

Data and feedback from Waste-to-Energy plant operators regarding nitrous oxide cylinders explosions

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Austria

Data from specific explosions

Deflagration in MK1 on May 19, 2021:

- Boiler downtime: 125 h
- Downtime costs: approx. 251,000 €
- Repair costs: approx. 126,000 €

Explosion in MK2 on May 19, 2023:

- Downtime 139 h
- Downtime costs: approx. 278,000 €
- Repair costs: approx. 90,000 €

Deflagration in MK2 on October 5th, 2023:

- Downtime 4.5 h
- Downtime costs: approx. 35,000 €

Deflagration on November 26, 2023 (no failure; SIM 2206516)

Deflagration on December 2nd, 2023 (no failure; SIM 2206438)

Belgium

Frequency of explosions

12 members of Belgian Waste-to-Energy (BW2E) reported weekly to multiple explosions daily.

2 members experienced no explosions.

Statistics:

- Plant A: 1/1/2024 to 11/03/2024 (70 days): 89 explosions on 2 oven lines. **4.45 explosions per week per line.**
- Plant B: 03/2023 to 12/2023 (305 days): 530 explosions on 3 oven lines. **4 explosions per week per line.**
- Plant C: 05/2023 to 03/2024 (305 days): 67 explosions on 2 oven lines. **0.7 explosions per week per line.**

Update November 2024

From January to July 2024, 2008 recorded explosions in 12 out of 14 members of BW2E. In all 14 plants, explosions led to 36 shutdowns for repairs. As a result, for 62 days out of 210 there was one Belgian WtE plant that had a line offline for repairs due to nitrous oxide.

Note: Belgium introduced a federal ban on the improper use of nitrous oxide in April 2024.

Cost of damages

Estimations:

- Cost depends on damage so can vary a lot.
- **One plant reported 10 M€ costs over 2023.**
- One plant reported direct cost of **20,000 € to repair, and 100,000 € additional for loss of revenues and other indirect costs** for 2 shutdowns.
- One plant reported **300,000 € due to 4 shutdowns**

Direct costs:

- Repairing the damage
- Maintenance costs due to shutdowns

Indirect costs:

- Precautions to sort out the cans
- Delivery and proper waste treatment for separated cans
- Losses in energy production
- Losses in temporary inability to burn waste

One plant example:

They lost **22 days of combustion capacity** as a result. This means on top of additional maintenance costs:

- 3,008 fewer tonnes of waste that could be incinerated;
- 729 MWh less electricity production;
- 109 MWh more electricity purchases;
- 32,058 Nm³ additional natural gas consumption

Number of additional shutdowns

60 additional shutdowns purely due to laughing gas in 5 WtE plants since the end of 2022. Each shutdown comes with costs (see above).

Unplanned shutdowns lasted several hours to several days depending on the intensity and location of the explosion.

Risks for workers

One employee was blown away by great pressure resulting from the explosion of a nitrous oxide cylinder during an intervention to remove a blockage. Fortunately, there were no injuries.

Any intervention (checks, maintenance) involves greater risk, especially if manholes or doors have to be opened:

- Daily controls of bottom ash conveyors below the grids
- On-line cleaning of ESP (electrostatic precipitators): manhole between boiler and ESP should be opened

Czechia



Brief description of events

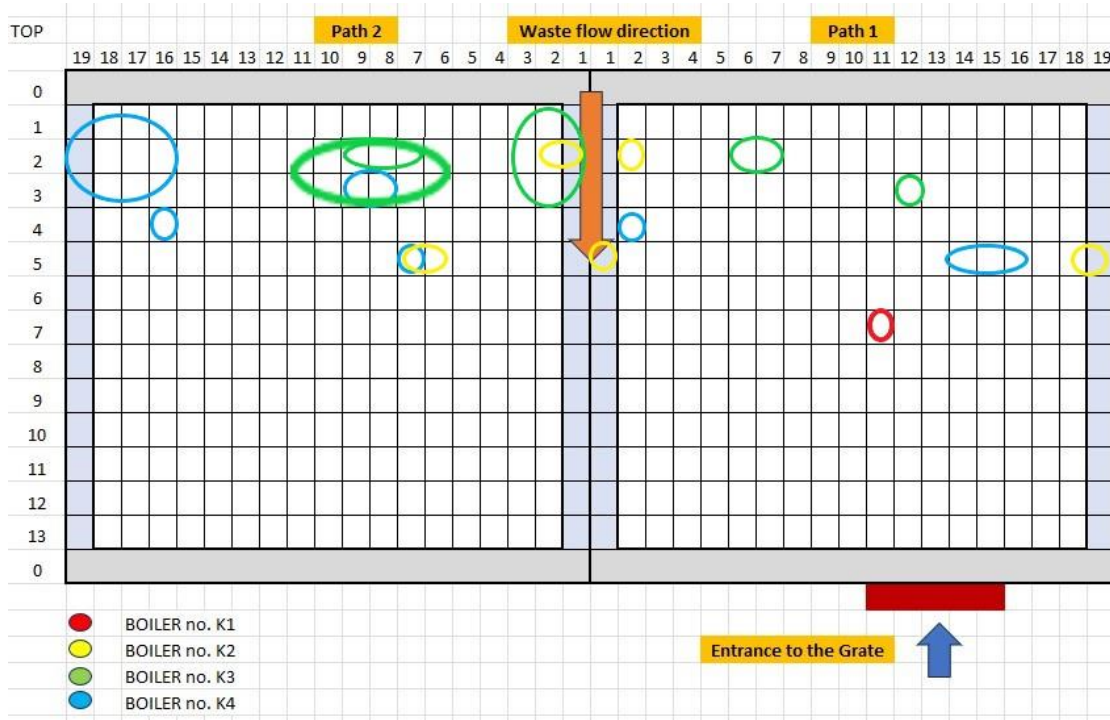
- From 5/2022 to 1/2024, the operator registered explosions of pressure cylinders in boilers, during which grates are damaged. In this way, a total of 29 grates were damaged during the mentioned period in 10 larger explosions (apparently depending on the residual content of the pressure cylinders). The average cost of one repair is EUR 20,000.
- The cause of the damaged grates is probably the explosion of steel pressure vessels. These containers are sold to make whipped cream. The container also includes a filling of nitrous oxide (N₂O, paradise gas), which, according to available information, is misused for intoxicating purposes.
- The problem with this product is the non-legislatively secured advance takeback and disposal in collection yards. In our opinion it is therefore necessary to submit an initiative to the relevant institutions in the Czech Republic (Czech trade inspection, Police of the Czech Republic, Ministry of Industry and Trade ČR, Ministry of the Environment ČR, etc.) and demand a solution to this issue at the pan-European level.
- At the same time, the operator solves the minimization of boiler shutdowns due to explosions and damaged grates of their innovations. The new type of grates will apparently be more resistant to these explosions. But also more expensive.

Overview and extent of damage

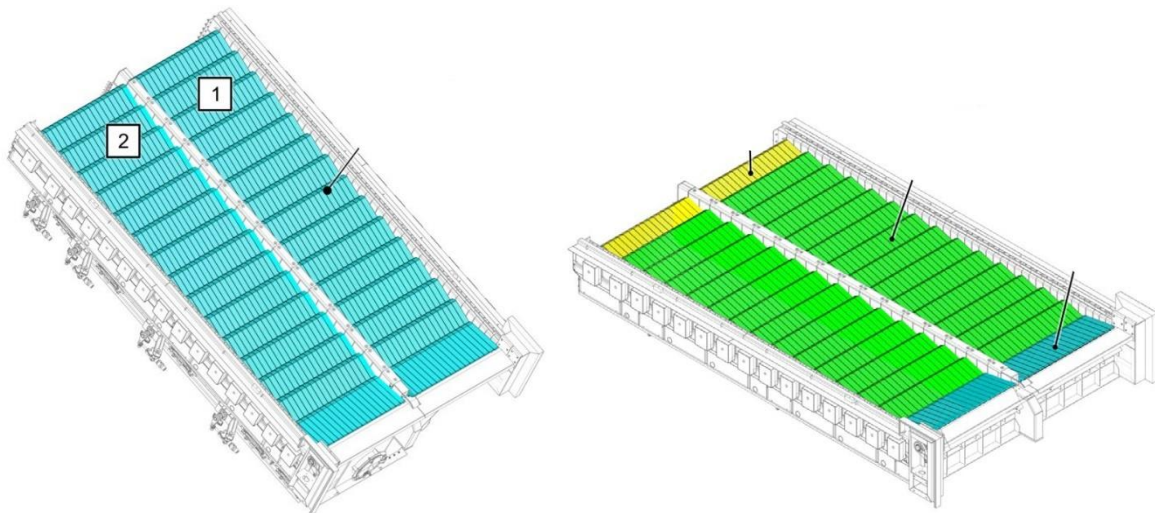


No.	Date of explosion	Boiler	Number of damaged Grate bar	Grate bar position
1	17.05.2022	K2	2	Grate 1/Zone 2
2	01.06.2023	K4	9	Grate 2/ Zone 2
3	03.07.2023	K3	8	Grate 2/ Zone 2
4	20.07.2023	K3	1 3	Grate 1/ Zone 2 Grate 2/ Zone 2
5	31.08.2023	K4	3	Grate 1/ Zone 3
6	01.09.2023	K2	1	Grate 1/ Zone 2
7	19.10.2023	K1	1	Grate 1/ Zone 3
8	24.11.2023	K4	1	Grate 2/ Zone 3
9	06.01.2024	K4	1	Grate 1/ Zone 2
10	17.01.2024	K2	1	Grate 1/ Zone 2
11	17.02.2024	K3	2	Grate 1/ Zone 2
12	24.02.2024	K3	9	Grate 2/ Zone 2
13	28.02.2024	K2	2	Grate 3/ Zone 2

Overview of the location of damaged Grate bars on the Boiler grate



3D model of the entire Grate and the composition of the Grate bars



Probable cause of damage caused by exploding pressure vessels

Type of pressure vessel	Filling	Mass/ Volume	Dimensions	Use	Manufacturer/ Distributor
disposable refill	nitrous oxide N ₂ O	3 l	37cm x 12cm	food industry (making whipped cream)	Bshock Whip-EU

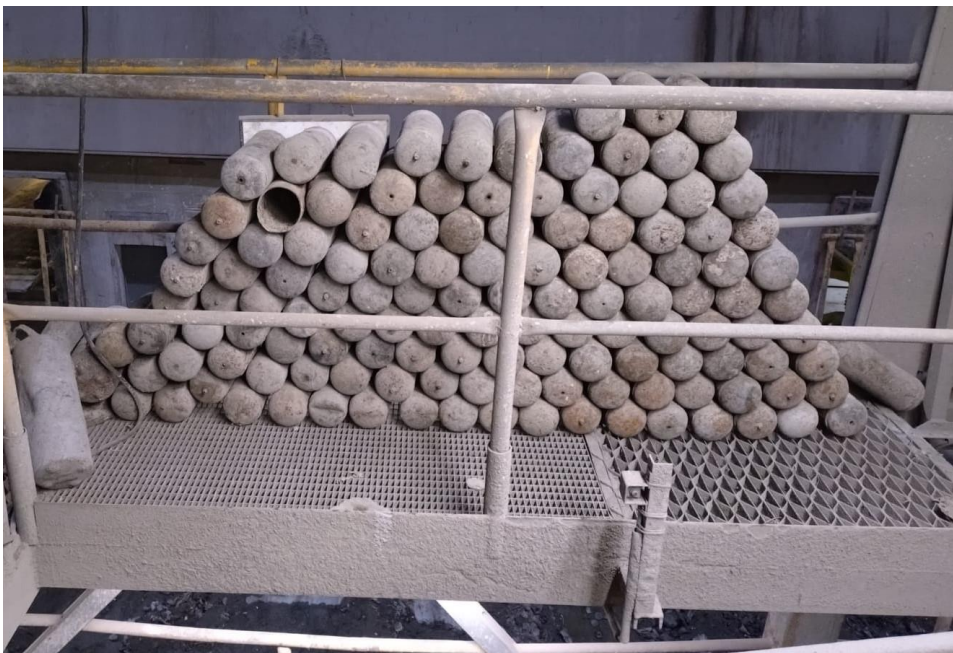
3x Cream Deluxe Maxxi 2000g N2O

5,00 ★★★★★ 9 hodnocení a 3 recenze | Produkt koupilo 21 lidí



Amount of bottles found from the Boiler

The photo shows the amount of approximately 120 pressure vessels found in the output slag in 1 week (January 15, 2024):



Ireland

- Plant 1: only one issue to date. This incident involved an exploded canister finding its way into the second pass of the boiler and blocking the double screw. The operator had to intervene to free the blockage, but there was no plant unavailability resulting from this issue.
- Plant 2: numerous explosions in the boiler, but only 5 events which caused damage to the plant. The exploded canisters ended up in the 2nd pass and dropped into the drag chain for the fly ash and caused significant damage to the drag chain. The cost of repair is c. €30,000 each event.

France

Nitrous oxide explosions affect around a third of French facilities, with major impacts:

- **Material damage:** Explosions damage furnaces, boilers and other equipment, causing shutdowns of 20 to 40 hours and repair costs of up to €200,000 per incident.
- **Economic impact:** Losses to the industry are estimated at between €15 and €20 million a year.
- **Operator safety:** Explosions can cause serious injuries to personnel, including burns, contusions and internal injuries due to blast effects.

Measures have been put in place:

- **Internal:** Reinforcement of safety equipment, secure access to furnaces and bottom ash extractors, awareness-raising among teams and local authorities.
- **External:** Following a warning from operators, a decree was published in July 2023 limiting the sale of nitrous oxide cylinders to private individuals to 8.6 g per cartridge. However, this measure has proved insufficient, with larger-capacity cylinders continuing to arrive at incinerators.

Plant example (municipality-owned and operated)

The plant has 3 x 5t/h waste incineration line, our legal capacity is 120 kt/year.

The plant experienced real issues regarding laughing gas explosions, which become more and more frequent.

For our site, the consequences are:

- **Combustion issue** (exceeding the limit value for carbon monoxide)

Exceeding on 3 lines for CO parameter:

2021 : 13 h

2022 : 5.5 h

2023 : 26 h !! (52 x 30' exceeding)

- **safety risk:** the glass in front of the camera is broken several times a month

Update November 2024

- Frequency: around one explosion per line per day
- Cost of damages:
 - Direct costs:
 - Grate repairs: 50,000 €
 - Oven safety: 17,000 €
 - Repair of refraction: 3,000 €
 - Oven sight glass + camera: 10,000 €
 - Indirect costs due to unavailability: circa. 250,000 €
- Additional hours of downtime:
 - L1: 160h in May 2024
 - L3: 155h in October 2024





- damage on the grate :





Luxembourg

17th January 2024: 3 explosions in the boiler, twice in the morning and one at 11:12 p.m. at night.

Looking back on the curve, there was an explosion on the morning shift on January 13th and January 14th.

All 5 explosions are between 3 and 3.5 mbar. Cartridges were found in the bottom ash.

Netherlands

Frequency of explosions

About 250-300 explosions a week, both heavy and relatively light explosions.

Update October 2024:

500,000 cannisters were found in the environment in the Netherlands in 2023. From that, 470,000 were collected and treated by municipalities and other waste services. The other 30,000 ended up in WtE plants. Of these, 10,000 exploded and 1 out of 6 explosions led to damage.

One plant reports that before the 2023 ban and end of deposit return system, there were on average 4 explosions per week. After the ban, the average jumped to 40 explosions per week.

Cost of damages

Estimated total costs for the Dutch WtE-industry: **65 million euros annually** including additional shutdowns and **excluding the costs for the customers of the plants (municipalities, collectors) to remove as many cylinders as possible from the waste.** These costs also amount to around 65 million euros. Despite these efforts, the number of explosions is not yet decreasing.

The Dutch government has not been willing to financially assist the sector in taking mitigating measures. Furthermore, liability is also not recognized for the damage suffered, because the government claims there is no causal link between the ban on recreational use of laughing gas

and the use of these dangerous, explosive cylinders. The waste industry obviously disputes this and an appeal will probably have to be made to the courts.

Environmental risk: Emission exceedances occur when restarting an incineration line after damage has been repaired.

Update October 2024:

The total cost for 2023 is estimated to 150 million euros, including WtE plants, sorting plants and additional cost for collection of the littered canisters.

Before the introduction of the ban on 1st January 2023, the deposit return scheme was collecting cans at a cost of 30€ per can. Damages now amount to 300€ per can.

Risks for workers

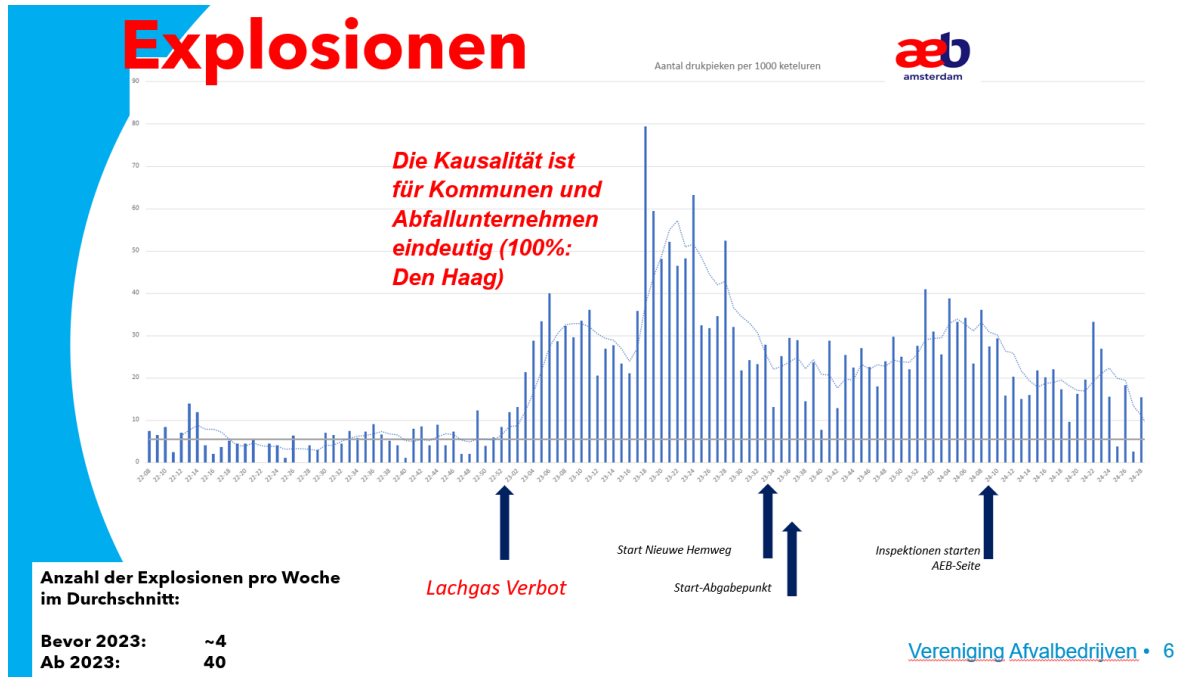
Risks to operational employees are a major concern for our members every day. Many costly measures have been taken to limit the risks as much as possible. The major concerns remain, of course.

Other information

The 'stop organizations' are very heavily burdened and there have been periods when they went 'from stop to stop'.

In 2023 an enormous number of approximately 0.5 million cylinders were found or intercepted in public spaces, waste chain or by Customs / Police.

Data from AEB Amsterdam

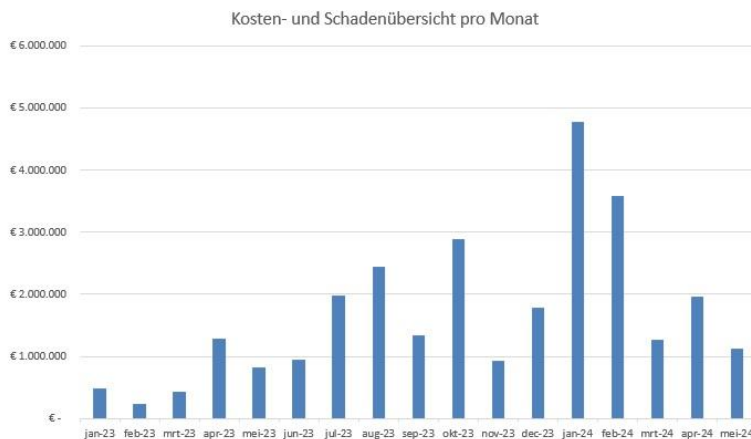


The graph shows pressure peaks per 1,000 boiler-hours. The peaks started after the ban and decrease due to inspections carried out by the operator.

Cost per month

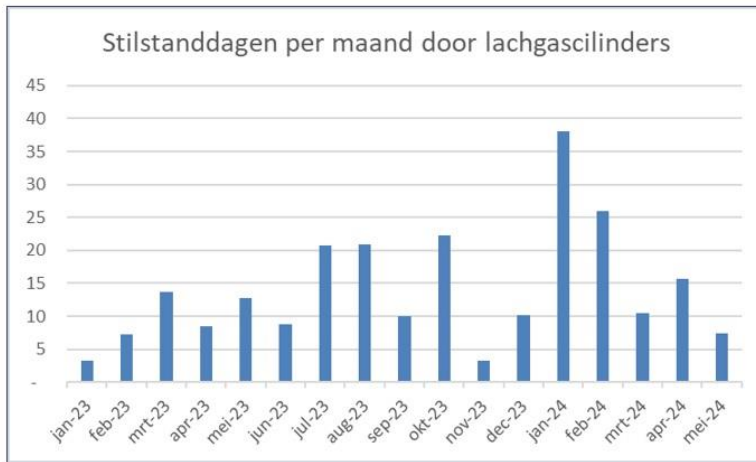
Schäden und Kosten durch Lachgasflaschen

durchschnittlich 1,7 Mio. EUR pro Monat
Bisher mehr als 28 Mio. Euro



Downtime in days per month

Der Tag des Stillstands

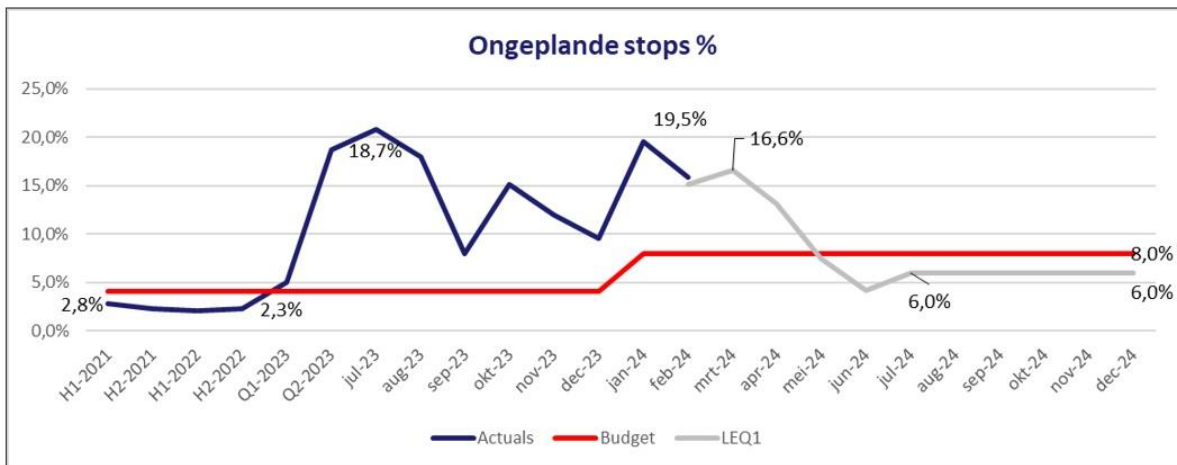


Insgesamt 247 Ausfalltage von Anfang 2023 bis Juni 2024 aufgrund von Lachgasflaschen



Unplanned stops

Verfügbarkeit des Kessels



Norway – Celsio Oslo WtE plant

Plant's characteristics: 3 lines and total waste incineration capacity of 350 000 tonnes/year.

Frequency of explosions: Approx. 2 to 3 a day. The operator has programmed an automated explosion counter. There were already 2 unplanned stops in 2024.

Cost of damages: 100,000€ so far in 2024, due to maintenance and loss of energy income (broken grate bars).

Environmental risk: several breaches of emission permits due to boiler trips. Some of the explosions cause the boiler to trip and lead to very high CO-emissions.

Risks for workers: Inspections are high-risk. No actual accidents, yet.

Sweden – Sysav

The facility has three WtE blocks consisting of five grate-fired boilers with associated flue gas cleaning. In total, with an incineration capacity of up to 600,000 tonnes (limiting by permit) of waste per year.

Each block produces both electrical energy for the local grid and district heating for the municipality.

Block	Electrical energy	District Heating
KV50	47 GWh	400 GWh
KV61	109 GWh	470 GWh
KV62	137 GWh	510 GWh

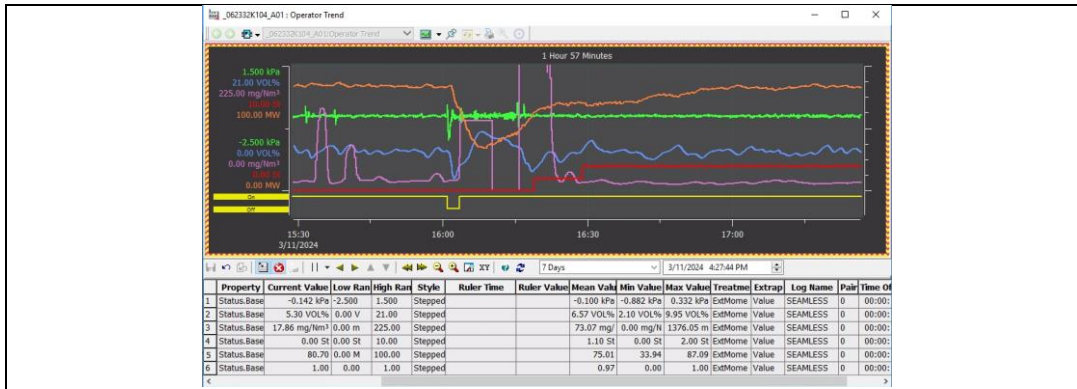
Operational problems related to gas cylinders.

During the last operating seasons, the operator has noticed a significant increase in explosions in the furnace of the boilers as vice many of Sweden's/Europe's other WtE companies. They recorded several explosions every week and even several per day in certain periods. Normally the explosions do not disturb the operation but sometimes can the boiler's safety system stops the boiler due to over pressure in the furnace. The flue gas composition is also affected and problems with keeping the CO limits occur.

Exceptionally, the operator has been forced to shut down a boiler due to damage related to the explosions. One example is from start of the boiler, KV62, just after revision 2023. The boiler had been in operation for a couple of weeks when there was a big explosion. The explosion resulted in a number of grate bars coming off and a big hole in the middle of the grate which prevented continued operation.

Example from an Explosion, KV62.





2024-03-11

In the course of an hour the plant experienced four explosions, the fourth of which tripped the boiler. In addition to affected environmental values and extra work for our operators, the operator lost approx. 20 MWh of steam.

Work environment assessment

The assessment, which is made from a work environment perspective, is that explosions inside the boiler are unlikely to lead to personal injury. The justification for the assessment is that there was no reports of broken sight glass or other damage that could entail risks of personal injury.

In the event of an emergency stop when waste remains on the grate, the operator has added to their routines that awareness of gas cylinders must be included in the risk analysis before entering the boiler. However, they have no experience of subsequent explosions either on the grate or in slag systems.

Summary of Explosions

Below is a summary of all explosions that have been reported.

2023	
Bunker	1
P1	6
P2	18
P3	27
P4	46
P5	24
Total	122

2024 (jan-mar)	
Bunker	0
P1	2
P2	11
P3	16
P4	27
P5	18
Total	74

Sweden – Plant 2

The frequency is hard to put a number on since our control room is >50m from the furnaces and all explosions are not heard. The operator will install acoustic measuring equipment in Q2 2024 and get real numbers on how many explosions there are and the different levels of sound from different sizes of pressure vessels.

Cost of damages, 1 breakdown of furnace floor is at least 40h stop times 3,000 €/h = 120,000 €. The loss of breakdown is 90% loss of income. At the rate today it will be around 4 breakdowns per year and a yearly loss of 500,000 €.

Risk of workers will be when there is a need for digging at the end of the furnace when there is not fully incinerated waste, and when observing the furnace through the glass for inspection.