Rupture of observation windows in a brewery
17 and 18 January, 2002
Champigneulles (54)
France

Rupture
Brewery / Agribusiness
Carbon Dioxide
Fermentation
Overpressure
Observation window
Check valve

THE INSTALLATIONS IN QUESTION

The brewery was created on January 1st, 1897.

This establishment is subject to the legislation of the Installations Classed for the Protection of the Environment. The orders governing the site date from April 18, 2000 (initial prefectorial decree) and January 29, 2001 (supplementary order of the prefect establishing the measures required to prevent and fight Legionella).

Authorised annual production is 360 million litres of beer, 20 million litres of cider and 15 million litres of carbonated beverages. On September 1st, 2003, there were 350 employees

Photo DR

For the beer production activity, the site has 64 metal tanks for fermenting and storing the beer. These tanks are located in a building, which dates back to 1957, that consists of a basement and three storeys, each level is designated as a "cellar". Each of the four cellars contains 16 tanks arranged in two rows of 8. The incidents took place in the cellar located on the second floor.

The components necessary to manufacture beer are water, barley, hop and yeast.

Water contributes its mineral properties to the beer with its hardness and pH.

Hop is a "source" of starch which is not assimilated by the yeast in its "natural" state, so it must first be transformed. The principle of the malting is to reproduce the natural growth of the barley grain so that it can produce the enzymes necessary for the transformation of starch into sugarThis process is divided into four operation :

The soaking which consists in flooding the barley during about 10 hours,

The germination, which is the period when the barley begins to germinate and to produce enzymes such as amylase. This step create the "green malt".

The kiln drying, which consists in drying the green malt (from 45% to 4% of moisture) in a kiln.

The last operation consists in taking off the radicelle from the malt.

The hop provides the beer with taste and bitterness. The tannins in the hob flower (non fertilised) clarify the beer wort and preserve the beer.

The yeast allows fermentation and thus the transformation of the sugar present in the malt into alcohol and carbon dioxide (CO_2). It is this part of the process that was involved in both accidents. The yeast also participates in giving the beer its final taste.

Photo DR

The fermentation tanks used on the site are made of coated steel. They measure 3 meters in diameter and 17 meters in length, for a volume of 120 m^3 used in the following manner:

- ✓ 80 m^3 of beer in fermentation;
- ✓ 40 m^3 of free space required for fermentation.

The tanks are are installed in a horizontal position and feature a Plexiglas observation window on the upper part to enable visual inspection of the beer during the fermentation phase.

Photo DR

They are equipped with an outlet and a fitting to connect a hose onto a pipe that conveys the carbon dioxide to be released to the atmosphere (pipe 1) or to the gas recovery system (pipe 2). These two pipes are each equipped with a check valve and manual valve. The check valves are cleaned after each use of a tank. The connection between the tank outlet and one of the two drain-pipes is made manually depending on the state of the beer's fermentation phase.

During the fermentation phases, the tanks are subjected to gauge pressures from 500 to 700 millibar. The carbon dioxide is released by simple overpressure. The installation are thus not subject to regulations on the pressurised equipment, namely decree No. 99-1046 of December 13, 1999 relative to pressurised equipment, the order of March 15, 2000 relative to their operation and the ministerial order of January 5, 1962 governing plant piping.

THE ACCIDENTS, THEIR BEHAVIOUR, THEIR EFFECTS AND CONSEQUENCES

The accident of 17 January, 2002

The tanks concerned are tanks of beer in the fermentation phase which are located on the second level. This fermentation period is composed of two phases:

- ✓ Start of fermentation: the air-CO_2 mixture is released to the atmosphere
- ✓ Fermentation: the carbon dioxide is recovered in a gas recovery station to be used in other purposes in the installations (lasting approximately 8 days).

Tank 224 was in fermentation phase with the vent positioned to release the CO_2 to the atmosphere. The casking took place January 16th at 1.15 pm.

Suddenly, at 10.10 am on January 17th, 2002, the window (a Plexiglas disk measuring 26 cm in diameter, screwed onto a metal support, and used to observe the level of the tank, at a height of 2.80 m) of tank 224 burst, resulting in the sudden release of carbon dioxide (approximately 40 m^3) and a small quantity of beer (approximately 250 litres) as well as the projection of Plexiglas which destroyed a light fixture.

The spilled beer was absorbed by the plant's water treatment facility.

The carbon dioxide spread throughout the workshop. The personnel present evacuated the cellars. A qualified member of the personnel put on a PBA (personal breathing apparatus) and inspected the cellars to ensure that everyone had managed to evacuate the premises. The fire and emergency services were informed by the guardhouse.

The SDIS ("Service Départemental d'Incendie et de Secours", departmental fire and emergency service) arrived at the scene 20 minutes after the explosion and checked that nobody was in the cellars, then provided forced ventilation to disperse the CO_2 present in the workshop to the atmosphere.

The personnel present in the workshop during the incident were examined by an occupational health physician who happened to be at the site at that time. The physician determined that no one was injured.

The accident of 18 January, 2002

On January 18th, 2002, at 4 am, while all of the personnel were in the break room relaying instructions between two shifts, the observation window of tank 226, located just opposite of tank 224, ruptured.

In an identical manner to the accident of the previous day, this rupture resulted in the release of carbon dioxide (approximately 40 m^3) and a small quantity of beer (250 litres). Here again, the spilled beer was absorbed by the plant's water treatment facility.

Carbon dioxide spread through the workshop in which no one was present. The fire department and emergency services were called. No one entered the workshop as PBA was no longer available.

The SDIS ("Service Départemental d'Incendie et de Secours", departmental fire and emergency service) arrived at the scene 15 minutes after the explosion and provided forced ventilation to disperse the CO_2 present in the workshop to the atmosphere.

Overall consequences

Loss of production due to the downtime following these incidents can be evaluated at 800,000 litres of beer.

The corrective actions implemented cost a total of approximately 800,000 Euros, including 350,000 for the tank equipment.

European scale of industrial accidents

By applying the rating rules of the 18 parameters of the scale made official in February 1994 by the Committee of Competent Authorities of the Member States which oversees the application of the 'SEVESO' directive, the accident can be characterised by the following 4 indices, based on the information available.

The parameters that comprise these indices and the corresponding rating method are available at the following address: http://www.aria.ecologie.gouv.fr.

The level 1 given to the economic consequences is due to the loss of production caused by theses accidents (parameter €16). The costs related to the corrective actions are not considered for the calculation of the economic consequences.

Moreover, these accidents did cause neither human consequences inside and outside the site nor significative environmental impact. In addition, there was no release of dangerous materials (in the meaning of the SEVESO Directive).

ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENTS

Origin and causes of the first accident

The first reports allow the possible causes of the tank 224 window explosion to be identified.

The following was noted on the atmospheric release piping:

- ✓ The hose was correctly connected on the CO_2 atmosphere release outlet;
- ✓ The "atmosphere release" valve was open;
- ✓ The "atmosphere release" check valve **was installed wrong way up**.

This check valve, thus blocking any release of CO_2 to the atmosphere, contributed to the overpressure in the tank, resulting in the window exploding which acted as a rupture disc.

The tanks are equipped neither with a rupture disc or valve in the case of overpressure nor with an automated pressure-measuring device.

Furthermore, the check valve is a screw-type device that is completely removed for cleaning during maintenance operations. This valve is symmetrical in appearance and has no distinctive marking showing the installation direction or feature preventing it from being installed backwards.

A leak on one of the window bolts was noted and repaired (screw changed) by the crew of the 4 am to 8 am shift in the morning of January 17th, 2003. This event did not alert the personnel.

Origin and causes of the second accident

In relation to the 1st incident, the only difference is that the check valve was correctly installed on the CO_2 atmosphere release pipe of tank 226.

The window explosion could thus have the following causes:

- ✓ The weakening and the loss of its mechanical characteristics as the window as nearly opposite the window of tank 224 that exploded the day before;
- ✓ The ageing of the material (Plexiglass). There is no long-term guarantee of the windows' mechanical characteristics. The windows are supplied by a company that machines the Plexiglas to the required dimensions;
- ✓ An overpressure in the tank due to blockage of the atmosphere release pipe (impurities, build up of ice, …). This hypothesis is the most probable from the operator's point of view.

ACTIONS TAKEN

The operator responded to all of the administration's requests. The new casking operations were partially renewed beginning Wednesday, January 23rd, 2002. The internal pressures of each tank in the fermentation phase was monitored once per each shift (that is, every 8 hours) until August 29th, 2002 noon, at which time all of the medium-term measurements were in place (sensors, rupture discs and discharge outlets). No other incident has occurred since January 18th, 2002.

Measures taken following the first accident

The following measures were taken in view of the inquiry's conclusions:

Short-term measures:

- ✓ Inspection of all check valves;
- ✓ Information provided to all operators concerning the incident and its probable causes. Their attention is drawn to the proper installation of the check valves.

Medium-term measures:

- ✓ "Foolproofing" devices are installed on the valves: initially, indelible paint on valves and piping, then installation of systems equipped with a "male" side and "female" side.

Measures taken following the second accident

Following these two accidents, the operator was to implement more stringent and security measures:

- ✓ All of the fermentation tanks in the workshop in question were connected with the carbon dioxide recovery pipe's atmosphere by-pass;
- ✓ Manual verification of the internal pressure of all tanks is conducted as well as all of the valves and observation windows;
- ✓ The cellar is barred;
- ✓ Filling of new tanks (casking) is suspended as of 6.15 am.

The investigations conducted immediately after the accident led to the following findings and decisions:

- ✓ No tank was in overpressure status;
- ✓ All of the valves and all the dampers were in the correct position;
- ✓ The atmosphere by-pass of the carbon dioxide recovery pipe was operating correctly; all of the tanks are thus configured to the by-passed recirculation pipe;
- ✓ 2 observation windows were bowed.

Not being able to exactly define the origin of the 2nd incident, the operator made the following decisions:

- ✓ Not conduct a new casking operation;
- ✓ Conduct manual internal temperature checks regularly over the entire weekend and on all tanks in fermentation phase (20 out of 32);
- ✓ Regularly purge the carbon dioxide recovery system to discharge the foam that it may contain;
- ✓ Decompress the tank and destroy the foam, resulting from the decompression, contained in the tank should any risk appear.

The operator requires that the following measures be undertaken prior to the restart of the installation:

- ✓ In the short term:
  - o Systematic changing of all observation windows;
  - o Inspection of the 2 pipe networks (release of gas to the atmosphere and recirculation systems);
  - o Installation of a pressure gauge on each tank and implementation of a procedure ensuring the regular inspection of said gauges;
  - o Implementation of a cellar "access authorization" procedure.
- ✓ In the medium term:
  - o Installation of a rupture disc on each tank with recovery of the gas and evacuation to the outside;
  - o Observation windows replaced by metal sheeting as visual inspection is not essential;
  - o Personnel supplied with a portable CO_2 detector and leak masks;
  - o Personnel are required to move about and work in teams of 2 in the cellars and to sign an in/out log;
  - o Ventilation of hallways, installation of CO_2 detection and alarm equipment;
  - o Emergency lighting;
  - o Increase the number of personal breathing apparatus at the plant.

The Inspectorate went to the site on the day of the accident and requested that the operator provide the following:

- ✓ An incident report and the compensatory measures undertaken (locking out of the workshop, release of the CO_2 to the atmosphere via a by-pass on the recovery piping, etc.);
- ✓ The accident causal and failure analysis including also a description of the safety devices installed;
- ✓ The corrective measures implemented to prevent such an incident from happening again.

Since these incidents, the operator has implemented the following additional means:

- ✓ Installation of pressure sensors on the tanks with remote display of values in the control room and triggering of a threshold alarm in case of a problem;
- ✓ Installation of pressure control equipment on half of the tanks. This equipment features a bubbling sight glass (avoiding the possible fouling of upline pipes and equipment) and a lever valve enabling the desired tank pressure to be adjusted. It can be cleaned "on site" and no longer requires disassembly and reassembly which can be a source of errors.
- ✓ Installation of a spring-loaded valve ensuring that a fixed amount of backpressure is applied for the other half of the tanks.

LESSONS LEARNT

In this case, the lessons learnt from that accident could be :

- ✓ Checking of the mechanical characteristics of the windows and, if necessary, replacement of weakened equipments by stronger materials;
- ✓ Installation of a pressure gauge on each tank and implementation of a procedure ensuring the regular inspection of said gauges;
- ✓ Installation of CO_2 detection in the workshop, and alarm equipment;
- ✓ Installation of a rupture disc or security vents on tanks likely to be under pressure or to contain a gaseous plenum;
- ✓ Installation of equipments and accessories which maintenance and use limit human intervention and thus the risk of error;
- ✓ Analysis of the probable causes of a pressure increase in the tanks and detection and installation of the safety devices in order to limit the risk of window explosion;
- ✓ Training of the personnel about the risks and causes of such a phenomenon;
- ✓ Implementation of advanced control procedures and of report in case of anomaly such as a leak on a bolt of a tank;
- ✓ Possession and maintenance of personal protective equipments (PBA, portable CO_2 detector, etc.) in sufficient quantities for the personnel.