NINTH PART

BED-BLENDING

Theory and Practice

PURPOSE AND PRINCIPLE OF BED-BLENDING

Many plants or devices operate much more efficiently or safely when they are fed with a material of quality **« as uniform as possible ».**

This point has been first understood by Lafarge Cements due to the fact that cement kilns are dangerously sensitive to quality fluctuations of their feed. So are metallurgical furnaces.

Most transformation processes would benefit from a uniform feed. Bed-blending is the key.

HOW TO UNIFORMIZE A HETEROGENEOUS PLANT FEED

The preparation of **a very uniform plant feed** requires …

- ♦ A carefully designed and operated …

TWO-STAGE BLENDING SYSTEM

- ♦ A carefully designed and operated …

CONTROL SYSTEM

EFFICIENT TWO-STAGE BLENDING SYSTEM

- **PROPORTIONING :** proportioning of various raw material categories to form a pile of the required **average** composition checked by sampling and assaying.
- **BED-BLENDING STAGE :** two-phase discontinuous process consisting of …
  - Stacking the material layer over layer,
  - Reclaiming the pile by transversal slices

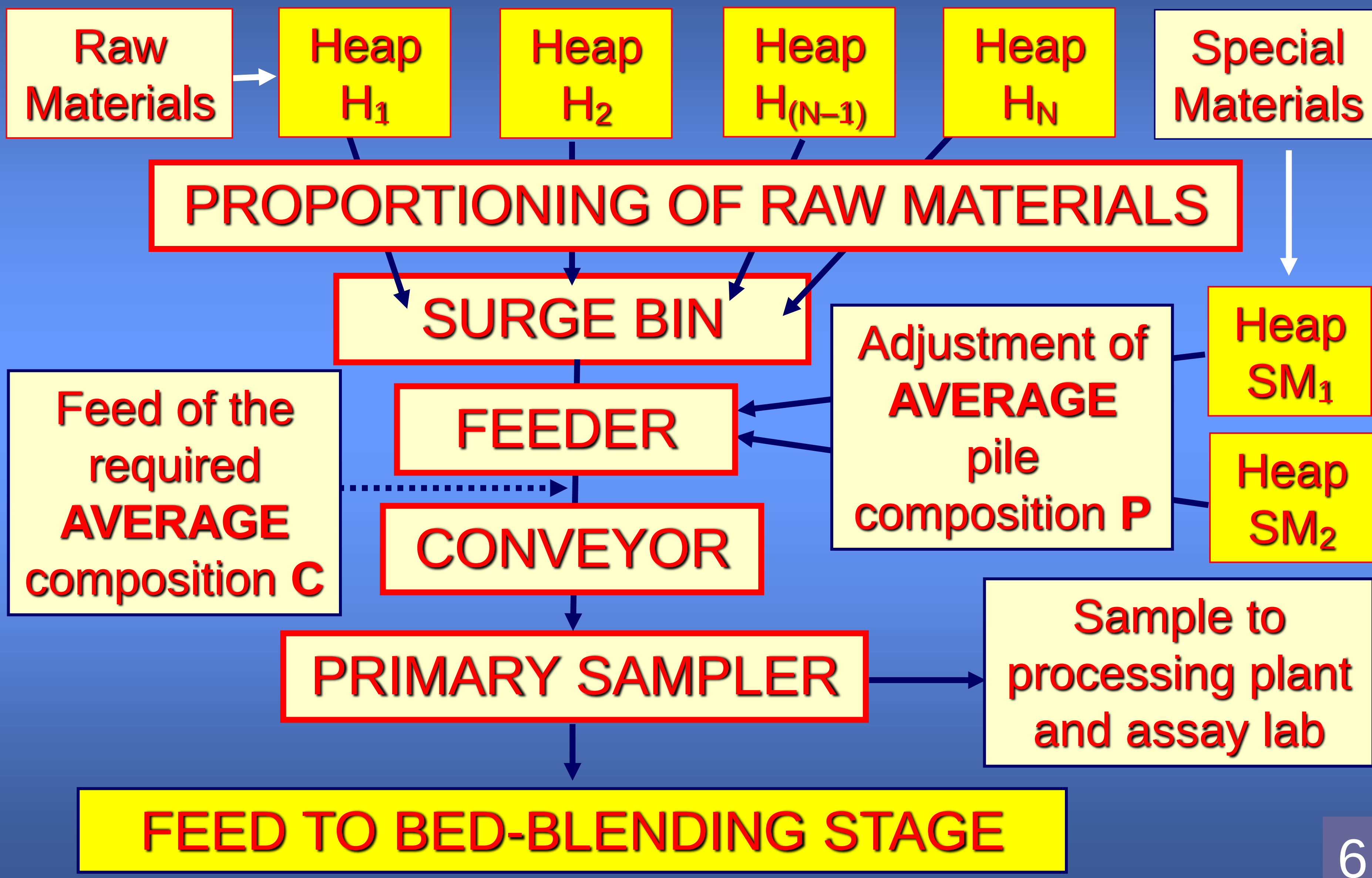
PROPORTIONING STAGE

A processing plant operates in an optimum way when it is fed with a uniform material of experimentally defined « **Required Composition C** ».

No materials are spontaneously uniform. They usually come in different categories that cannot be directly fed to the plant and must be blended in variable proportions to reach composition **C**.

These categories are stored in separate heaps H_1, … H_N. The purpose of « **Proportioning** » is to prepare a pile having an **average** composition as near **C** as possible.

PROPORTIONING ♦ PRINCIPLE



CONTROL OF A BLENDING SYSTEM

Efficient proportioning requires a control of the blend. This is carried out by a sampling system (primary sampling and sample reduction). The final sample is fed to an adequate analyser.

Time is of the essence. To be efficient, the control system must give a quick answer. In the cement industry, where bed-blending has been generalized, the critical components are Ca0, SiO_2, Fe_2O_3, Al_2O_3 and a few other minor components. X-ray fluorescence delivers its assays in less than one hour, which is convenient.

ACCURATE PROPORTIONING

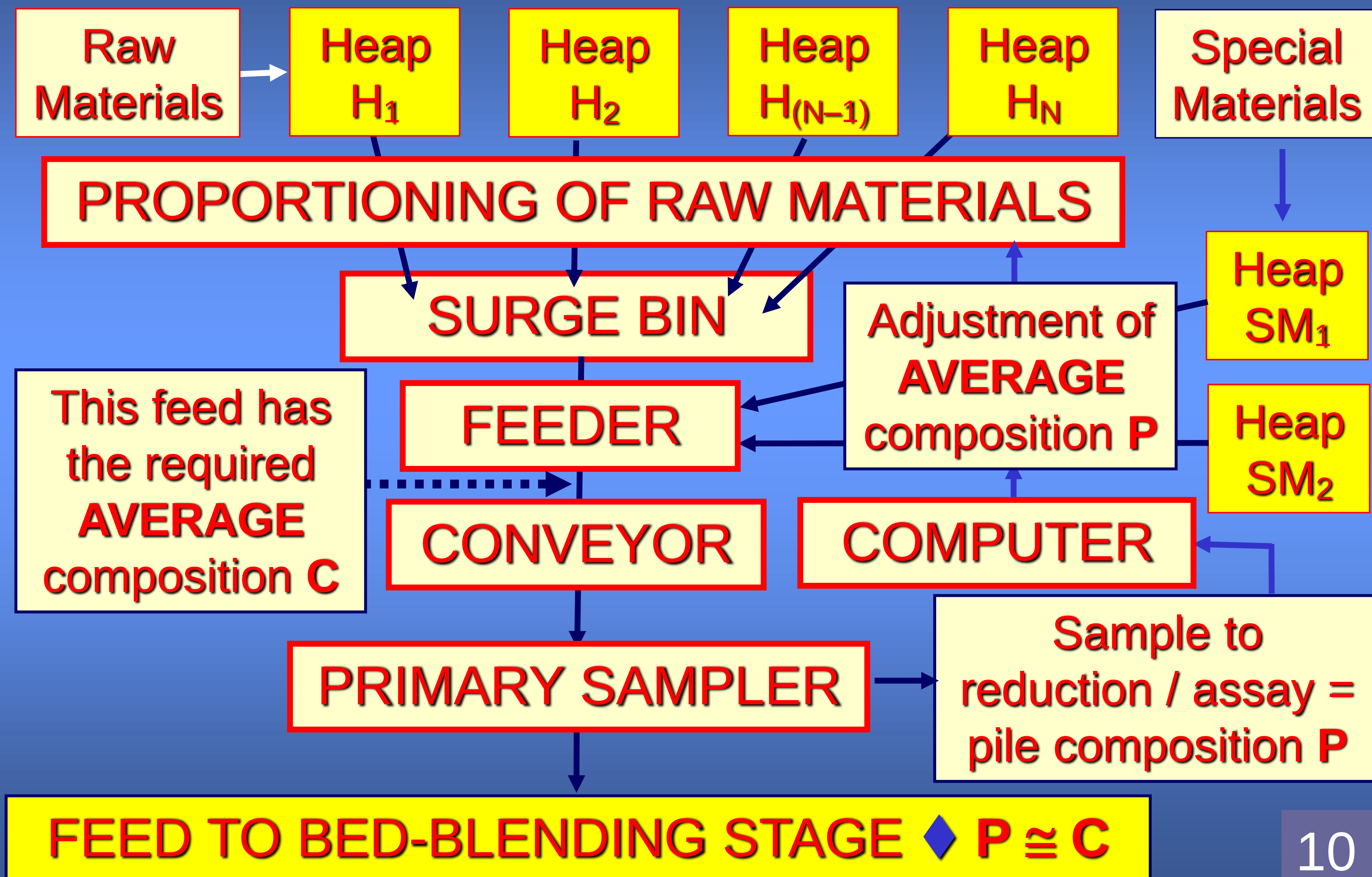
Take again the example of the cement industy

While the pile is being built, its feed is sampled. Every hour, the primary sample is assayed for the major components by X-ray Fluo. Within the next hour, the current weighted average composition **P** of the pile is computed and compared to the required composition **C**. Automatically or manually, the proportion of materials extracted from heaps H_1, … H_N is adjusted so as to reduce the difference **(P – C)**. Progressively, this difference tends asymptotically towards 0.

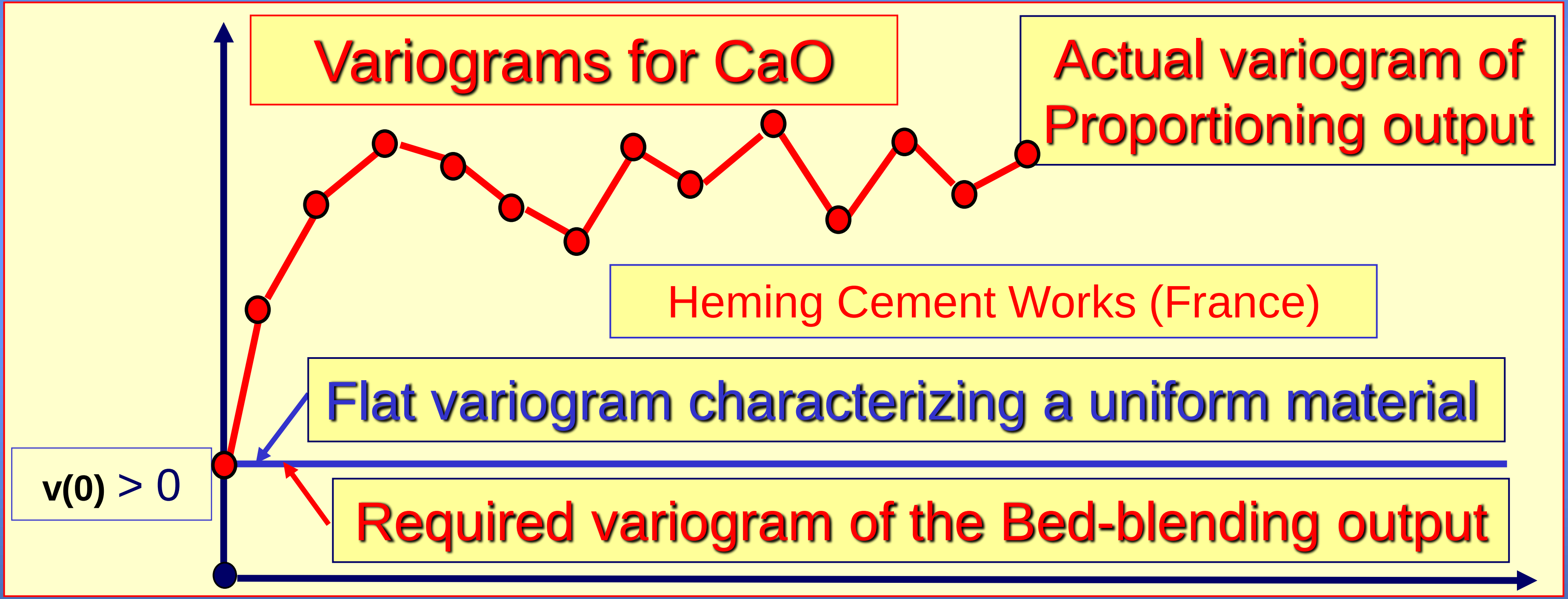
The time necessary to build a pile may reach hundreds of hours. If the heaps H_1, … H_N are adequately constituted, the convergence of **P** towards **C** is ensured. If that is not the case or if preparing special cements requiring « additional materials », we may have, at the end of the pile constitution, to add **« Special or Additive Materials »** stored in the **Special Heaps SM_1, SM_2** …

These special materials must cover **A WHOLE NUMBER OF LAYERS.** As soon as **P** is found and confirmed as near **C** as required, the feed to the pile must be stopped and the pile regarded as completed. Its reclaiming can start …

PROPORTIONING ♦ DETAIL

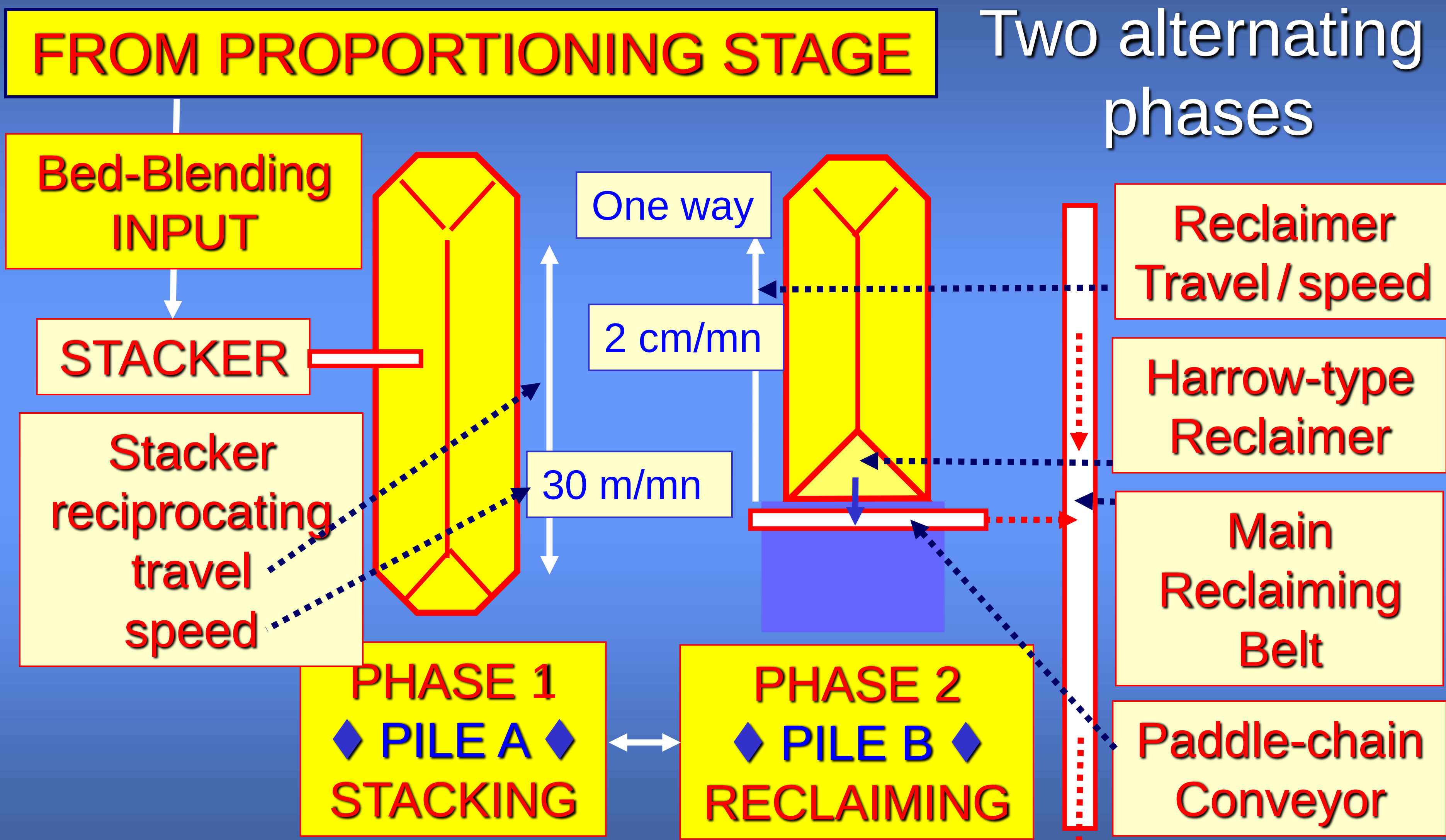


The output of the proportioning system has an **AVERAGE** composition **P** near the **REQUIRED** composition **C** but is absolutely **NOT UNIFORM**. Its variability is characterized by its variogram…



The purpose of Bed-Blending is to transform the RED variogram into a BLUE one (flat).

BED-BLENDING SYSTEM

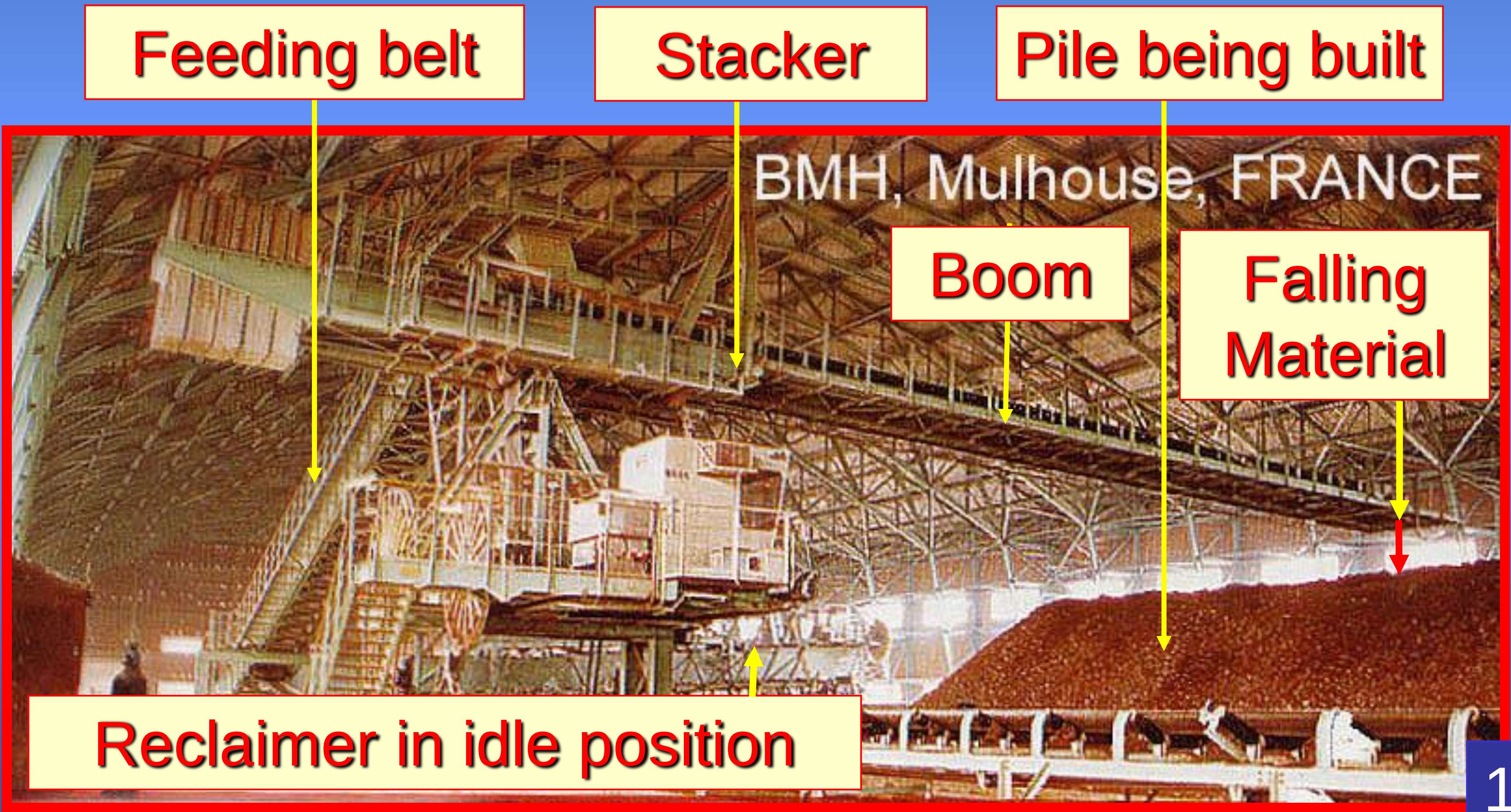


UNIFORM COMPOSITION BED-BLENDING OUTPUT

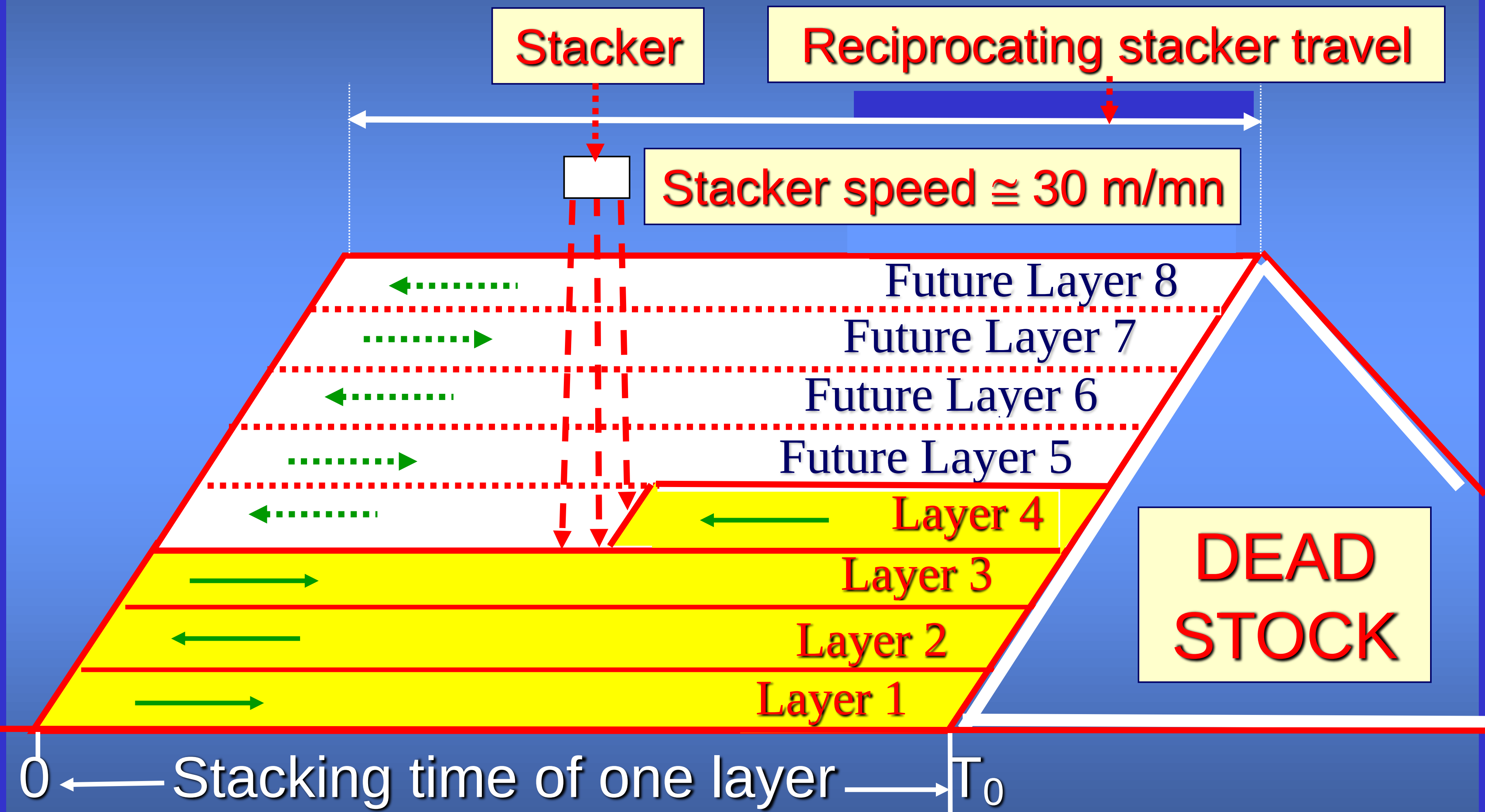
BED-BLENDING ♦ STACKING

Stacker speed along the pile ≅ 20 / 30 m/mn

Photos, courtesy of BMH, Mulhouse, France

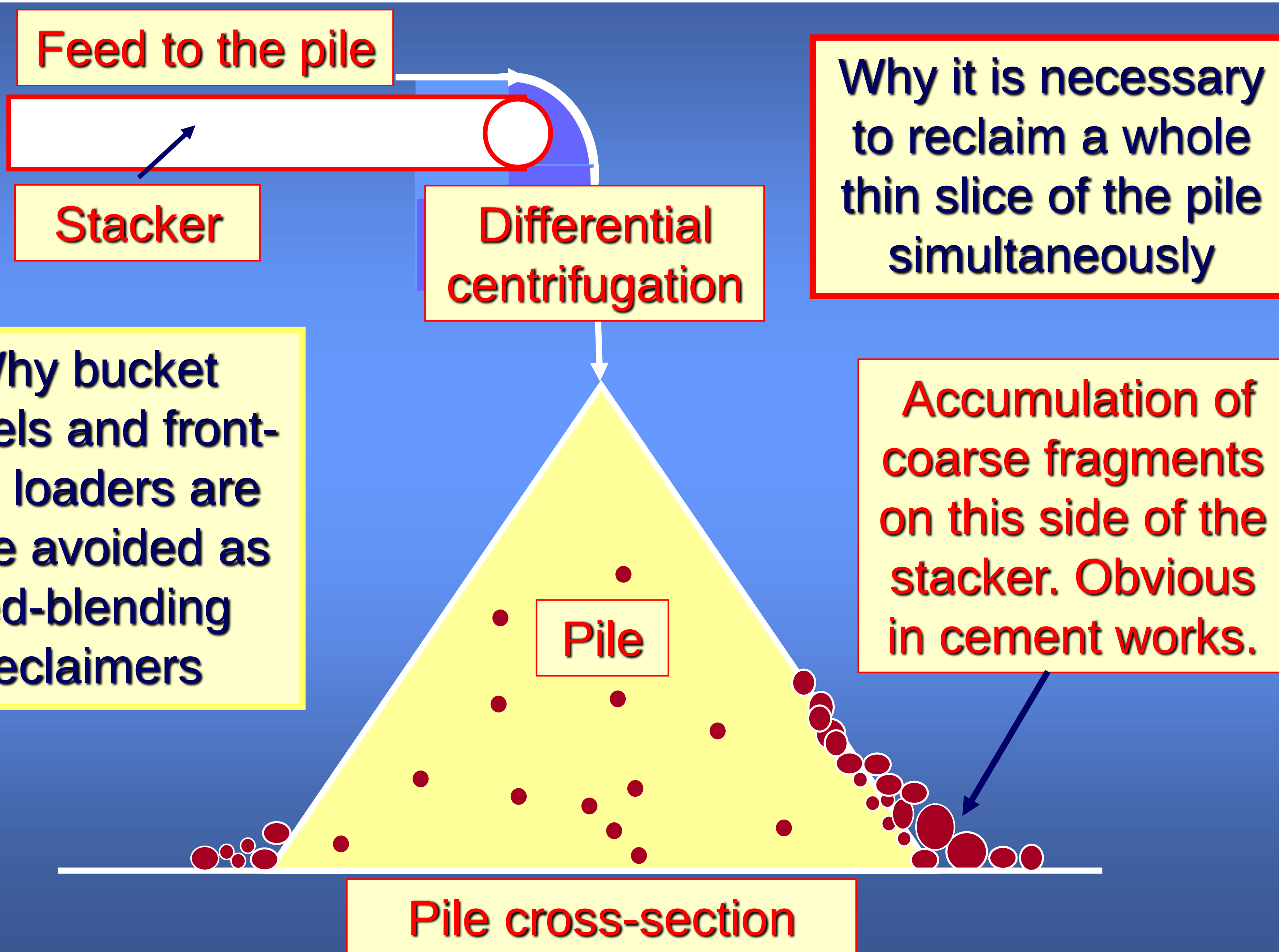


BLENDING THEORY ♦ STACKING



Vertical Cross-section of the pile

STACKING ♦ SIZE SEGREGATION



Why it is necessary to reclaim a whole thin slice of the pile simultaneously

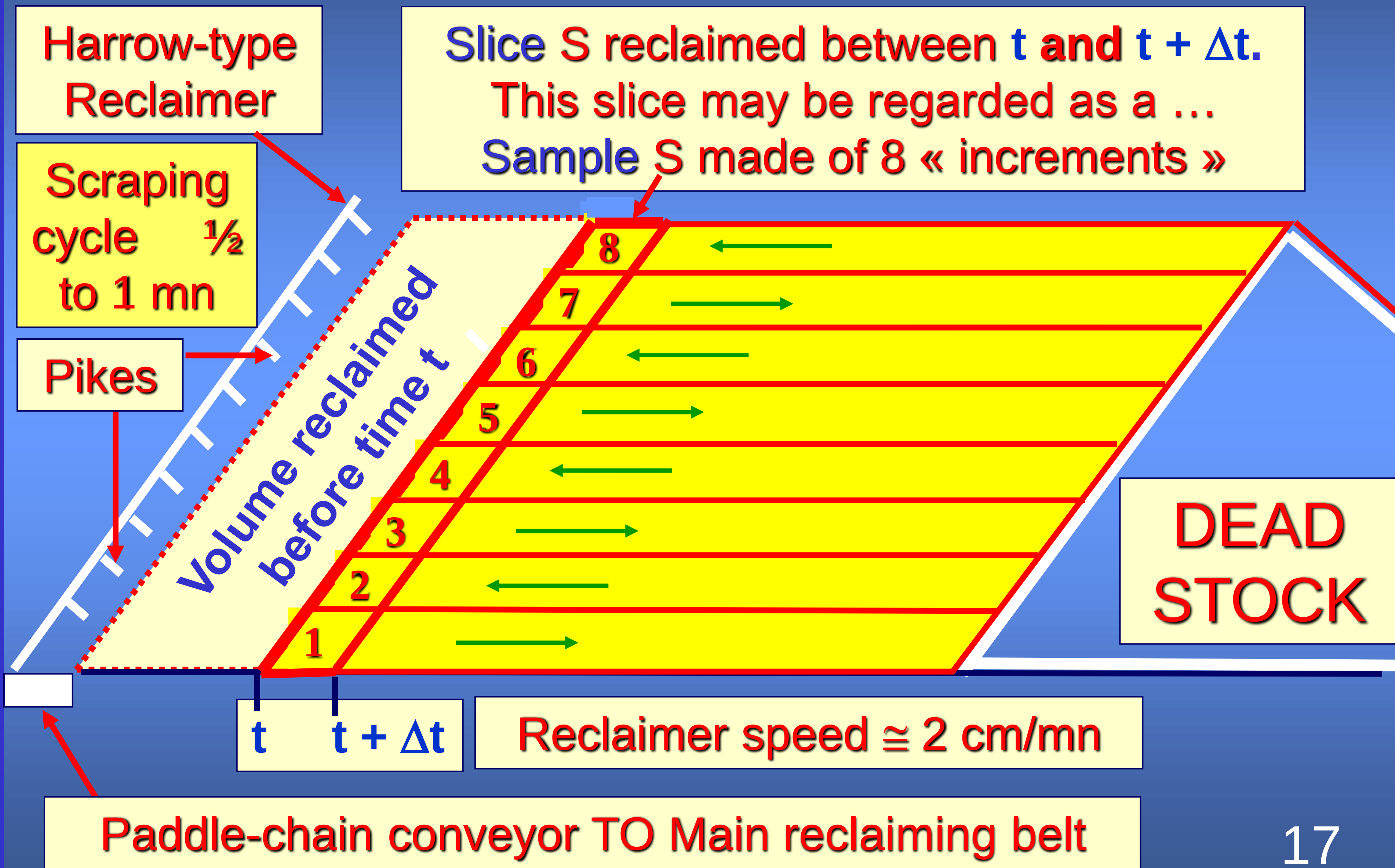
Why bucket wheels and front-end loaders are to be avoided as bed-blending reclaimers

BLENDING THEORY ♦ RECLAIMING

Many types of reclaiming devices. After studying the performances of all of them, the **« Harrow-type Scraper Reclaimer »** appears as the **MOST EFFICIENT** and can be used as a **MODEL FOR THE THEORY OF BED-BLENDING**.

Its major property is to reclaim a **THIN SLICE** of the whole pile cross-section **SIMULTANEOUSLY** (e.g. ≅ 2 cm/mn).

BLENDING THEORY ♦ RECLAIMING



PROPERTIES OF SLICE S

In this example **Lot L made of eight layers** : $T_L = 8\ T_0$

SLICE-SAMPLE S ≡ $l_1 + l_2 + l_3 + l_4 + l_5 + l_6 + l_7 + l_8$

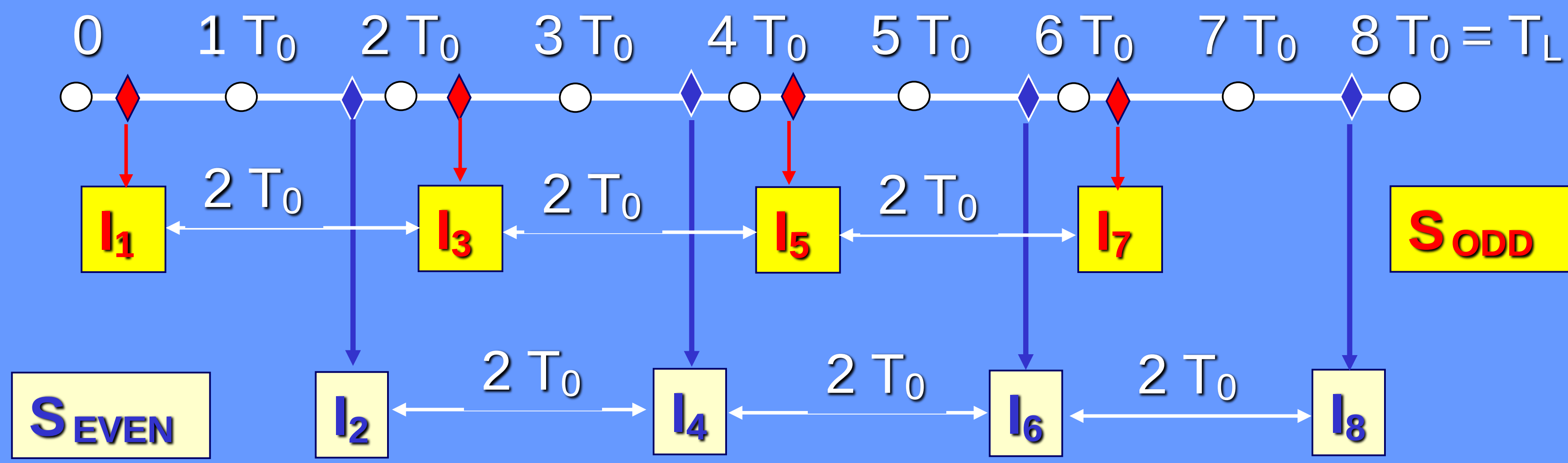
S_O ≡ odd increments

S_E ≡ even increments

Slice - Sample S ≡ $S_O + S_E$

Reclaimer speed along the pile : 0.02 – 0.05 m/mn

DEVELOPMENT OF THE STACKER FEED



Each group of increments S_{ODD} (red) and S_{EVEN} (blue) makes up a « **correct sample** » of lot L.

Their sum, the slice S is also a « CORRECT THEREFORE UNBIASED SAMPLE of lot L »

QUALITATIVE CONCLUSIONS

♦ **STACKING :** when the stacker moves at a constant speed and reverses its course at a uniform time interval T_0, **ANY WHOLE SLICE** of the pile cross-section is a **« CORRECT THERE-FORE UNBIASED SAMPLE OF LOT L ».**

BUT the constituent distribution throughout the pile cross-section is highly **HETEROGENEOUS**. This thin slice of the cross-section **IS A WHOLE** that must not be dissociated upon reclaiming.

♦ **RECLAIMING :** when the reclaimer recovers the **WHOLE OF A THIN SLICE simultaneously** the output is a sequence of CORRECT, **therefo-re UNBIASED samples of lot L whose compo-sition differs very little from C. Their sequen-ce is a material of fairly uniform composition**.

In a bed-blending system, the reclaimer is the most important item. Harrow-type reclai-mers are the most efficient of all types.

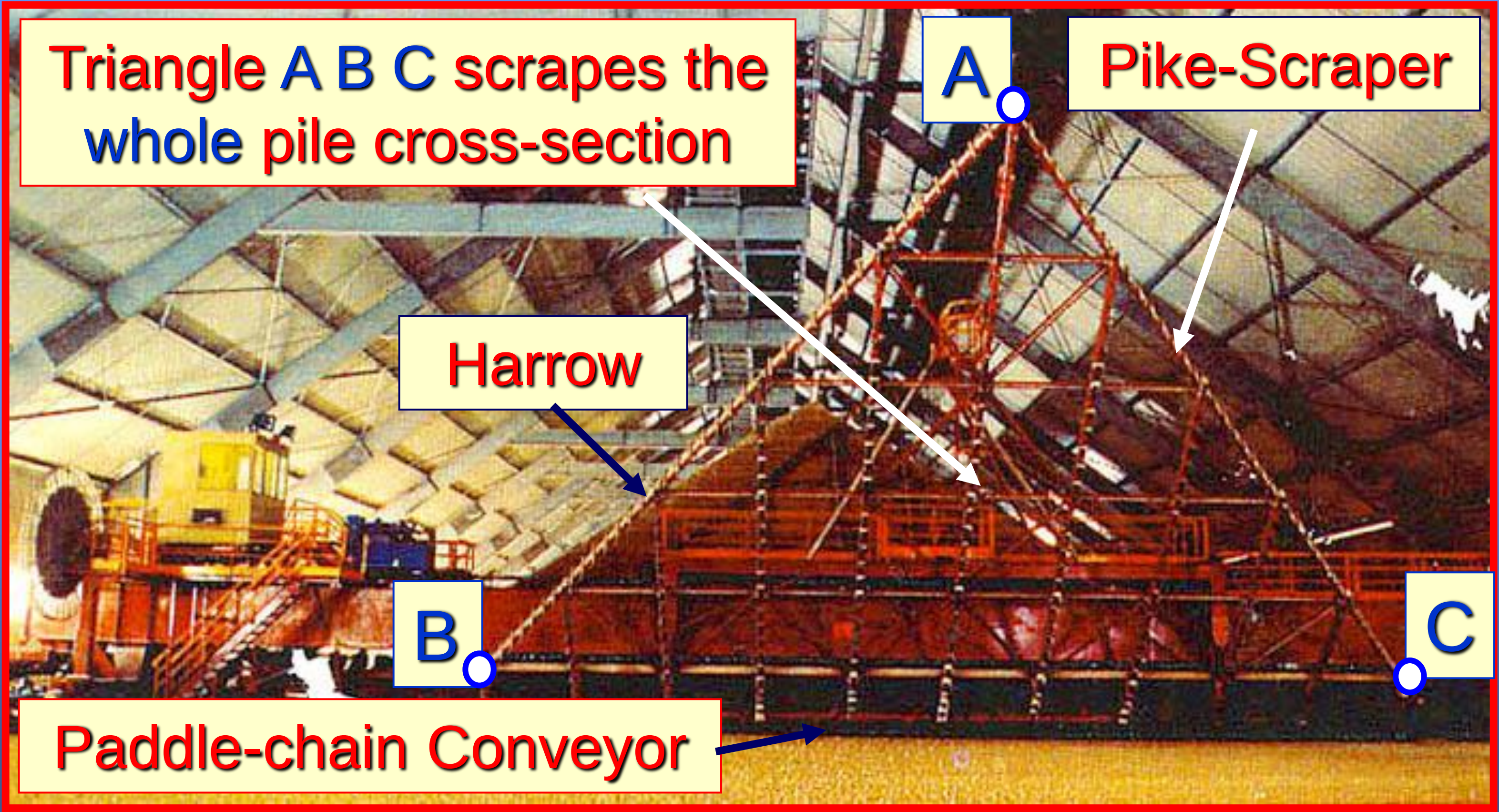
Bucket-wheel reclaimers, front-end loaders or mechanical shovels are totally inadequate. They are definitely the worst reclaimers.

BED-BLENDING ♦ RECLAIMING

RECLAIMING : Speed : 0.02 – 0.05 m/mn

Harrow-type Reclaimer-Scraper in idle position

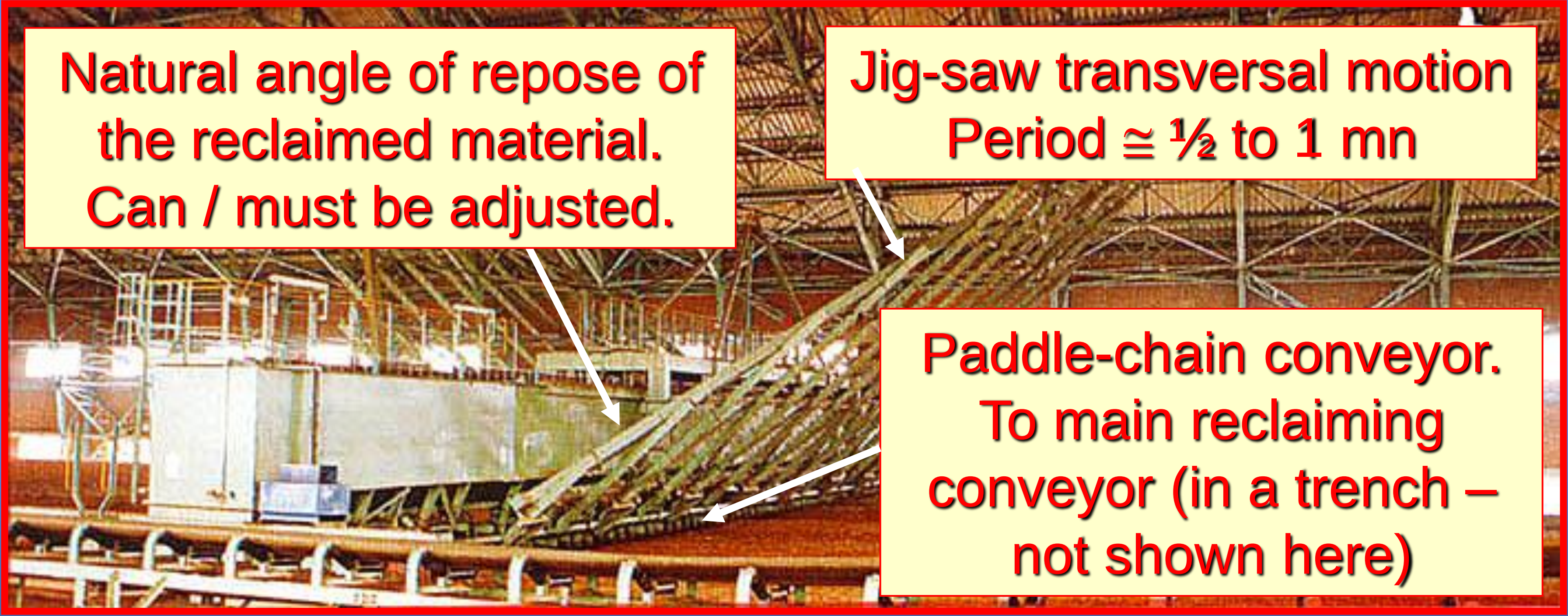
BMH – Mulhouse, France ♦ Front view



BED-BLENDING ♦ RECLAIMING

Harrow-type Reclaimer-Scraper in idle position

BMH – Mulhouse, France ♦ Side view



Reclaims a thin slice (0.02 – 0.05 m/mn)

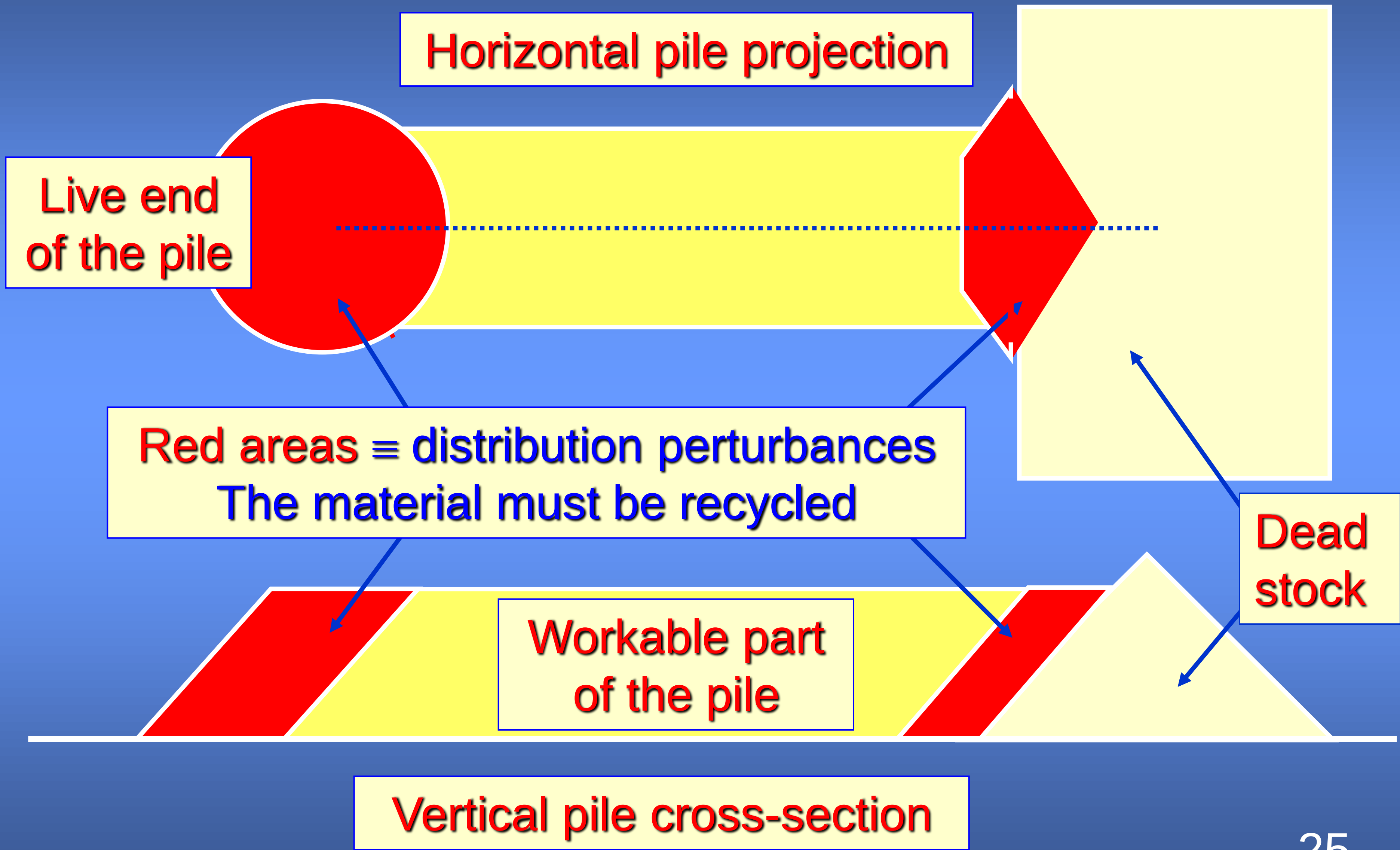
PROBLEM POSED BY THE PILE ENDS

Upon reversing its course, due to its inertia, the stacker must slow down, stop and reaccelerate progressively. This takes several seconds during which the flow-rate remains more or less even.

As a consequence, a certain mass of material accumulates, on both ends of the pile. This disturbs the material distribution and has to be taken care of upon reclaiming.

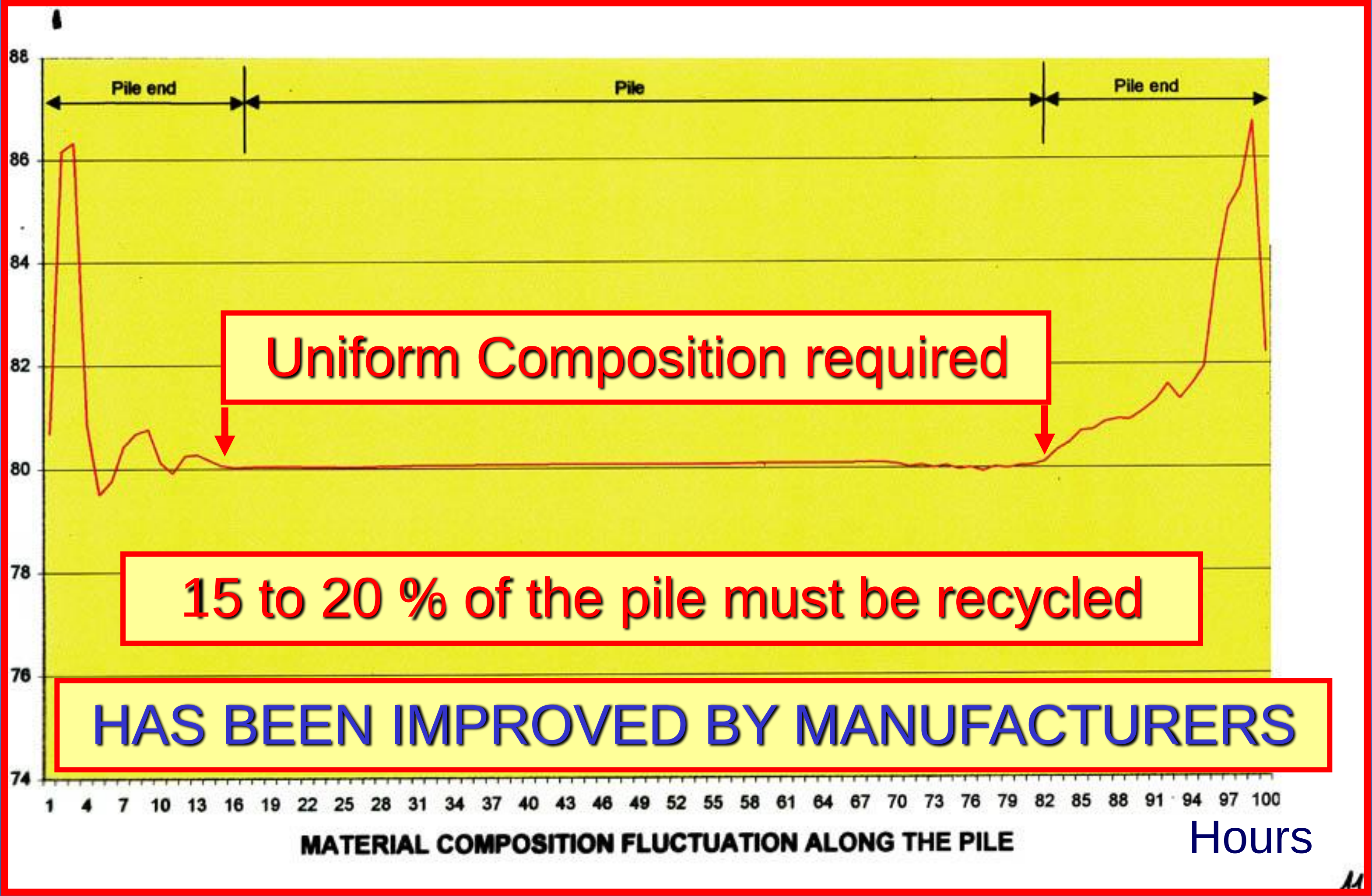
First conclusion: for a given pile capacity better a long and thin pile than a short and thick one

PROBLEM POSED BY THE PILE ENDS



PROBLEM POSED BY THE PILE ENDS

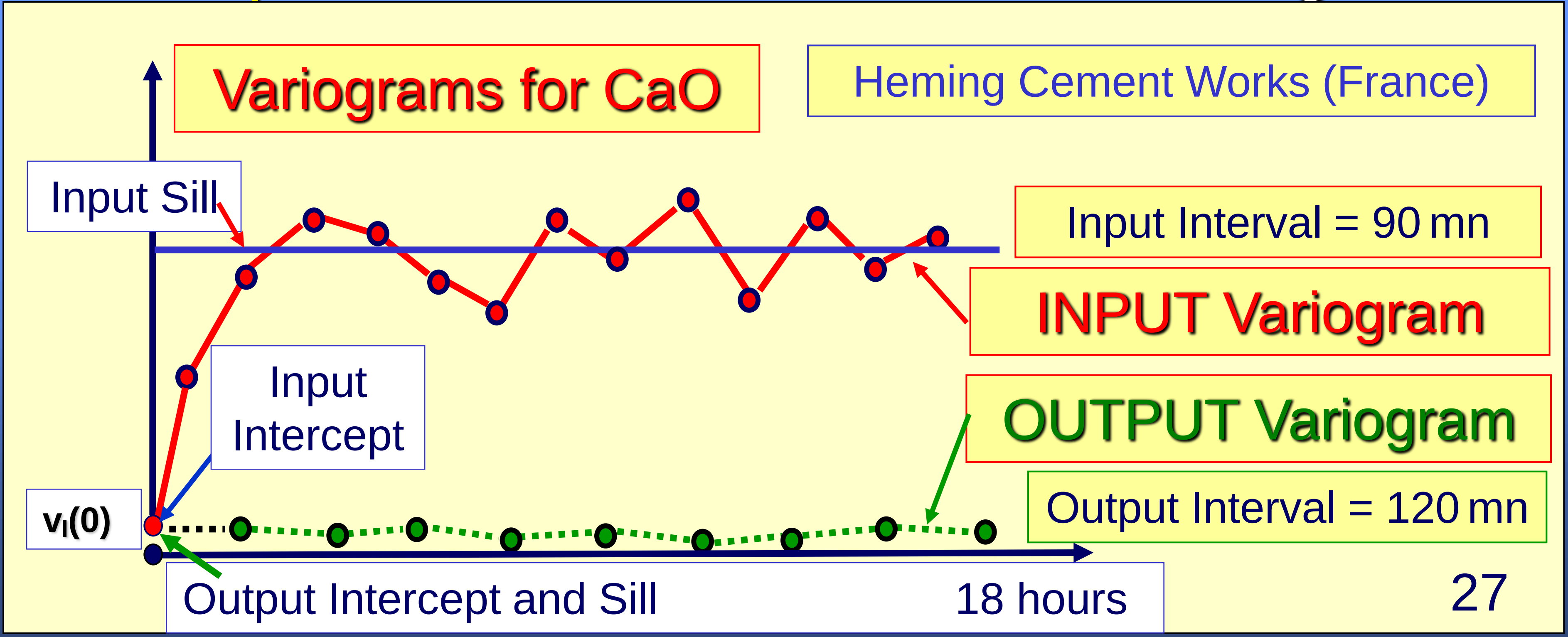
Experiment carried out by BMH, Mulhouse, France



VARIOGRAPHIC ANALYSIS OF A BED-BLENDING UNIT

The variogram is a mathematical tool that characterizes the variability of a one-dimensional flow.

To figure out the **efficiency** of a bed-blending unit we compare the **INPUT and OUTPUT** variograms.



CONCLUSIONS OF THE VARIOGRAPHIC ANALYSIS

Theory, confirmed by a variographic experiment carried out **six months AFTER its publication** at Héming, France, in 1978, shows that …

- **CONCLUSION 1 :** An efficient bed-blending system, with a well-adjusted harrow-type reclaimer, transforms …
  - ♦ **ANY Input Variogram** into …
  - ♦ **A FLAT Output Variogram**, graphical proof of the **FLOWING OUTPUT UNIFORMITY**

- **CONCLUSION 2 :** The Sill of the Output Variogram is practically equal to the Intercept $v_I(0)$ of the Input Variogram.
- **CONCLUSION 3 :** Contrary to the idea usually shared by manufacturers and users, the efficiency of a bed-blending system is limited by the intercept $v_I(0)$ of the Input Variogram which is the sum of the variances of the **Total Sampling Error TSE** and the **Total Analytical Error TAE.** With coarse materials, **σ^2(TSE)** is practically equal to the variance of the **Fundamental Sampling Error FSE,** which is proportional to d^3, cube of the top particle size.

- **CONCLUSION 4 :** As a corollary of conclusion 3, it would be meaningless and pointlessly expensive to feed the output of a bed-blending system to another bed-blending system .
- **CONCLUSION 5 :** To all intents and purposes AND CONTRARY TO Gerstel's THEORY, the importance of the number Z of layers making up a blending pile is secondary.

  The optimum number Z of layers lies between 100 and 1000.
- **CONCLUSION 6 :** The most important item of a bed-blending system is its reclaiming device

SAMPLING PLANT ♦ EXAMPLE

SOUTH-AMERICAN NICKEL MINE

Input to Bed-Blending Pile

Primary Sampler

Stacker

Reclaimer

Uniform Feed

Processing Plant

Primary Increments e.g. 12 per hour

Pre-Drying Tunnel

Primary Crushing Jaw Crusher

Secondary Crushing Rolls Crusher (s)

Several kg at ± 2.5 mm

Possible rough X-ray

Secondary Sampling Riffle ± 500 g

Tertiary Grinding Disk Pulverizer

Tertiary Sampling Riffle 50-100 g

Final Drying Oven at 105-110°C

Final Pulverizing 50-100 g at 150 μm

Precise X-Ray Analysis

UNEXPLORED POSSIBILITIES

- **SCALING DOWN :** So far, bed-blending has been implemented only on the scale of heavy industries such as **Cement or Metallurgy**. But it can very well be **scaled down** from hundreds of tons to hundreds of kg per hour.
- **GENERALIZATION :** Many industries would increase the quality of their products and their profits if they were fed with a uniform material.
- **EVEN IN HEAVY INDUSTRIES, the best way to operate a bed-blending system is NOT PROPERLY UNDERSTOOD.**