FIFTH PART

QUALITATIVE APPROACH

Answer to the question **" HOW ? "**

NUMBER OF DIMENSIONS OF AN OBJECT

- **THREE-DIMENSIONAL OBJECTS :**

  Strictly speaking all material objets extend in a three-dimensional space.

  Practically, this definition is restricted to objects irreducible to a smaller number of dimensions.

  Example : 800.000 t lot of bauxite.

- **TWO-DIMENSIONAL OBJECTS** : when the third dimension, usually vertical, is ...
  - ♦ small as compared with the other two and …
  - ♦ pratically uniform.

Model : a sheet of paper.

Examples : a flat truck-load, a forest, a corn field, a flat mineral deposit, a « blister » copper plate etc.

- **ONE-DIMENSIONAL OBJECTS**

  when the other two dimensions are :

  - small as compared with the first
  - practically uniform.

  Model : cable.

  Example : a batch of particulate solids, liquids or pulps **flowing** at a more or less uniform rate. A river. A rail.

  Frequent. Easy and cheap to sample correctly.

- **ZERO-DIMENSIONAL OBJECTS**

By convention : a population made of a **large number** of units that can have :

♦ either a **more or less uniform mass**

Example : all manufactured objects.

Case dealt with by classical statistics.

♦ or **different masses**.

Example : mineral fragments whose mass can vary in a ratio of **1 to 10^{20}** .

Case dealt with by Gy’s model (1951).

CORRECT SAMPLING AND NUMBER OF DIMENSIONS

Experience shows that …

- The larger the number of dimensions of an object, and the more difficult and costly its correct sampling.
- Correct sampling of irreducible three- or two-dimensional objects is …

ECONOMICALLY UNACHIEVABLE

REDUCTION OF THE NUMBER OF DIMENSIONS OF AN OBJECT

- **A CORRECT SOLUTION TO THE SAMPLING PROBLEM DOES EXIST ONLY** when it is economically feasible to reduce the number of dimensions of a 3- or 2-dimensional object to 1- or 0-dimension, **which requires its reclaiming**

The economical feasibility obviously depends on the mass to be handled.

- **REDUCTION FROM 3 / 2 to 1 dimension**

  The lot is reclaimed and transformed into **a flowing stream** :

  ♦ **particulate solids** : at the discharge of a conveyor belt,

  ♦ **liquids and pulps** : at the discharge of chutes or piping systems.

  Example : pumping or gravity flow at the bottom of a three-dimensional tank.

- **REDUCTION FROM 3 / 2 to 0 dimension**
  the lot is reclaimed and transformed into a population of usually ordered units :
  - **particulate solids** (trucks, waggons manual / mechanical shovelfuls, etc.)
  - **liquids and pulps of ground solids in a liquid** (drums, containers, etc .)

Example (world record, Japan) : 16.000 t lot of valuable mineral, reduced to an eight-ton sample processed in the lab.

QUALITATIVE APPROACH

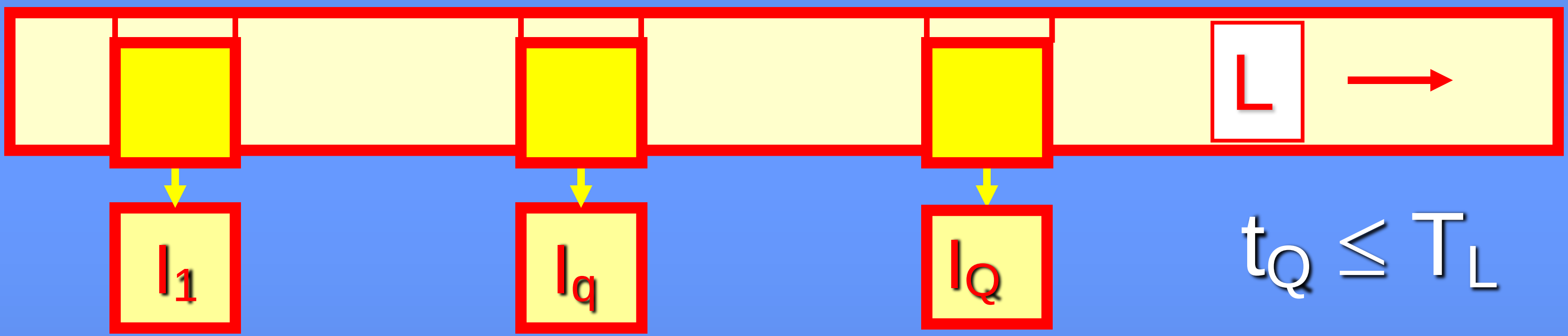
HOW TO ACHIEVE A MASS REDUCTION

FIRST MASS REDUCTION MODEL

- **INCREMENTAL SAMPLING**

  of a one-dimensional flowing lot :

  Lot L flows from instants $t = 0$ to $t = T_L$



$t_Q \leq T_L$

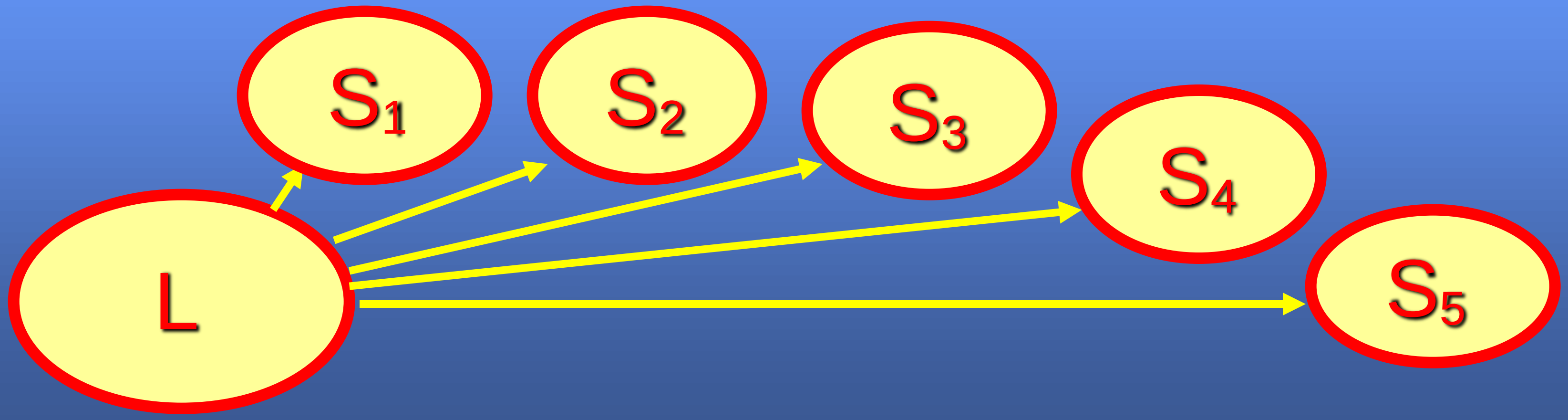
At instants $t = t_1$, $t = t_2$, $t = t_q$, $t = t_Q$

Q point-increments are selected and extended into **Q** material-increments I_q

Material Sample **S** is : $\mathbf{S \equiv \Sigma\, I_q << L}$

SECOND MASS REDUCTION MODEL

- **SPLITTING** of a zero-dimensional lot. Lot **L** is split between **N** twin-fractions that will become **N** twin potential sub-samples. Sample **S** is obtained by selecting and gathering one or several potential sub-samples $\mathbf{S_k}$: $\mathbf{L \equiv \Sigma_k S_k}$



THE SAMPLING OF ZERO-DIMENSIONAL MATERIAL BATCHES

CORRECT SAMPLING OF A ZERO-DIMENSIONAL LOT

Lot **L** is made of **N** unspecified units $\mathbf{U_n}$ the mass of which may be uniform or not.

n = 1, 2, … N ♦ **N** is large : **N >> 1**

Q units $\mathbf{I_q}$ are selected : **1 << Q << N**. No hypothesis re. a possible correlation between **n** and properties of $\mathbf{U_n}$ is made.

Sample $\mathbf{S = \Sigma_q I_q}$. Correctness is achieved by introducing a random factor.

LOT MADE OF N WELL-DEFINED UNITS OF COMPARABLE MASS

Three selection modes : **SY , ST , RA**

- **SY** : Systematic sampling with uniform interval $\mathbf{N_{sy}}$.

Random selection of increment I_1 in the first interval $\mathbf{1 \leq I_1 < N_{sy}}$.

Then, increment $\mathbf{I_q}$ is defined by :

$$I_q = I_1 + (q - 1)\, N_{sy} \leq N$$

- **ST** : Stratified random.

The lot **L** is first divided into **Q** strata $\mathbf{T_q}$ of equal length $\mathbf{T_{st}}$. An increment $\mathbf{I_q}$ is selected at random within each stratum $\mathbf{T_q}$

- **RA** : Random.

Q values of **q** are selected at random between **1** and **N**, which defines **Q** increments $\mathbf{I_q}$

- **SAMPLE**. In the three cases, sample **S** is the sum of the **Q** increments $\mathbf{I_q}$

SY : L ≡ 756 DRUMS OF RADIOACTIVE RESIDUES ♦ COMPARABLE MASS

Lot = 63 groups of 12 drums. **Selection of n°4 at random.** Interval = 12. **S = n° 4, 16, 28**

ST : L ≡ 756 DRUMS OF RADIOACTIVE RESIDUES ♦ COMPARABLE MASS

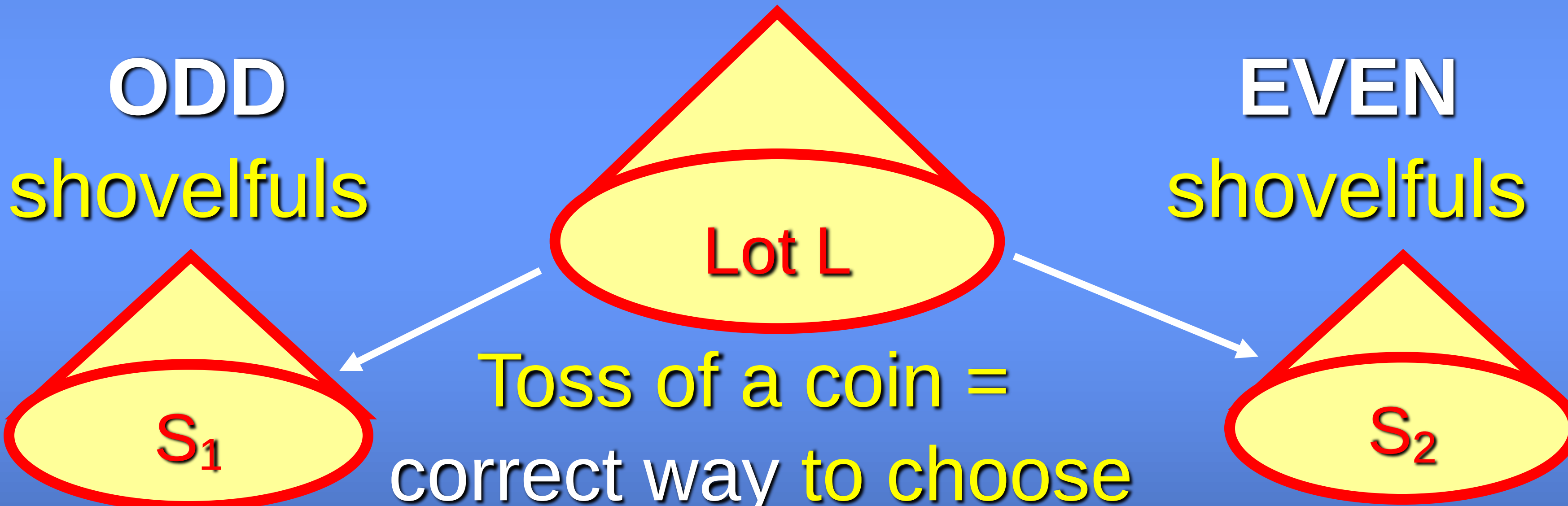
Lot = 63 strata of 12 drums. **S = random selection of n° 4, 23, 30** in strata 1, 2, 3.

SPLITTING L INTO TWIN-SAMPLES
♦ ALTERNATE SHOVELING ♦

Lot **L** split by alternate shoveling into $\mathbf{S_1}$ and $\mathbf{S_2}$ = twin potential samples

ODD shovelfuls

EVEN shovelfuls



Toss of a coin = correct way to choose between $\mathbf{S_1}$ and $\mathbf{S_2}$

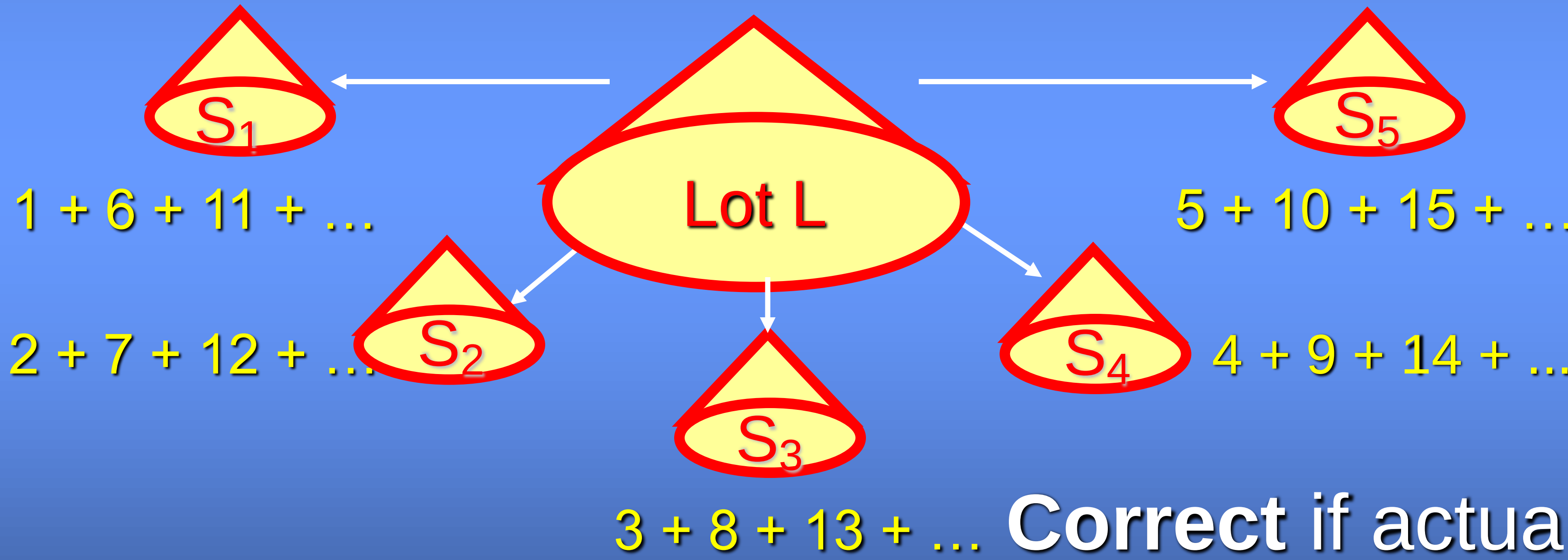
1 + 3 + 5 + …

2 + 4 + 6 + …

The operation is usually repetitive

EQUAL FRACTIONAL SHOVELING

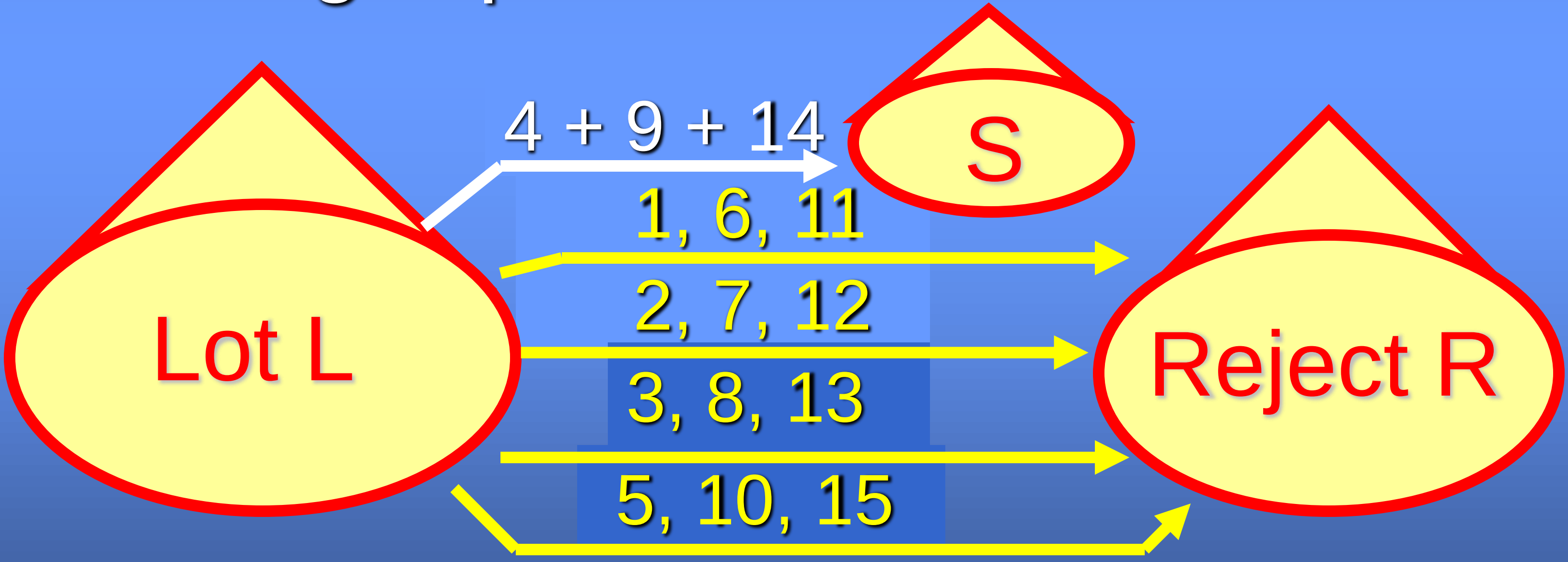
L split by **EQUAL** fractional shoveling between **N** twin-samples. Rate **1/N = 1/5**



Correct if actual sample selected at random : $\mathbf{S_1 / S_5}$

UNEQUAL FRACTIONAL SHOVELING

L is distributed between two non-twin fractions by **UNEQUAL** fractional shoveling. This method is **NON-PROBABILIST** Cheating is possible but can be avoided.



Japan : 16.000 t to 8 t : 1/20 ; 1/10 ; 1/10

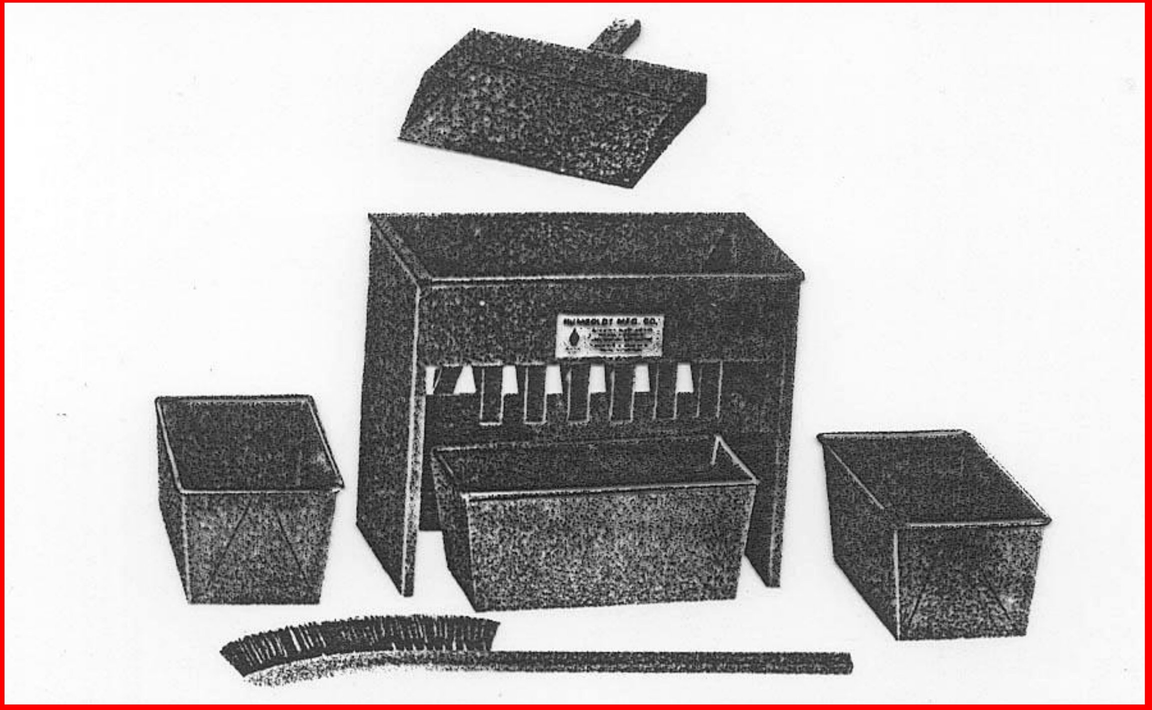
THE RIFFLE SPLITTER

Laboratory device meant to split into two « halves » lots weighing (in 2000) up to 1000 kg. Openings from 6 to 80 mm.

d_{max} < 2,5 to 30 mm

Repetitive operation

Commercial sampling



THE RIFFLE SPLITTER

Laboratory device. Reliable when implemented correctly (see below).

Number **N** of chutes of a riffle splitter :

$12 \le N \le 24$ with N even

Chute width **W = 6 to 90 mm**.

To prevent obstruction : **$W \ge 3 \times d$** (fragment diameter). Practically: **$2 < d < 30$ mm**

RIFFLE SPLITTERS ARE USUALLY CORRECTLY DESIGNED

Illustrations : Courtesy of Sepor, California

PRINCIPLE OF RIFFLE SPLITTING

ZERO-DIMENSIONAL LOT L SPREAD ON A RECTANGULAR SHOVEL

A_1	B_1	A_2	B_2	A_3	B_3	A_4	B_4

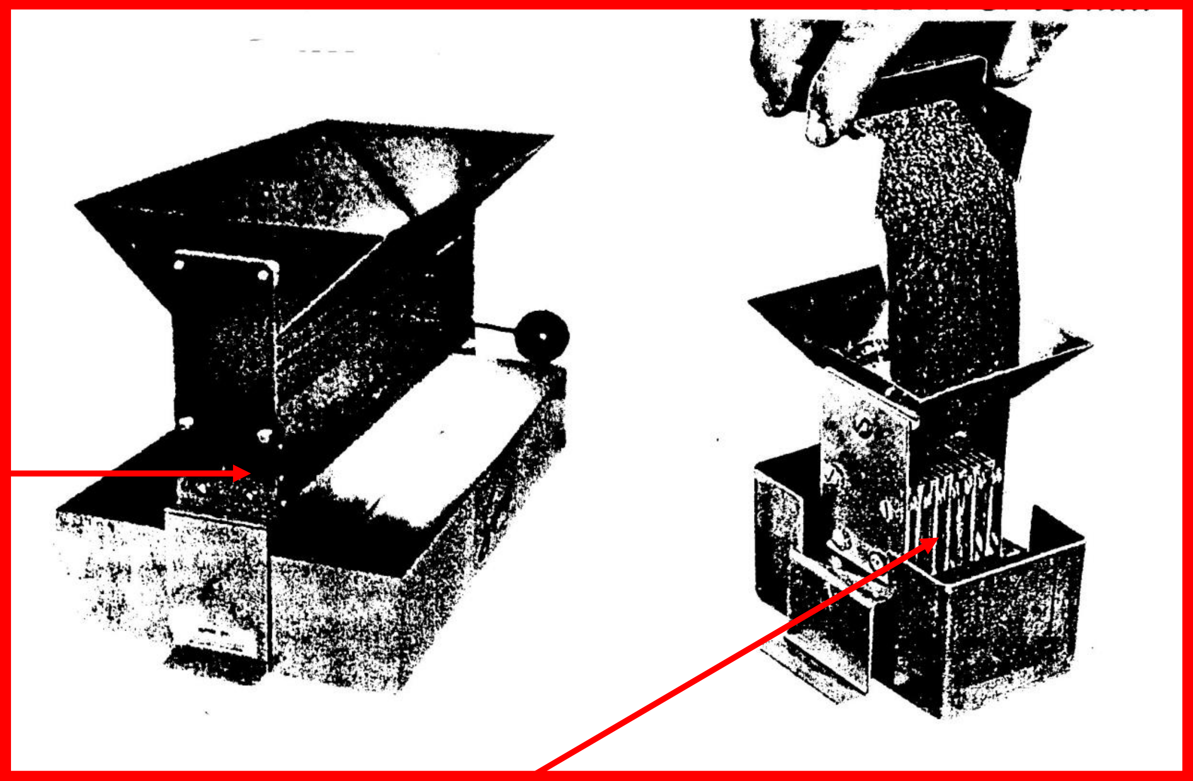
$A_1 + A_2 + A_3 + A_4 = S_A$

$B_1 + B_2 + B_3 + B_4 = S_B$

Correct selection of S_A **or** S_B by toss of a coin.

VARIOUS MODELS OF RIFFLE SPLITTERS

Hopper with gate : allows mixing prior to splitting.



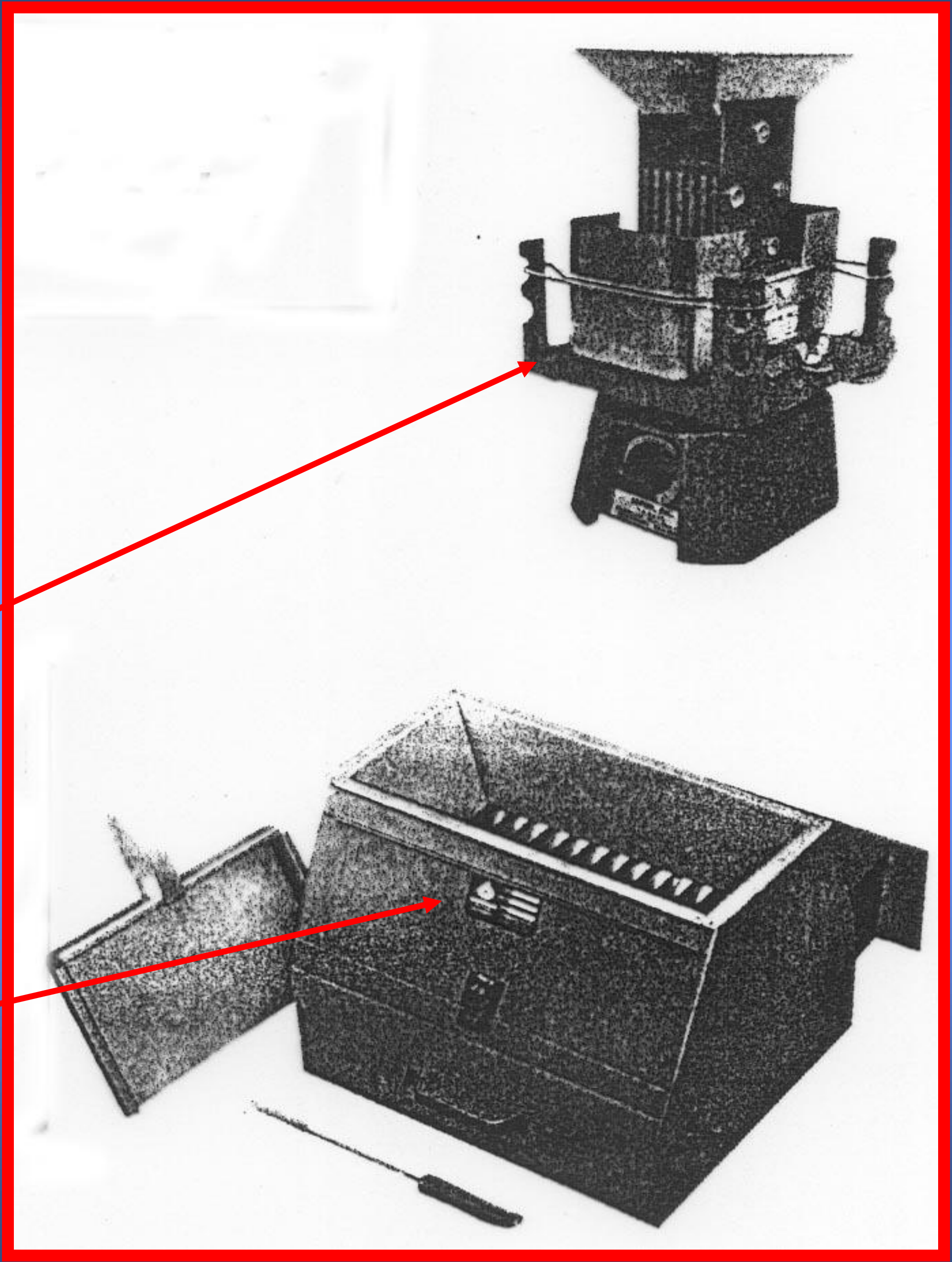
Micro-splitter : chute width 3 to 10 mm

RIFFLE SPLITTERS

Dust preventing systems

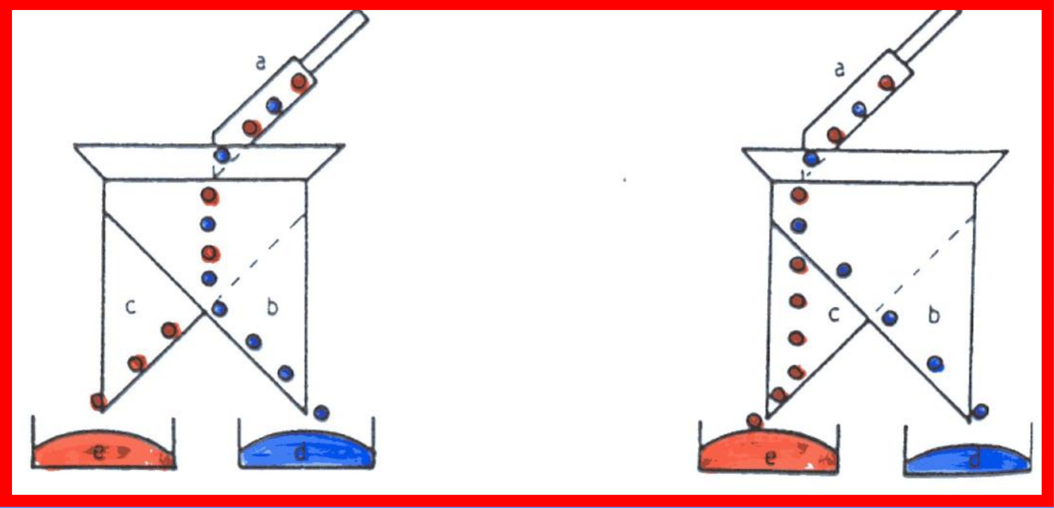
Vibrating

Enclosed



INCORRECT USE OF A CORRECT RIFFLE SPLITTER

Experiment carried out in 1952



Correct Incorrect

Four splitting stages → 16 samples

observed biases : G = left ; D = Right

Mass : G > D (6%) ♦ Pb : D > G (2%)

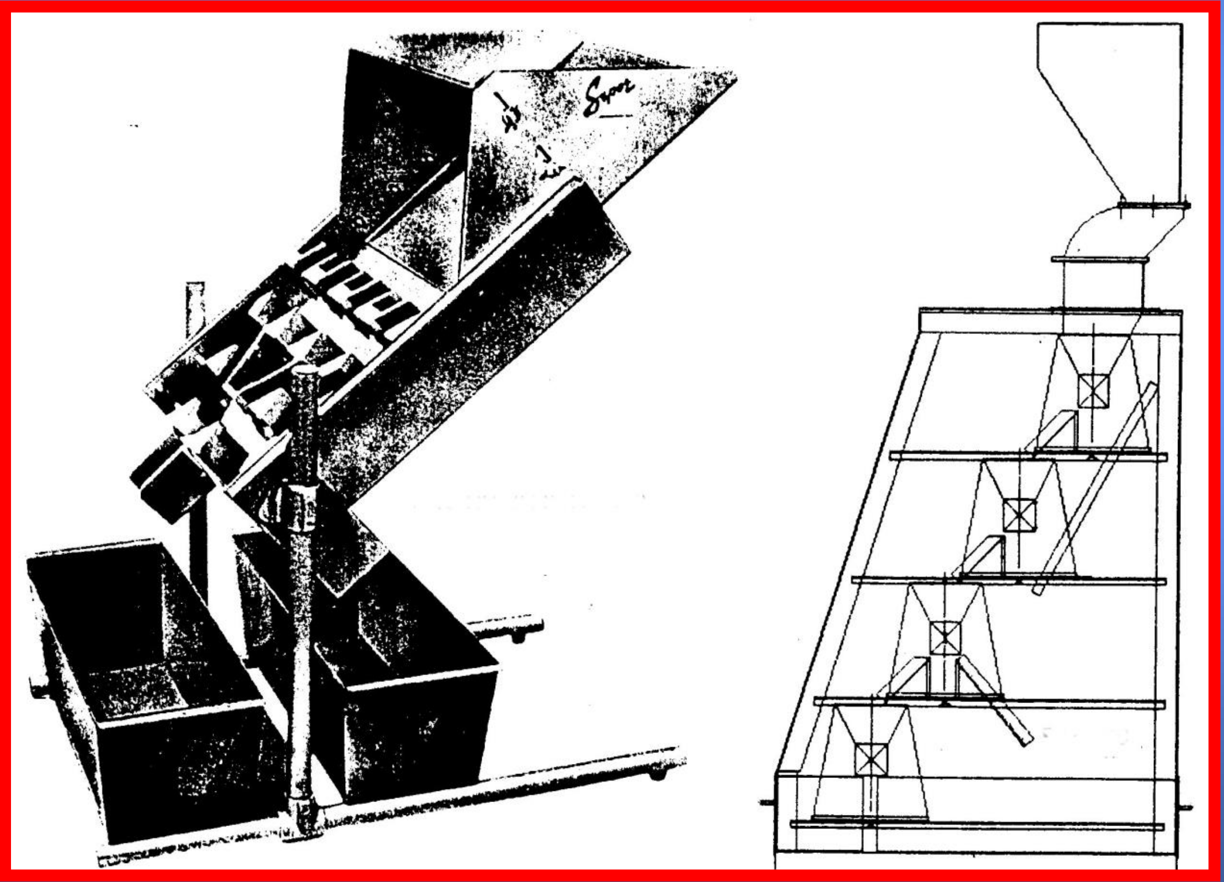
4 x G 0 x D	3 x G 1 x D	2 x G 2 x D	1 x G 3 x D	0 x G 4 x D
GGGG - 0,201	GGGD - 0,051	GGDD + 0,269	GDDD + 0,169	DDDD + 0,214
	GGDG - 0,221	GDGD + 0,174	DGDD + 0,139	
	GDGG - 0,341	GDDG + 0,084	DDGD + 0,094	
	DGGG - 0,281	DGGD - 0,251	DDDG + 0,109	
		DGDG - 0,101		
Negative bias	Negative bias	DDGG + 0,189	Positive bias	Positive bias

CASCADE OF RIFFLE SPLITTERS

Designed to extract 1/16 in a single pass.

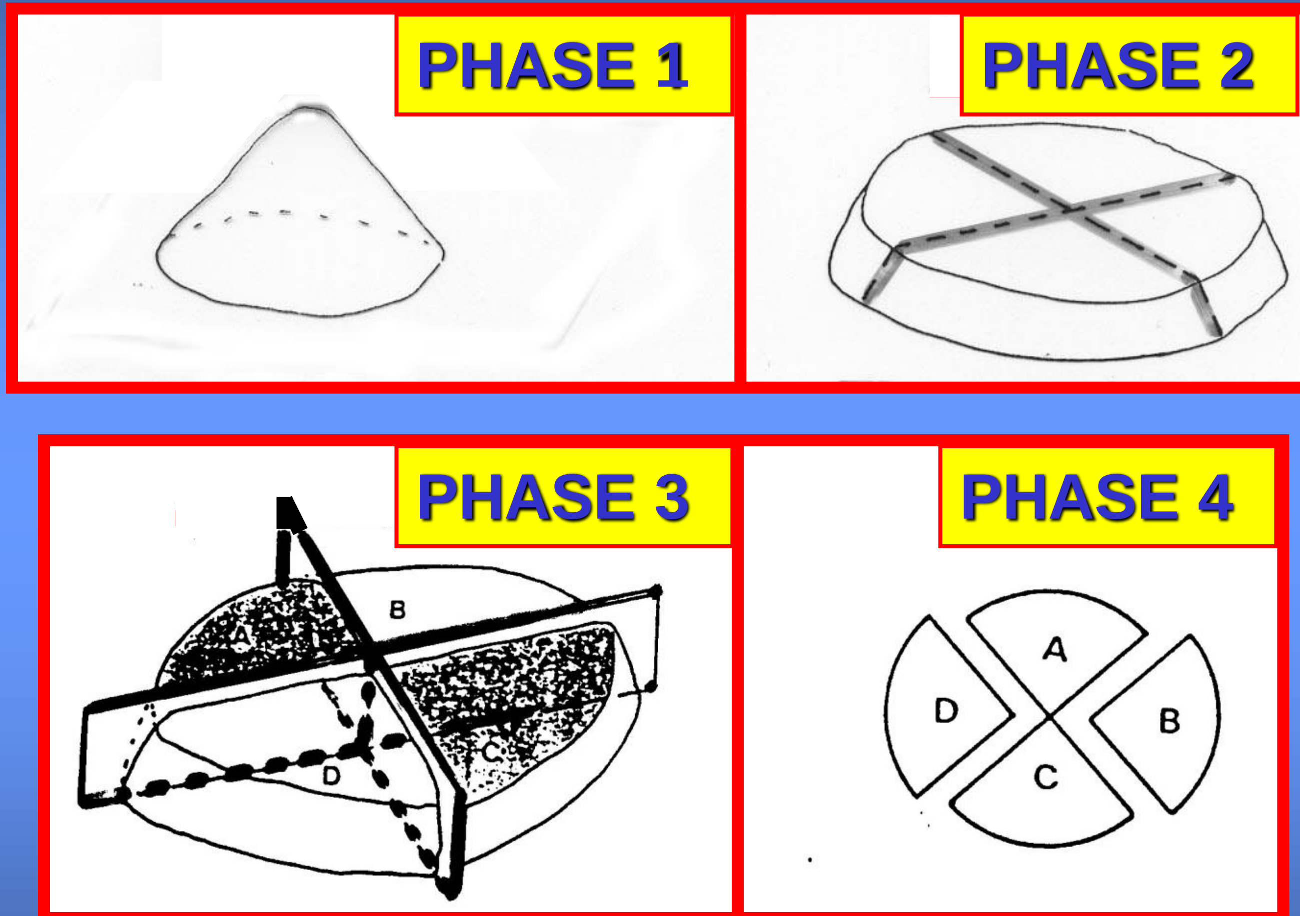
This device is **INCORRECT** in its principle

SHOULD BE AVOIDED : SAMPLES ARE BIASED



CONING AND QUARTERING

Uselessly costly hand method



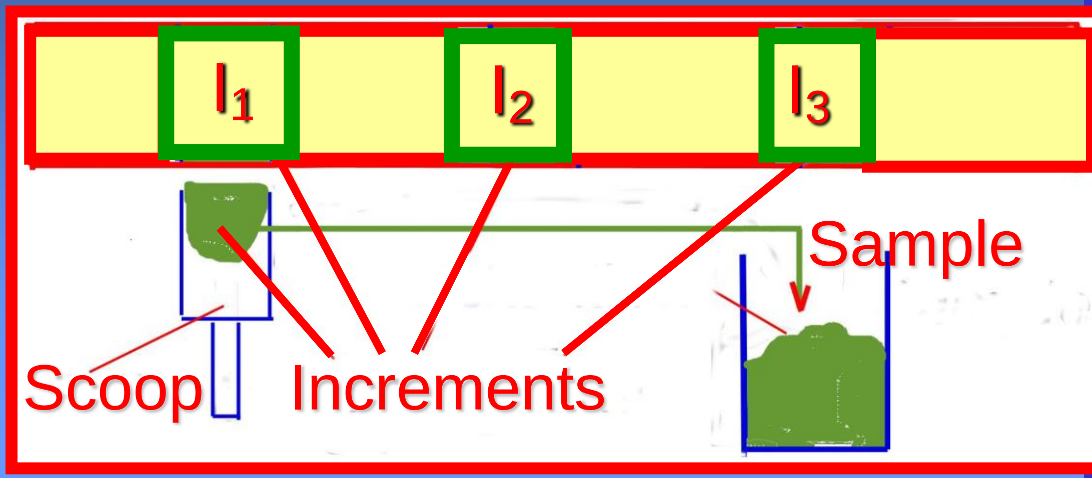
Alternate shoveling always better

Two potential samples (A+C) or (B+D)

THE JAPANESE SLABCAKES

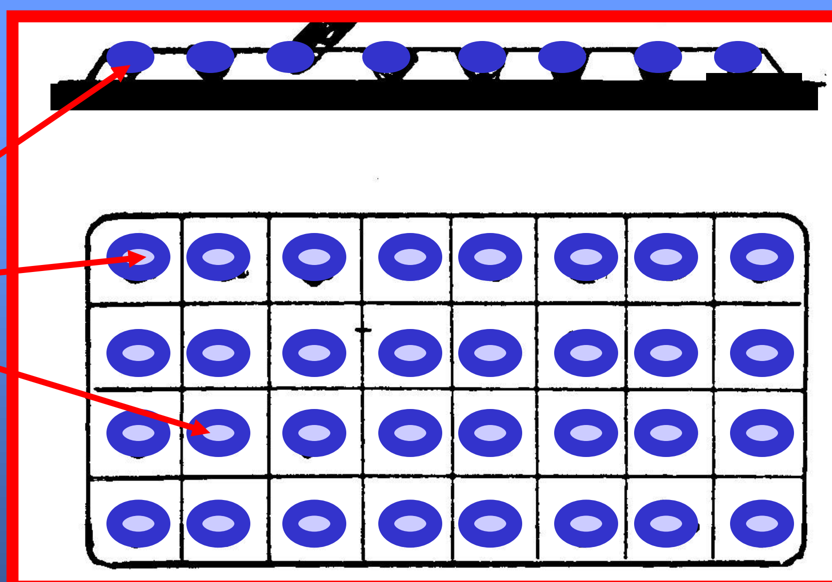
ONE-DIMENSIONAL

Possibly biased



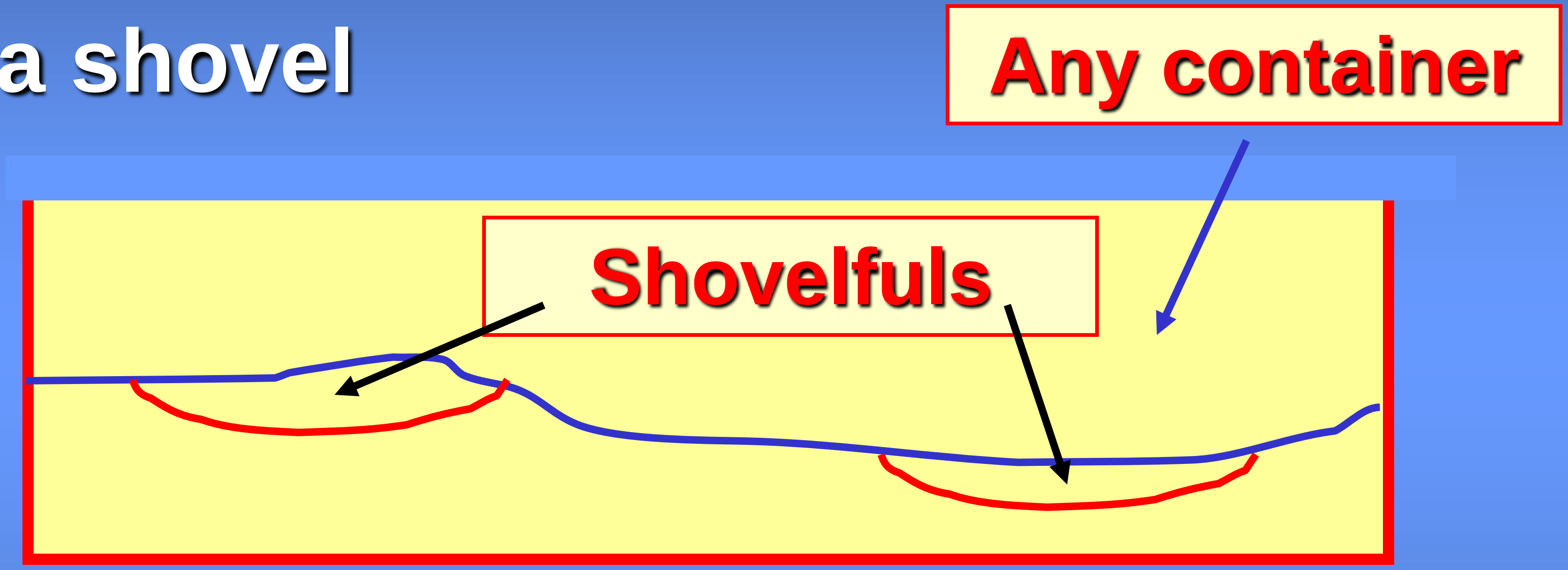
TWO-DIMENSIONAL

Increments



Very popular in the Pacific Area

Example : Cattle Food “SAMPLING” = NON-PROBABILIST Picking by means of a shovel

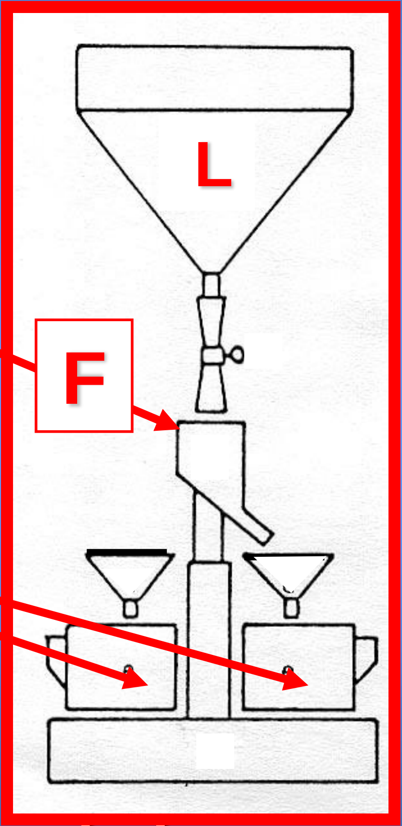


One shovelful = one increment

Specimen = Σ increments

SECTORIAL DIVIDER WITH A REVOLVING FEEDER

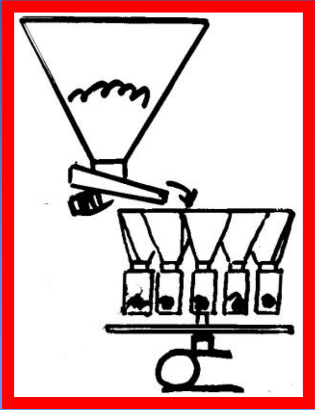
Usually correct laboratory but also pilot plant device. The feeder **F** revolves about its axis. Irrespective of its mass, lot **L** can be divided into **N** twin-fractions. Each of these can be redarded as a **1/N th** sample of **L**.



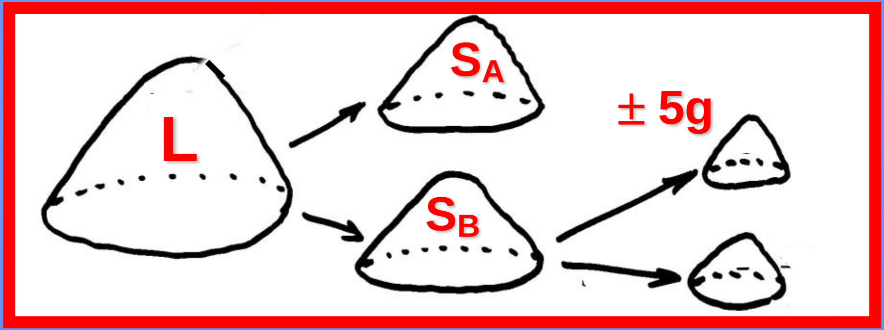
Typically : **N = 6, 8, 12**. Commercial.

OBTENTION OF A TEST-PORTION

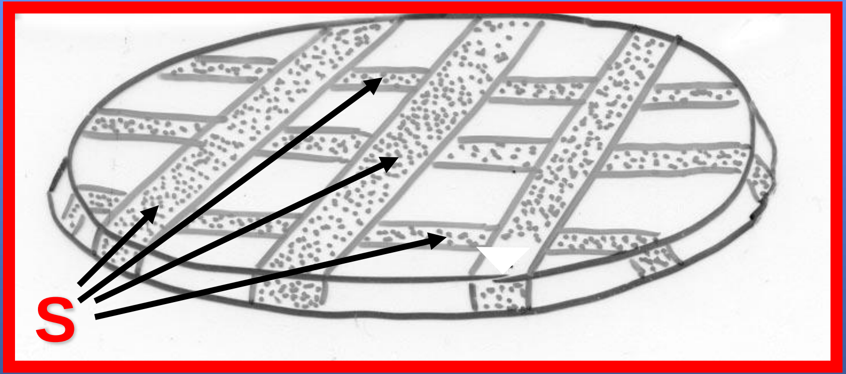
- **Use of a rotary divider** to obtain a 50-1000 g laboratory sample. This is a one-dimensional sampling.



- **Alternate shoveling** by means of a scoop to obtain 5-50 g



- **Mixing and taking the** test-portion (e.g. 1 g) by means of a spatula.



THE SAMPLING OF ONE-DIMENSIONAL MATERIAL BATCHES

PROPERTIES OF A ONE-DIMENSIONAL OBJECT

I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9

A one-dimensional, compact or flowing object can be regarded as a series of potential increments such as $I_1 \dots I_9$. Each increment I_q may be regarded as a zero-dimensional object, as autocorrelation is barely perceptible on a small scale. **Residual autocorrelation** generates a 0-dim. **Grouping and Segregation Error GSE**

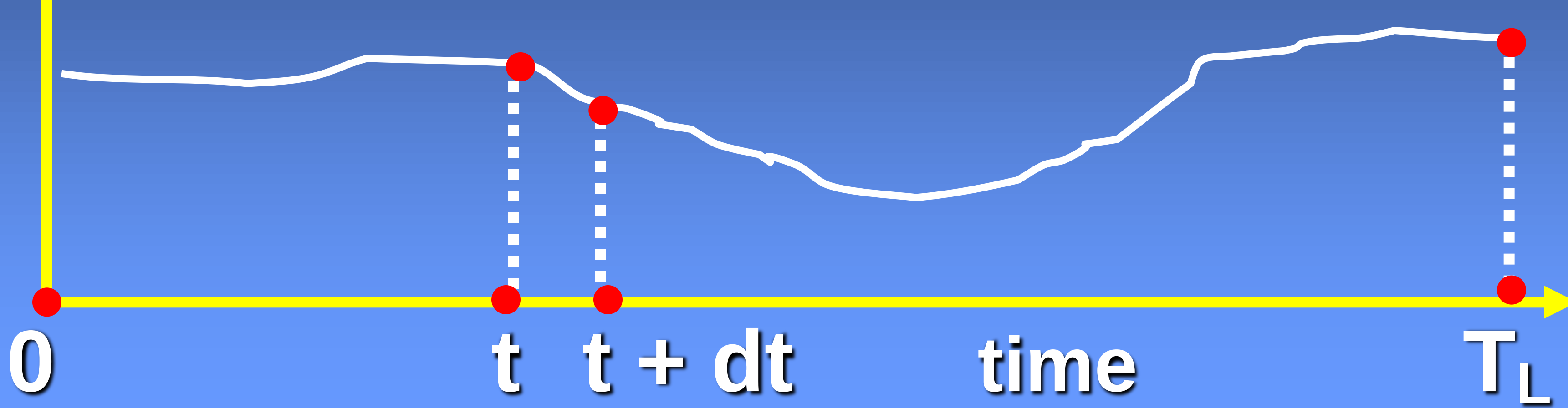
AUTOCORRELATION OF A SERIES

Correlation between two units of a series is called « autocorrelation of the series ». This is the correlation between the properties of increments I_q (taken at instant t_q) and I_{q+j} (taken at instant t_{q+j}) of this series. It is a function of the distance j T_0 (T_0 being the uniform interval).

This autocorrelation gives the series its dimension. Difference with a population.

It is represented by a quasi-continuous curve a(t) …

a(t) ≡ grade of the slice of matter that flows between time **t** and time **t + dt**



Correlation is sensible only in the long range.

On the scale of an increment of length **dt** or **Δt** it is negligible. For all practical purposes **such an increment can be regarded as a zero-dimensional object**.

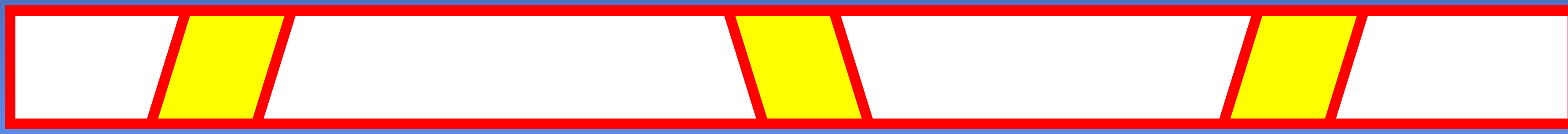
THE SAMPLING OF ONE-DIMENSIONAL FLOWING LOTS

Particulate solids, liquids, gases, fumes

Three ways to reduce their mass :

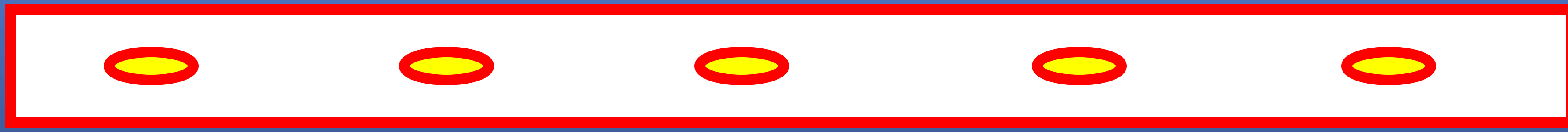
1. Taking the totality of the stream during a fraction of the flowing time,
2. Taking a fraction of the stream during the totality of the flowing time,
3. Taking a fraction of the stream during a fraction of the flowing time.

1 Taking the **TOTALITY** of the stream during a **FRACTION** of the time,



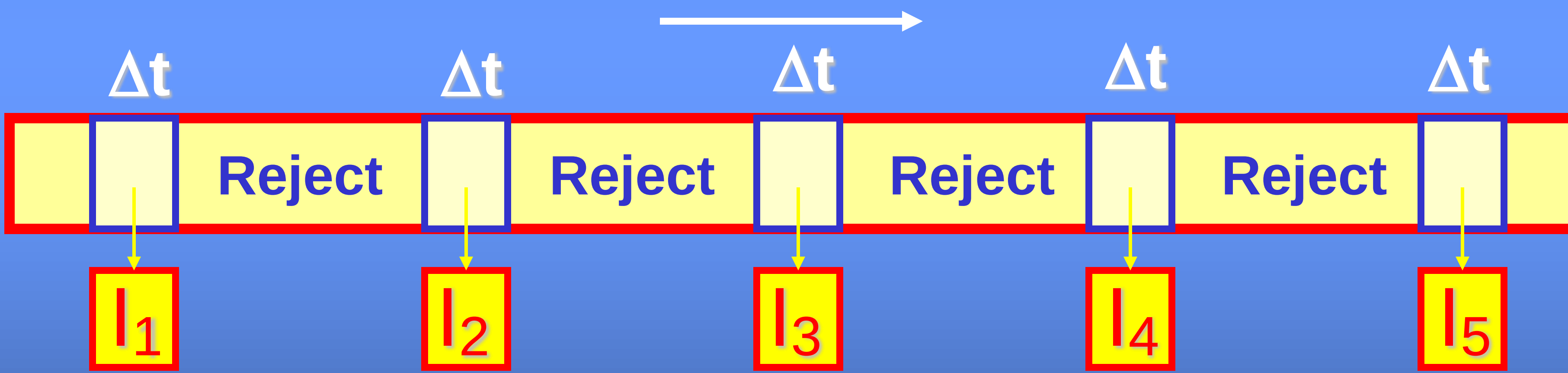
2 Taking a **FRACTION** of the stream during the **TOTALITY** of the time,

3 Taking a **FRACTION** of the stream during a **FRACTION** of the time,



1. TOTALITY OF THE STREAM DURING A FRACTION OF THE TIME

This can be achieved by **cutting the stream** at a uniform interval T_{sy} during a certain lapse of time **Δt** . Principle :

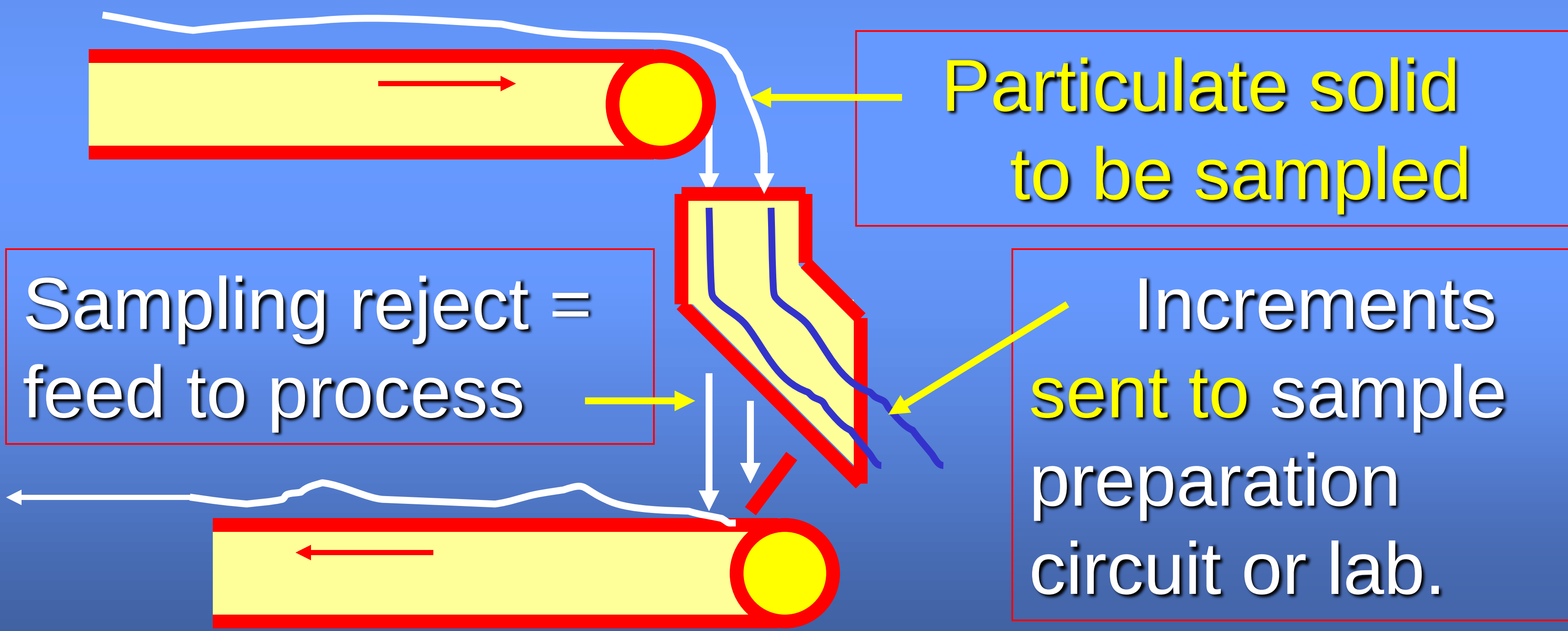


Increments **I_q** ♦ Sample **$S = \Sigma_q I_q$**

Sampling Reject = Main stream

CROSS-STREAM SAMPLERS

Extract the totality of the stream during a **FRACTION** of the time. Operate at discharge of belt conveyor or piping system.

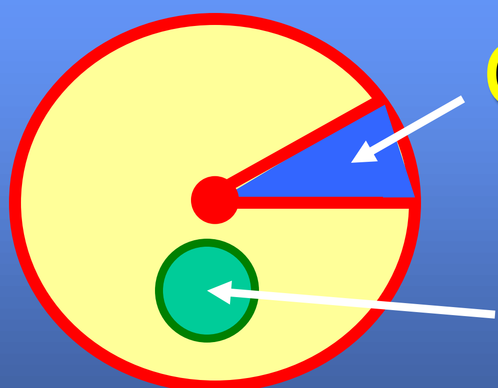


CROSS-STREAM SAMPLERS

- **STRAIGHT-PATH CUTTER :**

Moves between idle positions G and D.

- **CIRCULAR-PATH CUTTER :**



Cutter opening : angle $\alpha°$:

sampling ratio α / 360.

Stream to be sampled

CROSS-STREAM SAMPLING IS THE

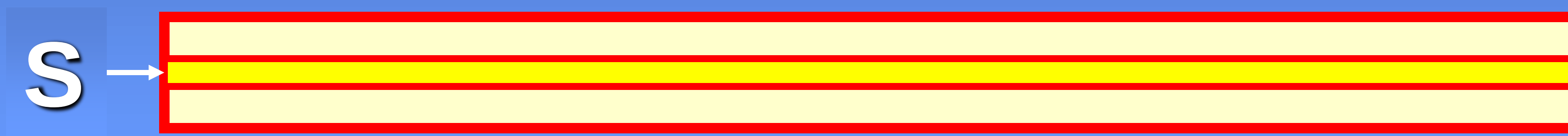
ONLY PROBABILIST SAMPLING METHOD

OF ONE-DIMENSIONAL OBJECTS. FURTHERMORE …

IT CAN EASILY BE RENDERED CORRECT

2 FRACTION OF THE STREAM DURING TOTALITY OF THE TIME

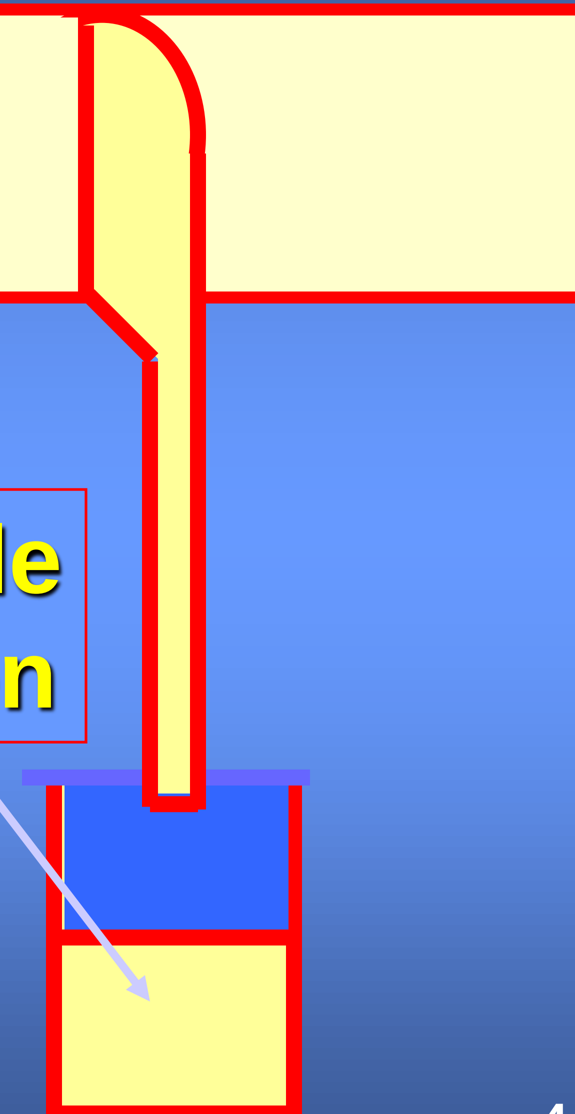
This method is **NON-PROBABILIST**



If there is a **correlation** between the properties of a constituent and its position in the stream cross-section (e.g. gravity segregation) the **specimen S may be heavily biased**. Often used in chemi- cal and pharmaceutical industries.

Implemented in chemical industries

LOT L TO BE SAMPLED



Hypothesis

of homogeneity throughout the cross-section.

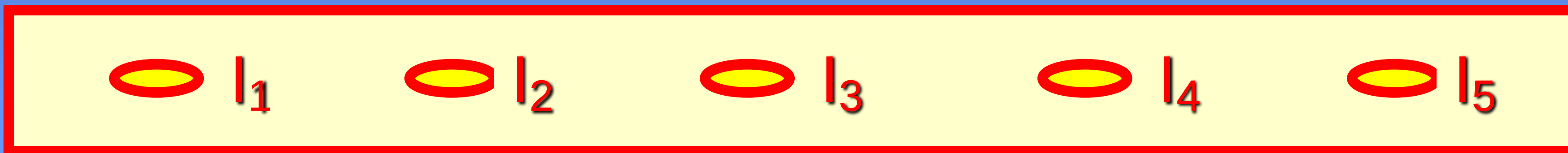
Unreliable Specimen

Practically never observed.

NEARLY ALWAYS BIASED

3 FRACTION OF THE STREAM DURING FRACTION OF THE TIME

This method is **NON-PROBABILIST**



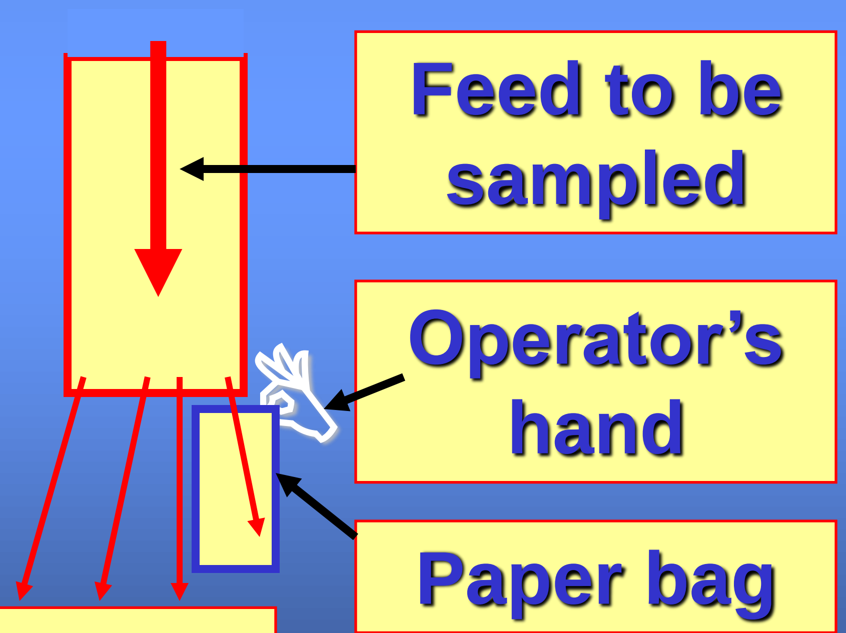
Examples : One shovelful every now and then on top of a belt load. Respon-sible for a $7 million cheating over 3 years (tin concentrates). Also used in chemical and pharmaceutical industries.

FRACTION OF THE STREAM DURING FRACTION OF THE TIME

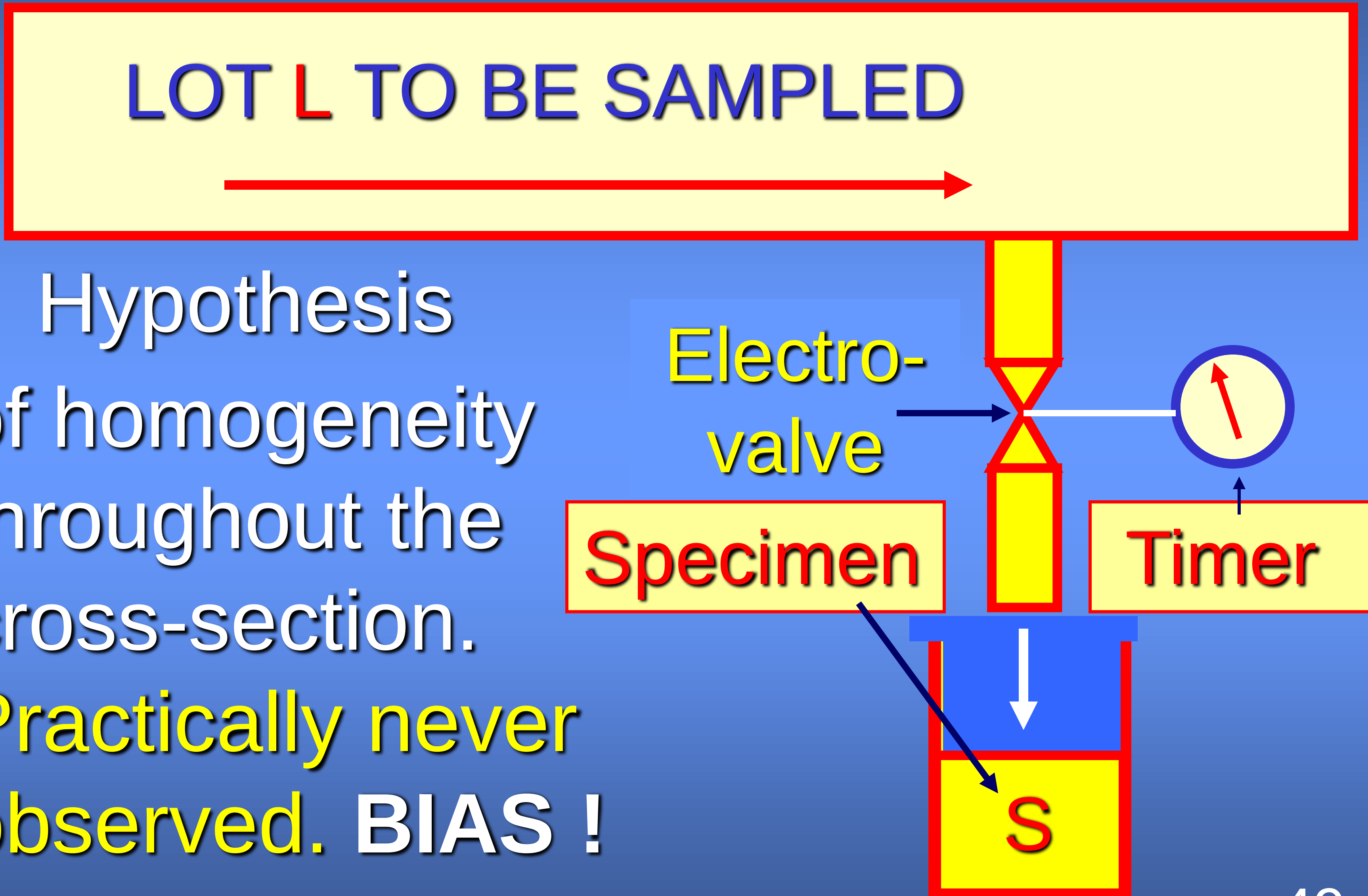
Example : Cattle Food "SAMPLING" :

NON-PROBABILIST Specimen-taking

The paper bag contains nothing but a VALUELESS DANGEROUS SPECIMEN !



Example borrowed from chemical industries



Hypothesis of homogeneity throughout the cross-section.

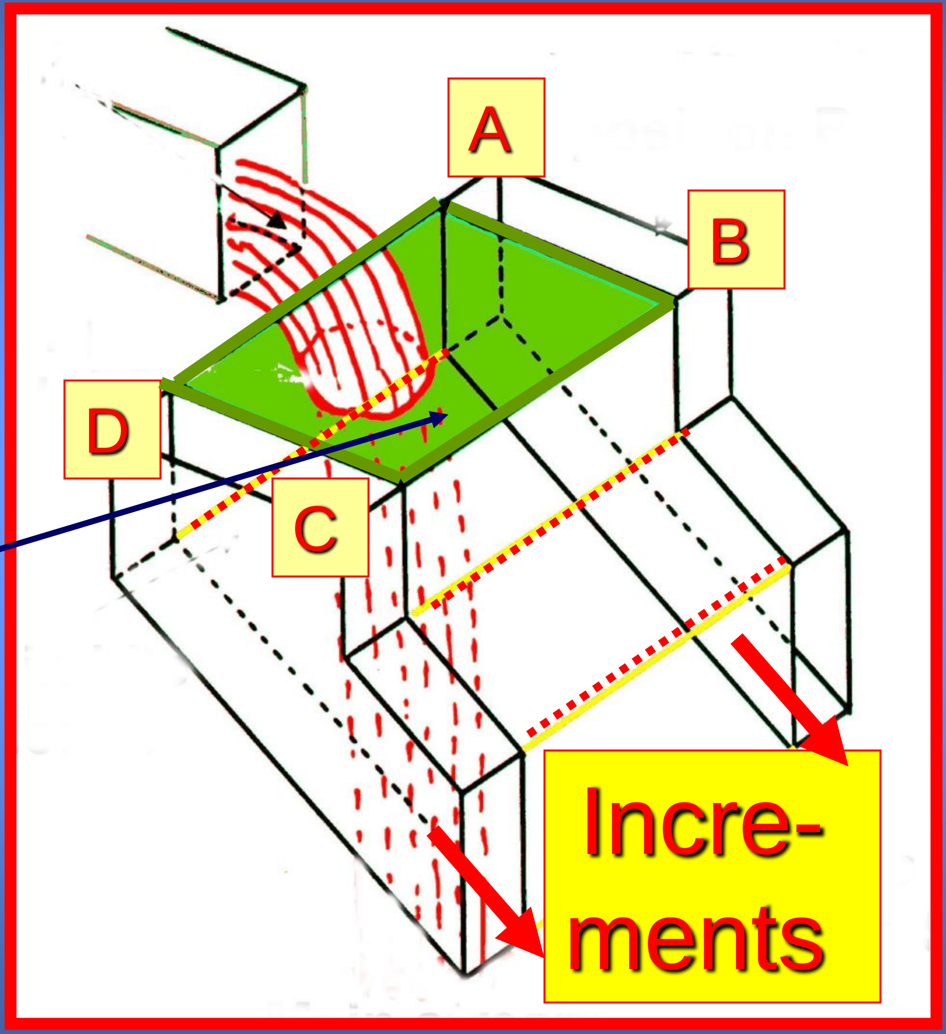
Practically never observed. **BIAS !**

THE SAMPLING PLANE ABCD

Straight-path cutter.

Sampling plane

≡ Area scanned by the cutter (green area ABCD)

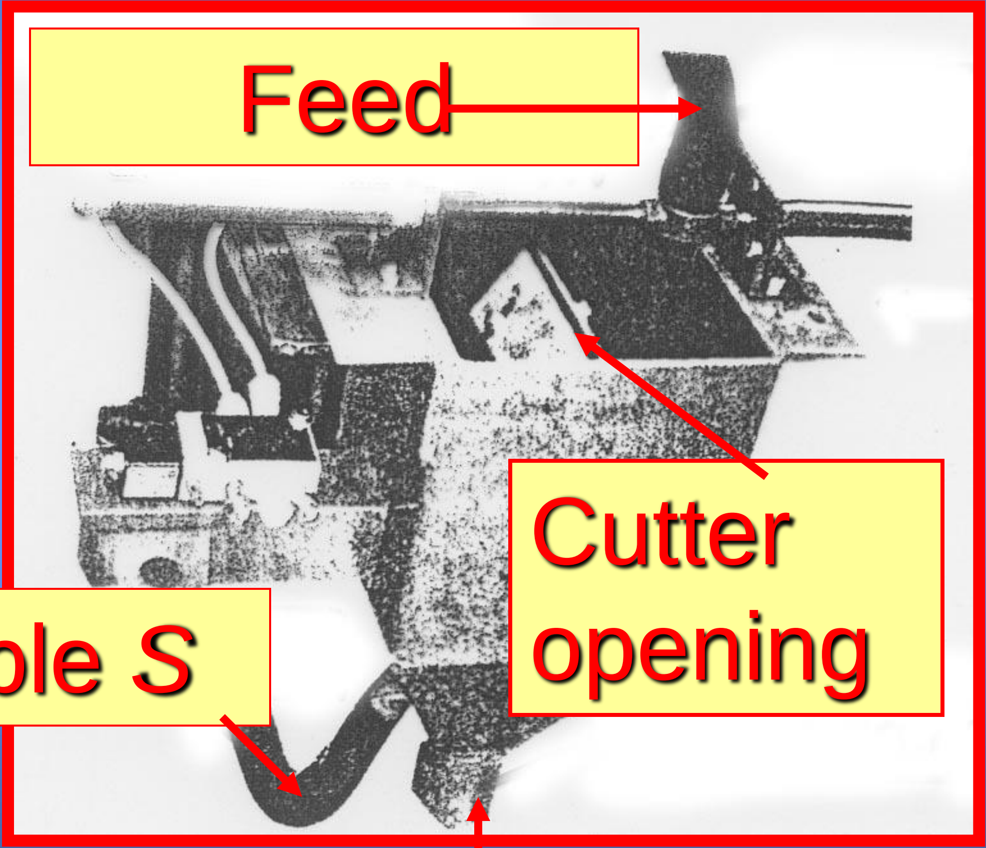


STRAIGHT-PATH CROSS-STREAM SAMPLER

Very small flow-rate (few t/h)

Hydraulic drive

Velocity often non-uniform.



REVOLVING SAMPLER (Vezin)

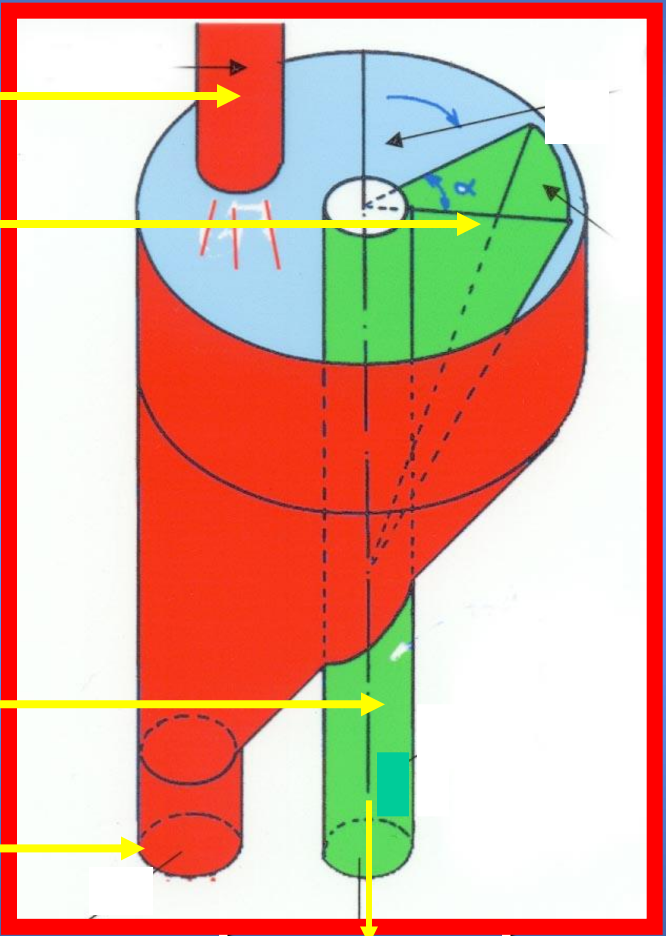
Small to very small flow-rates

Stream to be sampled

Increment cutter opening

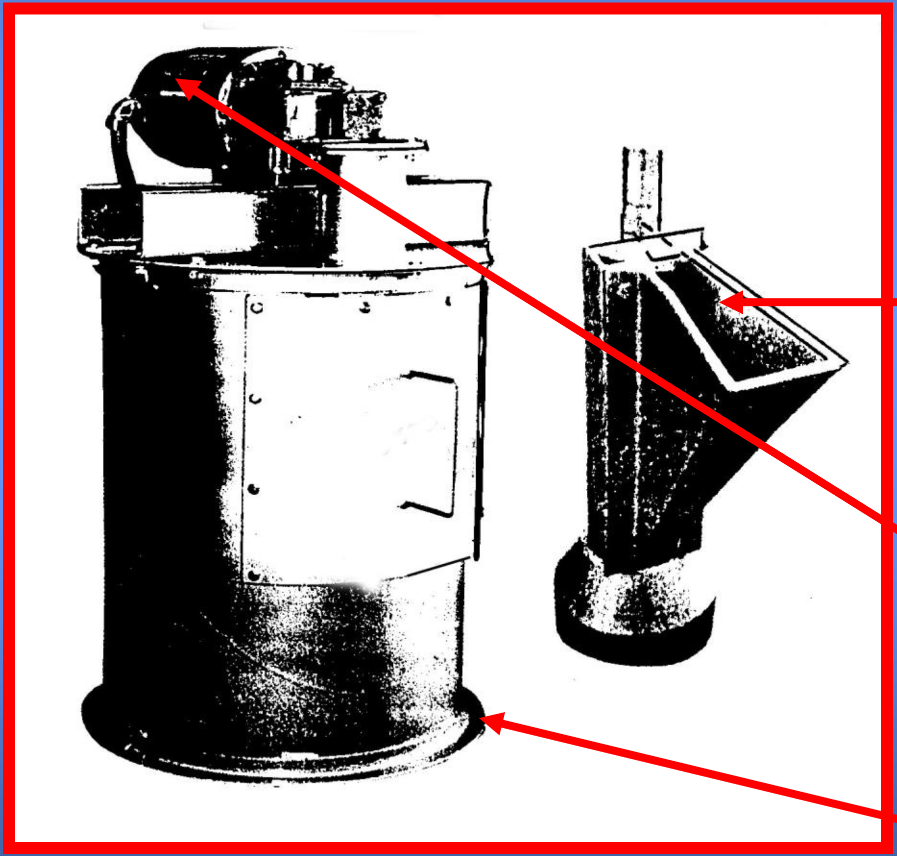
Axial pipe to drive cutter and evacuate increments

Main stream to process



Increments and sample

REVOLVING SAMPLER (Vezin-type)



Usually correct

Cutter and axial tube to evacuate increments

Electric drive (correct)

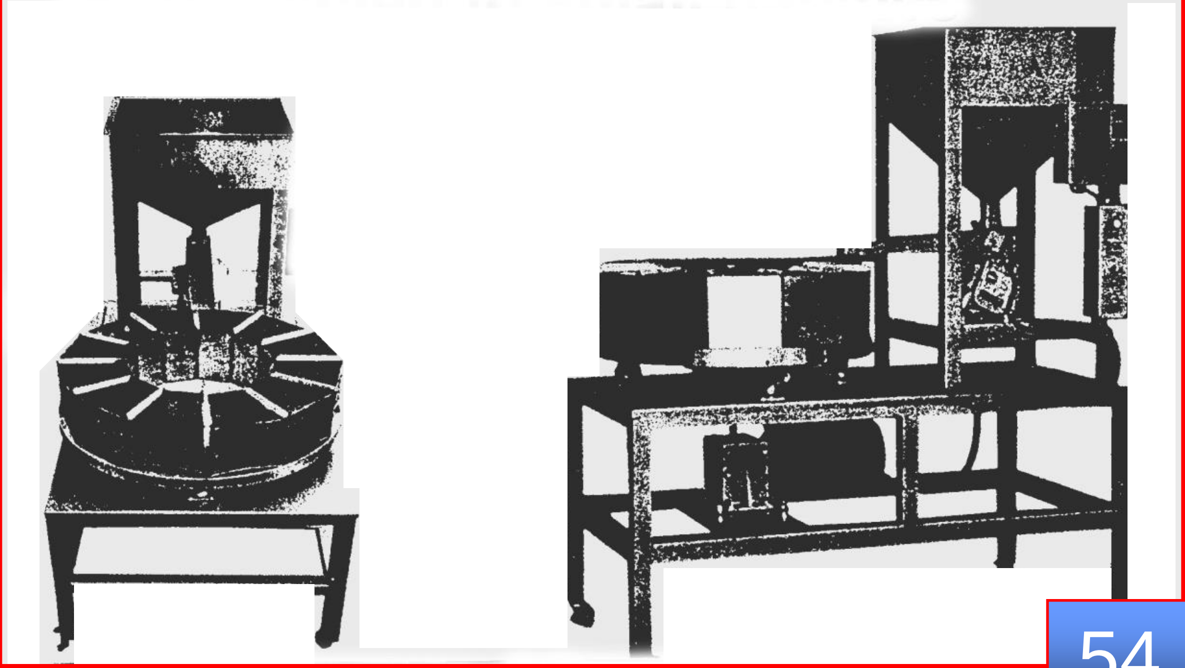
External view

REVOLVING SPLITTER WITH A FIXED FEEDER

Turn-table with **N** removable containers passing through the discharge of a vibra-ting feeder. Lot **L** is split between **N** twin-samples.

Very small capacity

Commercial operations.

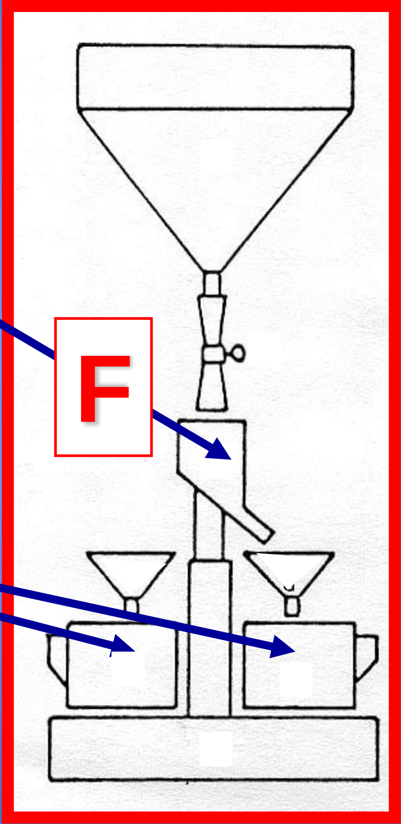


REVOLVING FEEDER SECTORIAL DIVIDER

Usually correct laboratory but also pilot plant device. The feeder F revolves about its axis.

Irrespective of its mass, lot **L** can be divided into **N** twin-fractions. Each of these can be taken as a **1/N th** sample of **L**.

Typically : **N = 6, 8, 12**



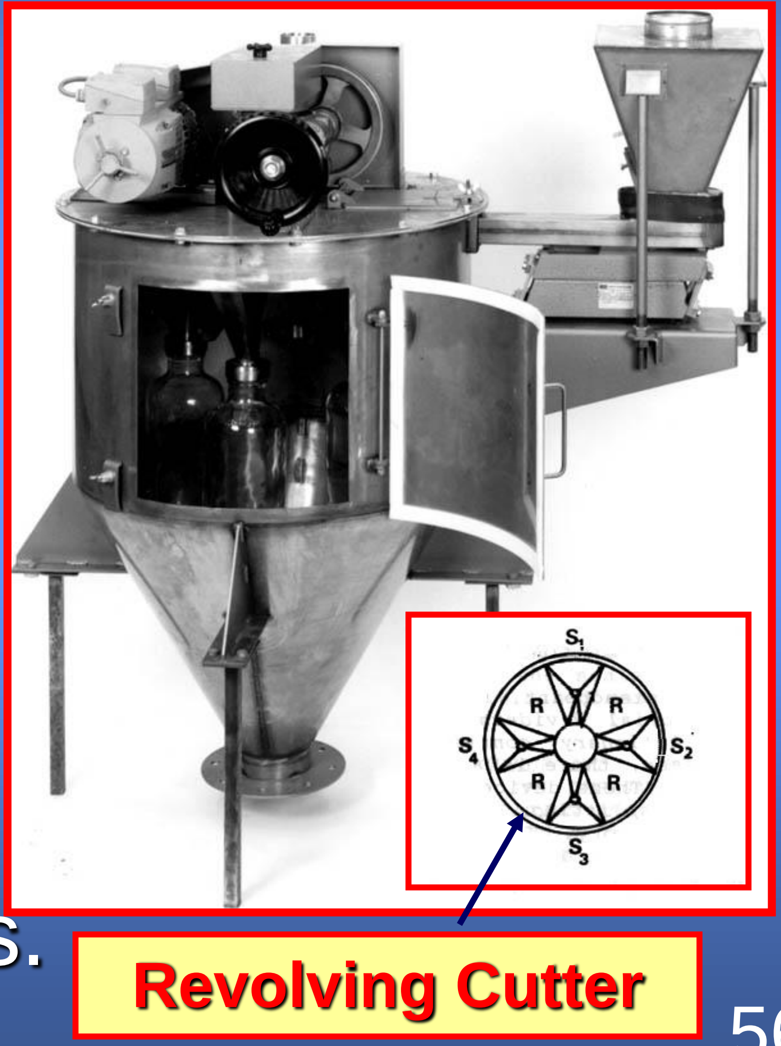
DIRECT BOTTLING UP REVOLVING SPLITTER

MINEMET device.

Fixed feeder.

Lot **L** is distributed between 4 two-liter jars + a reject **R**.

Completely enclosed dust-proof device desi-gned to split very fine and dry uranate powders.



DIRECT BOTTLING UP REVOLVING SPLITTER

Same design, smaller scale.

MINEMET device.

Final splitting of uranate powders (Equatorial Africa)

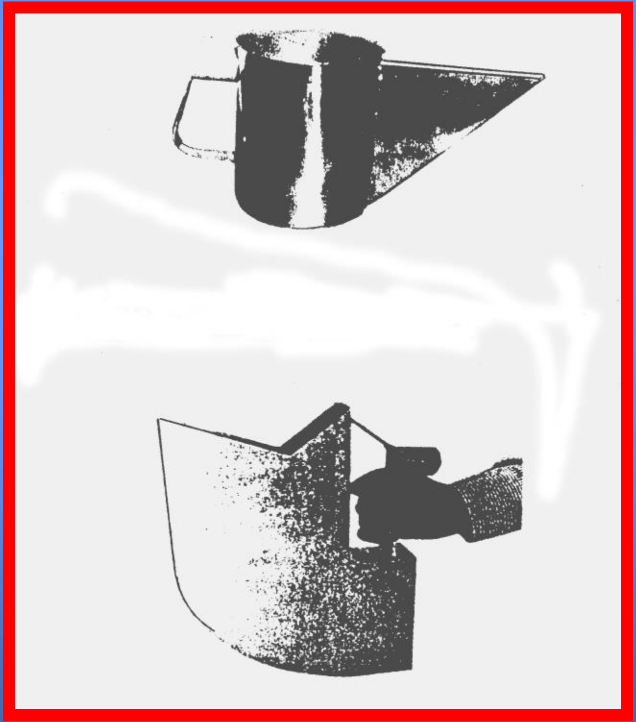
Air moisture and dust perfectly controlled.

Feeds 12 × 250 ml jars containing final samples (to parties / reserve).

HAND SAMPLING OF FLOWING STREAMS

Incorrect and **DANGEROUS** instruments

Some of these, have been standardized (!) and are still all too often used at industrial scale.

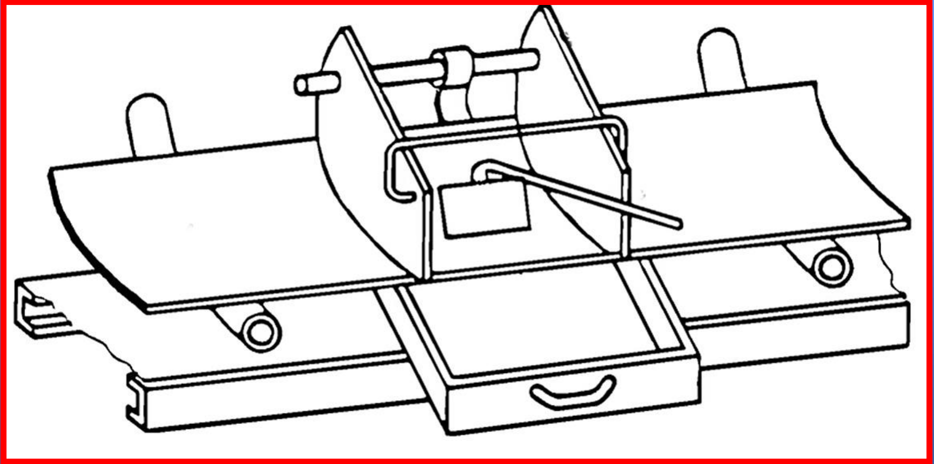


To be avoided whatever the flow-rate.

STOPPED BELT SAMPLING OF FLOWING STREAMS OF SOLIDS

This hand method is especially implemented as a **“REFERENCE METHOD”** when testing a sampler for bias. **Never implemented industrially**.

Correct when the operator does not try to cheat !



OVERFLOW « SAMPLER » ENSURING UNIFORM FLOW-RATE

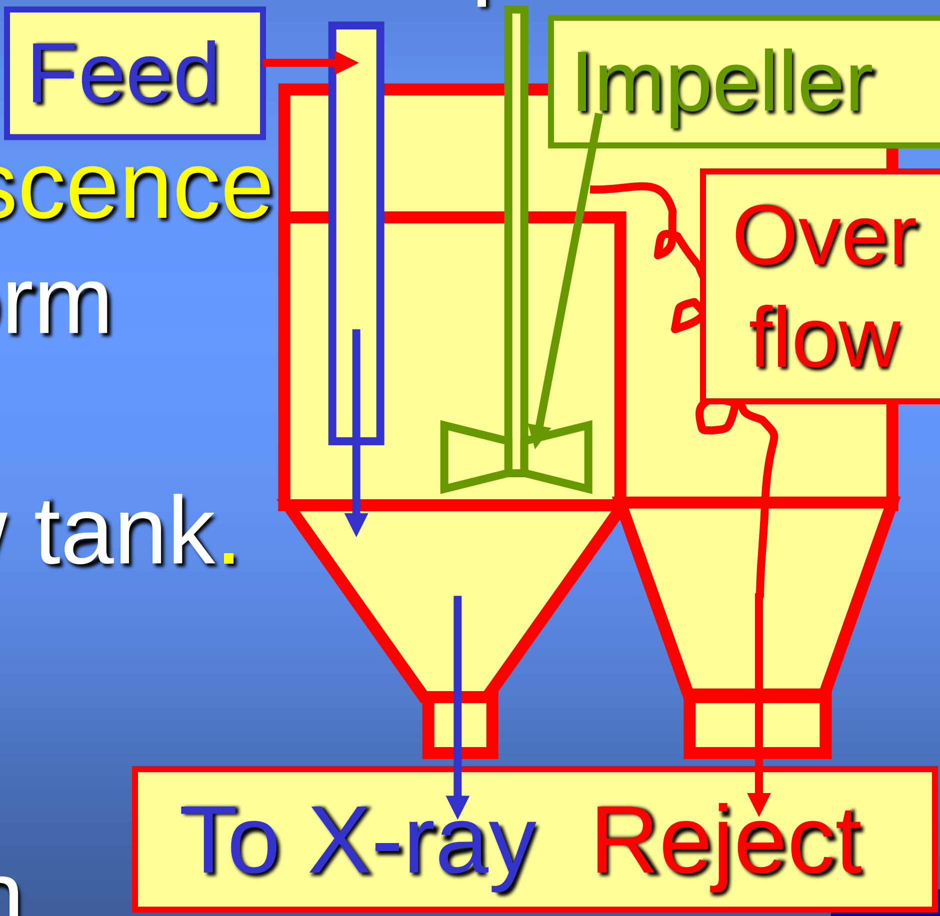
One of the most incorrect samplers !

The problem was to feed an X-ray fluorescence analyser with a uniform flow-rate of pulp.

Hence the overflow tank.

HUGE BIASES

due to differential gravity segregation



HOME-MADE ILL-DESIGNED SPECIMEN-TAKER

Nickel mine in South-America

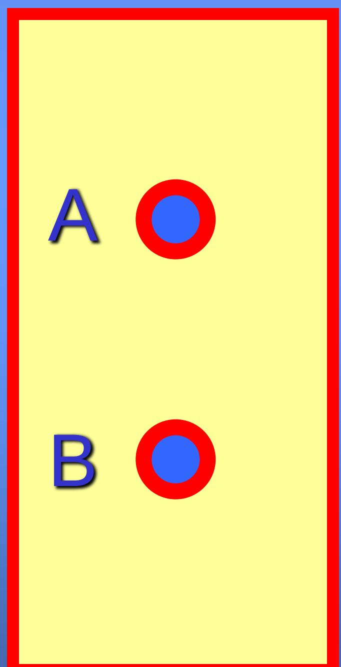
Geological drilling ♦ **Biased** ♦ **Unreliable**

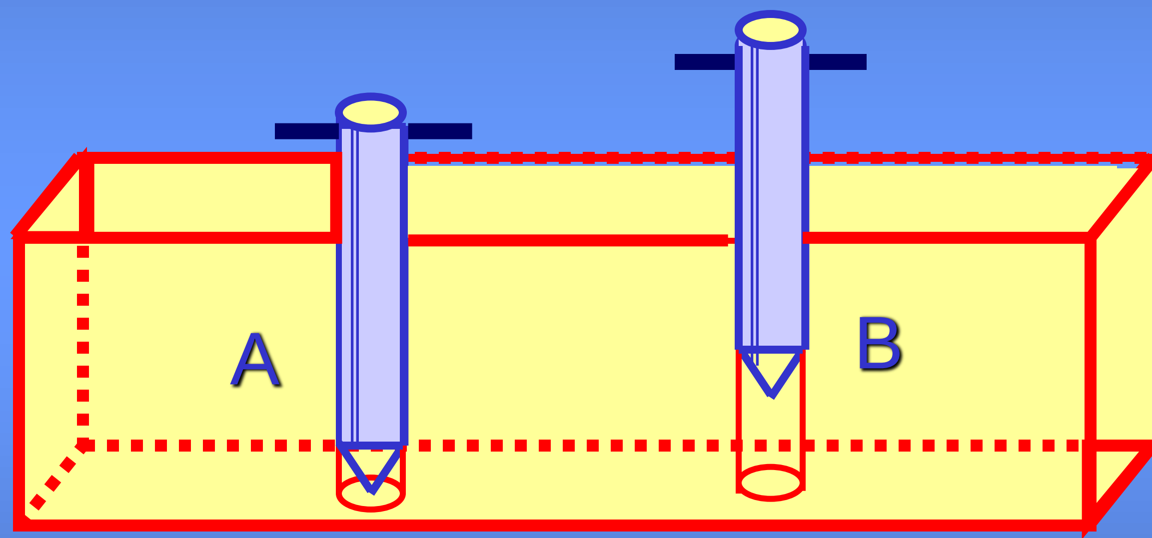
THE "SAMPLING" OF TWO-DIMENSIONAL MATERIAL BATCHES

Actually "Non-Probabilist Specimen-taking"

TWO-DIMENSIONAL SAMPLING ♦ HAND-PROBE ♦

EXAMPLE : Truckload of loose sandy material.





Model sample : whole cylinder

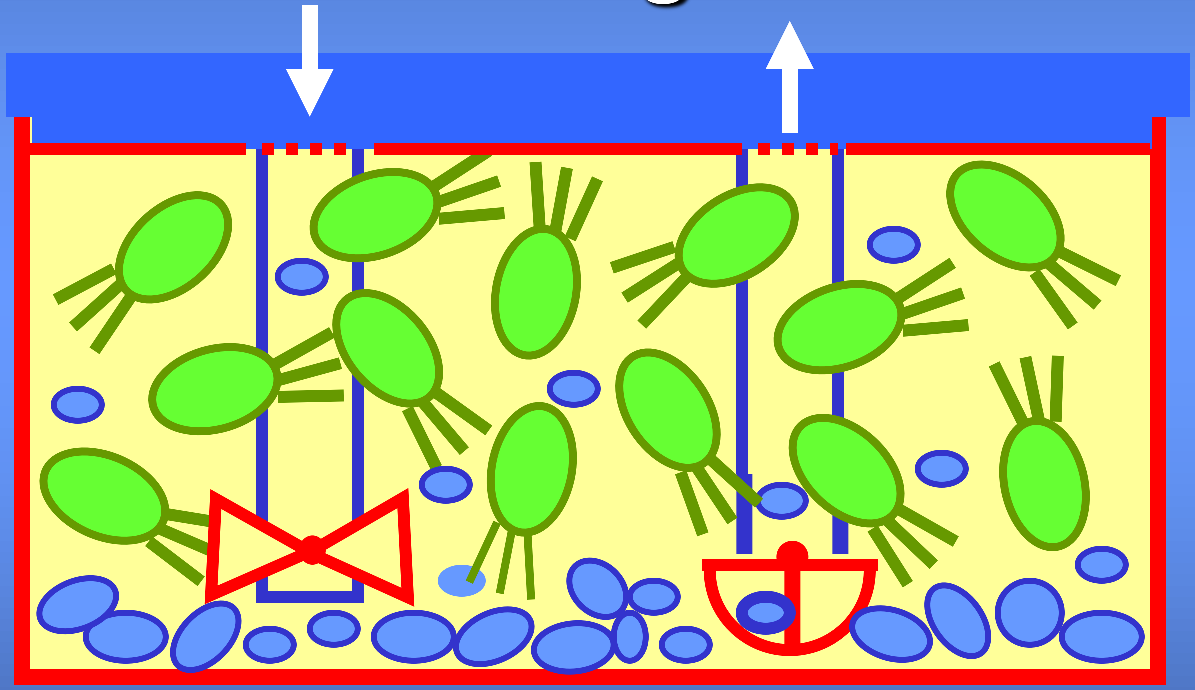
Specimen obtained : **BIASED**

Practically, never goes to bottom : Ex.

TWO-DIMENSIONAL SAMPLING ♦ MECHANICAL PROBE ♦

EXAMPLE : Truckload of **sugar beets**.

Hydraulically driven probe



Flint pebbles deposited on truck bottom by producers prior to loading. 1000 % bias on SiO_2%

DELIBERATE DEFRAUDING

THE “SAMPLING” OF THREE-DIMENSIONAL MATERIAL BATCHES

Actually “Non-Probabilist Specimen-taking”

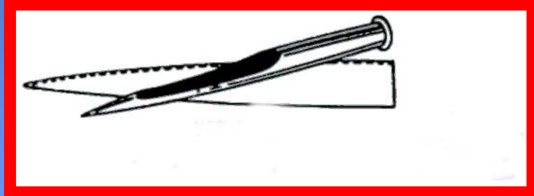
« SPECIMEN-TAKING » BY VISUAL SELECTION

The operator, a **"Sworn Sampler"**, chooses the fragments he regards as **"representative"** of the lot.

Actually unreliable **"Specimen taking"**.

"SPECIMEN-TAKING" BY MEANS OF THIEVES, PROBES, AUGERS

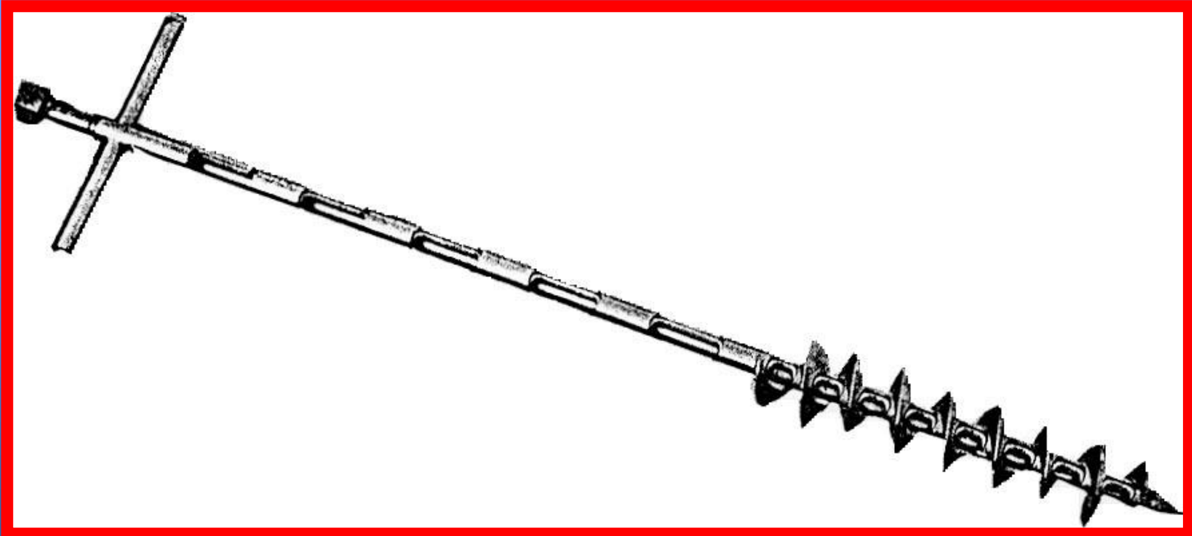
THIEF : spear-like implement. Textile sacks of coffee, etc.



PROBE :

AUGER =

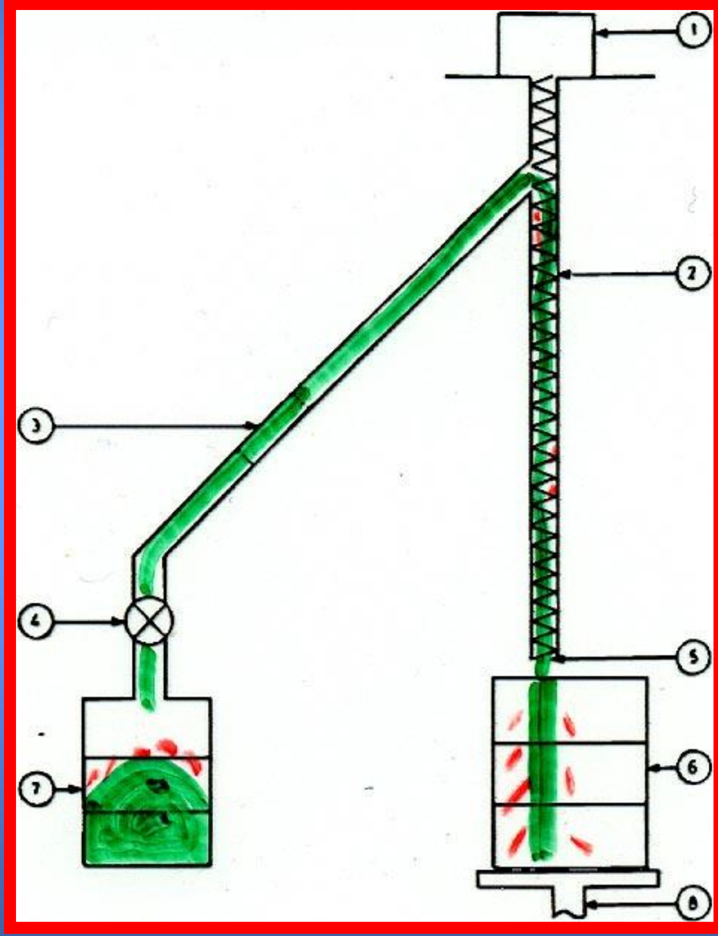
Corkscrew probe



“SAMPLING” DRUMS BY MEANS OF A SHEATHED AUGER

Experiment carried out by the U.S. Atomic Energy Commission (1960s) on uranates. Found biased.

The drum can be emptied !

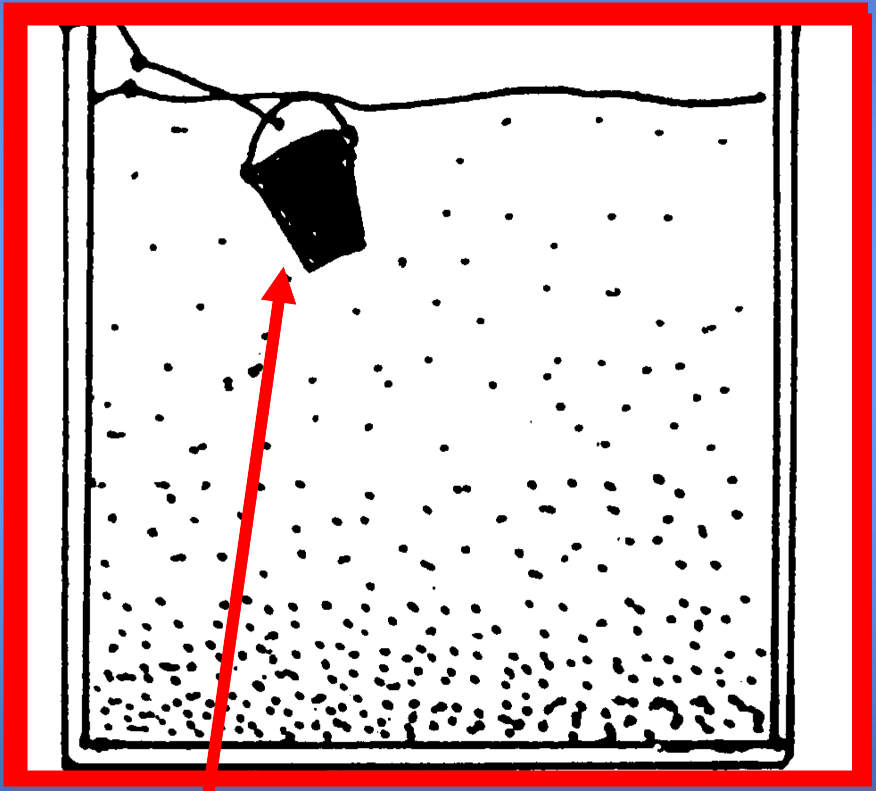


CROSS-STREAM SAMPLING WAS PREFERRED AND ADOPTED AS A ROUTINE METHOD

"SAMPLING" A TANKFUL OF A GROUND SOLID « PULP »

CHEAP INCORRECT MANUAL METHOD !

Due to selective gravity segregation, the "specimens" are always biased.

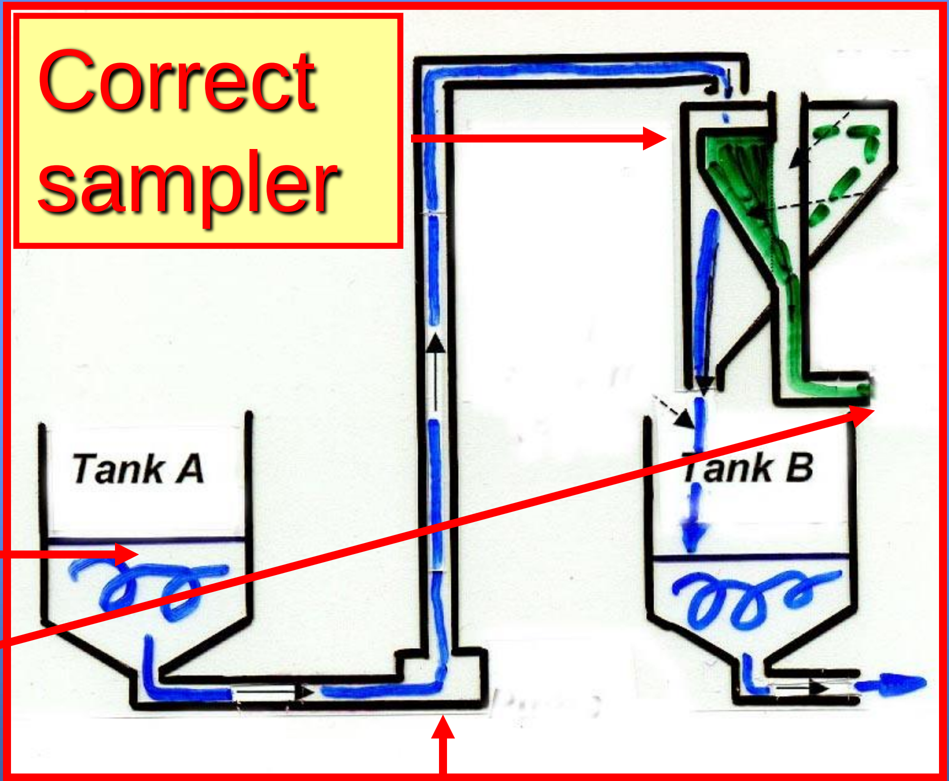


Bucket = specimen

« CORRECT SAMPLING » OF A TANKFUL

ONLY CORRECT METHOD

Lot **L** is transformed into a one-dimensional object and sampled as such.



« SAMPLING » A GOLD-CYANIDE SOLUTION FOR ITS ANALYSIS

Assayed for Au by Atomic Absorbtion :

The solution was …

CLEAR : absence of solids / gels

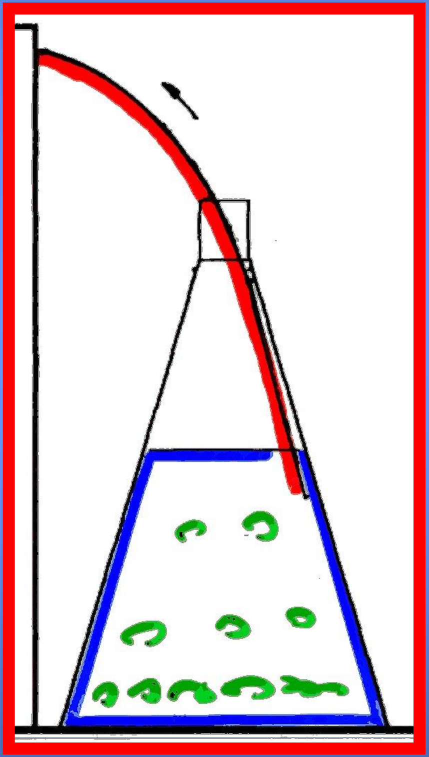
LIMPID : no optical distortion

After 11 hours of free settling :

1st reading (no stirring) : 387

2nd reading (mild stirring) : 550

3 to 8 (violent shaking) : 850 ± 2



TRAP !

INVISIBLE GOLD IONS DO SEGREGATE

NON-PROBABILIST SAMPLING ≡ SPECIMEN-TAKING

NON-PROBABILIST SPECIMEN-TAKING

Part of the lot is an unknown quantity

THEREFORE there can be NO THEORY of NON-PROBABILIST SAMPLING

NON-PROBABILIST SAMPLING ERRORS ARE THEREFORE UNPREDICTABLE

EXPERIENCE SHOWS they are USUALLY UNACCEPTABLE

- THE THEORY PRESENTED HERE IS A THEORY OF PROBABILIST SAMPLING CORRECT OR INCORRECT

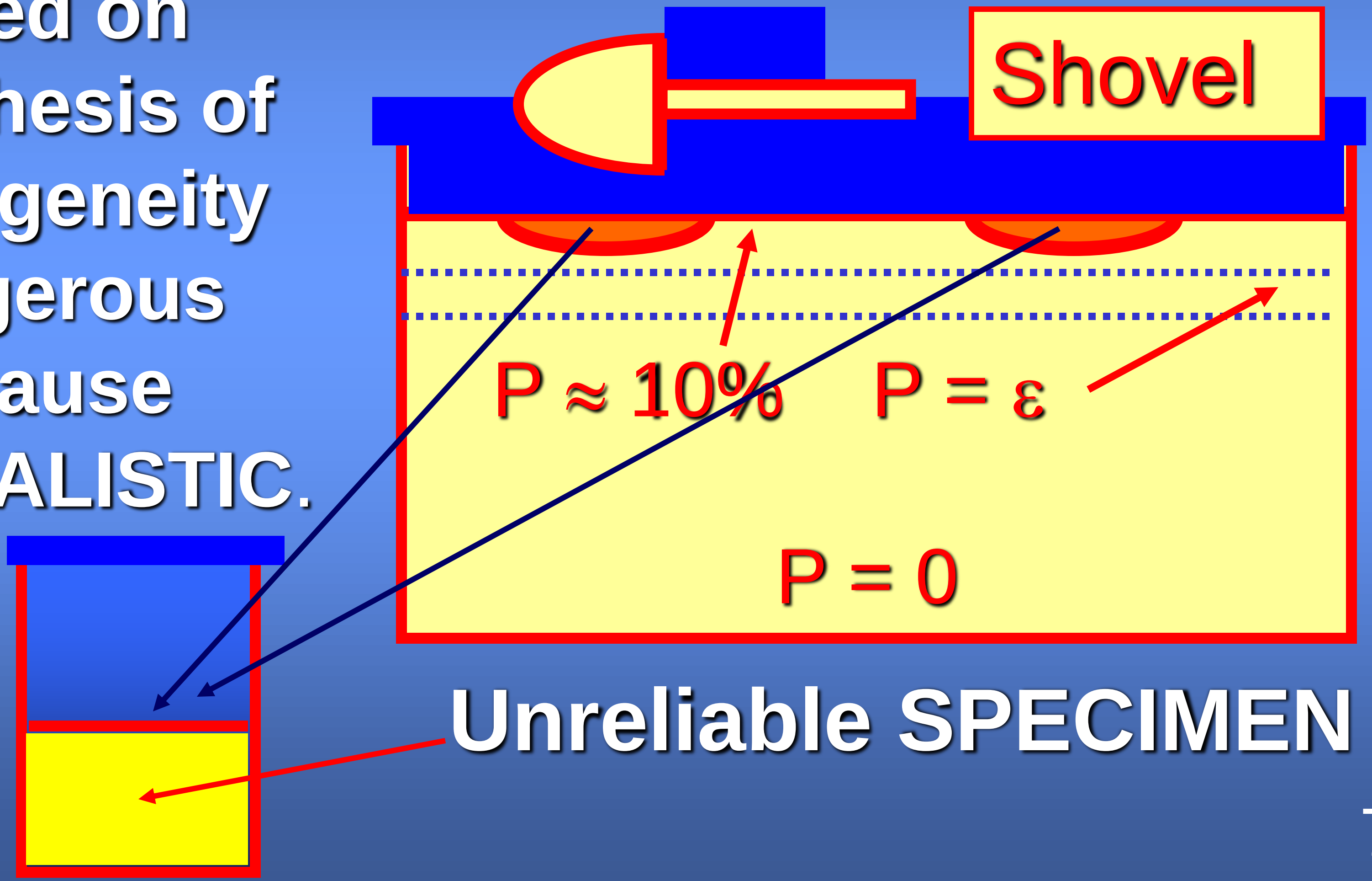
- NON-PROBABILIST SAMPLING **PROVIDES NOTHING BUT** UNRELIABLE SPECIMENS

- **THESE SPECIMENS ARE** DANGEROUS, ESPECIALLY IN COMMERCIAL SAMPLING

PICKING = SPECIMEN-TAKING

Picking on top of a container : drum, bag, waggon, truck, etc. Most accessible part of lot L.

Based on hypothesis of homogeneity dangerous because UNREALISTIC.



Unreliable SPECIMEN

EXAMPLES OF COSTLY SPECIMEN-TAKING ERRORS

- **MINERAL PROCESSING PLANT** : designed on basis of biased specimens : loss \$$10^7$ (1960)
- **TRADE OF TIN CONCENTRATE** : use of method No.3 providing biased specimens …

Loss of \$7 million over three years (cheating at the smelter).

- **BLAST HOLE CUTTINGS** : copper-gold mine. Specimen-taking as shown cost the mine $8 million a year. Two sources of loss :
  - valuable ore was sent to waste pile,
  - waste was sent to plant.

A correct sampling plant was amortized in weeks !