Explosion during a cupola drop inside a foundry

May 15, 2006

Vivier-Au-Court [Ardennes] France

Explosion
Metallurgy
Cupola furnace
Cupola drop
Molten residue
Water (in reaction)
Process (control)
Organization

THE FACILITIES INVOLVED

The site:

This foundry, located in the middle of the town of Vivier-au-Court in France's Ardennes department and in operation since 1929, is specialised in manufacturing cast iron parts used in the automobile industry, the building industry, heating installations, mechanical industry, farming etc.

The site employs a staff of 258 and belongs to a family-owned company that comprises six foundries and generated a turnover on the order of € 95 million in 2005.

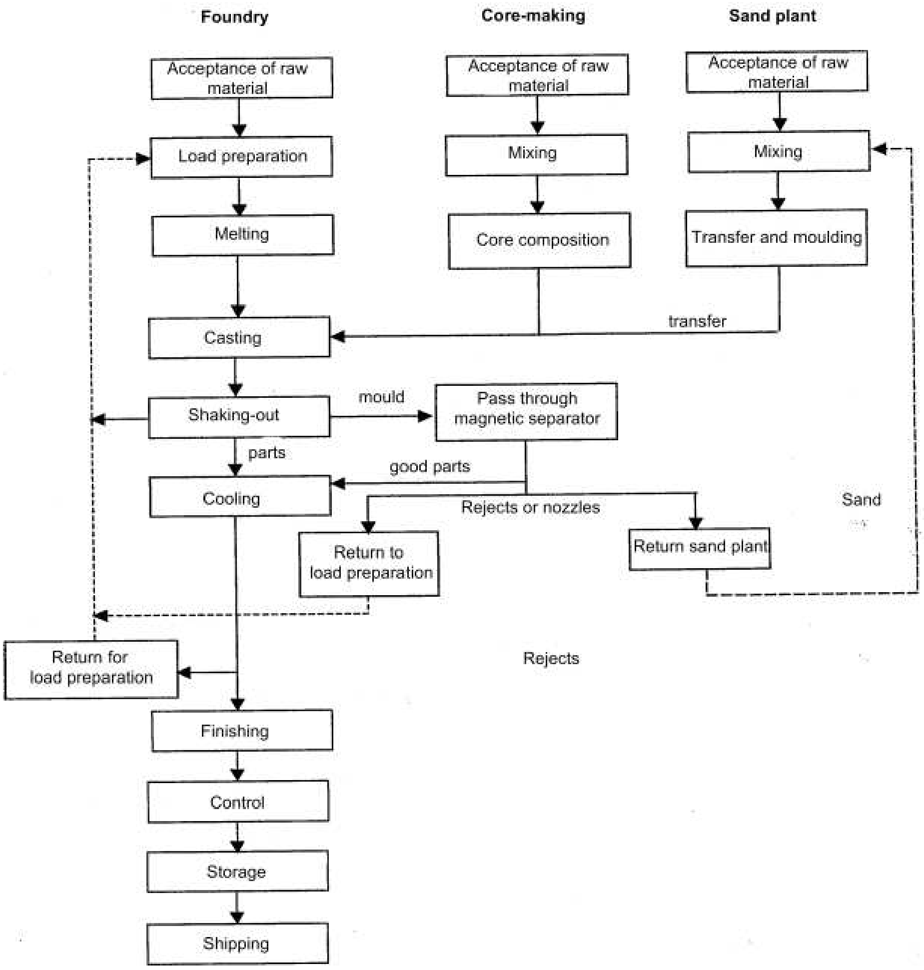
On an annual basis, the foundry produces approximately 25,000 tonnes of grey cast iron and 15,000 tonnes of spheroidal graphite (SG) cast iron.

Grey cast iron is produced using a cupola furnace, while the SG cast iron process involves electric ovens.

The installations requiring authorisation were addressed in an administrative review, via prefectural order issued on August 18, 2008 and superseding the previous order dated June 2, 1994. This latest administrative ruling is compliant with the IPPC Directive and incorporates the new set of melting tools.

Site entrance (source: operator)

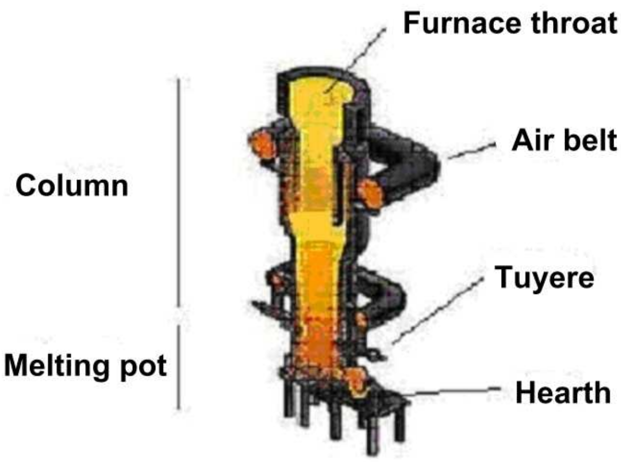
A useful schematic diagram of the plant's manufacturing process is shown below:



The involved unit:

The melting workshop involved in this accident comprises among other equipment two cupola furnaces each with a maximum production capacity of 150 tonnes/day. These furnaces are supplied with coke and operate in alternation every other day for periods extending at most 16 hours.


Cupola (source: operator)



Cupola operations (source: *Bref* Foundry)

The various manufacturing stages include:

Stage	***Operational details***
Load preparation	Mixing of alloy component elements Transfer onto the furnace loading platform
Cast iron melting	Introduction of load via a bridge crane / skip Melting of the load in either the cupola furnace or an induction furnace Slagging (manual removal of impurities)
Discharge	Emptying of ovens or cupola furnaces using a ladle
SG processing	Introduction of an alloy (iron-silicon-magnesium) in molten cast iron
Casting	Casting in the moulding machine: - mould installation - sand filling - compression and formation of the sand mould - manual or automatic ladle casting
Cupola drop	**Discharge (once a day) from the cupola furnace bottom of molten residue (slag, cast iron, coke) into a heat-resistant skip**
Shake-out	Separation of the parts and sand moulds using a vibrating belt
Finishing	Mechanical treatment of parts: shot-blasting, grinding, heat treatment

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

An explosion occurred on Monday, May 15, 2006 at 6:30 pm, corresponding to the time of a cupola drop. The door located on the lower section of the cupola furnace was opened as for discharging the products remaining once the melting process was completed (incandescent coke, cast iron and slag residue) into a skip set up below the furnace. This metallic receptacle was lined with refractory cement.

An employee was positioned at a distance of 10 metres from the skip as a precaution to control any eventual fire outbreak.

The explosion took place at the time the molten residue was being dropped into the skip.

Cupola zone (source: site operator)

Skip used for cupola drop (source: operator)

Consequences of the accident:

Pieces of coke, cast iron and slag were projected inside the building. Emergency response units were notified and company personnel evacuated and then reassembled at premises located beyond the danger zone. External fire-fighters secured the damaged zone and oversaw the safe evacuation of all personnel.

The employee positioned 10 metres from the cupola drop zone was burned on the face and arms by the hot air blast of the explosion, necessitating a 4-day hospital stay; a second employee, found in a state of shock and treated onsite by the fire-fighting crew, was able to report for work two days hence.

The roof was destroyed over a 30 m² area; property damage costs were estimated by the site operator at 10,000 euros. Technical equipment and installation of the cupola furnace sustained no damage whatsoever; production could thereby resume the next day according to the regular schedule and under normal operating conditions.

The explosion blast caused dust that had accumulated on the metal frame of the building to fall to the floor. The zone damaged by the explosion was quickly cleaned. No rainfall was recorded at the time of this event, which served to avoid any runoff of contaminated stormwater to the soil. Moreover, no fire extinction water needed to be sprayed.

The European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the '*SEVESO II*' directive on handling hazardous substances, and in light of the information available, this accident can be characterised by the four following indices:

Dangerous materials released	■	□	□	□	□	□
Human and social consequences	■	□	□	□	□	□
Environmental consequences	□	□	□	□	□	□
Economic consequences	□	□	□	□	□	□

The parameters composing these indices and their corresponding rating protocol are available from the following website: http://www.aria.developpement-durable.gouv.fr

Level 1 of the "Dangerous materials released" index characterises the explosion that occurred (parameter Q2: quantity of explosive substances in TNT equivalent less than 100 kg).

The hospitalisation of an employee for more than 24 hrs explains the level 1 ascribed to the "Human and social consequences" index (parameter H4).

The cost of property damage in the company did not reach the level 1 threshold of the "Economic consequences" index (parameter €15); production losses on the other hand were not quantified or notified to the inspection authorities for classified facilities, which prevented characterising the parameter €16.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Given the level of installation knowledge and accident history for this type of equipment, the most frequent accidents consist of projections of molten metal due to either the contact between water and metal or the formation of a gas accumulation (CO / H_2). Such projections are capable of initiating a fire.

The water / molten metal reaction was the cause of this accident: the refractory cement lining the residue recovery skip was only set into place the same morning and the drying period proved insufficient. This skip, intended to serve as a receptacle for residue after melting, contained residual humidity. Water entering into contact with molten residue either triggers a vapour explosion (purely physical phenomenon) or leads to the formation and subsequent explosion of hydrogen or CO (chemical redox phenomenon).

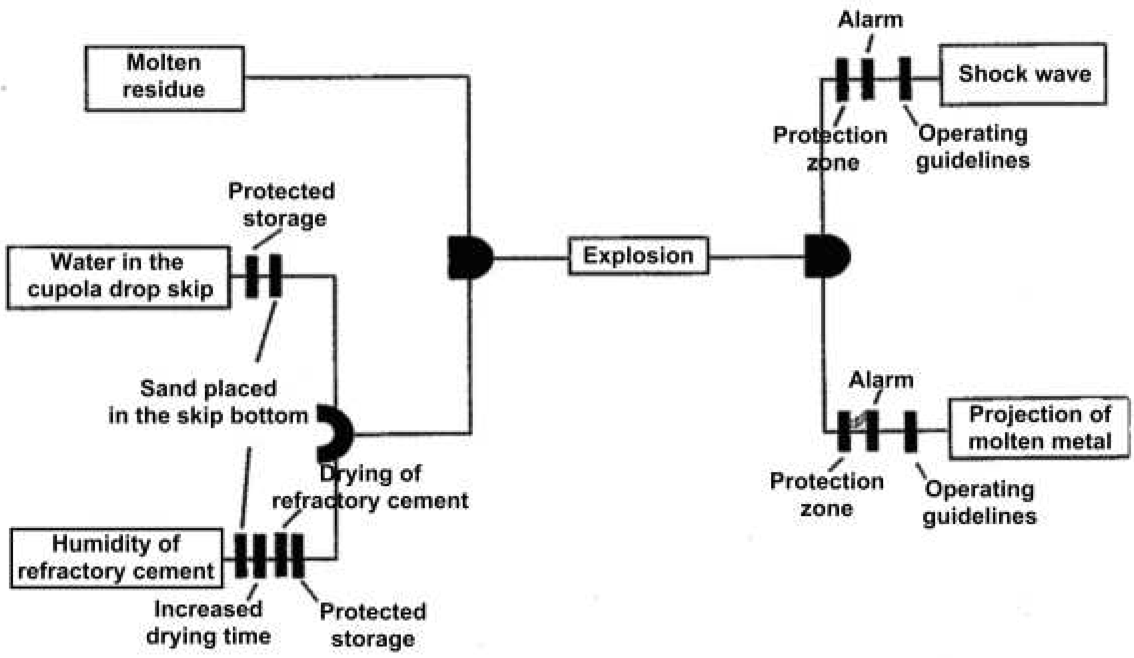
ACTIONS TAKEN

Following the accident, an extraordinary meeting of the Committee for hygiene, safety and working conditions (CHSCT) was convened; findings were delivered in a report dated May 29, 2006 confirming the accident causes cited above.

The facility operator also updated the Safety Report as part of the permit application file, which was on the verge of being submitted to the Prefecture.

LESSONS LEARNT

Several technical and organisational measures were adopted in order to reduce the probability that such an accident repeats as well as to remedy the effects of an eventual accident. The following identification of technical safety barriers for prevention and protection was performed as part of the Safety Report update:



→ the technical measures were primarily focused on removing humidity in the metal skip, for the purpose of eliminating the risk of explosion due to contact between residue after melting (cast iron residue) and water, i.e.:

- ✓ acquisition of three skips so as to better manage equipment utilisation and ensure sufficient drying time for the refractory cement (36 hrs). Skip labelling was also introduced;
- ✓ storage of this containment capacity at a site protected from water;
- ✓ drying of the skip intended for daily cupola drop using a gas burner;
- ✓ placement of a bed of black foundry sand at the bottom of the skip to both eliminate all eventual traces of residual humidity and provide additional protection at the skip bottom.

→ organisational measures to enable limiting the number of individuals working in the hazardous (so-called "protection") zone where the cupola drop takes place:

- ✓ clearly identifying the protection zone by demarcating a boundary around the cupola furnace;
- ✓ installing a sound alarm designed to notify personnel during the cupola drop period;
- ✓ designating a cupola drop supervisor with the responsibility to trip the alarm and ensure that the protection zone is always free of any unprotected or unauthorised individuals;
- ✓ revising operating guidelines and appointing a Head of Operations, who among other things is to verify that the refractory cement lining the skip is well dried;
- ✓ updating, in conjunction with employees, the list of individual protective gear (by occupation or by workstation) to be worn: helmet with a face shield, safety jacket and aluminised gloves, and appropriate pants;

- ✓ scheduling of evacuation drills to allow personnel to become acquainted with the alarm system and other onsite safety features.

Delimitation of the protection zone (source: operator)

This set of measures has made it possible to include the given accident scenario within the new Safety Report as being tolerable with a probable event of medium severity.