IMnI Safety Workshop
STAVANGER May 2, 2011

A modelisation attempt of a Blasting Effect and its Consequences

Pierre Rousseau, Deputy to Eramet Group Environment V.P.

DES ALLIAGES,
DES MINERAIS ET DES HOMMES.

ERAMET

Objective

- Review of blasting accidents in metal industry
- Assess consequences on health
- Come with an idea of safety distances regards to disability or death
- List some safety measure to prevent or protect

Two steps : Hazard identification and analysis

- ***HAZID / Hazard identification based on:***
  - Knowledge of the operating units and their environment
  - Inventory and nature of chemicals, operating conditions, *phase of operation* (start up, normal, maintenance, slow down, shut down…), energy input (electrodes, high tension, …), waste gases, …
  - Analysis of accidents occurred in similar facilities or processes

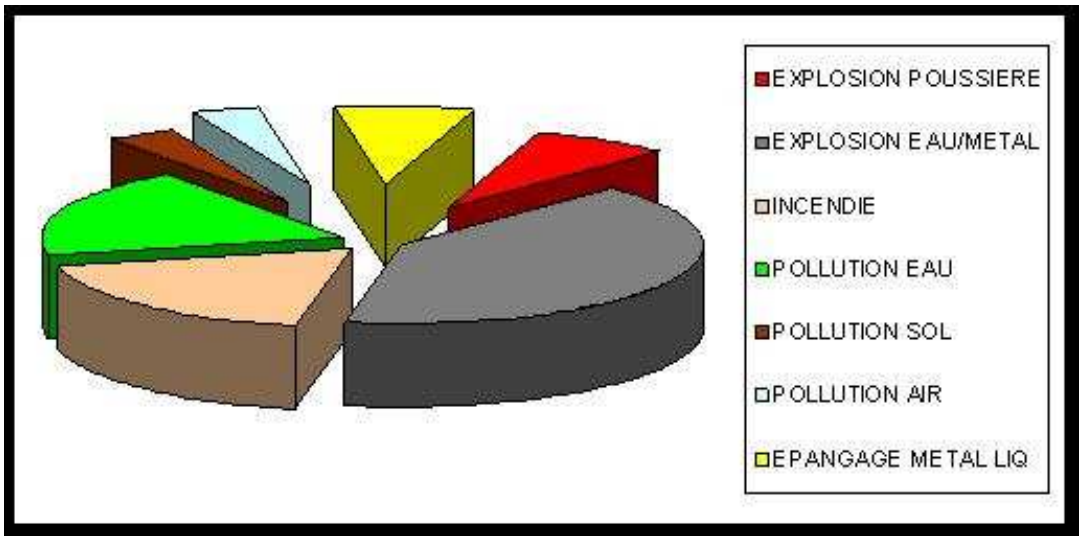
- ***Hazard detailed analysis based on:***
  - Detailed accident, failure scenarios
  - Possible consequences assessment
  - Are the possible consequences acceptable?
  - Mitigation measures to prevent or to protect.

Historical survey

- ***Analysis based on :***
- ***http://www.aria.developpement-durable.gouv.fr/index_en.html***
- ***40.000 reported accidents (worldwide)***
- ***Classified in type of business, type of accident….***

- A search based on :
  - C24.10 « Steel making plants » ;
  - C24.43 « Metallurgy of lead, zinc, tin…» ;
  - C24.45 « Metallurgy of ferrous and non ferrous metals » ;
  - C24.51 « Foundries»
  - And similar.
- Few specific accidents linked to Manganese metal or Manganese ferro-alloys.
- A selection of about 85 accident scenarios and 27 with root causes and consequences that could occur in Mn pyrometallurgy.

Significant accidents for pyrometallurgy



EVENT	NUMBER	PERCENT
DUST EXPLOSION	2	7.4%
METAL WATER EXPLOSION	11	40.8%
FIRE	5	18.5%
WATER POLLUTION	5	18.5%
SOIL POLLUTION	1	3.7%
AIR POLLUTION	1	3.7%
LIQUID METAL ON SOIL	2	7.4%
TOTAL	27	100.0%

FOCUS ON MOLTEN METAL / WATER BLASTING

- H_2O liquid $\rightarrow$ H_2O vapor
- Hot metal + H_2O vapor $\rightarrow$ metal oxide + H_2
- …and $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ (explosion as a result of combustion with O_2 of air)
- $C + H_2O \rightarrow CO + H_2$
- …and $CO + \frac{1}{2} O_2 \rightarrow CO_2$ (explosion as a result of combustion with O_2 of air)

- Molten metal/ water contact can lead to vapor explosion as a result of water vaporization.
- As consequences : liquid metal projection and volume expansion with blast wave
- Water to vapor transformation leads to a volume increase of a factor 1700 ! (one liter of water will give a 1,7 m3 boiling vapor cloud)
- Hydrogen or CO with violent reactions with the O_2 of the air.

Blasting possibilities during operations

- Mostly in any production phases in case of liquid metal presence:
  - During smelting process in the furnace
  - During tapping
  - During casting
  - During operations with liquid slag
  - During liquid metal transfer
  - …/…
- During other phases
  - During waste gases picking up and treatment (CO)

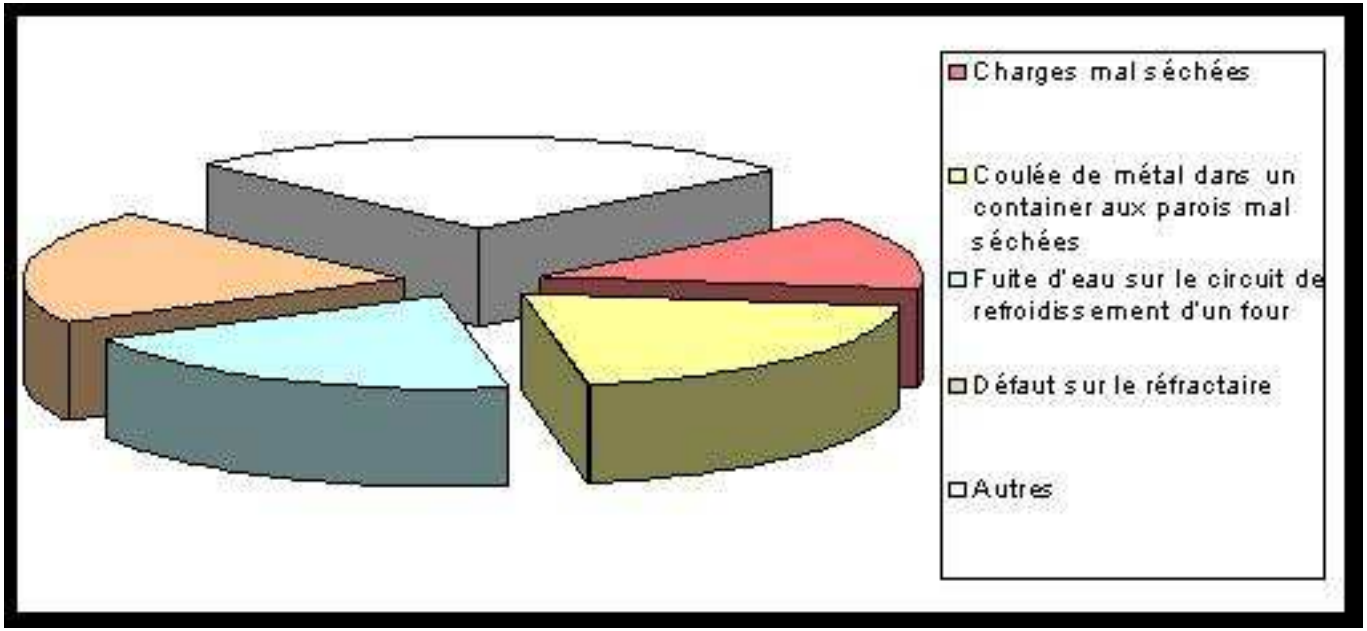
Some examples from accidents survey

- Organizational or human deviations
  - A liquid steel hearth falling down (lack of maintenance) (ARIA 28574),
  - Feeding the furnace with wet load (ARIA 34513)
  - Refractory's erosion (ARIA 8044)
  - Leakage of the furnace cooling system (ARIA 4876)
  - Roof water leakage (ARIA 33059)
  - Process deviation (ARIA 33059).

How to react ?

- Need of top safety levels
  - Adapted processing procedures
  - Their perfect knowledge
  - Their perfect respect (periodical safety audits)
  - Continuous safety training (including periodical drills)
  - Clean and dry containment devices
  - Protective measures with, at the end, PPE
  - Limited number of duly authorized operators present in dangerous perimeters on site
  - Limited access to indentified potential dangerous areas
  - Close contact with local emergency assistance
  - Good knowledge of the facilities and their risks by local emergency assistance (fire brigade, …) and joint periodical drills

Metal / water blasting causes



CAUSE	NUMBER	PERCENT
Wet load in furnace	2	13.3%
Liquid metal tapping in wet hearth	3	20.0%
Water leakage on furnace cooling circuit	3	20.0%
Refractoty erosion	3	20.0%
Other	4	26.7%
TOTAL	15	100.0%

Another consequence : fire

- Liquid molten metal is a source of fire
- All leakage or projection has its fire potential
- Hot fumes or hot particles can also lead to fire - dust filters
- Dust explosion hazard
- Electric or hydraulic fire risk (technical rooms, wiring, …)

How to react ?

- Again and specifically focus on fire :
  - Close contact with and risk analysis by the fire brigade and the engineering team of the insurance companies
  - Adapted processing procedures
  - Adapted fire fighting procedures
  - Their perfect knowledge
  - Their perfect respect (safety audits)
  - Continuous safety training (periodical drills, some of them organized with the local fire brigade)
  - Adapted fire fighting equipment (automatic fire detection and fire protection systems, appropriate water source, adapted type, number and localization of water hoses and manual extinguishers) in accordance with insurance codes (e.g. NFPA) and insurer recommendations
  - Perfect fire fighting equipment follow up
  - High maintenance level
  - Containment devices

An attempt to determine zones of high risk

- Model based on a serious accident occurred in center of France in 2004 :

  - Metallurgical activity treating metallic waste to produce ferro-alloys
  - Furnace burn through due to refractory's erosion
  - Molten metal at about 1500℃
  - Straight contact between liquid metal and possibly slag with water
  - 2 to 3 t of liquid metal and 35 t of slag in containment
  - 5 to 6 vapor explosions within one minute

  - Blasting effect similar to 200 g of TNT
  - Sudden pressure reduction from 55 down to 1 bar of about 1 l of water at the maximum overheating temperature (270 ℃)

- *As an hypothesis, let's consider 1 kg TNT for a blasting scenario*

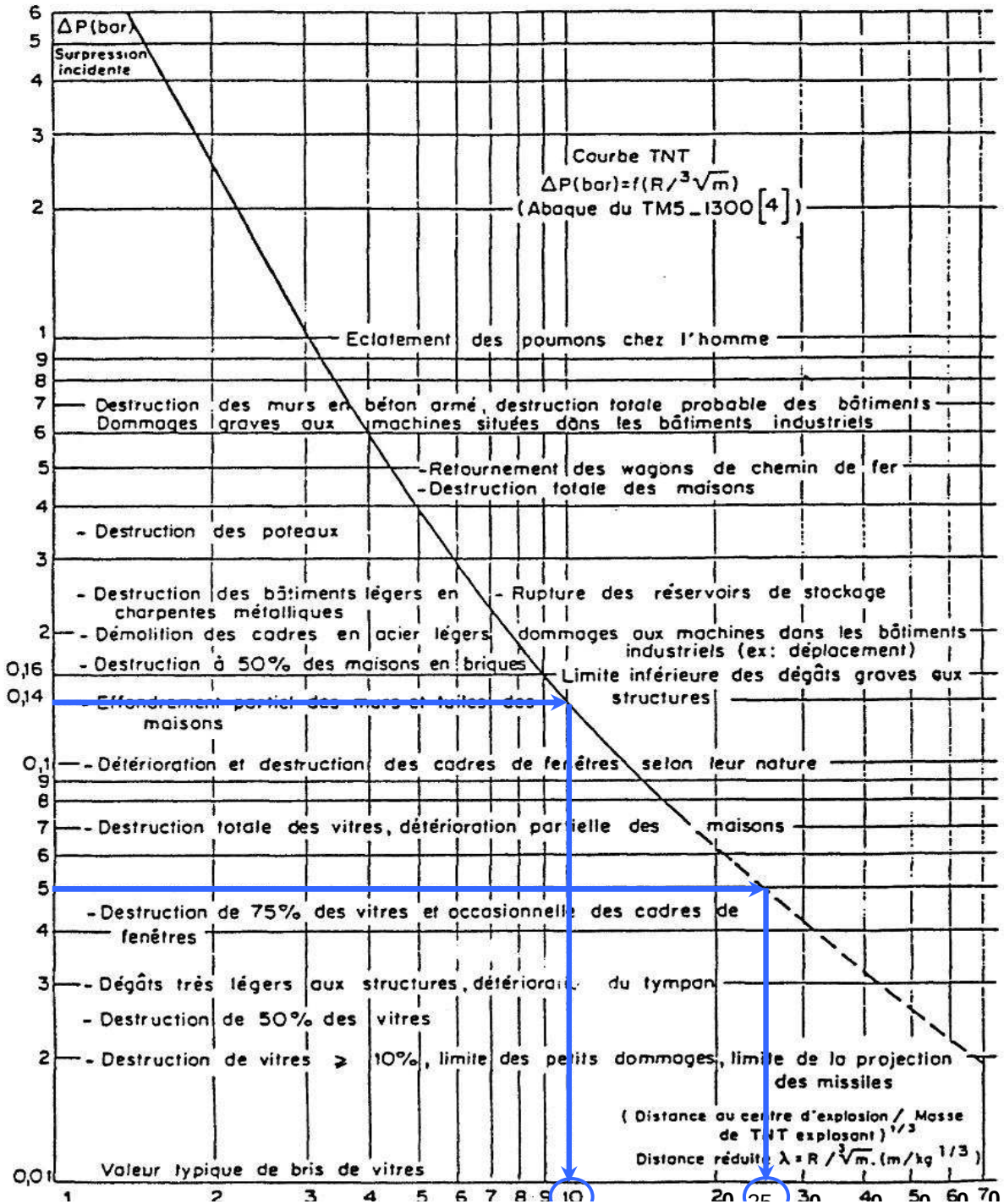
Thresholds…

- Two threshold levels are considered to define hazard perimeters:
- They are based on pressure increase:
  - 140 mbar as a threshold for first deadly effect
  - 50 mbar as a threshold for first high wounded level as well as for big significant material impacts.

references

Major blasting effects are pressure wave and projections
Both have consequences in proportion of pressure increase
Let's have a look to effects on man and buildings

Pressure increase (mbar)	Effects on men	Effects on buildings and structures
20	Some disabilities	Glass destroyed
50	Significant disabilities /severe injury	Slight effects on structures
140	First effects leading to death	heavy effects on structures
200	Significant lethal effects	Domino effects

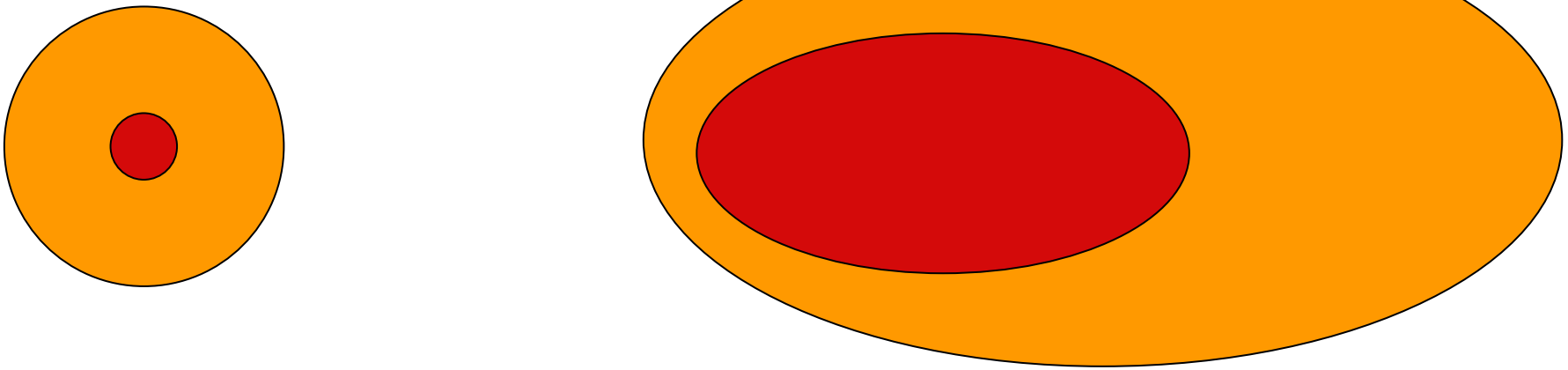


Graph showing the relationship between pressure increase and distance

Blasting effect of 1 Kg of TNT

Blasting compared to toxic cloud….

Blast / Toxic cloud SOx, NOx,



	Blast	Toxic cloud
Death perimeter	Low = 10 m	High = 80 to 100 m
Disability perimeter	Low = 25 m	High = 300 to 500 m
Impacts on buildings & structures	Yes + domino effect	No
Weather conditions influence	No	Yes
Where ?	In the plant	Inside and outside the plant

Conclusions

- **This type of calculation is to be considered in basic design**
- **Location of control room and its protection against blasting is important**
- **Better not to position a furnace at the limit of a plant facing population**

- **No significant environmental consequence - Mostly environment risk is assessed as ALARP**

→ **Focus on occupational safety**

Thank you

for your attention!