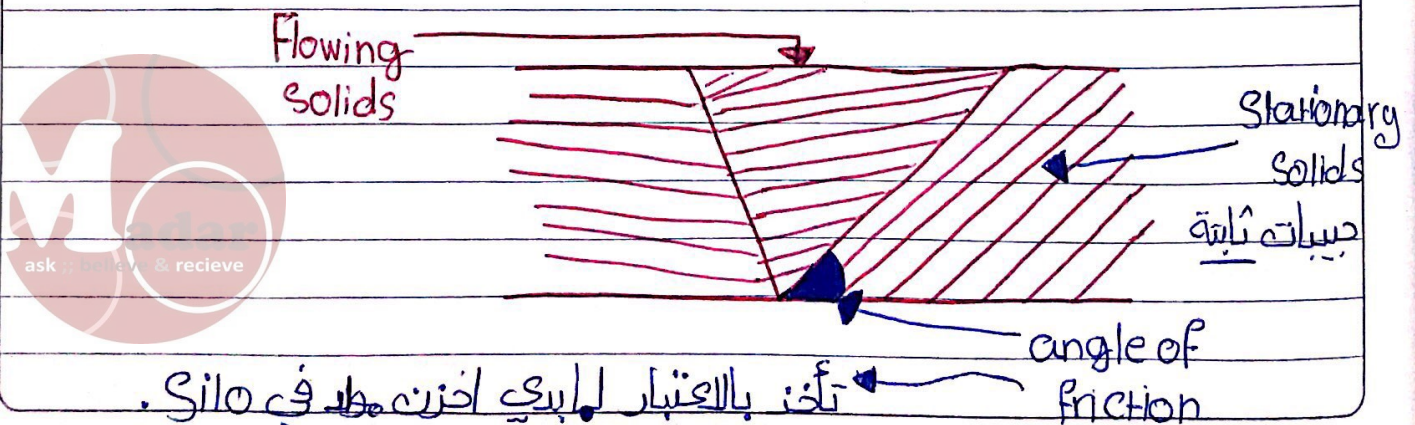


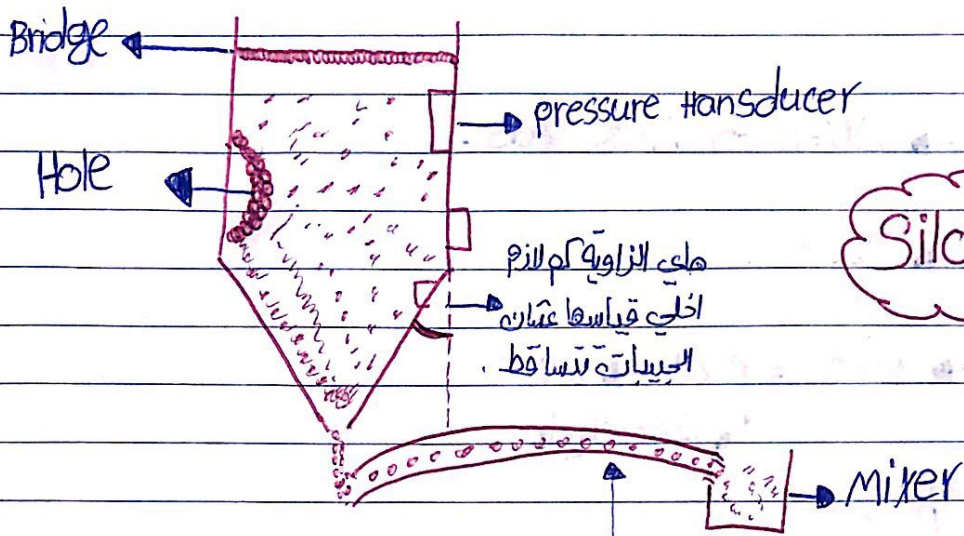
هذه الفراغات تسمى
 (Voids)

هذه الفراغات هي التي يملأها الهواء + المواد تكون هذه الفراغات مسامية

* Agglomeration [مكان يماي مشاكل]

- ① Mechanical interlocking → نتيجة تواجد الجسيمات مع بعضها
 ↳ ناتج عن اتي ميكانيكي
- ② Surface attraction $< 10 \mu m$ → Result from forces like V.V force
 ↳ نتيجة الخيط
- ③ Plastic welding (Irregular particle) → تكون الجسيمات خشنة
 ↳ ناتج عن اتي ميكانيكي
- ④ Electrostatic Attraction → من خواص الجسيمات يصير عليها شحنات
 ↳ ناتج عن الطوبية
- ⑤ Effect of moisture (H_2O) → زي الطحين لها احتكاك عاليه
 ↳ ناتج عن الرطوبة
- ⑥ Temperature fluctuations → لو زودنا الحرارة مكان بعض الجسيمات تنزوب
 ↳ نتيجة التغير في الحرارة





Silo Chopper

* باقر الحبيبات ويوريها - Unit على Flow rate حبيبات يتساقط بواسطة القشاطر الناقل

* في مشكلة ما ان الحبيبات ممكن يصير عليها Agglomeration وتضرب فتضرب باقي الحبيبات

* Conveying of solids : نقل الحبيبات

① Gravity shutes → pipe على موري ويتساقط بفعل الجاذبية

② Air slides → pipe + Air (at low p) → حثيف للأعلى
أي مانع الشد

③ Belt conveyors → قشاطر متحرك → يتحكم بسرعتو

④ Screw → وهو يلف ويسحب مع الحبيبات

⑤ Bucket elevators → اوعية كبيرة يتلف

⑥ Vibrating conveyors → في مانع الأوية

⑦ pneumatic → ينفث الحبيبات لسافات كبيرة Fluidization

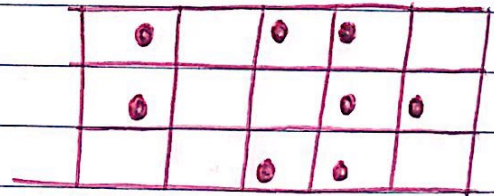
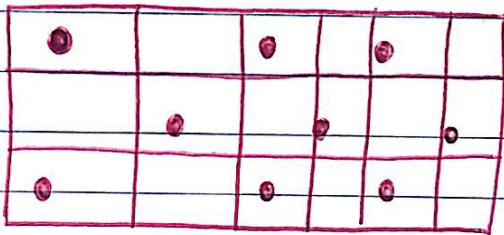
* Blending (Mixing)

نوعیة جهاز الخلط بتلعب mechanism
نور.

① Convective → قطع من Solid تغير مكانها

② Diffusion → جزيئات تنتقل من مكان
ليكان

③ Shear → طبقات تنتقل



* Uniform
نادرًا
* point Uniformity

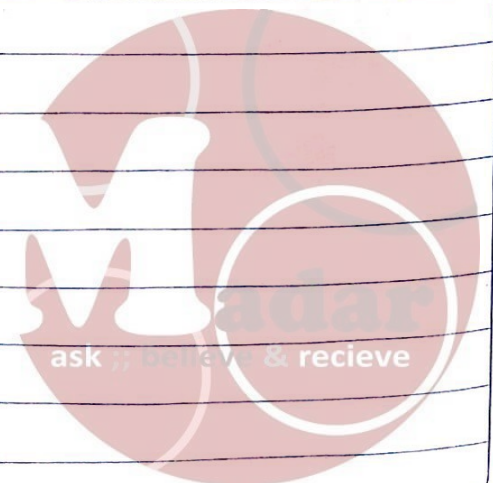
* OVER all Degree of
Randomness

* Degree of Mixing :-

① properties of the required mix.

② Should be easy to measure.

③ Suitable for a variety of different mix.



* For a completely Random mix of uniform particles:

$$S_r^2 = \frac{p(1-p)}{n}$$

S^2 : variance

n : Numb of particles

p : overall propotion of particles. → كم نسبة المادة الصلبة الى احتفاظ المادة الى سائل.

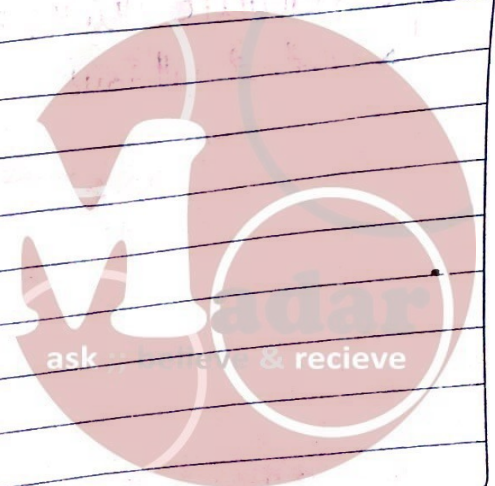
* For a completely un mixed system:

$$S_o^2 = p(1-p)$$

* Index or degree of Mixing:

$$M = \frac{S_o^2 - S^2}{S_o^2 - S_r^2}$$

S^2 : Unmixed material from large number of sample.



Ex: Assess the following mixer

S^2	0.25	0.006	0.015	0.018	0.019
Mixing Time	30	60	90	120	150

$p = 20\%$ of the mix

Each Sample = 100 particles

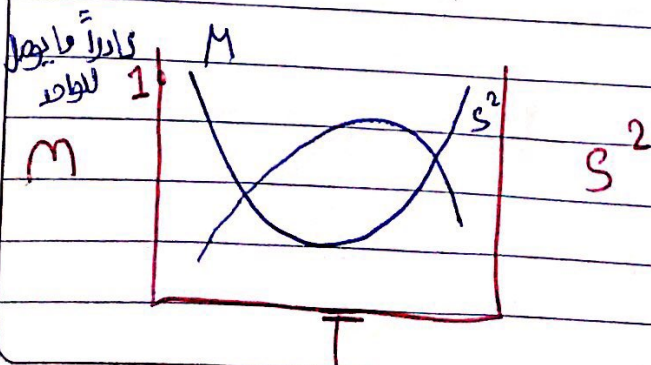
* Unmixed sys $\rightarrow S_0^2 = p(1-p) = 0.2(1-0.2) = 0.16$

* Random mix $\rightarrow S_r^2 = p(1-p)/n = 0.2(1-0.2)/100 = 0.0016$

* $M = \frac{S_0^2 - S^2}{S_0^2 - S_r^2} = \frac{0.16 - S^2}{0.16 - 0.0016} \rightarrow M = 1.01 - 6.3 S^2$

$M = 1.01 - 6.3 S^2$

TC(s)	30	60	90	120	150
S^2	0.025	0.006	0.015	0.018	0.019
M	0.652	0.972	0.915	0.696	0.691



8-10

Mixer $\rightarrow$ Horizontal

Filled $\rightarrow$ 30% capacity with 20% Black Sand.

Rotates $\rightarrow$ at 21 rpm $\rightarrow$ Nine Rotate

Sample No.	No. of Black	Tot. particle	p_i	p_i^2
1	36	114	$(36 \times 114) / 100 = 31.58$	997.3
2	-	-	-	-
30	20	112	17.9	318.9
Tot			629.5	14372.2

* Mean Concentration of Black Sand

$$\bar{x} = \frac{\sum x_i}{n}$$

$$\bar{p} = \frac{\sum_{i=1}^{30} p}{n} = \frac{629.5}{30} = 20.98$$

* Standard deviation: ($x=p$)

$$S = \sqrt{\frac{\sum x_i^2 - \bar{x} \sum x_i}{n-1}} = \sqrt{\frac{14372.1 - (20.98/629.5)}{30-1}} = 6.33$$

* Mixer inclined on angle



① First case

② Second case

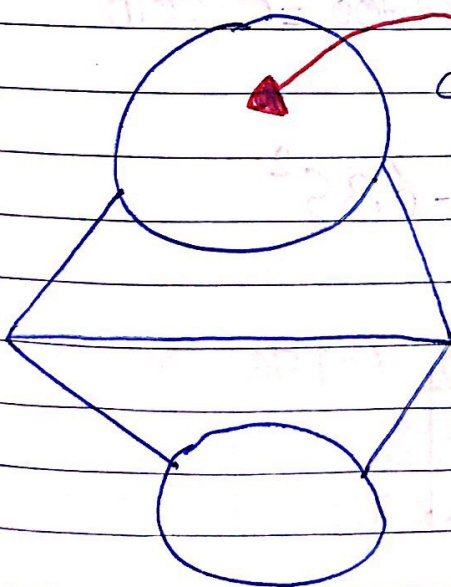
$S_2 = 7.21$ (Cencline)

$S_1 = 6.33$ (Horizontal)

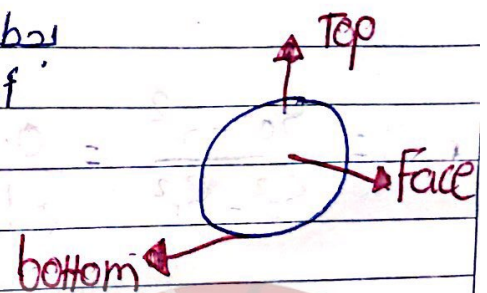
* Low Standard deviation $\rightarrow$ high uniformity. كل ما كان الانحراف

* High $\rightarrow$ poor mixture. البياري أقل كان
المix أفضل

Double Cone mixer:



بسط مارة داخله وهو يلف كالمصين
أخذ مياته من ال
Top
Bottom face.



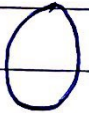
* Size reduction of Solids : التآسير

① Combustion → Surface Area ↑

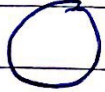
② Drying →  → الحبة الصغيرة بها حرارة عالية عن الحبة الكبيرة
تجف.

③ Mixing

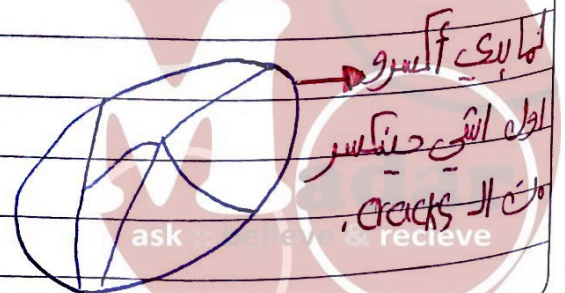
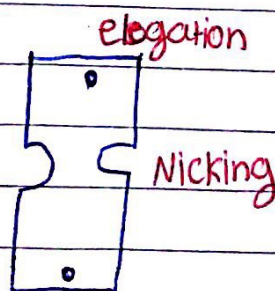
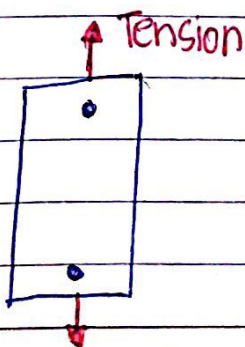
* Mechanism

Sudden Impact  → Relative few large particles.
" " Intermediate " "
" " " " " "
No. of fine particles.

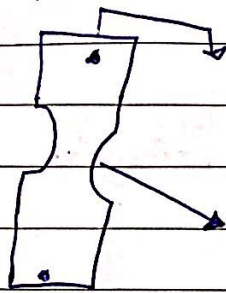
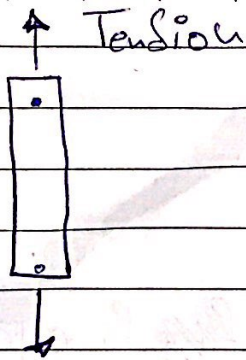
* Energy of Blow Increased :-
لو زينا الطاقة خروج الكميات الصغيرة.

 → Smaller size / numerous

* Fissures (cracks) :- تشققات Fine / Increasing

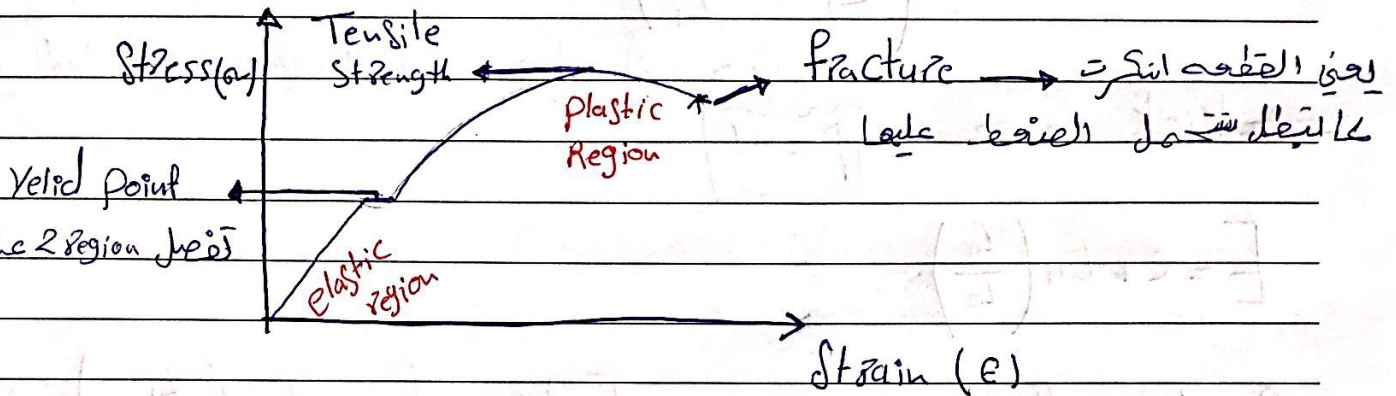


*10/10



Elongation استطالة

Necking $\rightarrow$ Decrease in cross sectional of area



Elastic Region $\leftarrow$ لو جبنا قفصه مطاط و مت بناها بعد نردك الحوتر راح ترجع نفس ما كانت

Yield point $\leftarrow$ لو زدت القوة او الضغوط والقفصه ما رجعت نفس ما كانت فهي راح تتحول من Elastic $\leftarrow$ plastic يعني هونقطة تحول

$$\frac{dE}{dL} = -cL^p$$

Energy required

change of unit mass

$\rightarrow$ Rittenger's law $\rightarrow$ $p = -2$ "empirical approach"

$$E = c \left(\frac{1}{L_2^2} - \frac{1}{L_1} \right)$$

ask : believe & recieve

$$C = \underline{KR} * \underline{f_c} \rightarrow \text{fracture strength}$$

Rittenger's Constant

$$E = Rf * f_c * \left(\frac{1}{L_2} - \frac{1}{L_1} \right) \rightarrow \text{Used for fine grinding}$$

يعني المعادلة يتغير في حالة لو بيت حبات ناعمة جدًا

$$\Rightarrow \text{Kick's law} \Rightarrow \boxed{p = -1}$$

$$E = c * \ln \left(\frac{L_1}{L_2} \right)$$

$$C = \underline{K_k} * f_c \rightarrow E = K_k * f_c * \ln \left(\frac{L_1}{L_2} \right)$$

Kick's Constant

Used for coarse crushing

للحبات الكبيرة (2mm)

$$\Rightarrow \text{Bond law} \Rightarrow \boxed{p = -3/2}$$

$$E = 2 * C * \left(\frac{1}{\sqrt{L_2}} - \frac{1}{\sqrt{L_1}} \right)$$

Used for intermediate size

يعني انه متوسط

* Energy Utilization $\rightarrow$ الطاقة المأثلة وين يتروح

1] Elastic, plastic (plastic + Elastic) $\rightarrow$ Region

2] friction between particles and with machine

3] Nose

ask : believe & recieve

* Methods of Operating Crushers

A] Free crushing

1] Feeding the material at low rate $\Rightarrow$ the product escape readily

يعني اذا عندك ماكينة بتخمن بخلوها ال Flow rate شوي شوي $\leftarrow$ ال Product راح يطلع سالم

2] Residence time $\Rightarrow$ Short (مقيصر) $\Rightarrow$ تكون فيه الكمية في الماكينة (مقيصر)

3] Under Size Material $\Rightarrow$ Avoid (تجنب) $\Rightarrow$ يعني طراح تطلع فيه حبات اصغر من الحجم المطلوب وادها طلع حتكون كمية صغيرة جداً

B] Choke feeding $\Rightarrow$ الفكرة فيها الماكينة تكون ممتلئة بالمادة فالمحرك وراحت الحركة طراح تكون موجودة مثل الحالة الزدلي وحيثون فيها تأخير ال Flow rate قليل

1] Machine is kept full of material $\Rightarrow$ discharge of product is impeded

2] Residence time $\Rightarrow$ long

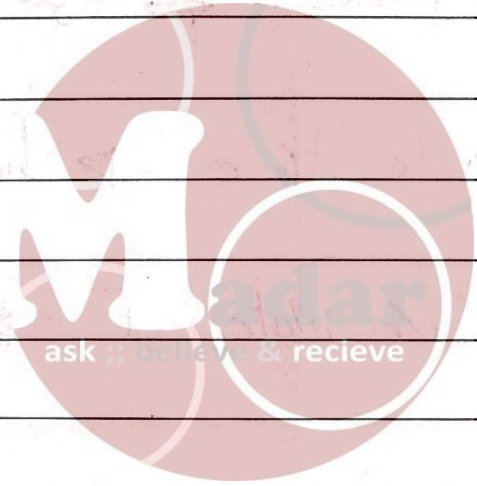
3] Higher degree of crushing $\Rightarrow$ Energy Consumption is high

حجم الحبات الي اريدھا	Feed Size	Product Size
Coarse crushers	1500 - 40	50 - 5
Intermediate "	50 - 5	5 - 0.1
Fine "	5 - 2	0.1 - 0.7
Colloid mills	0.2	0.1

* انواع من الحما كينار - *

* Hammer mill → ذك السوا كين

* Jaw → كتوي على قنكيت واحد ثابتي وللثاني متحرك



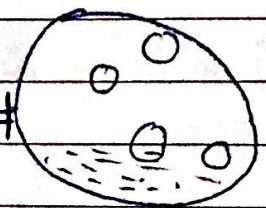
13/Oct

* Ball mill → من أشهر المكينات التي تستخدم في طحن الخام جيدًا

Capacity ~ almost 50% volume

* هذه عبارة عن أسطوانة طولها (5-6m) وقطرها 3m هذه الأسطوانة تقطع درون الفترة التي أعينها بنسبة (50-60%) من الكادة المراد طحنها + كرات من مواد مختلفة منة إذا الكادة مبلية جيدًا اطح معها كرات من ال Steel

هذه الأسطوانة كاتلف حثفت معها الكيات الكبيرة ثم تساقط على الكادة وتطحنها



Large → Feed

* Steel Ceramics → Crushing Strength

Small → Fine

* Types

- Wet → كلها مبلية (ماء + الكادة المراد طحنها + الكرات) تسهل الطحن / أقل وقت / أقل استهلاك للطاقة
- Dry → مبلية بنسبة 50% من المواد المراد طحنها

ask

& recieve

Five Apple

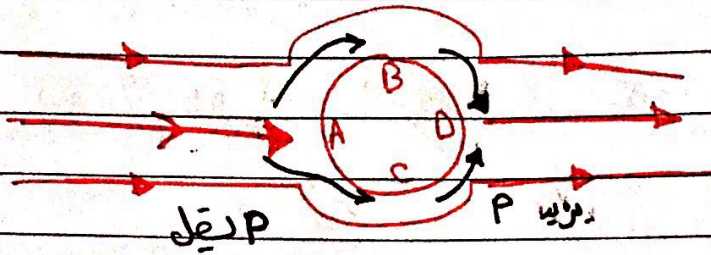
* Factors Affecting milling

- 1- Rate of feed - ما يصبها مثل ما سمته choke
- 2- Speed of rotation - ٨٠م تكون السرعة متوسطة لأنه إذا كانت السرعة عالية
مراح تلتفت الحبيبات بالحبيبات
- 3- Weight of Balls - نوع الكرات المبراج أحدها بيختر على صلابه الكاده الكفحة
- 4- Discharge material
- 5- Slope of the mill - ٨٠م تكون مائلة بزاوية حتى استطيع اخذ المنتج منها

* Chapter 3

* Particals / Fluid System

→ Fluid past Cylinder in a direction $\perp$ to its axis



* Non-Viscous fluid

- A and D $\rightarrow$ fluid at rest

- B and C $\rightarrow$ Velocity is at max

* Kinetic energy $\Rightarrow$ max at B and C $\rightarrow$ بیش انرژی حرکتی
Zero at A and D $\rightarrow$ no velocity

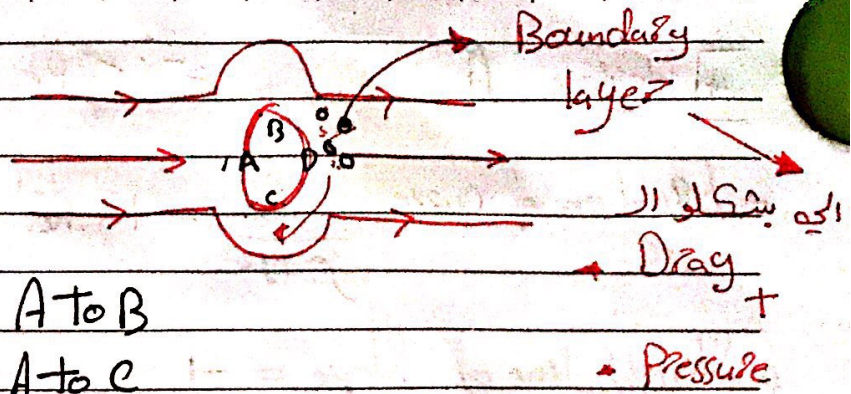
* Pressure falls from A to B
and A to C } کم می شود

* Pressure Rises from B to D
and C to D } زیاد می شود

* P at A and D $\Rightarrow$ the Same

* No Net force exerted by the fluid on the cylinder
 $\therefore$ No Drag

* Viscous fluid



* Pressure $\rightarrow$ Decrease A to B
and A to C

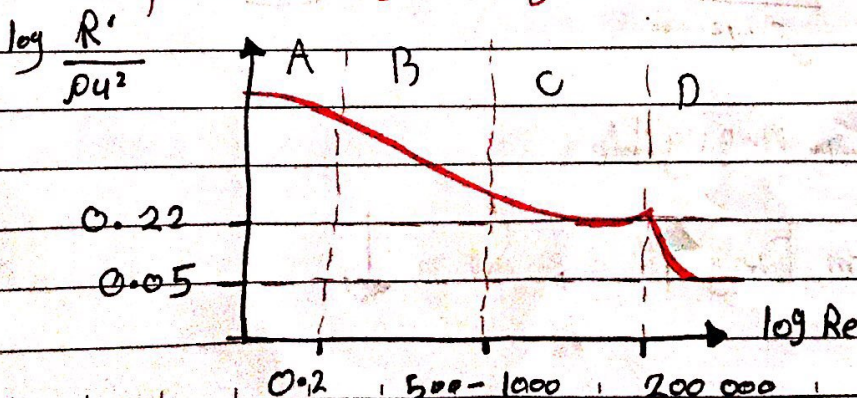
* $P \uparrow \rightarrow$ B to D
and C to D

$\rightarrow$ Total force $\rightarrow$ 1) Skin friction
2) Form Drag

* Stokes law $F = 3 \pi \mu d u$
 Drag force $\leftarrow$ F $\leftarrow$ μ viscosity $\leftarrow$ d Diameter of the sphere $\leftarrow$ u velocity of fluid

$$Re = \frac{\rho \cdot u \cdot d}{\mu}$$

* $R' \rightarrow$ Force exerted on unit projected area of ~~sphere~~ Particle
in plane at right angles to its direction of motion



* 15/10

* **Region A** $\rightarrow 10^{-4} < Re' < 0.2$

* Equation of curve $\frac{R'}{\rho u^2} = 12 Re'^{-1}$ --- [1]

* Straight line of Slope = -1

* Form friction = $1/3$

* Skin friction = $2/3$

* $Re \downarrow$

* **Region B** $\rightarrow 0.2 < Re' < (500 - 1000)$

* Equation I $\rightarrow \frac{R'}{\rho u^2} = \frac{12}{Re'} \left[1 + \frac{3}{16} Re' \right]$ --- [2]

Equation II $\rightarrow \frac{R'}{\rho u^2} = 12 Re'^{-1} \left[1 + 0.15 Re'^{0.687} \right]$ --- [3]

Leaving the flow as LA

* Form Drag $\rightarrow$ Increasing

* **Region C** $\rightarrow (500 - 1000) < Re' < 2 \times 10^5$

* Equation of curve $\frac{R'}{\rho u^2} = 0.22$ --- [4]

* Skin friction $\rightarrow$ negligible

* $Re \uparrow \rightarrow$ Form Drag $\uparrow \rightarrow$ Skin $\downarrow$

* Region D $\rightarrow Re' > 2 \times 10^5$

Eq of curve $\frac{R'}{\rho u^2} = 0.05$ --- [5]

*** Total Force on the particle

[*] In Region A

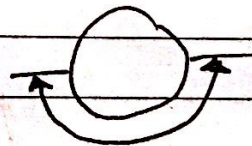
$\rightarrow$ from eq 1 $\rightarrow \frac{R'}{\rho u^2} = 12 Re^{-1}$

$$R' = 12 \rho u^2 \frac{\mu}{4 \rho d}$$

$$R' = \frac{12 \mu u}{d}$$

*** Projected area of particle = $\frac{1}{4} \pi d^2$

*** Total force $R'(\text{force}) \times \frac{\text{drag}}{\text{Area}}$



$$F = \frac{12 \mu u}{d} \times \frac{1}{4} \pi d^2 = 3 \pi \mu d u \text{ (Stokes eq)} \text{ --- [6]}$$

* In Region B $\rightarrow$ from eq 3 $\rightarrow \frac{R'}{\rho u^2} = 12 Re' \left[1 + 0.15 Re'^{0.687} \right]$

$$R' = 12 \rho u^2 \frac{\mu}{u d \rho} \left[1 + 0.15 Re'^{0.687} \right] =$$

$$\frac{12 \mu u}{d} (1 + 0.15 Re'^{0.687})$$

$$F = \frac{12 \mu u}{d} (1 + 0.15 Re'^{0.687}) * \frac{1}{4} \pi d^2$$

$$F = 3 \pi \mu u d (1 + 0.15 Re'^{0.687}) \text{ --- [7]}$$

* In Region C $\rightarrow$ Eq 4:-

not pure Stoke

$$\frac{R'}{\rho u^2} = 0.22$$

$$F = 0.22 \rho u^2 \cdot \frac{1}{4} \pi d^2$$

$$F = 0.055 \pi d^2 \rho u^2 \text{ --- [8]}$$

⊕ Newton's law

* In Region D $\rightarrow$ Eq 5

$$R' = 0.05 \rho u^2$$

$$F = 0.05 \rho u^2 \cdot \frac{1}{4} \pi d^2$$

$$F = 0.0125 \pi d^2 \rho u^2 \text{ --- [9]}$$

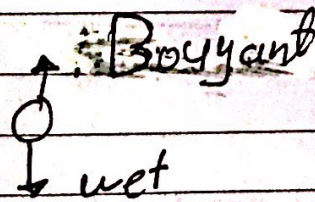
Frictional Fluid (Drag)

*** Drag and Buoyant

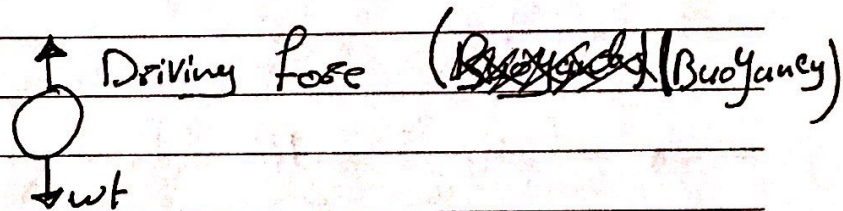


Driving Force due to gravity

*** Driving force Due to gravity



*** Gravity Driving force



$$\rightarrow F_G = (\rho_s - \rho) g V_p$$

$F_G \rightarrow$ gravity Driving force

$\rho_s \rightarrow$ Solid Density

$\rho \rightarrow$ fluid "

$V_p \rightarrow$ Volume of particle

Drag Coefficient

* Drag force $\rightarrow F_D = \frac{C_D * A_p * \rho * U_s^2}{2}$

projected area of particle

Settling velocity of particle

* Drag Coefficient

$$* C_D = 24 / Re$$

$$\hookrightarrow F_D = \frac{24}{Re} \cdot \frac{\pi}{4} \cdot d^2 \cdot \rho u^2 \quad \because Re = \frac{\rho u D}{\mu}$$

$$\hookrightarrow F_D = 3 \pi \mu u \rightarrow \text{Same as region A} \\ \text{eq 6 (Stokes law)}$$

17/Oct

AT equilibrium

→ In Region A

$$V_p (\rho_s - \rho) g = 3 \pi \mu d U \quad \rightsquigarrow \quad V_p = \frac{\pi}{6} d^3$$

$$U_0 = \frac{d^2 g}{18 \mu} (\rho_s - \rho)$$

→ Terminal Settling Velocity

→ In Region C

$$(\pi/6) d^3 V_p (\rho_s - \rho) g = 0.055 \pi d^2 \rho U^2$$

$$U_0^2 = 3 d g (\rho_s - \rho) / g \quad \rightsquigarrow \quad \text{AT Highest Re. No}$$

→ Region A

* Particle A → $U_{0A} = \frac{d_A^2 g (\rho_A - \rho)}{18 \mu}$

* Particle B → $U_{0B} = \frac{d_B^2 g (\rho_B - \rho)}{18 \mu}$

* if $U_{0A} = U_{0B} \rightsquigarrow \frac{d_B}{d_A} = \sqrt{\frac{\rho_A - \rho}{\rho_B - \rho}}$

→ In Region C

$$* \text{Particle A} \rightarrow U_{0A}^2 = \frac{3 d_A g (\rho_A - \rho)}{\rho}$$

$$* \text{Particle B} \rightarrow U_{0B}^2 = \frac{3 d_B g (\rho_B - \rho)}{\rho}$$

$$* \text{if } U_{0A} = U_{0B} \rightarrow \frac{d_B}{d_A} = \frac{\rho_A - \rho}{\rho_B - \rho}$$

$$\frac{d_B}{d_A} = \left(\frac{\rho_A - \rho}{\rho_B - \rho} \right)^S$$

→ when $S \geq 1/2$ (Region A)

$S \geq 1$ (Region B) Newton's

$1/2 < S < 1$ (Region b) Intermediate region

Unknown Re

$$Eq (10) \rightarrow F_G = (\rho_s - \rho) g V_p$$

$$F_G = (\rho_s - \rho) g \frac{1}{6} \pi d^3$$

$$\rightarrow R_o \frac{1}{4} \pi d^2 = \frac{1}{6} \pi d^3 (\rho_s - \rho) g$$

$$\rightarrow R_o = \frac{2}{3} d (\rho_s - \rho) g$$

→ Divide By ρU_0^2

$$\left(\frac{R_0'}{\rho U_0^2} = \frac{2}{3} \frac{d g (\rho_s - \rho)}{\rho U_0^2} \right) * Re^2$$

$$- \frac{R_0'}{\rho U_0^2} * Re^2 = \frac{2 d g (\rho_s - \rho)}{3 \rho U_0^2} * Re^2$$

$$- \frac{R_0'}{\rho U_0^2} \frac{U_0^2 d^3 \rho^2}{\mu^2} = \frac{2 d g (\rho_s - \rho)}{3 \rho U_0^2} \frac{U_0^2 d^3 \rho^2}{\mu^2}$$

$$= \frac{2 d^3 \rho g (\rho_s - \rho)}{3 \mu^2} \quad \text{~~Galileo's No~~}$$

$$- \frac{R_0'}{\rho U_0^2} * Re^2 = \frac{2}{3} Ga$$

$$\rightarrow Ga = \frac{d^3 \rho g (\rho_s - \rho)}{\mu^2}$$

$$Ga \approx 18 Re' \quad \text{Galileo's No}$$

$$\rightarrow Ga = 18 Re \quad ; \quad Ga < 3.6$$

$$\rightarrow Ga = 18 Re + 2.7 Re^{1.687} \quad ; \quad 3.6 < Ga < 10^5$$

$$\rightarrow Ga = \frac{1}{3} Re^2 \quad ; \quad Ga > 10^5$$

* Table 3.2

* Diameter (Unknown)

$$- Ro' = \frac{2}{3} d (\rho_s - \rho) g$$

$$- Ro' \frac{1}{4} \pi d^2 = \frac{1}{6} \pi d^3 (\rho_s - \rho) g$$

$$- \frac{Ro'}{\rho u_o^2} = \frac{2}{3} \frac{d (\rho_s - \rho) g}{\rho u_o^2}$$

20-10

Unknown Re:

$$F_G = (P_s - P) g V_p$$

$$F_G = (P_s - P) g \frac{1}{6} \pi d^3$$

$$R_o \frac{1}{4} \pi d^2 = \frac{1}{6} \pi d^3 (P_s - P) g$$

$$R_o = \frac{2}{3} d (P_s - P) g$$

Divide by $\rho \mu_o^2$

$$\frac{R_o}{\rho \mu_o^2} = \frac{2}{3} \frac{d g g (P_s - P)}{\rho \mu_o^2}$$

$$L \times Re_o^2$$

$$Re_o^2 = \frac{2 d^3 \rho g (P_s - P)}{3 \mu^2}$$

$$\frac{R_o}{\rho \mu_o^2} Re_o^2 = \frac{2}{3} Ga$$

$$Ga = \frac{d^3 \rho g (P_s - P)}{\mu^2} \quad \text{Galelio No.}$$

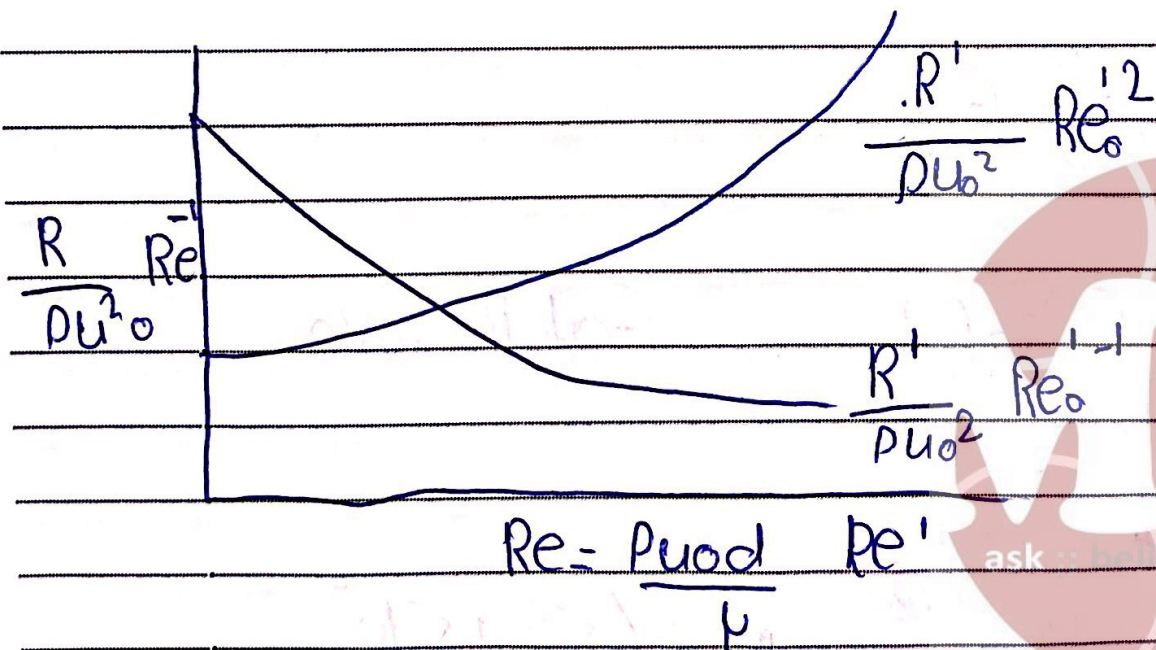
Dia unknown

$$\frac{R_0}{\rho U_0^2} Re_0^{-1} = \frac{2}{3} \frac{d(Cp_s - P)g}{\rho U_0^2} Re_0^{-1}$$

$$\begin{aligned} \frac{R'_0}{\rho U_0^2} Re_0^{1-1} &= \frac{2}{3} \frac{d(Cp_s - P)g}{\rho U_0^2} \frac{\mu}{U_0 d P} \\ &= \frac{2}{3} \frac{\mu g (Cp_s - P)}{\rho^2 U_0^2} \end{aligned}$$

Table 3.3

General Graph



Example:

U_0 ?

Spherical steel particle

Dia 0.4 mm

Sett. in oil?

oil sp. gr. 0.82

μ 10 mNs/m²

sp. gr. steel = 7.87

$$\frac{Re_0}{\rho U_0^2} Re_0^{12} = \frac{2d^3 \rho g (p_s - p)}{3\mu^2} = 24.2$$

$$\log(24.2) = 1.384$$

Table 3.2

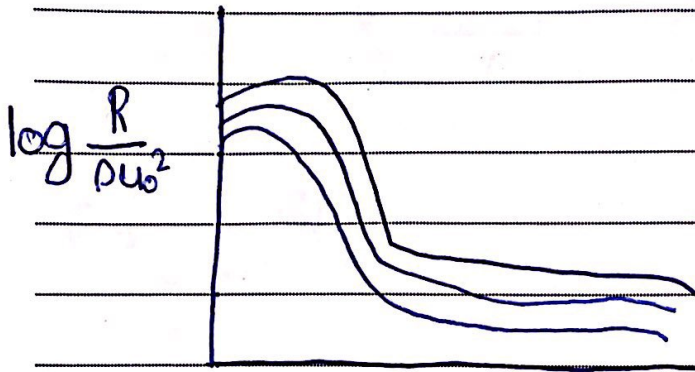
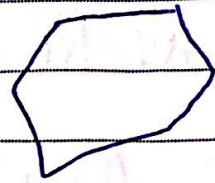
$$\log Re_0 = 0.222$$

$$Re_0 = 1.667$$

$$Re = \frac{U d \rho}{\mu}$$

$$U_0 = 51 \text{ mm/s}$$

* Non-Spherical particles

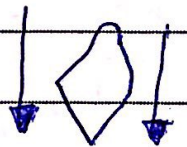


separate curve for each shape $\rightarrow$ must be obtained.

Region a

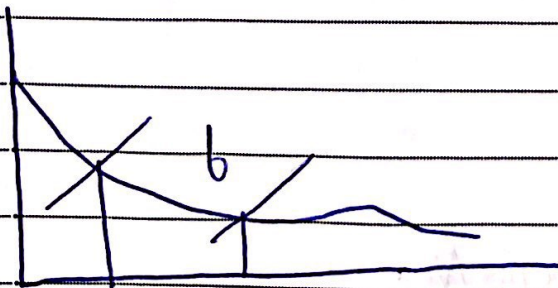
Flow $\rightarrow$ Streamline $\rightarrow$ Low Re

Drag $\frac{R'}{\rho u^2} = k Re^{-1}$ k always 12



Region b

Transition conditions. All values will be shifted,



Region C

- cylinders with axes // to the direction of motion.

$$\frac{\text{Length}}{\text{Dia}} = 1 \rightarrow \frac{R}{\rho u^2} = 0.45$$

- cylinders with axes $\perp$ to the direction of motion

$$\frac{\text{Length}}{\text{Dia}} = 1 \rightarrow \frac{R'}{\rho u^2} = 0.3$$

$$\frac{\text{Len}}{D} = \infty \rightarrow \frac{R}{\rho u^2} = 0.35$$

$$\frac{L}{D} = 20 \rightarrow \frac{R}{\rho u^2} = 0.45$$

$$\frac{L}{D} = \infty \rightarrow \frac{R}{\rho u^2} = 0.6$$

Terminal falling velocity

$$u_0 = \frac{gd^2(\rho_s - \rho)}{18\mu}$$

values are higher than the value of 0.22 for spheres

ask :: believe & receive

- Mean projected dia is defined as the dia of a circle having the same area as the particle when viewed from above and lying in its most stable position.

$$No = k d_p^3$$

k : constant depends on shape
 $= \frac{\pi}{6} d^3$ (sphere)

* Heywood Approach

Use table 3.4

Corrections $\log \frac{R'}{\rho u^2} Re'^2 = \text{corrections}$

Table 3.5 $\log \frac{R'}{\rho u^2} Re'^{-1} = \dots$

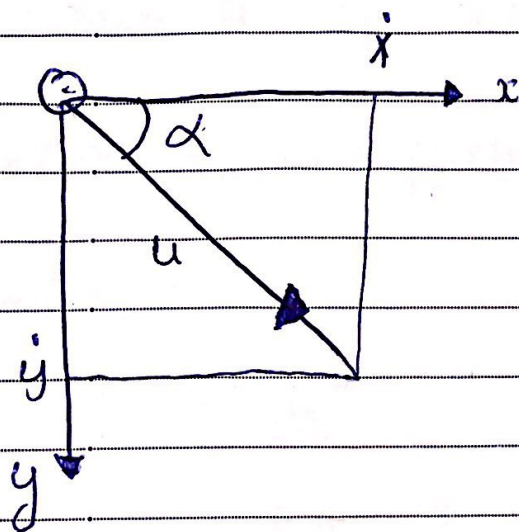
$$\frac{Ro}{\rho u_0^2} = \frac{4k d_p g (P_s - P)}{\pi \rho u_0^2}$$

$$\textcircled{1} \frac{Ro}{\rho u_0^2} Re_o^2 = \frac{4k d_p^3 g (P_s - P)}{\mu^2 \pi} \quad No \mu$$

$$\textcircled{2} \frac{Ro}{\rho u_0^2} Re_o^{-1} = \frac{4k' \mu g (P_s - P)}{\pi \rho^2 u_0^2} \quad No d.$$

22-10

* Acceleration motion :-



• The velocity u can be resolved into 2 components $\dot{x}, \dot{y}$

• $\dot{x}$ and $\ddot{x}$ → Denote the 1st & 2nd deriv. of the displacement x in the x -dir with respect to time.

• $\dot{y}$ and $\ddot{y}$ → For y direction

$$\cos \alpha = \frac{\dot{x}}{u} \quad \sin \alpha = \frac{\dot{y}}{u} \quad u = \sqrt{\dot{x}^2 + \dot{y}^2}$$

1 In the vertical direction, Apparent weight of the par

$$N g (P_s - P)$$

$$\frac{m}{P_s} g (P_s - P)$$

$$m g \left(1 - \frac{P}{P_s}\right)$$

← forces acting on particle :-

ask :: believe & recieve

2. The Drag Force

$$F = R' A'$$

$$F = \frac{R}{\rho u^2} \rho u^2 A$$

- The component in x-direction

$$\frac{R}{\rho u^2} \rho u^2 A \cos \alpha = \frac{R}{\rho u^2} A' \rho \dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}$$

- The y-direction

$$\frac{R}{\rho u^2} \rho u^2 A' \sin \alpha = \frac{R}{\rho u^2} A' \rho \dot{y} \sqrt{\dot{x}^2 + \dot{y}^2}$$

* The equation of motion in the x & y direc

$$m \ddot{x} = - \frac{R}{\rho u^2} \rho A \dot{x} \sqrt{\dot{x}^2 + \dot{y}^2} \quad \text{--- (1)}$$

$$m \ddot{y} = - \frac{R}{\rho u^2} \rho A \dot{y} \sqrt{\dot{x}^2 + \dot{y}^2} + mg \left(1 - \frac{\rho}{\rho_s}\right) \quad \text{--- (2)}$$

Ass

Assumption:-

① Motion of a particle when Form Drag is negligible.

• Non spherical particle

→ Region a

$$\frac{R'}{\rho u^2} = k' Re^{-1}$$

substitute into eq 1 & 2

$$\ddot{x} = - \frac{A' \dot{x} \rho}{m} \frac{k \mu}{u d \rho} \sqrt{x^2 + y^2}$$

$$\ddot{x} = - \frac{k \mu}{m d} A' \dot{x} \dots \textcircled{3}$$

$$\ddot{y} = - \frac{k \mu}{m d} A' \dot{y} + g \left(\frac{\rho_s - \rho}{\rho_s} \right) \dots \textcircled{4} \quad (\text{No } \dot{x})$$

$$k = 12$$

$$m = \rho V$$

$$V = \frac{\pi}{6} d^3$$

$$A = \frac{\pi}{4} d^2$$

$$u = \sqrt{\dot{x}^2 + \dot{y}^2}$$

$$\chi'' = - \frac{\pi}{4} d^2 \psi$$

$$\frac{\pi}{6} d^3 \rho_s d$$

$$= -18 \frac{\psi}{d^2 \rho_s} \chi''$$

const.

$$= -a \chi''$$

24-10-2019

Spher par

$$\ddot{y} = \frac{\frac{\pi}{4} d^2 12 \mu}{\frac{\pi}{6} d^3 \rho_s} \dot{y} + \left(1 - \frac{\rho}{\rho_s}\right) g$$

$$= -18 \frac{\mu}{d^2 \rho_s} \dot{y} + \left(1 - \frac{\rho}{\rho_s}\right) g$$

$$= -a \dot{y} + b$$

$$a = 18 \frac{\mu}{d^2 \rho_s}$$

$$b = \left(1 - \frac{\rho}{\rho_s}\right) g$$

$$\frac{b}{a} = U_0 = \frac{d^2 g (\rho_s - \rho)}{18 \mu} \text{ settling velocity.}$$

y -direction

$$\ddot{y} = -a \dot{y} + b$$

$$\dot{y} = -a y + b t + \text{constant}$$

$$y = \frac{b}{a} t + \frac{v}{a} - \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{v}{a}\right) e^{-at} \quad \dots (6)$$

where v = initial component of the velocity of the particle in the y direction.

x-direction

$$\ddot{x} = -ax$$

$$\dot{x} = -ax + \text{constant}$$

$$x = \frac{w}{a} (1 - e^{-ax})$$

w = component of the velocity of the particle at $x=0$ at time $t=0$

$$e^{-ax} = 1 - \frac{ax}{w}$$

$$t = -\frac{1}{a} \ln \left(1 - \frac{ax}{w} \right) \quad \text{Into (6)}$$

$$y = \frac{b}{a} \left\{ -\frac{1}{a} \ln \left(1 - \frac{ax}{w} \right) + \frac{v}{a} + \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{v}{a} \right) \left(1 - \frac{ax}{w} \right) \right\}$$

$$y = F(x)$$

* 27/Oct

A region ϕ for no form Drag - ϕ is the region of no form Drag

* ~~scribble~~

الفئة الثانية - ϕ is the region of no form Drag

II] Assumptions & ~~scribble~~ Absence of Gravity

$$1) \ddot{x} = -\frac{R}{\rho u^2} \rho A \dot{x} \sqrt{\dot{x}^2 + \dot{y}^2} \quad \dot{y} = 0$$

$$M \ddot{x} = -\frac{R}{\rho u^2} \rho A \dot{x}^2$$

$$\textcircled{*} A = \frac{1}{4} \pi d^2$$

$$\textcircled{*} m = \rho_s \frac{\pi d^3}{6}$$

$$\textcircled{*} U = \sqrt{\dot{x}^2 + \dot{y}^2}$$

$$\textcircled{*} \ddot{x} = -\frac{R}{\rho u^2} \frac{1.5 \rho}{d \rho_s} \dot{x}^2$$

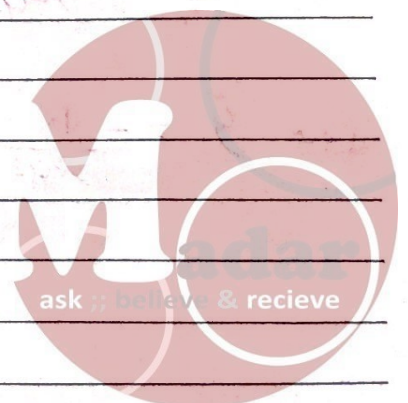
~~scribble~~ Absence of Gravity

in Region I a $10^{-4} < Re < 0.2$

$$* \frac{R}{\rho u^2} = 12 Re^{-1}$$

$$* \ddot{x} = -\frac{18 \mu}{d^2 \rho_s} \dot{x}$$

$$* x = \frac{\omega}{a} (1 - e^{-at})$$



⊗ In Region C $(500-1000) < Re < 10^4$

$$* \frac{R'}{\rho u^2} = 0.22$$

$$* \ddot{x} = - \frac{0.33}{d} \frac{\rho}{\rho_s} \dot{x}^2$$

→ New Constant $C = \frac{0.33}{d} \frac{\rho}{\rho_s}$

→ $x = \frac{1}{C} \ln(wct + 1)$

⊗ Region b (graphical solution)

III Assumption g Under the action of gravity

$$m\ddot{y} = - \frac{R'}{\rho u^2} \rho A \dot{y} \sqrt{\dot{x}^2 + \dot{y}^2} + mg \left(1 - \frac{\rho}{\rho_s}\right) \quad [2]$$

$$\dot{x} = 0$$

$$m\ddot{y} = - \frac{R}{\rho u^2} \rho A \dot{y}^2 + mg \left(1 - \frac{\rho}{\rho_s}\right)$$

$$*** \ddot{y} = - \frac{R}{\rho u^2} \frac{1.5 \rho \dot{y}^2}{d \rho_s} + g \left(1 + \frac{\rho}{\rho_s}\right)$$

* In Region A $\rightarrow \frac{R'}{\rho u^2} = 12 Re^{-1}$

$$\ddot{y} = \frac{-18}{d^2 \rho} \mu \dot{y} + g \left(1 - \frac{\rho}{\rho_s}\right)$$

$$y = \frac{b}{a} + \frac{1}{a} - \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{1}{a}\right) e^{-ab}$$

* In Region C $\rightarrow \frac{R'}{\rho u^2} = 0.22$

$$\ddot{y} = -c \dot{y}^2 + b$$

* Region B $\rightarrow$ graphical solution

Ex $\rightarrow$ Calculate the distance a spherical particle of lead Diazo-

$\rho = 11400 \text{ Kg/m}^3$, settling in water before it reaches 99% of

its U_0

~~water~~ $\rho = 1000 \text{ Kg/m}^3$

$\mu = 10 \text{ mNs/m}^2$

$\rightarrow$ Stoke Region $U_0 = \frac{g d^2 (\rho_s - \rho)}{18 \mu}$

$$\frac{\frac{d^2 \rho_s}{18 \mu} g \left(1 - \frac{\rho}{\rho_s}\right)}{\frac{1}{4}} = b$$

ask :: believe & receive

Five Apple

$$B = 9.81 \left(1 - \frac{1000}{11400} \right) = 8.9 \frac{\text{m}}{\text{s}^2}$$

$$A = 18 \times 10 \times 10^{-3} / (0.1 \times 10^{-3})^2 \times 11400 = 1579 \text{ s}$$

$$\rightarrow u_0 = \frac{b}{a} = \frac{8.9}{1579} = 5.7 \times 10^{-3} \text{ m/s}$$

$$(5.7 \times 10^{-3})(0.99) = 5.91 \times 10^{-3} \text{ m/s}$$

$$y = \frac{b}{a}t + \frac{v}{a} - \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{v}{a} \right) e^{-at}$$

$$y = \frac{b}{a} (1 - e^{-at})$$

$$5.91 \times 10^{-3} = 5.67 \times 10^{-3} (1 - e^{-1579t})$$

$t = 0.003 \text{ s}$ Substitute into the y eqn

$$y = (5.67 \times 10^{-3} \times 0.003) - \left(\frac{5.67 \times 10^{-3}}{1579} \right) \left(1 - e^{-1579 \times 0.003} \right)$$

$$y = 1.3 \times 10^{-5} \text{ m} = 0.013 \text{ mm}$$

* Motion of Particle in a Centrifugal field

$$V_p (\rho_s - \rho) g = 3\pi\mu du$$

• $g \rightarrow$ Replaced by Centrifugal acceleration $r\omega^2$

• $r \rightarrow$ Radius of Rotation

• $\omega \rightarrow$ Angular Velocity

$$\frac{\pi}{6} d^3 (\rho_s - \rho) r \omega^2 = 3\pi\mu d \frac{dr}{dt}$$

$$= \frac{\pi}{6} d^3 \rho_s \frac{d^2 r}{dt^2} = ma$$

$$\rightarrow \frac{d^2 r}{dt^2} + \left(\frac{18\mu}{d^2 \rho_s} \right) \frac{dr}{dt} - \left(\frac{\rho_s - \rho}{\rho_s} \right) \omega^2 r = 0$$

$$\rightarrow \frac{d^2 r}{dt^2} + a \frac{dr}{dt} - \eta r = 0$$

$0 = \leftarrow$

$$\rightarrow a \frac{dr}{dt} - \eta r = 0$$

$$\rightarrow t = \frac{18\mu}{d^2 \omega^2 (\rho_s - \rho)} \ln \frac{r_2}{r_1}$$

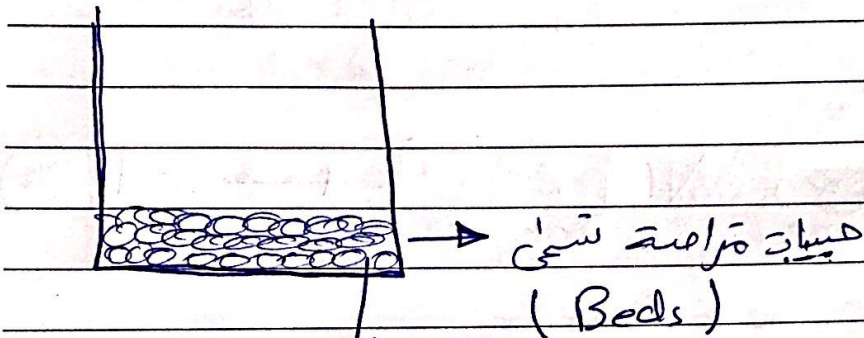
الوقت الذي يتأخّر فيه Particle من سرعة إلى سرعة

29/10

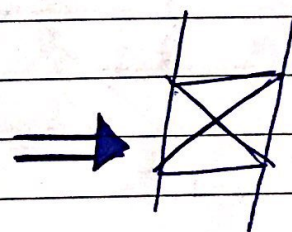
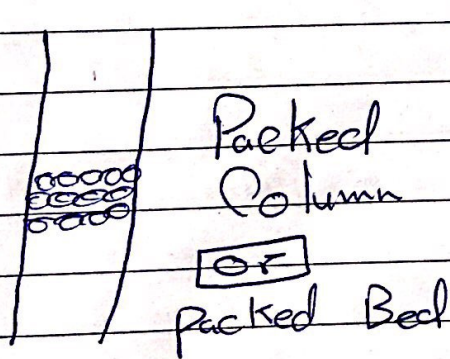
* Packed Bed

Flow of Fluids through granular Beds and Packed Columns

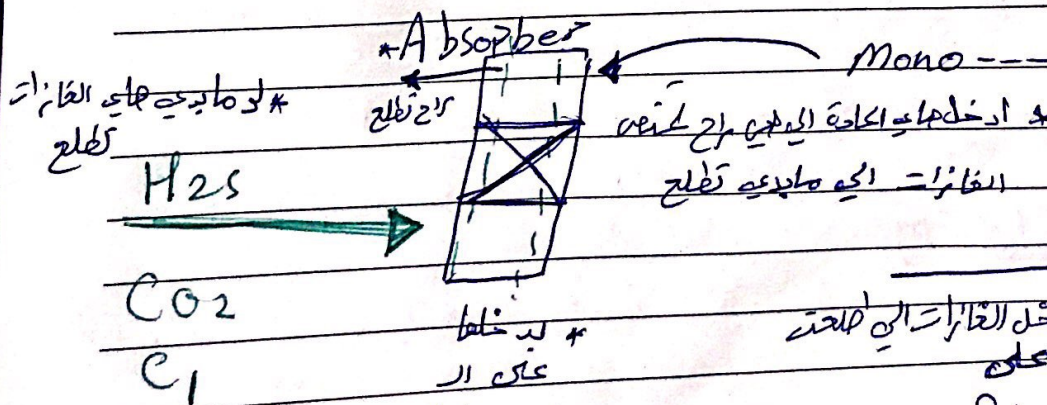
* ستدفق السوائل (fluid + gas) من خلال (granular Beds) (حبيبات متراصة)
من خلال أعمدة التعبئة (Packed Columns)



هذه الفراغات تسمى (Voids)
وهذه الفراغات هي التي يمر فيها السائل
وتسمى بـ Channel



في هذه الأعمدة يتم فصل
المزيج بـ (Distillation)



Stripper

ask
realt
Five Apple

* Darcy's law

$$\frac{1}{A} \frac{dV}{dt} = U = \frac{K(-\Delta P)}{L} \quad \text{--- [1]}$$

* Pressure drop across the bed

(L) → thickness of the bed

→ cross sectional area of the bed
 * avg. velocity of flow of fluid $\frac{1}{A} \frac{dV}{dt} \frac{m^3}{s \cdot m^2}$

* V → Vol. flow rate

* K → Constant depends on the physical properties of the bed and fluid

(viscosity) given in fluid dynamics

$$U = \frac{K(-\Delta P)}{L} \quad \text{--- [2]}$$

⇓

$$\frac{B(-\Delta P)}{\mu} \quad \text{--- [3]}$$

* B → Permeability coefficient of the bed

التفاضلية → الخصائص الفيزيائية للbed

* Table 4.1

* B → high ⇒ ease of passage

الكثافة أو B كبيرة كانت هناك سهولة في (fluid flow) (voids) المساحة

*** Definitions:

* S_B → Surface Area presented to the fluid per unit Vol of the Bed

$$\frac{\text{Area}}{\text{Vol}} = \frac{(\text{length})^2}{(\text{length})^3} = (\text{length})^{-1}$$

(*) $e \rightarrow$ Fraction of the volume of the bed not occupied by solid ~~mat~~ material

(Beds) $\parallel$ ~~अंतर~~ $\parallel$ (Voids) $\parallel$ $\downarrow$

$\rightarrow$ Fractional void $\frac{\text{voids}}{\text{total volume}}$ porosity

$\rightarrow$ ~~Dimensionless~~ Dimensionless

(*) $1-e \rightarrow$ Fractional volume of the bed occupied by solid material.

* 3/Nov

* $S_B \rightarrow \frac{\text{Area}}{\text{Vol}}$
 $\downarrow$
Bed

* for a Sphere

$$S = \frac{\pi d^2}{\frac{\pi}{6} d^3} = \frac{6}{d}$$

* $e \rightarrow$ voids (not occupied)

* $1-e \rightarrow$ (Occupied)

* $S \rightarrow$ Specific Surface of the Particles

$$\downarrow$$

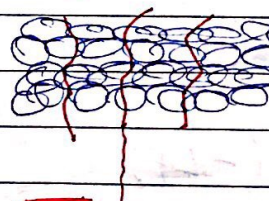
 $\text{Particle} = \frac{\text{Area of Particles}}{\text{Vol of Particles}} = (\text{length})^{-1}$

* $S \neq S_B \rightarrow$ Table 4.1 $\Rightarrow B/S/e$

$$* S_B = (1-e) S$$

Shear force $\rightarrow$ $\frac{1}{2} \rho v^2$ dia $\rightarrow$ $\frac{1}{2} \rho v^2$

* $\Delta P, U, e, S_B, S$

 $\rightarrow$ fluid flow through channels

$\rightarrow$ velocity of fluid

$$* U_t = \frac{d^3}{32 \mu} (-\Delta P)$$

[4]

$\rightarrow$ length of tube

$\rightarrow$ Diam of tube

$$* f \propto \frac{1}{d}$$

$$* U_t = \frac{d^2 (-\Delta P)}{K' \mu f}$$

[5]

$\rightarrow K' \rightarrow$ dimensionless depends structure of the bed

* $d \rightarrow$ equivalent dia of the pore channel

$\rightarrow$ length of channel

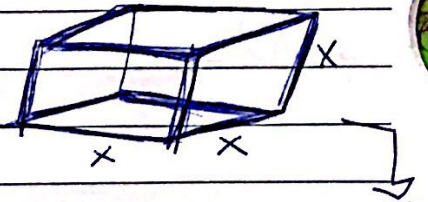
* $U_t \rightarrow$ avg velocity through pore channel

5/Nov

* Dupuit approach

→ In a Cube of Side x

→ Vol of Cube $= x^3$



→ Vol of free space $= e x^3$

تحتوي مساحتها وارتفاعها

*** Mean x-sectional area for flow $= \frac{\text{free Vol}}{\text{height}} = \frac{e x^3}{x}$

$$= e x^2$$

*** Vol flow rate through the cube $= U x^2 \left(\frac{m}{s} \times m^2 \right)$

*** linear velocity through pores

$$U_i = \frac{U x^2}{e x^2} = \frac{U}{e} \quad \boxed{6}$$

الفردية U و U_i ← U_i هي سرعة الجريان في المسام

* Kozeny

$$f'_m = \frac{e}{S_B} = e / S(1-e)$$

* In Summary

$$* U_i = U/e \quad * f'_m = e / (e(1-e) S)$$

$$f' \propto f \quad * e \approx 0.5 \rightarrow U_i = \frac{1}{K''} \frac{e^3}{S_B^2} \frac{1}{\mu} \frac{-\Delta P}{L}$$

$\boxed{7}$

Five Apple

$$* U = \frac{1}{K''} \frac{e^3}{s^2(1-e)^2} \frac{1}{\mu} \left(\frac{-\Delta P}{L} \right) \quad \text{--- [8]}$$

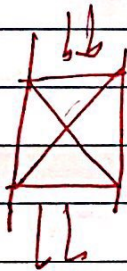
$K'' \rightarrow$ Kozeny's Const = 5

dependent on porosity & particle shape

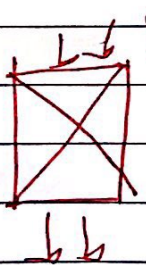
* Compare with eq 2 of Permeability Coefficient

$$B = \frac{1}{K''} \frac{e^3}{s^2(1-e)^2} \quad \text{--- [9]}$$

* Kozeny's applicati



Packed bed
eq 8



Slurry
filtrate eq 8



eq. 8 fluidization

* Streamline & Turbulent flow

$$u_1 = \frac{u}{e}$$

$$\text{by } \frac{R'}{R_0^2}$$

$$d_1' = \frac{e}{s_0} = \frac{e}{e + (1-e)s}$$

$$Re_1 = \frac{u_1 d_1' \rho}{\mu}$$

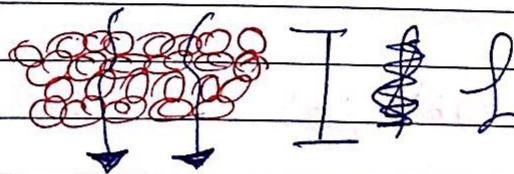
log Re

* Substitute

$$\rightarrow Re_1 = \frac{u}{e} \frac{e}{s(1-e)\mu} \frac{\rho}{\mu}$$

$$Re_1 = \frac{u \rho}{s(1-e)\mu} \quad [10]$$

* Consider the forces acting on the fluid in a bed of unit X-sectioned area and thickness l



$$* \text{ Vol of Particle in the Bed} = l(1-e)$$

$$* \text{ Total Specific Surface of Particle} = s l(1-e)$$

$$* \text{ Thus, the resistance force} = R_1 s l(1-e)$$

fluid passes the voids

$$(-\Delta P) e = R_1 S f (1-e)$$

$$R_1 = \frac{e}{S(1-e)} \frac{(-\Delta P)}{f} \quad [11]$$

$$u_1 = \frac{4}{e} \quad \text{" Divided By } \rho u_1^2$$

$$\frac{R_1}{\rho u_1^2} = \frac{e^3}{S(1-e)} \frac{(-\Delta P)}{f} \frac{1}{\rho u_1^2} \quad [12]$$

$$\log \frac{R_1}{\rho u_1^2} \quad \text{eq 12}$$

$$\log R_1 \quad \text{eq 10}$$

پاکستان

Good Contact between fluid in down flow & gas up flow

Good Contact between fluid in down flow & gas up flow

7/Nov *Streamline & Turbulent flow

→ For flow through packed beds of solid particles

$$\frac{R_1}{\rho u_1^2} = 5 Re_1^{-1} + 0.7 Re_1^{-0.1} \quad \text{--- [13]}$$

* if $Re_1 < \text{about } 2$

$$\frac{R_1}{\rho u_1^2} = 5 Re_1^{-1} \quad \text{--- [14]}$$

* For a flow of fluids through beds of hollow

$$\frac{R_1}{\rho u_1^2} = 5 Re_1^{-1} + Re_1^{-0.1} \quad \text{--- [15]}$$

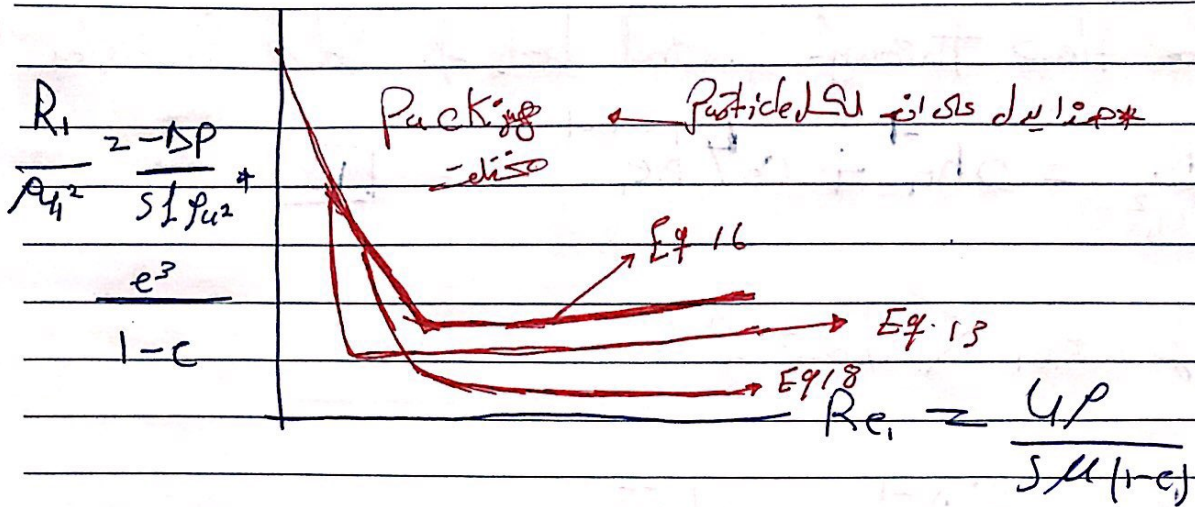
* For flow through ring packing → Ergun Eq

$$\frac{-\Delta P}{L} = \frac{150(1-e)^2}{e^3} \frac{\mu u}{d^2} + 1.75 \frac{1-e}{e^3} \frac{\rho u^2}{d} \quad \text{--- [16]}$$

$$* S = 6/d \Rightarrow d = 6/S$$

$$\text{eq 12} \left\{ \frac{-\Delta P}{L \rho u^2} \frac{e^3}{(1-e)} \right\} = 4.17 \left\{ \frac{\mu S(1-e)}{\rho u} \right\} + 0.29 \quad \xrightarrow{Re^{-1}}$$

$$\rightarrow \frac{R_1}{\rho u_1^2} = 4.17 Re_1^{-1} + 0.29 \quad \text{--- [17]}$$



* k''

* Carman

$$k'' = \left(\frac{l'}{l} \right) k_0 \quad \text{--- [18]}$$

$\frac{l'}{l} \Rightarrow$ Tortuosity $\rightarrow$ Measure of the fluid path length through the bed compared with the actual depth of the bed

* $k_0 \rightarrow$ Factor depends on the Shape of the X-sectional Area of a Channel

* Circular Pipe $k_0 = 2$

* Rectangle $k_0 = 2.65$

**** wall effect**

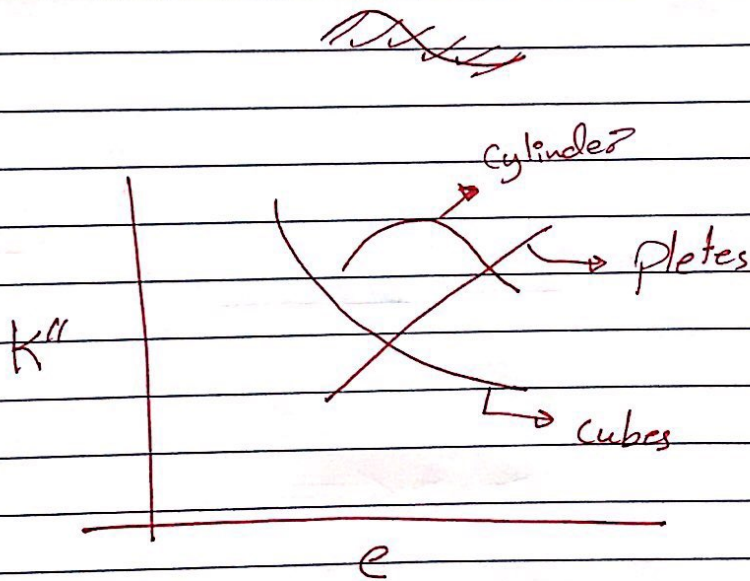
→ Correction factor

$$f_w = \left(1 + \frac{1}{2} \frac{S_c}{s}\right)^2$$

* S_c → Surface of Container per unit vol of Bed

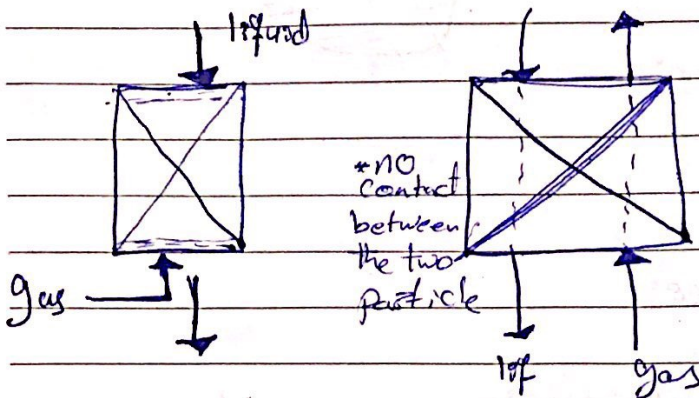
→ Eq 8 becomes

$$U = \frac{1}{k''} \frac{e^3}{S^2(1-e)^2} \frac{1}{\mu} \frac{-\Delta P}{L} f_w \quad (21)$$

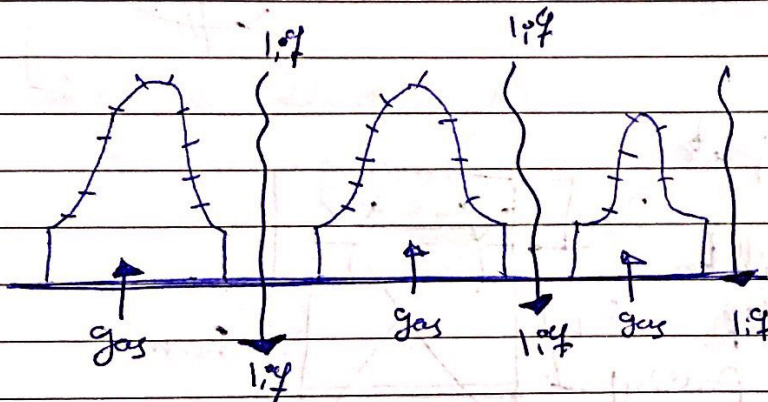


10/Nov

* Application (Absorption)



* Vessel design & Bottom



يرسل الغاز من تحت سطح من السطح
في الأعلى وراح نعالج absorption مع
ال fluid في الأعلى و
نخرج liquid من تحت

* Vessel design & Top

* Types & 1 Simple Orifice Type & * Fine distribution
* Risk of plugging

1/4 من ال Top (نعالج من تحت ال 1/4 في أعلى ال vessel)

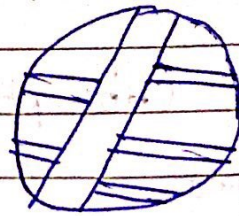
2 Notched chimney type &

* No plugging
* use for medium & upper flows

تدخل ال Top من أعلى ال tube
و في Pipe نعالج ال fluid و نخرج
في الأسفل



3] Notched Trough Distribution



* large size of tower

* higher gas rates

~ ليل Pipe ~ ريل Pipe حارة

4] Perforated Ring type

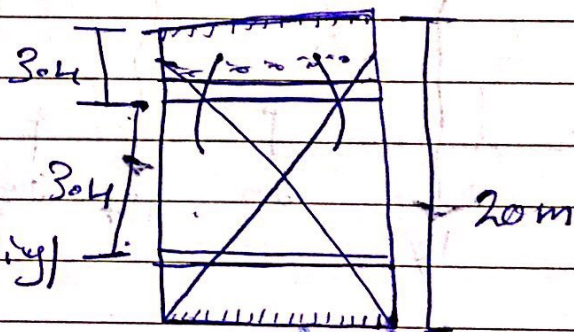
* High Gas Rates & Small liquid Rate

* Suitable where ρ must be minimized



Redistribution Plate

* To make sure there will be
a good distribution @ top
thawing the Bed (not passing)



Only in Channel

* Packings or 1 Broken Solids

2 Shaped Package → a) Should be uniform size

b) uniform characteristics of bed

3 Desired Voidage

4 No Channelings

5 Resistance to flow → less

6 More effective Surface Unit Vol.

* Raschay Rings

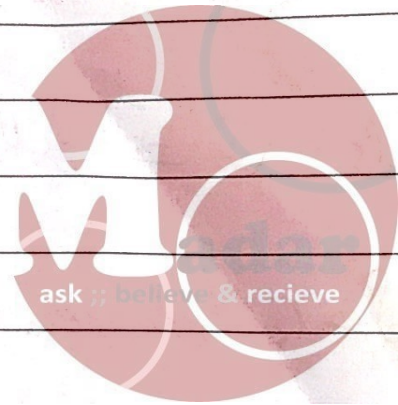
Figs- 4.13 / 4.14 / 4.15

* Intalox

* Saddle

Table 4.3

Wires



~~20/11/20~~ * 20/NOV

* Size of Packings
* influences

- 1] H/D of the Column
- 2] ΔP (الضغط ΔP كبير)
- 3] Cost

* Grids (الشواط) ex: cooling tower

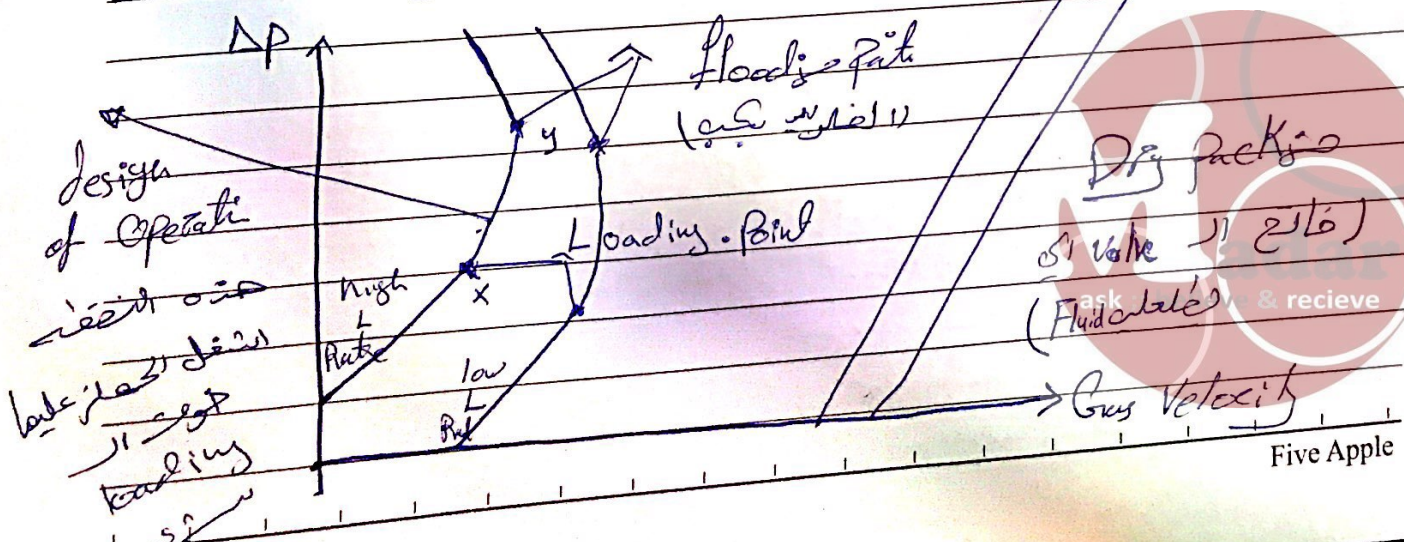
1] large space between individual grids



2] Give low ΔP (بأقل ضغط ممكن)

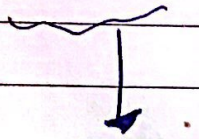
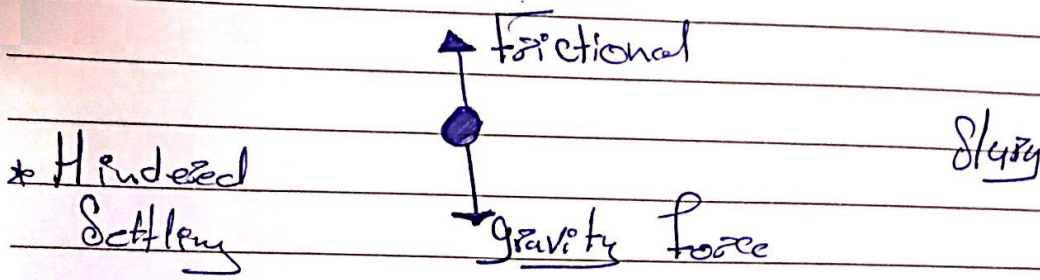
3] Accept fluid with Suspended Particle

* Gas Velocity Vs. ΔP



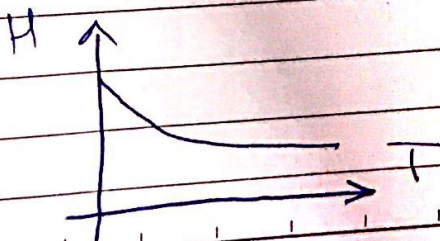
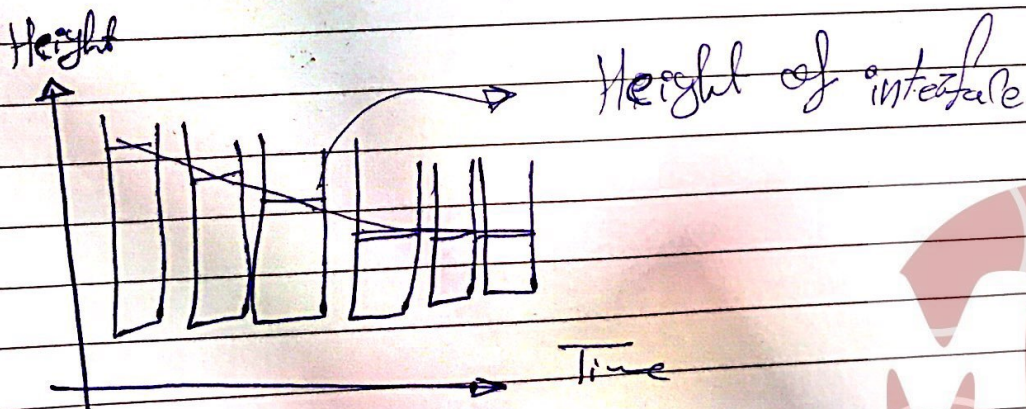
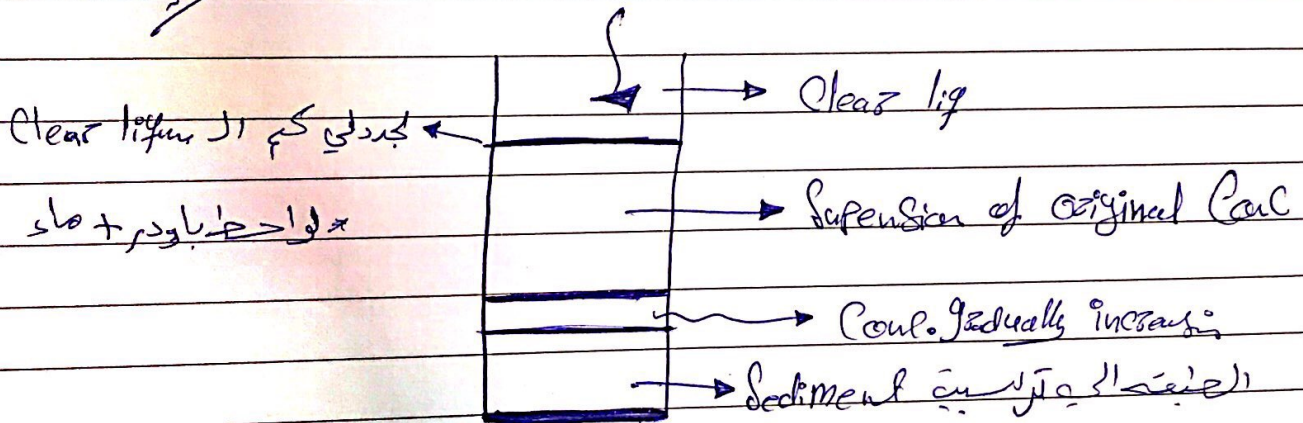
Ch.5

* Sedimentation

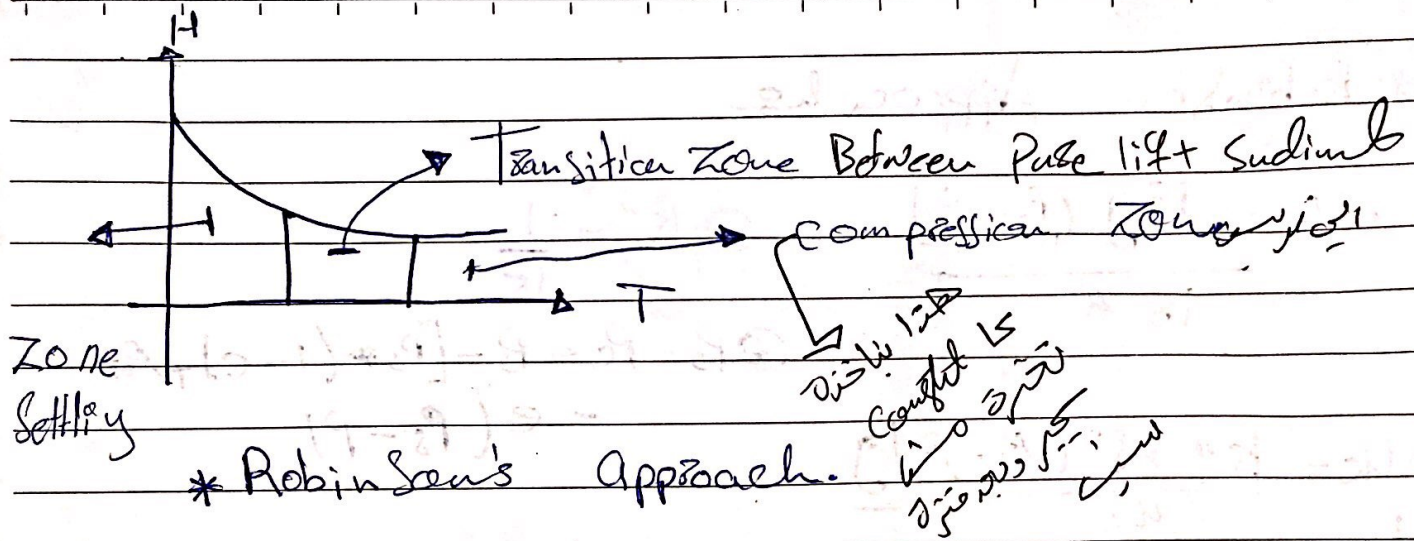


Settling Velocity $\rightarrow$ سرعة الغوص

منطقة التداخل
منطقة التداخل



* 28/Nov



* Robinson's Approach.

$$* U_0 = \frac{d^2 g (\rho_s - \rho)}{18 \mu}$$

→ هذا باقية
الواحدة

هذا باقية - كبريت مع الحصى

$$* U_c = \frac{k'' d^2 (\rho_s - \rho) g}{\mu_c}$$

For Suspension (مواد عالقة)

$$* k'' = \frac{1}{18}$$

voids باقية او دلتا

$$\rho_s - \rho = \rho_s - [\rho_s (1 - e) + \rho_e]$$

(حصى + شوائب)

density of solid

$$= e (\rho_s - \rho)$$

Suspension (Solid + liq)

كافى شوائب
كافى شوائب
Bed

* Hindered Settling → كافي شوائب - كثرة شوائب

* Discrete Settling → كافي شوائب - كثرة شوائب

1-12-2019

Robinson Approach:-

$$u_0 = \frac{d^2 g (P_s - P)}{18 \mu}$$

$$k'' = \frac{1}{18}$$

$$P_s - P_c = P_s - [P_s(1-e) + P_e] \\ = e(P_s - P)$$

$$u_c = \frac{k'' d^2 (P_s - P) g}{\mu_c}$$

↳ For suspension

* For low concentrated suspension

$$\mu_c = \mu (1 + k'' C) \quad k'' = 2.5 \quad e \approx 0.02 (\text{vol conc. of part})$$

* For high conc sup

$$\mu_c = \mu e^{k'' C / (1 - a' e)}$$

$$a' = 0.609$$

} Robinson

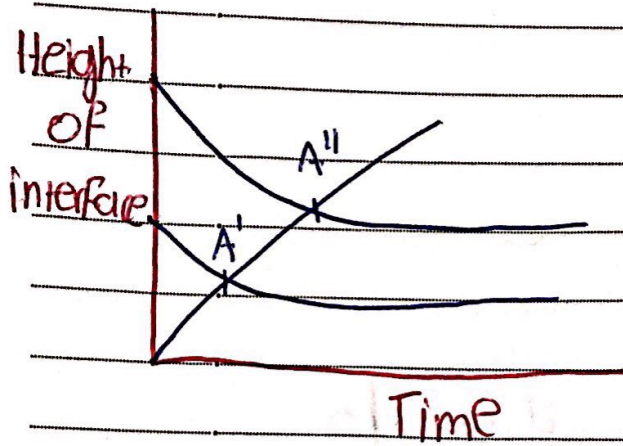
* Flocculation (Agglomeration)

Flocc, Agg, prevention → ① Agitation ② chemicals

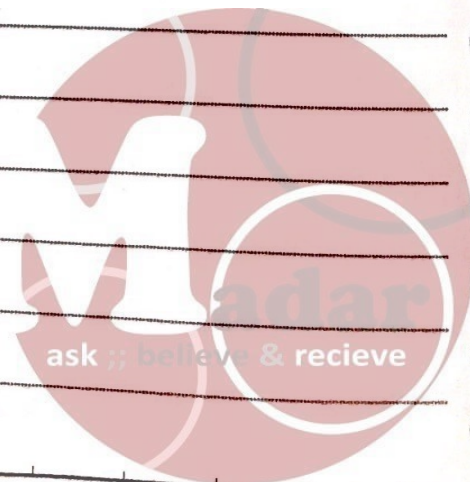
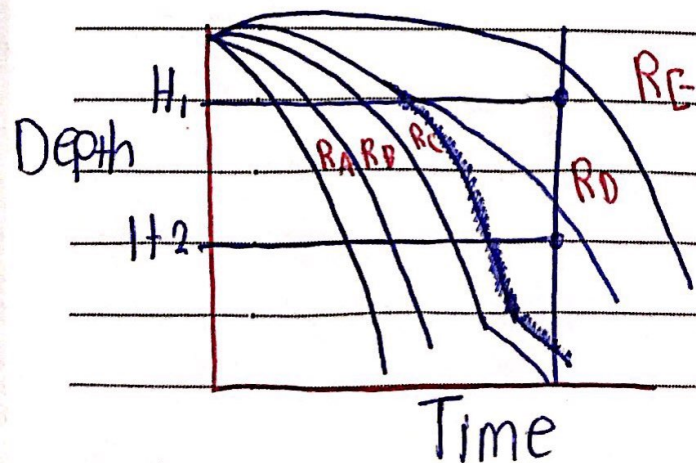
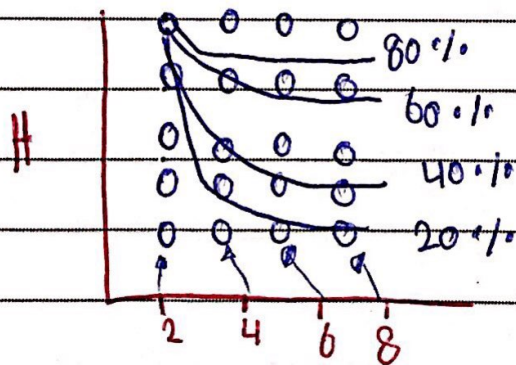
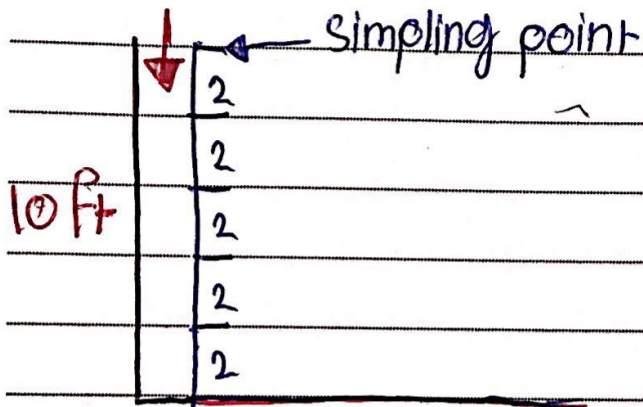


$$\frac{D_{\text{vessel}}}{D_{\text{part}}} > 100$$





$$\frac{dA'}{dA''} = \text{Const}$$



Fraction Removed:

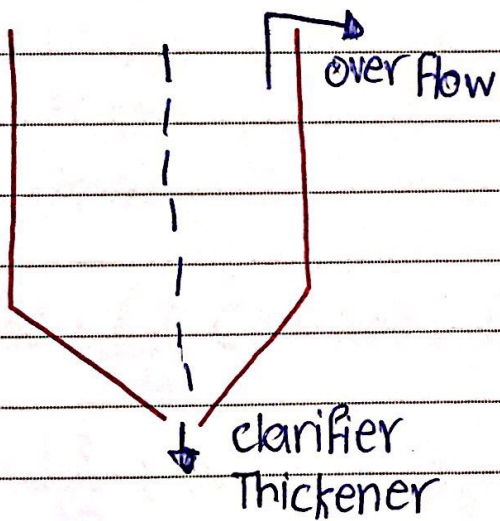
$$R_T = R_c + \frac{H_2}{H} (R_D - R_c) + \frac{H_1}{H} (R_E - R_D)$$

over Flow rate:

$$N_o = \frac{H}{t} \times \text{conversion Factor}$$

$$N_o = \frac{10 \text{ ft}}{16 \text{ min}} \times \frac{1440 \text{ min}}{\text{day}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \approx 6730 \frac{\text{gal}}{\text{day} \cdot \text{ft}^2}$$

Ex:



3-12-2012

Ex8

Clarifier is to be designed to treat waste water having 320 mg/l suspended solids and a flow of 2 MGD Batch → hand out

① Determine the design time & design over flow rate if 65% of solids are to be removed.

② Determine Dia & Depth of vessel.

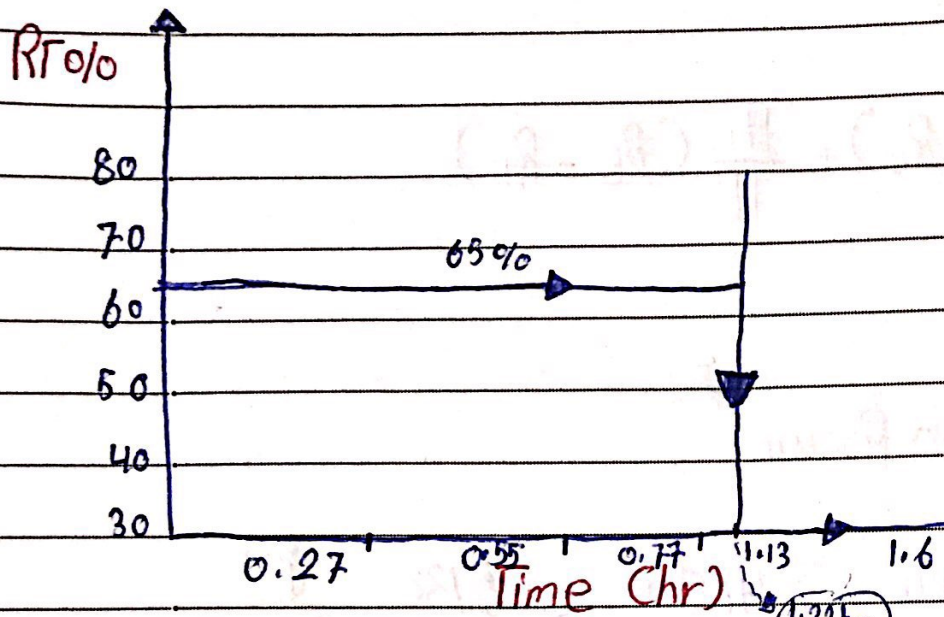
	Mid. point
20-30 %	6.7
30-40 %	2.9
40-50 %	2
50-60 %	1.3
60-70 %	0.8

$$R_T = 20 + \frac{6.7}{10} (30-20) + \frac{2.9}{10} (40-30) + \frac{2}{10} (50-40) + \frac{1.3}{10} (60-50) + \frac{0.8}{10} (70-60) = 33.7 \%$$

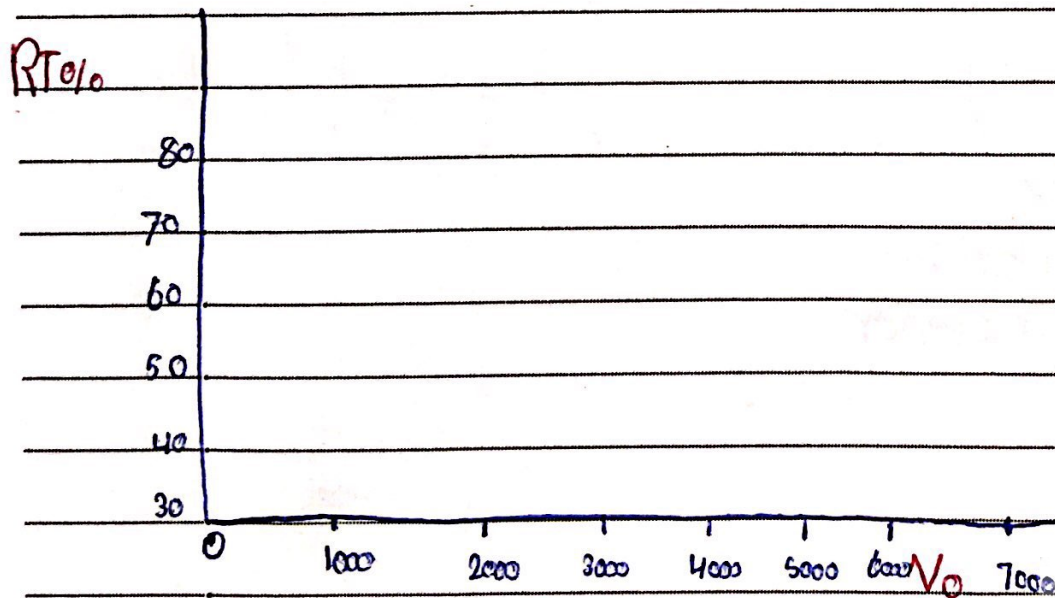
$$V_0 = \frac{10 \text{ ft}}{16 \text{ min}} \times \frac{1440 \text{ min}}{\text{day}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \approx 6736 \frac{\text{gal}}{\text{day} \cdot \text{ft}^2}$$

cm	Time (hr)	V_0	RT %
16	0.27	6736	33.7
33	0.55	3260	48.7
46.2	0.77	2340	56.7
67.8	1.13	1596	63.8
96	1.6	1120	68.6

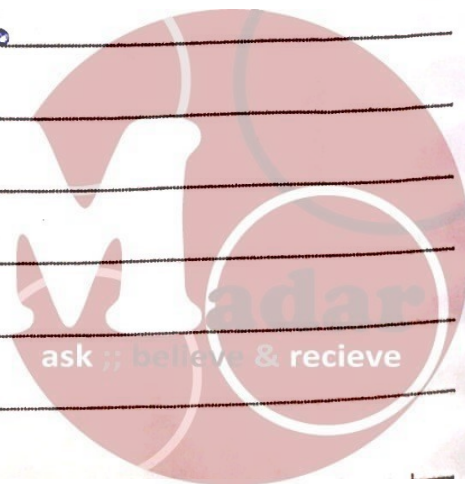
بررسی فیلتر



هذه النسبة هي الفرق بين



الفرق بين $V_0 = 1420$ و $V_0 = 1420$ و $V_0 = 1420$



5-12-2019

Scaling up and down

$$\text{Design Detention Time} = \frac{(1.22)(1.75)}{\text{over Flow rate}} = \frac{\text{hr}}{\text{gal/day} \cdot \text{ft}^2}$$

$$A = \frac{2 \times 10^6 \text{ gal}}{\text{day}} \times \frac{\text{day} \cdot \text{ft}^2}{923 \text{ gal}} = 2167 \text{ ft}^2$$

$$A = \frac{\pi}{4} D^2 \quad D = 52.5 \text{ ft} \approx 55 \text{ ft}$$

$$D = \frac{V}{Q} \quad V$$

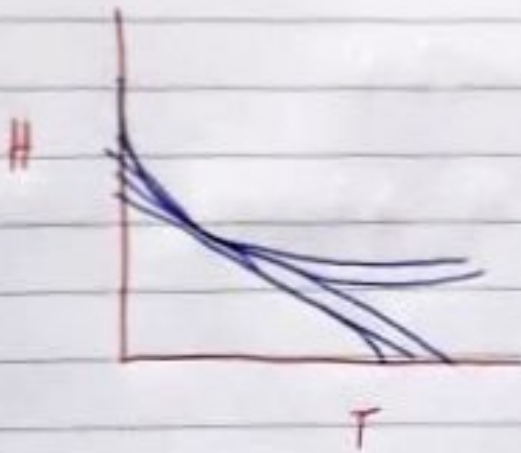
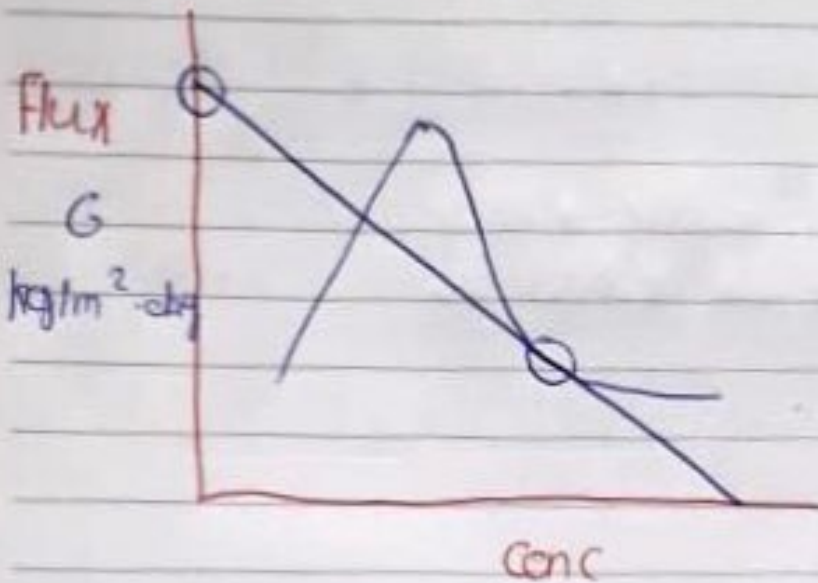
$$= \frac{\pi}{4} D^2 H$$

$$H = \frac{Q \times \text{Time}}{\frac{\pi}{4} D^2} = 10 \text{ ft}, 3 \text{ in}$$



8-12-2019

keynch Theory:-



$$\text{Conc } C = C_0 \frac{\partial A}{\partial T}$$

$$\psi = C u_0 = C_0 \frac{\partial A}{\partial T} u_c$$



A thickener treats $0.044 \text{ m}^3/\text{s}$ (1 MGD) of a suspension containing 2000 mg/L of Solids

Solid conc	S.V
1000	2.74
1500	2.01
2000	1.37
2500	0.73
3000	0.42
4000	0.22
5000	0.13
6000	0.07

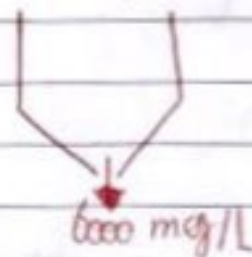
* calc the area of thickener required to give underflow conc of 6000 mg/L .

Flux conc

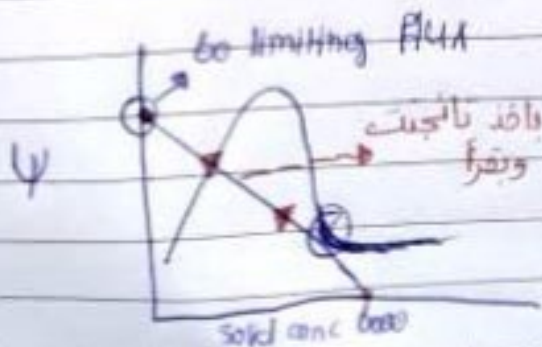
$$G = X_i V_i$$

$$2500 \text{ mg/L} = 2.5 \text{ kg/m}^3$$

$$V_i = 0.73 \frac{\text{m}}{\text{h}} = 17.4 \frac{\text{m}}{\text{day}}$$



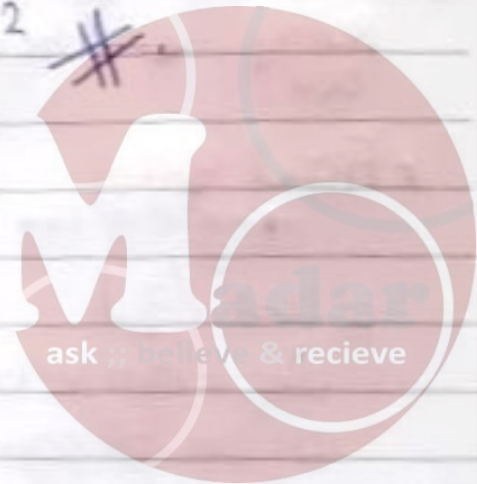
$$G = 17.4 \frac{\text{m}}{\text{day}} \times 2.5 \frac{\text{kg}}{\text{m}^3} = 43.8 \text{ kg/m}^2 \cdot \text{day} \rightarrow \text{طاقة لكل متر مربع}$$



• Feed Solids

$$0.044 \frac{\text{m}^3}{\text{s}} \times \frac{2 \text{ kg}}{\text{m}^3} \times \frac{8.64 \times 10^5 \text{ s}}{\text{day}} = 7600 \text{ kg/day}$$

$$\text{Area} = \frac{7600 \text{ kg/day}}{60 \text{ kg/m}^2 \text{ day}} = 127 \text{ m}^2 //$$



10-12-2019

Fluidization

Gas-Solid
Liq-Solid

Streamline

Δp & rate of flow, Expression of equations.



$\Delta p \propto$ low rate of flow.

Frictional Drag on the part = Their apparent wt.

apparent wt = actual wt - buoyancy

* velocity increase $\rightarrow$ loosest packing.

* vel increasing again $\rightarrow$ fluidization.



- The part become rearranged $\rightarrow$ offer less resistance to flow of fluid.

- velocity of fluid $\uparrow$ $\rightarrow$ individual part separate from one another

$\hookrightarrow$ freely supported by fluid $\rightarrow$ fluidized bed

• At high vel of flow $\rightarrow$ Distinction between gas, liq.

• With Liq:

Maintains uniform character $\rightarrow$



$\rightarrow$ particulate fluidization

with gas: Aggregative fluidization.

2 separate phase

1- Continuous phase $\rightarrow$ Dense phase $\rightarrow$ Liquid

2- Discontinuous phase $\rightarrow$ Lean / bubble $\rightarrow$ vapor

Boiling bed $\leftarrow$ Bed في حالة يطبخ على النار

* Froude group

$\rightarrow$ min vel of flow

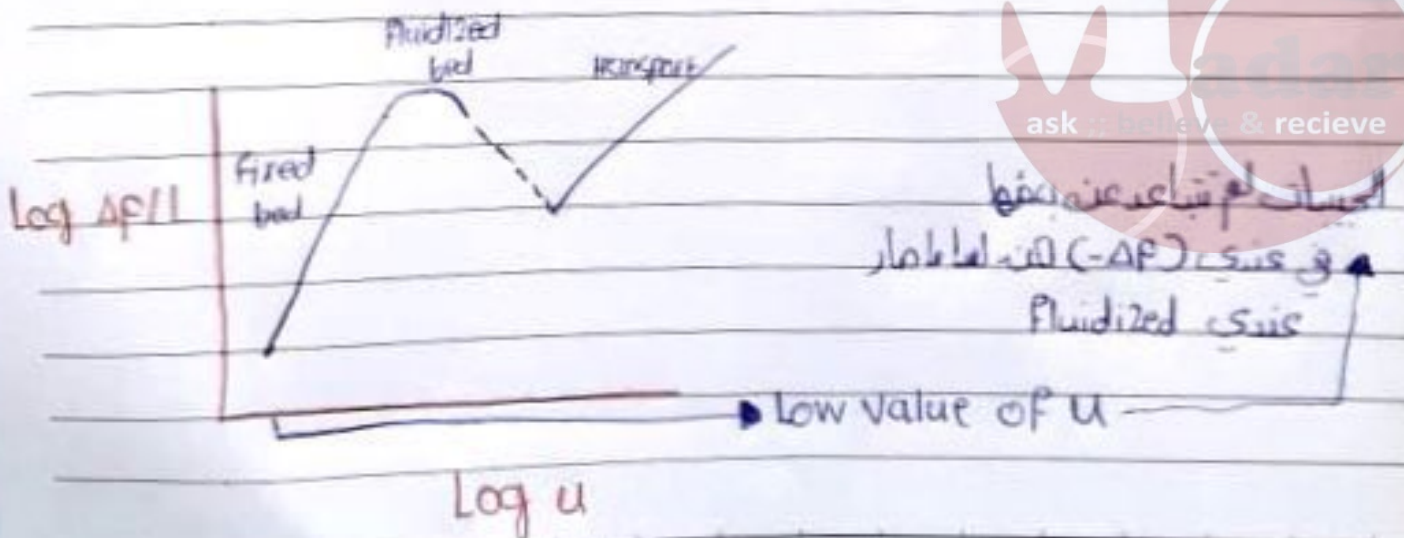
$$= U_{mf}^2 / gD$$

U_{mf} = min velocity of flow

D = Dia of part

Froude value $<$ unity $\rightarrow$ particulate (Liq)

~~particulate~~ Froude value $>$ unity $\rightarrow$ Aggregative (gas)



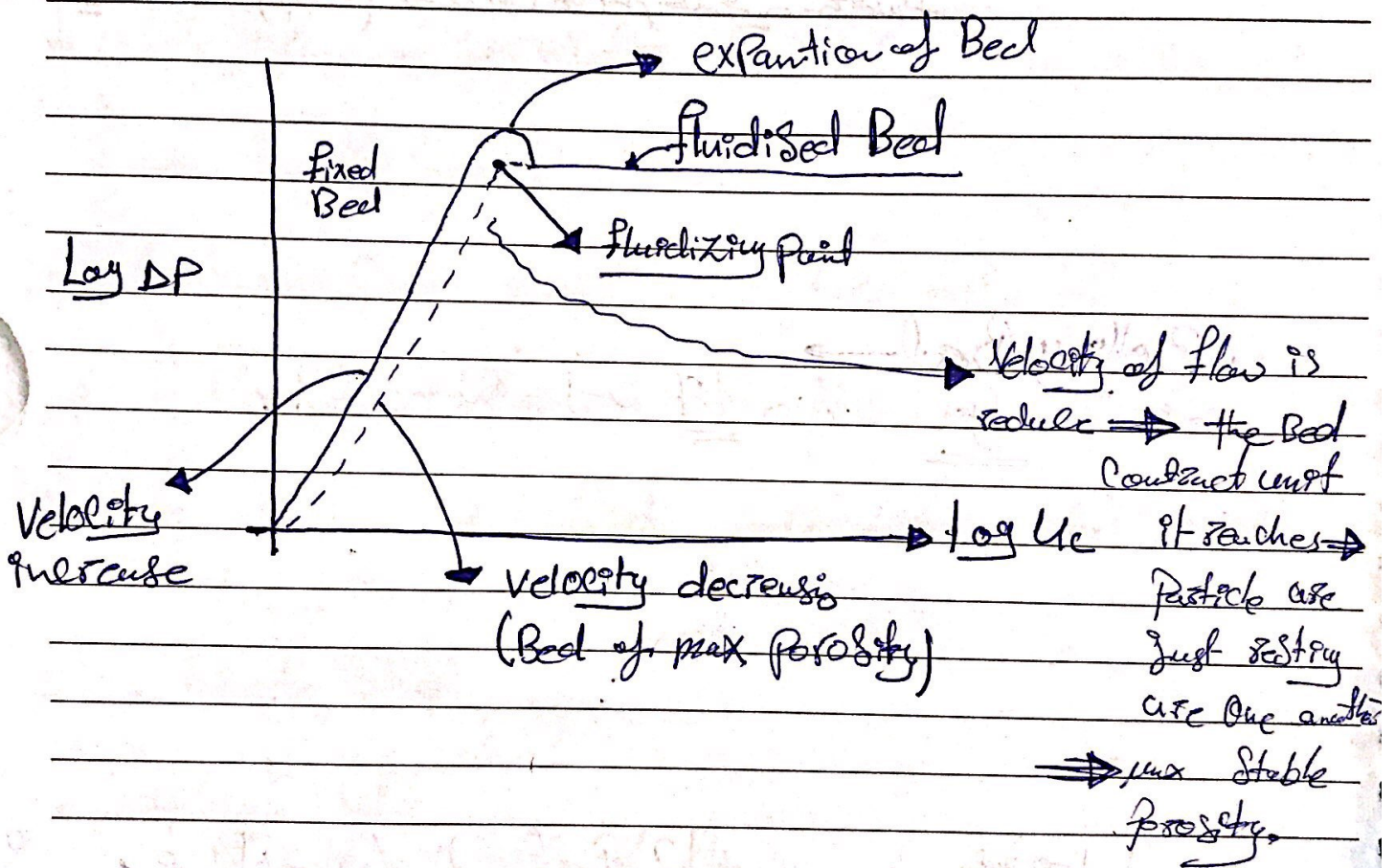
12/12/2019

* Requirement or

1 Particle Shape

2 Free irregular & Channelling

3 Hard $\rightarrow$ Agglomeration



high U_c just $\Rightarrow$ in Bed U_c

* Bed high

let $L_0 \rightarrow$ high of Bed where $C=0$ (single lump)

$L \rightarrow$ high of fluidized Bed

ask & recieve

$$\text{Then } e = (h - h_0) / h$$

$$= 1 - (h_0 / h) \quad \text{--- eq 1}$$

* Porosity is a function of the height of the Bed.

$$h_2 = h_1 ((1 - e_1) / (1 - e_2)) \quad \text{--- eq 2}$$

$h_2 \rightarrow$ Bed height of any new value

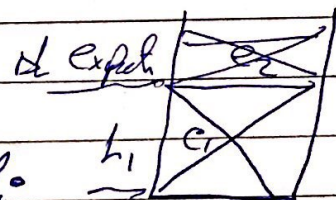
$h_1 \rightarrow$ Known Bed height @ e_1

$\rightarrow$ Calculate e_1 or any other value

* Force Δp it exerts on the solid = Force of gravity - Buoyant force of displaced fluid.

let $l_m \rightarrow$ Bed height @ the start of fluidization.

$A \rightarrow$ Cross sectional Area.



$e_m \rightarrow$ min porosity for fluidization.

$$\Delta p A = \frac{g}{g_c} (l_m A \rho_s (1 - e_m) - l_m A \rho (1 - e_m)) \quad \text{--- eq 3}$$

$$\frac{\Delta p}{l_m} = \frac{g}{g_c} (1 - e_m) (\rho_s - \rho) \quad \text{--- eq 4}$$

Now or

if $l \rightarrow$ height of expanded Bed

$e \rightarrow$ porosity of the expanded Bed

* Combining eq 2 & 4

$$\frac{-\Delta P}{1} = \frac{y}{g_c} (1-e) (P_s - P) \text{ --- eq 5}$$

$$\frac{-\Delta P}{1(1-e)} = \frac{y}{g_c} (P_s - P) = \text{const} \text{ --- eq 6}$$

15-12-2019

Streamline condition

$$u = \frac{1}{54} \frac{e^3}{k^{11} s^2 (1-e)^2} \frac{1}{\mu} \frac{-\Delta p}{l} \rightarrow \frac{g}{g_c} (1-e)(\rho_s - \rho)$$

Eq 6 into the above for spherical part.

$$u_c = 0.0055 \frac{e^3}{1-e} \frac{d^2 (\rho_s - \rho) g}{\mu} \quad \text{--- (7)}$$

• Min Fluidizing velocity

Eq 7 becomes

$$u_{mf} = 0.005 \frac{e_{mf}^3}{1-e_{mf}} \frac{d^2 (\rho_s - \rho) g}{\mu} \quad \text{--- (8)} \quad \begin{matrix} \text{mf} \rightarrow \text{min fluidizing} \\ \text{general eqn} \end{matrix}$$

IF $e_{mf} = 0.4$ Into eq (8)

$$u_{mf} \text{ at } e_{mf} = 0.4$$

$$= 0.00059 \frac{d^2 (\rho_s - \rho) g}{\mu} \quad \text{--- (9)}$$

• No longer Stream Line for larger part

$$\frac{-\Delta p}{l} = 150 \frac{(1-e)^2}{e^3} \frac{\mu u}{d^2} + 1.75 \frac{1-e}{e^3} \frac{\rho u^2}{d} \quad \text{From eqn (7)}$$

min Fluidizing

$$\frac{-\Delta p}{l} = 150 \frac{(1-e_{mf})^2}{e_{mf}^3} \frac{\mu u_{mf}}{d^2} + 1.75 \frac{1-e_{mf}}{e_{mf}^3} \frac{\rho u_{mf}^2}{d}$$

ask ; be & recieve

$\frac{\Delta p}{L}$ From eq 5 & eq 10

multiply both side by

$$\frac{\rho d^3}{\mu^2 (1 - e_{mf})}$$

$$\underbrace{\frac{\rho (P_s - P) g d^3}{\mu^2}}_{\text{Galelio}} = 150 \underbrace{\frac{1 - e_{mf}}{e_{mf}^3}}_{\text{Re}} \underbrace{\frac{U_{mf} d \rho}{\mu}}_{\text{Re}} + \frac{1.75}{e_{mf}^3} \left[\underbrace{\frac{U_{mf} d \rho}{\mu}}_{\text{Re}} \right]^2 \quad \text{eq (11)}$$

This eq can be solved for U_{mf}

$$Ga = \frac{\rho (P_s - P) g d^3}{\mu^2}, \quad Re_{mf} = \frac{U_{mf} d \rho}{\mu}$$

Eq 11 becomes

$$Ga = 150 \frac{1 - e_{mf}}{e_{mf}^3} Re_{mf}^1 + \frac{1.75}{e_{mf}^3} Re_{mf}^2 \quad \text{eq (12)}$$

For $e = 0.4$

$$Re_{mf}^2 + 51.4 Re_{mf}^1 - 0.0366 Ga = 0$$

Thus:

$$(Re_{mf}^1)_{at e_{mf}=0.4} = 25.7 (\sqrt{1 + 5.53 \times 10^5 Ga} - 1)$$

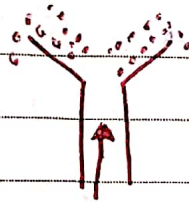
$$Re_{mf}, U_{mf} = \frac{\mu Re_{mf}}{d \rho} \quad \begin{array}{l} \text{length} \\ \text{and time} \end{array}$$

$K'' = 3.36 \rightarrow$ eq (10) becomes

$$(U_{mf})_{at e_{mf}=0.4} = \frac{0.0083 d^2 (P_s - P) g}{\mu} \quad \text{eq (16)}$$

17-12-2019

$$Re_o = \frac{u_o d \rho}{\mu}$$



$$Re_{mf} = \frac{u_{mf} d \rho}{\mu}$$

$$1. Ga = 18 Re_o$$

$$Ga = 18 Re_o^{11.687}$$

$$Ga = \frac{1}{3} Re_o^2$$

$$Ga < 3.6$$

$$3.6 < Ga < 10^5$$

$$Ga > 10^5$$

Re_o

You know u_o



Ga

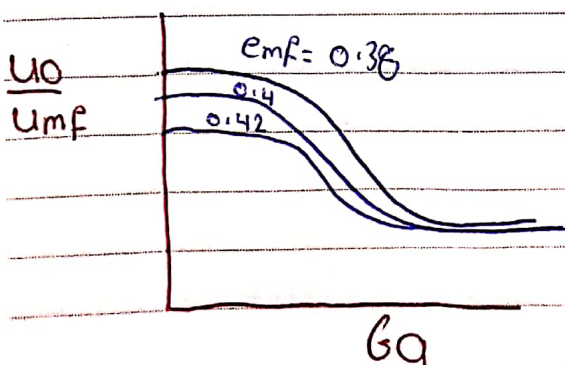
eq 1, 2, 3



for any value of emf

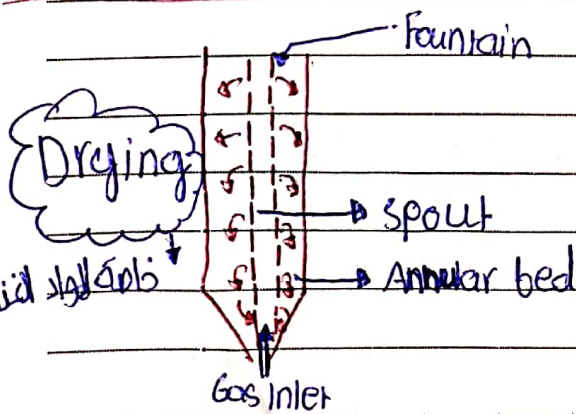
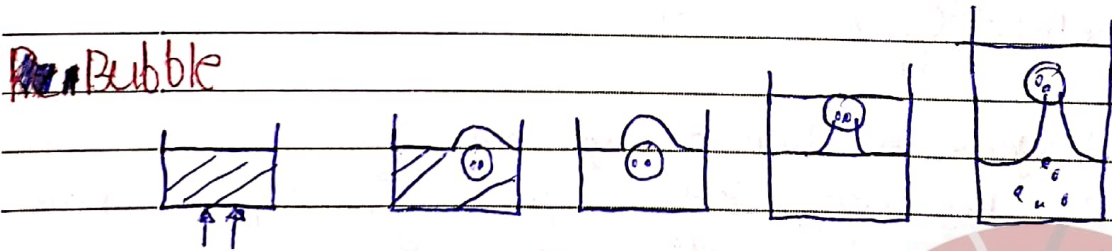
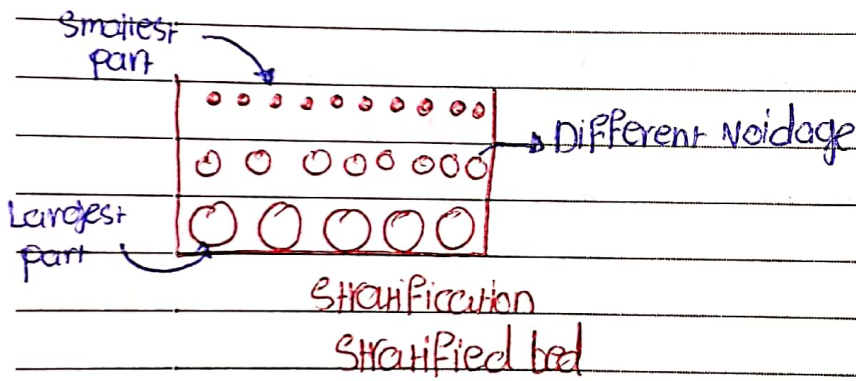
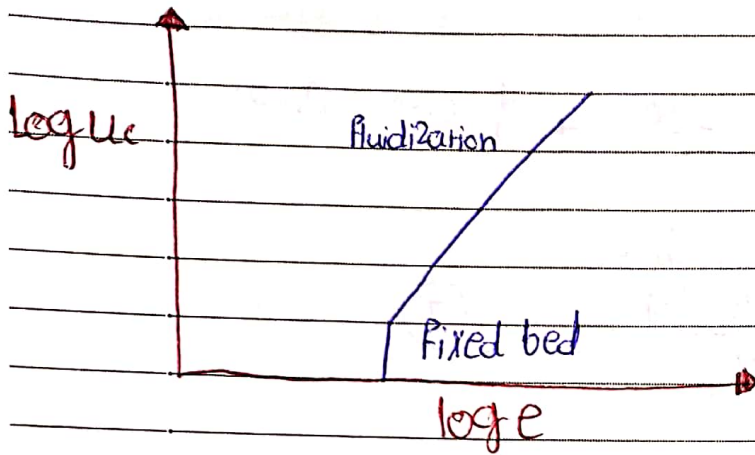
calculate Re_{mf} for eq 12

$$u_{mf} \left[\frac{Re_o}{Re_{mf}} = \frac{\frac{u_o d \rho}{\mu}}{\frac{u_{mf} d \rho}{\mu}} \right] = \frac{u_o}{u_{mf}} \quad \text{eq (17)}$$

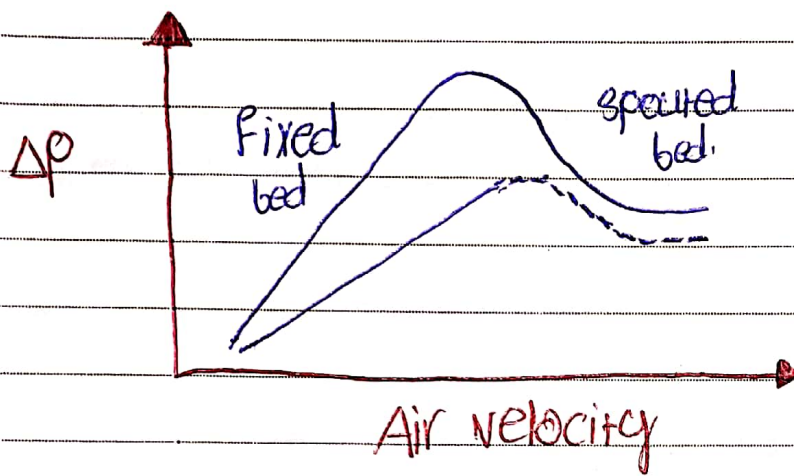


$$Re_o = \frac{u_o d \rho}{\mu}$$

ask, believe & receive



* Spouted bed *



19-12-2019

Pr. 2.11

Oil passes upward through a bed $\rightarrow$ part 10⁴ m

$$\rightarrow \rho_s = 2600 \text{ kg/m}^3 \rightarrow e = 0.48, \rho = 900 \text{ kg/m}^3, M = 3 \times 10^3 \text{ N/m}^2, g = 9.81 \text{ m/s}^2$$

* Calc the mass flowrate of oil per unit of bed at which fluidization of transport of particles occur.

$$\textcircled{1} U_{mf} = 0.0055 \frac{e^3}{1 - e_{ur}} d^2 \frac{(\rho_s - \rho)}{M} g$$

$$\rightarrow G = \rho U_{mf}$$

$\textcircled{2}$ In transport

$$u = \frac{gd^2(\rho_s - \rho)}{18\mu}$$

Re $\rightarrow$ $\frac{\rho u d}{\mu}$

region 1 $\rightarrow$ $Re < 1$

$$\left(\frac{R}{\rho u^2}\right) Re^2 = \frac{2d^3 \rho g (\rho_s - \rho)}{3\mu^2}$$

table 1 $\rightarrow$ Re $\rightarrow$ $\frac{\rho u d}{\mu}$

$$Re = \frac{(\rho u d)}{\mu}$$

#Filtration

* Selection of equip / operating parameters.

① properties of ~~fluid~~ fluid.

M, ρ

② " " Solids

③ Solid conc

④ Quantity to be handled.

⑤ Valuable product.

Solids Liq

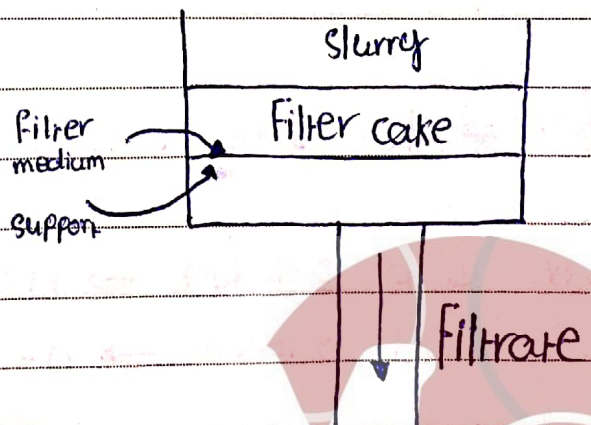
⑥ Heat needed

⑦ pre treatment

Types:

① Cake filtration

② Deep bed filtration



Filtration rate:

① Δp

② Area of surface

③

④ M of filtrate

⑤ Resistance of Filter cake + medium

22/12

* Formation of cake.

1] The Rate of flow is greatest at the beginning $\rightarrow$ resistance is minimum.

2] high initial rates of filtration may result in plugging of the pores of the filter $\rightarrow$ very high ~~resistance~~ resistance.

3] Orientation of particle

* Theory

* Filtration Pressure Const $\rightarrow$ Rate of flow will progressively diminish.

* Flow Rate Maintained Const $\rightarrow$ The pressure must be gradually increase.

$$u = \frac{1}{K''} \frac{e^3}{s^2(1-e)^2} \frac{1}{\mu} \frac{(-\Delta P)}{l}$$

$$u = \frac{1}{A} * \frac{dV}{dt} = \frac{e^3 \Delta P}{5(1-e)^2 s^2 \mu l}$$

1] Cake $\rightarrow$ uniform (voidage caught) $e \Rightarrow$ cutt

2] $V \rightarrow$ vol of filtrate which has passed in time t

3] $A \rightarrow$ total x-section area of filter cake

4] $u \rightarrow$ velocity of filtrate

5] $l \rightarrow$ Cake thickness

6] $s \rightarrow$ Specific surface of particle

7] $F \rightarrow$ voidage

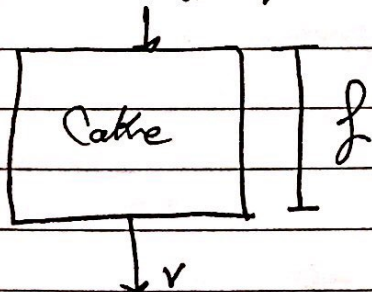
8] $\mu \rightarrow$ viscosity

$$\frac{1}{A} \frac{dv}{dt} = \frac{-\Delta P}{r \mu l} \quad \text{Basic eq}$$

$$r = \frac{5(1-e)^2 s^2}{e^3} \rightarrow \text{const}$$

$r \rightarrow$ Specific resistance.

* Thickness of cake & Vol of filtrate.



(*) Mass of Solids in filter cake $= (1-e) A l \rho_s$

(*) Mass of liq retained on filter cake $= e A l \rho$

* if J Mass fraction of solids in original suspension

* Mass Balance between the Solid in the Slurry & in Cake

$$(1-J)(1-e) A l \rho_s = J V \rho + A e J l \rho$$

$l \rightarrow$ eq from above

#

$$V_i = e l \rightarrow \text{new path } \text{مسار جديد}$$

if v vol of cake deposited by passage of unit vol of filtrate

مس (معدل التدفق) هو $\frac{V}{A}$

$$v = \frac{Q}{A} \text{ or } Q = vA$$

* Substituted for 1 into eq 1 Basic eq

$$\frac{1}{A} \frac{dV}{dt} = \frac{(-\Delta P)}{r\mu} \frac{A}{vV}$$

$$\frac{dV}{dt} = \frac{A^2 (-\Delta P)}{r\mu V}$$

Constant $P \rightarrow$ Flow Rate $\downarrow$
Constant Flow Rate $\rightarrow P \uparrow$

* For filtration @ Constant Rate

$$\frac{t}{V} = \frac{r\mu}{A^2 (-\Delta P)} V \quad -\Delta P \propto V^2$$

* For filtration @ Const P

$$\frac{t}{V} = \frac{r\mu}{2A^2 (-\Delta P)} V$$

** Flow of filtrate through the cloth & cake combined

$$\frac{1}{A} \frac{dV}{dt} = \frac{(-\Delta P)}{r\mu} \rightarrow \frac{1}{A} \frac{dV}{dt} = \frac{(-\Delta P)}{r\mu (L + \delta)}$$

δ $\rightarrow$ Cake thickness

L $\rightarrow$ filter medium thickness + initial layer

* For Constant Rate

* For Constant P

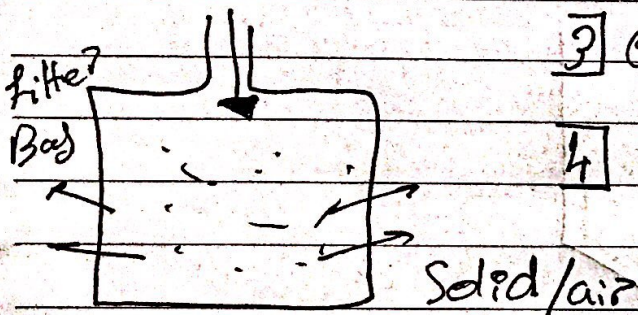
** Filter Medium or

- 1] Strong

- 2] Resistance to Corrosivity

- 3] Offer little (acceptable) resistance

- 4] Woven materials

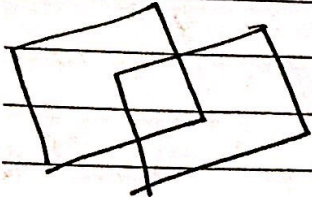


* electrostatic precipitators



24/12

* Electrostatic Precipitators → الکترستاتیک پریسیپیتور

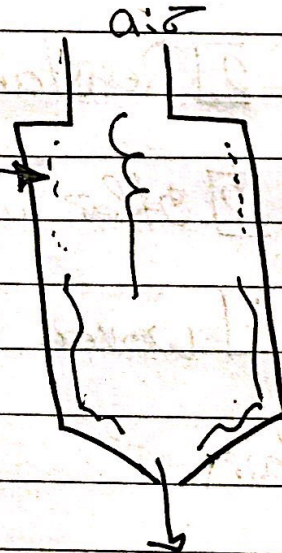


Solid / Air

→ very efficient → 99%

* Cyclone → دو چرخه ای وسیله ای که ذرات را جدا می کند

Gas / Solid



* Plate and Frame Press

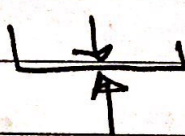
* Read Equip

→ pretreatment



Bars

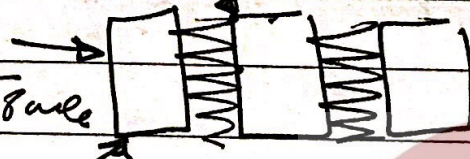
→ Back wash



Frame

Flu

Plate



ask ; believe & recieve