

INSTALLATION AND METHOD FOR CLEANING INTERIORS OF RECEPTACLES AND FACILITIES

The invention relates to the field of cleaning interiors of receptacles and facilities. It relates to an installation and a method for removing deposits in interiors of receptacles and facilities by way of explosion technology.

The installation and method especially serve for cleaning dirty and slagged receptacles and facilities with caking on their inner walls, in particular of incineration facilities.

The wall surfaces of combustion chambers or incineration boilers, heat recovery boilers or empty passes, as occur e.g. in waste incineration facilities or thermal power stations, or very generally of incineration boilers, are generally subjected to high contamination. This contamination has inorganic compositions and typically arises due to deposits of ash particles on the wall. Coatings in the region of high flue gas temperatures are mostly very hard, since they remain stuck to the wall either in molten form or are melted on the wall or are stuck together by way of substances melting or condensing at a lower temperature when solidifying on the colder boiler wall. Such coatings are very difficult to remove and are inadequately removed by way of known cleaning methods. This leads to the facility or parts thereof having to be being periodically taken out of service and cooled for the purpose of cleaning. For this, the construction of a scaffold in the boiler is often necessary, since such boilers mostly have extremely large dimensions. This moreover requires an operational interruption of several days or weeks and is extremely unpleasant and unhealthy for the cleaning personnel due to the large occurrence of dust and dirt. One consequence which mostly inherently occurs with an operational interruption of a facility is damage to the receptacle materials themselves as a result of the large temperature changes. The facility standstill costs due to the production losses or income losses are likewise an important cost factor, additionally to the cleaning and repair costs.

A cleaning method which is applied in shut-down facilities is for example sandblasting.

Cleaning methods which for example can also be carried out in running operation of the facility are for example boiler beating, as well as the use of steam jet blasters, water jet blasters or soot blasters.

Moreover, cleaning methods are known, with which the cooled-down or the hot boiler which is in operation is cleaned by way of introducing and igniting explosive bodies. With the

method described in the published document EP 1 067 349, a cooled explosive body is brought by way of a likewise cooled lance into the proximity of the fouled heating surface, where the explosive charge is ignited. The heat surface caking is blown away due to the impact of the detonation, as well as due to the wall oscillations produced by the shock waves. The cleaning time can be significantly shortened with this method in comparison to conventional cleaning methods. With the necessary safety precautions, the cleaning can take place during the operation of the incineration furnace, which is to say still in the hot state of the receptacle. Thus it is possible to clean a boiler in this manner within hours and without an operational interruption, for which conventional cleaning methods require days.

A cleaning method which likewise makes use of means for the production of an explosion is known from EP 1 362 213 B1. Instead of explosive, according to this method however a container envelope which is inflatable with an explosive gas mixture is attached onto the end of a cleaning lance. The cleaning lance then together with the empty container envelope is introduced into the boiler space and positioned in the proximity of the location to be cleaned. Subsequently, the container envelope is inflated with an explosive gas mixture. An explosion is produced by way of igniting the gas mixture in the container envelope, and the shock waves of this explosion lead to the detachment of fouling on the boiler walls, pipe bundles of heat exchangers and other heat exchangers. The container envelope is shredded and combusted by way of the explosion. It therefore represents a consumable material.

Compared to the aforementioned blasting cleaning with explosives, this method has the advantage that the method is less expensive with regard to operation and the procurement and handling of the mentioned gases in comparison to explosives requires no special permits or qualifications, so that anyone who has accomplished a corresponding training is capable of carrying out the method. Moreover, in contrast to explosives, there is no danger or at least a significantly reduced danger of damage to the facility structures given the application of explosive gas mixtures.

Common to the aforementioned cleaning methods is the fact that these are mobile cleaning methods whose associated cleaning devices need to be operated on location by trained personnel. These cleaning methods have the disadvantage that for the cleaning, one needs to mobilise personnel who in stages clean the individual regions of the interior of the receptacle or facility by way of the mobile cleaning devices.

Since the operator of the facility as a rule cannot provide his own, suitably trained personnel for this activity, such mobile cleaning as a rule is carried out by external companies. This is accordingly expensive and demanding. This also results in the cleaning only being carried

out periodically. The facility can therefore become contaminated to a great extent in the time interval between cleanings, by which means its operation becomes less efficient.

Apart from mobile cleaning methods, there are also permanently installed and completely automated cleaning systems which carry out cleaning in the interior of the receptacle or of the facility at regular intervals. These systems as a rule are installed on the boiler wall, e.g. in the region of a boiler door. A particular type of permanently installed cleaning system is the so-called pressure wave generators. The functioning principle of pressure wave generators is based on a closable burn-off chamber, in which in the closed state a combustible gas mixture is provided at a very high pressure, e.g. of several dozen bar, from case to case even several hundred bar, and a reaction initiated by way of a controlled ignition. The burn-off chamber is hereby opened around the point in time of the ignition of the combustible gas mixture, by which means the pressure wave which is generated by the ignition of the combustible gas mixture propagates into the interior of the receptacle or facility to be cleaned. The burn-off chamber as a rule is closed by a movable piston. Such a pressure wave generator is described for example in WO2019185736 A1.

However, the pressure wave generators have the disadvantage of a high wear, in particular of the moving parts, such as the closure piston. Amongst other things, this is due to the fact that the ignition is effected into the gas mixture which is at a very high pressure, wherein the pressure wave which comes from the detonation of the gas mixture corresponds to a multiple of the already very high starting pressure on ignition. The high detonation pressure together with the compression shocks which are feared with detonations and which propagate at supersonic speeds lead to a high wear.

For this reason, the pressure wave generators of a new generation are designed such that the reaction of the explosive gas mixture is no longer accompanied by a detonation. In contrast, the reaction corresponds to a deflagration which propagates as subsonic speed and therefore exerts a lower wearing effect upon the mechanical parts of the cleaning system.

It is an **object of a first aspect of the invention** to provide an installation for cleaning interiors of containers and facilities, said installation being able to be installed in a fixed manner, providing a good cleaning performance and in particular being low in wear. Moreover, the installation should be operable in a fully automated manner, so that no personnel need to be present on site for the cleaning.

The installation should accordingly comprise as few as possible parts and be low in maintenance.

Installations which are designed for cleaning by way of explosion technology as a rule are monitored by way of pressure sensors. The pressure sensors serve for example for detecting the explosion and thus the normal ignition of the gas mixture in the course of a cleaning cycle. Herewith, the absence of the ignition and therefore a failure of the cleaning cycle can be detected in an indirect manner.

Furthermore, pressure sensors can also serve for detecting misfiring, e.g. undesired backfiring from the interior of the receptacle or of the facility to be cleaned. A further application possibility is the monitoring of non-return devices such as non-return valves. Non-return devices are applied, in order to prevent the propagation of the explosion pressure wave into the introduction channels or feed conduits upstream. Non-return devices which no longer operate according to specification and permit the explosion pressure wave to propagate upstream in the introduction channels or in the feed conduit to a complete or partial extent, can be detected with the pressure sensors.

Common to all applications of pressure sensors on such installations is the fact that these measure the (gas) pressure in the gas-leading part of the installation. The pressure sensors are accordingly attached to the installation.

It has now been found that the pressure sensors are compromised by the high vibrations of the installation which inevitably arise in the course of a cleaning cycle given the explosion of the explosive gas mixture. This means that the pressure sensors have a comparatively short service life. Thus electrical contacts or electronic components in the pressure sensor can become damaged due to the structure-borne sound of the explosion which is transmitted further from the installation to the pressure sensor.

It is therefore the object of a **second aspect of the invention** to suggest a sensor device with a pressure sensor for determining the (gas) pressure in a gas-leading part of the installation, said sensor device being resistant to shaking, vibration and very generally structure-borne sound, as are generated given explosions.

The objects according to the two aspects of the invention are achieved by the features according to the claims.

The object is achieved by way of an installation for removing deposits in interiors of receptacles or facilities by way of explosion technology, wherein the installation comprises an explosion generator. The explosion generator in turn comprises:

- an explosion chamber;
- at least one inlet device with an inlet opening for admitting a gaseous substance into the explosion chamber for the purpose of providing an explosive gas mixture in the explosion chamber;
- an ignition device for igniting the explosive gas mixture in the explosion chamber;
- an outlet device with at least one outlet opening for letting out a pressure impulse for the purpose of removing deposits in the interior of the receptacle or of the facility.

According to the first aspect of the invention, the at least one outlet opening is open to the outside during the ignition and explosion of the explosive mixture. In particular, the outlet opening is open to the outside during the introduction of the explosive gas mixture into the receiving space. In particular, the outlet opening is open to the outside during a complete cleaning cycle.

A cleaning cycle in particular comprises the leading of the at least one gaseous substance into the explosion chamber of the explosion generator as well as the igniting of the explosive gas mixture and the subsequent explosion of the explosive gas mixture.

In particular, an explosion is characterised by the mechanical action of the sudden pressure and temperature increase, such increase occurring given a deflagration or detonation of the explosive gas mixture. The explosion can thus be the result of a detonation as well as a deflagration of the explosive gas mixture.

In particular, the at least one outlet opening is closure-free. This means that on operation the outlet opening is not temporarily closed via a closure element.

The explosion generator in particular is designed for the stationary installation on the receptacle or the facility, in particular on a wall of the receptacle or of the facility, said wall comprising a through-opening.

The term "stationary" in particular means that the explosion generator is assembled or installed on the receptacle or the facility in a fixed or stationary or permanent manner. In particular, the explosion generator is rigidly assembled or installed on a wall of the container or of the facility.

An installation according to the invention which is designed as a fixed installation has the advantage that this can be operated by the operator of the facility himself and in particular in a fully automated manner, so that no service team need be provided for the cleaning. Significant

costs can be saved by way of this. Moreover, by way of this one can carry out a more frequent cleaning, by which means the degree of contamination and thus the effort for an individual cleaning process can be kept within limits.

The automation of the cleaning installation according to the invention can also encompass an integrated process monitoring, concerning which measurement data, e.g. of sensors such as pressure sensors and/or temperature sensors as well as operating data such as the number of cleanings, points in time of cleaning, consumption of starting material, etc. of the cleaning installation can be acquired and evaluated in a central manner. Hence for example the data of several cleaning installations according to the invention of a facility or even the data of several cleaning installations according to the invention of different facilities can be centrally acquired and evaluated from the same location or from different locations.

The data can be acquired and evaluated by way of an IT platform, such as e.g. a cloud-based IoT (Internet of Things) platform. Accordingly, the data or the evaluations can be retrieved independently of location via external electronic devices, such as smartphones, laptops, tablets PC, etc and represented graphically.

By way of this, the operator or manufacturer of the cleaning installations can be continuously informed regarding the cleaning activity, any occurring errors or abnormalities, the condition of the cleaning installation as well as the current maintenance requirement, without having to be on site himself.

In particular, the explosion generator is designed in a multi-part manner and comprises a (wall outer-side) first component with the at least one inlet device, the explosion chamber and the ignition device, as well as a (wall inner-side) second component which forms the outlet device. The two components form a continuous explosion chamber in the assembled state.

"Wall outer-side" means that the component is arranged outside the interior of the receptacle or of the facility which is to be cleaned. "Wall inner-side" means that the component is arranged in the interior of the receptacle or of the facility which is to be cleaned. The outlet device of a fixed installation is therefore arranged in the interior of the receptacle or of the facility.

The first and second component can each comprise a fastening flange. Hence a first fastening flange is arranged on the first component, in particular at the wall side and in particular forms a wall-side closure of the first component. In particular, the fastening flange is arranged on the second part-body which is yet described hereinafter.

Furthermore, a second fastening flange is arranged on the second component, in particular at the wall side and in particular forms a wall-side closure of the second component. In particular, the fastening flange is arranged on the tubular gas receiving body of the second component which is yet described hereinafter.

"At the wall side" means towards the wall of the receptacle or of the facility in the installed state. With regard to the first component, this is synonymous with towards the second component in the installed state and with regard to the second component is synonymous with towards the first component in the installed state.

The two fastening flanged of the first and second component are directed towards one another in the installed state. In particular, in the installed state the two fastening flanges are directed towards the wall of the receptacle or of the facility and enclose this.

The first and second component are fastened to the wall of the receptacle or of the facility by way of the fastening flange, for fastening the explosion generator to the wall of the receptacle or of the facility. By way of this, the two components are indirectly connected with each other via the wall.

However, the first and second component can also be connected to one another in a direct manner via the fastening flange. In this case, the installation is fastened to the receptacle or to the facility or their wall in another manner.

The fastening of the components to the wall of the receptacle or of the facility, e.g. via the fastening flange is effected in particular by way of screw connections.

The fastening of the explosion generator or its components to the wall of the receptacle or of the facility is effected in particular via a door opening in the wall of the receptacle or of the facility. The explosion generator or its components can be fastened to the wall of the receptacle or of the facility e.g. via an assembly insert which is installed on the door opening and is with a through-opening.

According to a further development of the invention, the wall outer-side, first component in particular comprises a single-part basic body with an inlet-side, first part-body and a wall-side or outlet-side, second part-body.

The two part-bodies in particular enclose an obtuse angle in a manner such that the first component forms a bending in the transition from the first part-body to the second part-body. In particular, the bending is designed in a manner such that the first, inlet-side part-body leads away obliquely upwards in the installed state.

The wall-side, second part-body now in particular comprises a funnel-shaped widening. The funnel-shaped widening in particular is effected towards the outlet device or to the wall of the receptacle or of the facility. The funnel-like widening in particular coming from a mixing zone is effected towards the outlet device or towards the wall of the receptacle or of the facility.

In particular, the funnel-like widening of the first component ends or runs out in an outlet-side, physical interface for fastening the first component. The outlet-side physical interface comprises e.g. a fastening flange. In particular, the funnel-like widening ends or runs out with its largest cross section in the fastening flange.

The first component can be fastened to the receptacle or to a wall of the receptacle via the physical interface.

The first component can be connected to the second component via the physical interface.

The first component can be connected to the receptacle or the wall of the receptacle as well as to the second component via the physical interface.

The funnel-like widening in particular leads to a cross-sectional widening towards the outlet device or towards the wall of the receptacle or of the facility. For this reason, the funnel-like widening amongst other things serves for the enlargement of the explosion chamber towards the outlet opening. By way of this, a larger volume of explosive gas mixture can be provided in the explosion generator. The explosive gas mixture is at atmospheric pressure, in particular in the region of the funnel-like widening.

The funnel-like widening is characterised by a continuous enlargement of the flow cross section, by which means optimal flow conditions are achieved in the explosion chamber in contrast to a step-like cross-sectional widening.

The opening angle of the funnel-like widening is for example 60° or smaller, in particular 45° or smaller, very particularly 30° or smaller. The opening angle of the funnel-shaped

widening is for example 10° or larger, in particular 15° or larger and very particularly 20° or larger.

In particular, the explosion chamber forms a gas receiving channel for the explosive gas mixture, said gas receiving channel leading to at least one outlet opening.

According to a further development of the invention, the explosion chamber comprises at least one chamber section which is arranged in the wall outer-side first component, as well as at least one further chamber section which is arranged in the wall inner-side, second component of the explosion generator.

According to a further development of the invention, the explosion chamber comprises a first chamber section, a second chamber section which connects onto the first chamber section and a third chamber section. The explosion chamber in particular consists of the mentioned three chamber sections.

In particular, the second chamber section comprises a funnel-shaped widening. The angle of the funnel-shaped widening of the second chamber section in particular corresponds to an opening angle which is disclosed in the context of the second part-body. In particular, the third chamber section is part of the outlet device.

In particular, the first and second chamber sections are a constituent of the wall outer-side, first component. In particular, the third chamber section is a constituent of the wall inner-side component of the explosion generator.

The first chamber section in particular is a constituent of the inlet-side, first part-body and the second chamber section in particular is a constituent of the wall-side, second part-body of the wall outer-side, first component.

The first chamber section in particular forms the mixing zone which is yet described further below.

The at least one inlet device and the ignition device in particular are arranged on the inlet-side, first part-body.

In particular, the inlet opening of the at least one inlet device is arranged on the run-in (of the introduction channel) into the explosion chamber or into the first chamber section or into the mixing zone of the explosion chamber.

The ignition device is effective in ignition in particular in the first chamber section or in the mixing zone of the explosion chamber.

The ignition of the explosive gas mixture can be effected with means which are known from the state of the art. Preferably, this is effected by way of electrically activated spark ignition, by way of auxiliary flames or by way of pyrotechnical ignition with the help of suitably arranged ignition means of the ignition device. In particular, the ignition device is an electrical ignition device. This is characterised in that this is designed for the ignition of an ignition spark or in particular an electric arc.

However, it is also conceivable for the ignition device to comprise an ignition chamber or antechamber, in which a gas mixture is brought into deflagration or explosion. The deflagrating or exploding gas mixture activates the explosion or detonation in the explosion chamber. The onward transmission of the deflagration or explosion into the explosion chamber can be effected by way of suitable flow-technological means, such as a through-ignition conduit.

The ignition device is connected via an ignition lead to a control device which is yet described hereinafter.

According to a further development of the invention, the wall inner-side component comprises an in particular one-part basic body. In particular, the basic body comprises a tubular gas receiving body. In particular, the tubular gas receiving body is a pipe which runs in a straight line and is of an in particular round, such as circular cross section.

In particular, the tubular gas receiving body extends perpendicularly from the wall into the interior of the receptacle or of the facility.

An outlet body can connect onto the tubular gas receiving body at one end, in particular at its end which is remote from the wall. The outlet body forms the at least one outlet opening. In particular, the outlet body is part of a single-part basic body.

The tubular gas receiving body can also form a free end which is remote from the wall and which forms the outlet opening.

At its end which faces the wall, the basic body or the gas receiving body in particular forms the fastening flange.

In particular, the installation is designed for forming a cloud of explosive gas mixture in the interior of the receptacle or of the facility. Since the cloud formation is influenced by the geometry of the outlet device, the outlet device or the outlet body in particular is designed such that an optimal cloud formation with as little as possible intermixing of the explosive gas mixture with the surrounding atmosphere is effected. Thus it has been found that the geometry of the outlet device has an effect on the flow conditions given the exit of the explosive gas mixture from the at least one outlet opening.

Furthermore, it is also advantageous if the recoil which is activated by the explosion pressure wave and which acts upon the fastening on the receptacle or on the facility can be kept as low as possible.

According to an embodiment, the tubular gas receiving body with the outlet opening is designed such that the explosion pressure wave and/or the explosive gas mixture flow through the outlet opening is parallel to the longitudinal axis of the tubular gas receiving body.

According to a further development of the invention, the wall inner-side component however comprises an outlet body with the at least one outlet opening, said outlet body connecting onto the tubular gas receiving body.

The outlet body with the at least one outlet opening can be designed such that the explosion pressure wave and/or the explosive gas mixture in the outlet body is deflected or diverted out of the longitudinal axis of the tubular gas receiving body. Accordingly, the exit direction through the at least one outlet opening runs at in particular acute angle to the longitudinal axis of the tubular gas receiving body. This angle can be e.g. 10° or more, 20° or more, 30° or more, in particular 45° or more and very particular 60° or more. According to a particular embodiment, the angle is 90°. The at least one outlet opening is herein directed towards the side.

According to a further development of the invention, the outlet body comprises at least two and in particular precisely two outlet openings. The at least two outlet openings in particular lie in a common plane. In particular, the plane is aligned vertically in the installed state of the explosion generator.

In particular, the outlet body is designed in a mirror-symmetrical manner with the (middle) longitudinal axis of the tubular gas receiving body as the axis of symmetry. The at least two outlet openings are accordingly likewise arranged mirror-symmetrically to one another with the (middle) longitudinal axis of the tubular gas receiving body as the axis of symmetry. The exit

direction for the explosion pressure wave or for the explosive gas mixture through the outlet openings runs at an angle to the longitudinal axis of the tubular gas receiving body. In particular, the angle is identical for the at least two outlet openings.

In particular, the outlet device or the outlet body is designed to simultaneously form at least two separate clouds of explosive gas mixture via the at least two outlet openings in the course of a cleaning cycle.

Given a total volume of generated explosive gas mixture which remains the same, the volumes of these clouds are accordingly dimensioned smaller. The clouds can have a volume e.g. of 110 litres or smaller, of 50 litres or smaller, and in particular of 40 litres or smaller, of 20 litres or smaller or of 10 litres or smaller. The clouds can have a volume e.g. of 1 litre or larger, of 10 litres or larger and in particular of 20 litres or larger.

Smaller clouds have the advantage that the losses due to de-mixing in the edge zones are smaller, in particular given a strong flow in the surrounding atmosphere, so that a comparatively high explosion force is achieved despite the low size of the cloud. Moreover, the time for the formation of smaller clouds is shorter. By way of this, on the one hand the danger of self-ignition at high temperatures is lower. On the other hand, short cloud formation times are advantageous given pulsed explosions.

The generation of several smaller clouds further has the advantage that the explosion generator can be designed smaller.

If moreover the explosive gas mixture which is generated in a cleaning cycle is not ignited in a controlled manner due to malfunction, then the cloud which is not brought to an explosion is either intermixed with the surrounding atmosphere or merely burns off due to the heat on the incineration boiler.

According to an embodiment, the outlet device is designed in a T-shaped manner. This comprises the tubular gas receiving body and two tubular outlet conduits of the outlet body which branch from this each at an angle of 90° to the longitudinal axis of the gas receiving body. The outlet conduits form a corresponding bending or pipe arching.

By way of this, the outlet body forms two outlet opens which are each directed to one side. According to this embodiment, the gas flow in the outlet body and each part-flow is deflected to the side by 90°. The T-shaped design of the outlet device has the advantage that the recoil forces mutually cancel due to the outlet openings which lie opposite one another.

According to a further embodiment, the outlet device comprises an outlet body with two tubular outlet conduits which coming from a branching lead away laterally in an oblique manner and mutually enclose an acute angle of 90° or smaller and thus in particular form a V-shaped arrangement. In particular, the two outlet conduits are arranged in a mirror-symmetrical manner about a middle longitudinal axis. Accordingly, the outlet body forms two outlet openings which are each directed laterally in an oblique manner. According to this embodiment, the gas flow divides in the outlet body and is deflected to the side each at an acute angle.

According to a particular further development of this embodiment, the outlet device is designed in a Y-shaped manner and comprises a tubular gas receiving body and two tubular outlet conduits of the outlet body which at a branching each branch from the gas receiving body at an acute angle of less than 90° to the longitudinal axis of this gas receiving body.

Such an outlet device amongst other things has the advantage that the recoil forces partly cancel one another out.

According to a particular variant, the opening plane of the outlet openings in particular runs parallel to the middle longitudinal axis or to the longitudinal axis of the tubular gas receiving body. Such a geometry acts positively on the flow conditions in the region of the outlet opening.

The outer diameter of the tubular gas receiving body can be e.g. 5 cm or larger, 10 cm or larger and in particular 15 cm or larger. The outer diameter of the tubular gas receiving body can be e.g. 30 cm or smaller and in particular 25 cm or smaller.

The gas receiving body can have a length of 250 cm or less, 150 cm or less, 100 cm or less, 50 cm or less or 20 cm or less.

The gas receiving body can have a length of 10 cm or more, 20 cm or more, 50 cm or more, 100 cm or more or 150 cm or more.

The total length of the outlet device can be 300 cm or less, 250 cm or less, 200 cm or less, 150 cm or less, or 100 cm or less.

The total length of the outlet device can be 50 cm or more, 100 cm or more, 150 cm or more, or 200 cm or more.

In particular, the at least one inlet device comprises an inlet fitting for the controlled inlet of the gaseous substance into the explosion chamber. In particular, the inlet fitting is or comprises an inlet valve. The inlet valve can be a magnet valve or a pneumatic valve. Both valves are characterised by short switching times.

In particular, the inlet fitting is a metering fitting for the metered inlet of the gaseous substance into the explosion chamber.

In particular, the at least one inlet fitting is arranged on or attached to the basic body or the first part-body of the wall outer-side, first component of the explosion generator.

In particular, the explosion generator or the wall outer-side, first component of the explosion generator or its basic body forms an inlet-side, physical interface with at least one feed opening for connecting the inlet fitting of the at least one inlet device. The inlet-side physical interface can be designed e.g. as a basic body connection plate, in which the at least one feed opening is arranged.

The at least one inlet fitting can be connected to the basic body or to its basic body connection plate via a fitting connection plate, e.g. by way of screw connections.

According to a further development of the invention, the at least one inlet device comprises a non-return device. The non-return device is to prevent the explosion pressure wave from moving upstream through the introduction channels or feed conduits in the direction of the storage container. Moreover, the non-return device in particular should also protect the inlet fitting or the sensitive parts of the inlet fitting from the explosion pressure wave.

The non-return device thus closes the feed conduit or the introduction channel given the occurrence of a pressure force which is directed upstream, as occurs for example given a gas flow which is directed upstream or given an explosion pressure wave.

The non-return device can be designed as a non-return valve. The non-return device can be part of the inlet fitting. In particular, the non-return device is arranged downstream of the inlet valve. The non-return device however can also be designed independently of the inlet fitting and be arranged e.g. downstream of the inlet fitting.

In particular, the inlet opening of the at least one inlet device is arranged after the inlet fitting and possibly after the non-return device. In particular, the inlet opening defines the inlet cross section for the gaseous substance in the explosion chamber.

The explosive gas mixture which is formed from the at least one gaseous substance in particular comprises a combustible as well as an oxidant, such as e.g. (gaseous) oxygen.

The combustible can be liquid or gaseous. This can be e.g. of the group of combustible hydrocarbons, such as acetylene, ethylene, methane, ethane, propane, petrol, diesel, oil, etc. The combustible however is preferably a gas, such as acetylene, ethylene, methane, ethane or propane and very particularly natural gas.

According to a first variant, the explosive gas mixture can be formed from a gaseous substance which is led into the explosion chamber. This means that the introduced gaseous substance already forms the explosive gas mixture.

According to a second, preferred variant, the explosive gas mixture is formed from at least two, in particular precisely two gaseous substances, also called components, which are led into the explosion chamber in a separate manner. The at least two gaseous substances are mixed with one another into an explosive gas mixture in a mixing zone of the explosion chamber.

Gaseous substance means that this is present in gas form on forming the explosive gas mixture in the explosion chamber and in particular already on introduction into the explosion chamber. The at least one gaseous substance, also called starting substance or starting component, can however also be present in liquid form under pressure in the storage container. In particular, the at least one gaseous substance, in particular a combustible, can also be a rapidly evaporating liquid.

Thus e.g. a first gaseous substance can be an oxidant and a second gaseous substance a combustible.

The first gaseous substance is e.g. (pure) oxygen or an oxygen-containing gas, such as e.g. air. Since an explosion is to be generated by way of a detonation of the explosive gas mixture by way of the installation, in particular the oxidant is (pure) oxygen. In particular, the second gaseous substance is an aforementioned combustible.

Hence the installation according to the first variant comprises at least two and in particular precisely two inlet devices for admitting at least one first and second and in particular precisely one first and second gaseous substance into the explosion chamber for generating the explosive gas mixture in the explosion chamber. The explosion chamber herein forms a mixing zone for mixing the explosive gas mixture from the at least two gaseous components.

Thus in particular a first inlet device is provided for admitting the oxidant and a second inlet device for admitting the combustible.

According to a further development of the invention, the first and second inlet opening of the at least two inlet devices have a different inlet cross section. The inlet openings herein in particular act as orifices which limit the volume flow of the gaseous substance which flows into the explosion chamber.

The size of the inlet cross sections of the first and second inlet opening in particular is selected such that the first and the second gaseous substance flow into the explosion chamber in a stoichiometric ratio.

Thus in particular the inlet cross section of the inlet opening of the first inlet device, by way of which the oxidant is admitted into the explosion chamber, is larger than the inlet cross section of the inlet opening of the second inlet device, by way of which the combustible is admitted into the explosion chamber.

According to a particular further development of the invention, the at least two inlet devices are designed, or the inlet openings of the at least two inlet devices arranged, such that the at least one first and second gaseous substance flow into the explosion chamber at an angle, in particular at a right angle to one another.

The inlet device, in particular the first inlet device in particular is arranged or designed with its inlet opening such that the gaseous substance, in particular the gaseous oxidant flows into the explosion chamber with a flow component which is directed to the outlet opening or flows into the gas receiving channel at the face side, said gas receiving channel being formed by the explosion chamber.

The inlet device, in particular the second inlet device, with its inlet opening in particular is arranged or designed such that the gaseous substance, in particular the gaseous combustible flows into the gas receiving channel in a lateral or transverse manner.

In particular, the at least one inlet device comprises an introduction channel for leading the gaseous substance into the explosion chamber. In particular, the introduction channel runs in the basic body of the first component. In particular, the introduction channel begins at the feed opening in the basic body. In particular, the introduction channel ends at the inlet opening at the end of the introduction channel at the run-in into the explosion chamber.

According to a further development of the invention, a first inlet device comprises a first introduction channel for leading a first gaseous substance into the explosion chamber and a second inlet device comprises a second introduction channel for leading a second gaseous substance into the explosion chamber. In particular, the end sections of the introduction channels which each run out into the inlet opening are arranged at an angle, in particular at a right angle to one another.

The end section of an introduction channel which runs into the inlet opening, in particular of the first introduction channel in particular has a direction component which is directed towards the outlet opening.

The feeding of the one gaseous substance, in particular of the combustible according to the cross-flow principle ensures a good intermixing of the gaseous substances into an explosive gas mixture, said substances being led into the explosion chamber. The good intermixing in particular is based on turbulent conditions which are created given the transverse inflow of the one gaseous substance.

According to the second aspect of the invention, the installation comprises at least one sensor device with a pressure sensor for measuring a (gas) pressure in a gas-leading part of the installation.

The object according to the second aspect of the invention is achieved by way of the sensor device comprising a pressure transmission conduit which connects the pressure sensor to the gas-leading part of the installation, wherein at least one conduit section of the pressure transmission conduit is designed in a flexible and in particular bendable manner. In particular, the flexible conduit section herein serves as a structure-born noise damping.

The pressure sensor is therefore not arranged at or on the gas-leading part of the installation in a direct manner, but is distanced to this part via the pressure transmission conduit. In particular, the pressure transmission conduit is an elongate conduit element which projects laterally from the gas-leading part of the installation.

In particular, the pressure transmission conduit is an elongate hollow body. The pressure transmission conduit can comprise one or more rigid conduit sections which are designed as a pipe.

In particular, the pressure transmission conduit is of metal.

In particular, the at least one flexible conduit section of the pressure transmission conduit which is essential to the invention in the context of the second aspect of the invention is designed as a hose. The hose, although being bendable, it is in particular also self-supporting, i.e. intrinsically stable.

In particular, the at least one flexible conduit section is of metal, such as stainless steel. In particular, the at least one flexible conduit section comprises a flexible corrugated hose.

According to a further development of the at least one flexible conduit section, this is constructed in a multi-layered manner. The multi-layered flexible conduit section in particular comprises an inner-lying hose and an outer-lying hose which surrounds the inner-lying hose.

In particular, the inner-lying hose is of metal. In particular, the inner-lying hose is a corrugated hose. However, the inner-lying hose can also be of plastic, such as e.g. of a polytetrafluorethylene (PTFE).

In particular, the outer-lying hose is of metal. In particular, the outer-lying hose is a braided hose.

According to a particular embodiment, the multi-layered, flexible conduit section comprises an inner-lying corrugated hose of metal and an outer-lying braided hose of metal which surrounds the corrugated hose.

In particular, the pressure sensor is arranged at the free end of the pressure transmission conduit. In particular, the pressure sensor can be screwed to the pressure transmission conduit via a screw connection. The pressure transmission conduit for its part can be screwed to a suitable connection on the explosion generator via a screw connection.

The pressure transmission conduit can comprise a shield. The shield e.g. can serve to shield the pressure sensor from the heat of an explosion. The shield can also serve for weakening the pressure shocks in the pressure transmission conduit, such shocks being generated with the explosion.

In particular, the pressure sensor is a pressure transmitter or pressure transducer, as is known from the state of the art and is marketed e.g. by the company Trafag AG.

In particular, the pressure transmitter comprises a pressure transducer which via a physical principle converts pressure or a pressure change into an electrical signal. Furthermore, the pressure transmitter in particular comprises transducer electronics which process the sensor signal and converts it into a standardised electrical output signal. The output signal is provided at an electrical terminal. The pressure upon the pressure transducer is applied via the pressure transmission conduit. In particular, the pressure transducer and electronics are accommodated in a housing which protects these sensitive components from environmental influences and connects them to the electric terminal as well as the pressure transmission conduit.

The application of a pressure transmission conduit which is flexible at least in sections and in particular is designed as a hose effects a damping of the structure-born noise or the vibrations which are activated by the explosion of the explosive gas mixture in the explosion chamber. Thus the structure-borne noise or the vibrations are absorbed to a large extent by the flexible conduit section of the pressure transmission conduit.

The gas-leading part of the installation can comprise e.g. the non-return device or the inlet fitting, in which the non-return device is integrated. The pressure transmission conduit is connected to the non-return device or to the inlet fitting in a manner such that the gas pressure in a gas-leading region of the non-return device or of the inlet fitting can be measured by way of the pressure sensor. In this case, the pressure sensor serves for example for the monitoring of the non-return device. Hence e.g. one can deduce whether the non-return device functions correctly or not from the determined pressure measurement values.

The gas-leading part of the installation can be the explosion chamber of the installation. The pressure transmission conduit is connected to the explosion chamber such that the gas pressure in the explosion chamber can be measured by way of pressure sensor. The pressure sensor in this case serves for example for monitoring the ignition in the gas receiving space by the ignition device. Hence e.g. from the determined pressure measurement values one can deduce whether an explosion and thus an ignition of the gaseous explosive gas mixture has taken place or not in the explosion chamber during a cleaning cycle. Here the pressure sensor serves for monitoring the ignition.

The sensor device according to the second aspect of the invention can be applied for example in an installation or an associated explosion generator as is described further above. In particular, the aforementioned sensor device can be applied in an installation or in an associated explosion generator according to the first aspect of the invention.

The sensor device according to the second aspect of the invention however can very generally be applied to installations for cleaning interiors of receptacles or facilities by way of explosion technology, by way of which in particular an explosive gas mixture is brought to explosion or deflagration. Hence the sensor device according to the second aspect of the invention can also be applied to pressure wave generators with a closure element, such as a closure piston, as is described for example in WO2019185736 A1.

Furthermore, the sensor device according to the second aspect of the invention is also applied in mobile cleaning appliances as are described for example in WO 2014/121409 or WO 2015/120563. These systems are characterised by a cleaning lance and possibly also by a container envelope which is attached to the cleaning lance and which is filled with the explosive gas mixture.

The installation further in particular comprises at least one storage container for storing the at least one starting material. The term starting material is used here since the at least one gaseous substance which is led into the explosion generator does not need to be present in the storage container in a gaseous manner. Hence in particular the storage container is a pressure container, in which the starting substance is present under pressure in liquid form.

The storage container is connected to the at least one inlet device of the explosion generator via a feed conduit for the purpose of leading the at least one starting material or gaseous substance out of the at least one storage container into the explosion chamber of the explosion generator.

The at least one storage container, in particular together with a control device can be part of a metering unit for the metered admission of the at least one gaseous substance into the explosion chamber. In the installed state, the metering unit is arranged in particular in the proximity of or very particularly directly at the explosion generator, e.g. on the wall of the receptacle or of the facility at the outer side.

In particular, the at least one feed conduit is designed in a flexible manner and very particularly as a hose. The at least one feed conduit can be constructed in a multi-layered manner and for example comprise an inner-lying, gas-tight first hose and an outer-lying second protective hose which surrounds the inner-lying, gas-tight hose, or consist of such. In particular, the outer-lying hose is a protective hose.

The inner-lying hose can consist of plastic, such as PTFE or of metal and be e.g. a corrugated hose. The outer-lying hose can be a braided hose, in particular of metal.

If the explosive gas mixture is created in a mixing zone of the explosion chamber from at least two or of two gaseous substances, then the installation comprises at least one first storage container with a first feed conduit for the first gaseous substance and a second storage container with a second feed conduit for the second gaseous substance, for respectively leading the at least one first and second gaseous substance into the explosion chamber via the feed conduits.

The storage containers can be designed as metering containers which each contain the quantity of starting material which is necessary for a cleaning cycle.

In turn, the at least one storage container can be connected to a gas store, from which the at least one storage container is supplied with the starting material e.g. from gas bottles. The storage containers thus have a significantly lower storage capacity than the respective gas bottles in the gas store.

A metering unit which is arranged between the explosion generator and the gas store has three essential advantages:

1. The storage of the starting materials in the gas store can be effected at a secured location and at a distance to the operative running of the explosion generator. It is only the quantity of starting material which is necessary for one or very few cleaning cycles which is (intermediately) stored in the at least one storage container of the metering unit. The overall safety is increased by way of this.
2. Since the at least one storage container of the metering unit only receives the quantity of starting material which is necessary for one or a very few cleaning cycles, its size is comparatively small. This permits the placement of the metering unit in the proximity of or directly at the explosion generator, even given restricted spatial conditions.
3. The at least one starting material can be led into the explosion chamber of the explosion generator from at least one storage container of the metering unit via a short feed conduit. The short feed conduit permits a rapid leading of the at least one starting material into the explosion chamber amid a low pressure loss. This permits a pulsed operation of the explosion generator.

According to a preferred embodiment, the installation is designed for leading explosive gas mixture into the interior of the receptacle or of the facility and for forming a cloud of the explosive gas mixture in the interior of the receptacle or of the facility.

This means that a part of the explosive gas mixture which is provided in the course of a cleaning cycle is led into the interior of the receptacle or of the facility via the outlet opening of the explosion generator. Herein, the cloud of explosive gas mixture is formed in the interior. This cloud is brought to explosion in the explosion chamber by way of igniting the explosive gas mixture.

In particular, the cloud is characterised in that this in the interior is not separated with respect to the surrounding atmosphere via physical means or via a barrier, such as e.g. a container envelope. In contrast, the edge region of the cloud is in direct contact with the surrounding atmosphere.

In particular, the installation also comprises a control device. The control device amongst other things in particular serves for the control of the ignition device. The control device further in particular serves for the control of the at least one inlet fitting for leading the at least one gaseous substance into the explosion chamber. In particular, the control device is designed for a metered introduction of the at least one, in particular of the at least two gaseous substances so that these are admitted into the explosion chamber e.g. in a stoichiometric ratio. The control device consequently serves for the generation of the explosive gas mixture and in particular also for the formation of the cloud. The control of the at least one inlet fitting as well as the ignition device is matched to one another with regard to control technology.

The invention now also relates to a method for removing deposits in interiors of receptacles and facilities by way of explosion technology amid the use of an aforementioned installation. The method comprises the following steps:

- leading at least one gaseous substance into the explosion chamber;
- providing an explosive gas mixture from the at least one gaseous substance in the explosion chamber;
- controlled igniting of the explosive gas mixture in the explosion chamber by way of the ignition device, wherein the explosive gas mixture is brought to explosion.

In particular, the at least one gaseous substance is led from the storage container into the explosion generator via a feed conduit.

In particular, the at least one outlet opening is open to the outside during the introduction of the at least one gaseous substance as well as during the ignition and explosion of the explosive gas mixture.

Preferably, a part of the explosive gas mixture which is provided in the explosion chamber flows into the interior of the receptacle or of the facility via the at least one outlet opening, wherein a cloud of the explosive gas mixture is formed in the interior.

The total volume of explosive gas mixture which consists of the explosive gas mixture in the explosion chamber and possibly in the cloud is provided or generated and brought to explosion in a controlled manner in particular in a time period of 1 second or less, preferably 0.5 seconds or less, in particular 0.1 seconds or less. A time period of 0.01 to 0.2 seconds has been found to be optimal.

The mentioned time period in particular encompasses the leading of the at least one gaseous substance into the explosion chamber and the igniting of the explosive gas mixture in the explosion chamber by the ignition device.

The mentioned time period in particular is computed from the opening of the inlet fitting(s) for leading the at least one gaseous substance into the explosion chamber until the closing of the inlet fitting(s) for the purpose of ending the introduction and igniting of the explosive mixture. The ignition and consequently the explosion of the explosive gas mixture, with regard to control technology in particular are matched to the point in time of the closure of the inlet fitting(s). In particular, the ignition is effected directly after the closure of the metering fittings. In particular, the ignition at most has a very short delay.

The very short cycle times permit the generation of pulsed explosions. Pulsed explosions means that a plurality of explosions is generated successively in short time intervals.

Thus one or more explosions can be generated e.g. within a second. It is thus possible to generate 2 to 10 explosions within a second. Pulsed explosions have the advantage that these can produce vibrations in the facility or in the receptacle, such vibrations assisting in the cleaning process.

According to a preferred further development of the invention, at least two, in particular precisely two gaseous substances are led into the explosion chamber of the explosion generator. The at least two gaseous substances are intermixed into an explosive gas mixture in a mixing zone of the explosion chamber.

The at least two gaseous substances are each led from a storage container into the explosion chamber each via at least one inlet fitting, in particular in a stoichiometric ratio to one another.

In particular, the explosive gas mixture is ignited in the mixing zone in a controlled manner by the ignition device. In particular, the explosion which is led into the explosion chamber is transmitted onto the cloud of the explosive gas mixture outside the explosion generator.

During the introduction of the at least one gaseous substance up to the ignition of the explosive gas mixture in the explosion chamber, in particular a maximal gas overpressure of 100 kPa (1 bar), in particular of 50 kPa (0.5 bar), very particularly of 20 kPa (0.2 bar) is built up in the explosion chamber.

The overpressure corresponds to the pressure difference between the actual pressure and the (atmospheric) ambient pressure. The ignition of the explosive gas mixture in particular is effected in the aforementioned overpressure conditions.

The mentioned overpressures are comparatively small in comparison to the overpressures which are built up in the closed burn-off chambers of conventional pressure wave generators. This is due to the fact that the outlet opening remains open during the complete cleaning cycle

At first glance, this appears to be disadvantageous since the starting pressure enters the computation of the expected pressure of the explosion as a multiplier. Hence the explosion pressure is a multiple of the starting pressure of the explosive gas mixture before the explosion. The explosion pressure can be for example 25-fold the starting pressure. If now the explosive gas mixture has an overpressure, then the explosion pressure also increases by the corresponding multiple. Accordingly, the explosion pressure and hence the cleaning effect is very much higher if the explosive gas mixture which is brought to ignition has an overpressure in the cleaning apparatus.

For this reason, it is also the object of conventional pressure wave generators to build up a high as possible starting pressure in a closed burn-off chamber, said starting pressure on ignition leading to an accordingly high pressure wave whose pressure reaches a multiple of the starting pressure. Since conventional pressure wave generators have moving parts, such as closure pistons, a detonation of the explosive gas mixture however is undesirable. Otherwise a damage to or high wear of the moving parts is to be expected.

Since with regard to the pressure wave generator, the explosion or detonation takes place within the explosion chamber which is closed on ignition, concerning the explosion generator, the cleaning effect is not produced by the explosion or detonation itself, but by the pressure wave

which originates from this. However, pressure wave generators with a closure system have outflow losses, so that the pressure waves which are generated with the installation according to the invention without outflow losses are equally high or even higher despite the much lower starting pressure. According to the installation according to the invention, furthermore the explosion or detonation which acts through the open outlet opening or the explosion or detonation of the cloud also contributes directly to the cleaning effect.

In contrast, the explosion of the explosive gas mixture is activated with the method according to the invention preferably by way of a detonation of the explosive gas mixture which propagates at supersonic speed and in a manner coupled to a shock wave.

Despite a comparatively low starting pressure, a higher cleaning effect is achieved with an explosion which is activated by a detonation. Since the explosion generator has no moving parts in the region of the explosion chamber, this is also resistant with regard to detonations.

According to a variant of the invention, the cloud of explosive gas mixture has not yet formed or is not yet completely formed at the point in time of the ignition. Hence, the explosion pressure wave which propagates or moves in the direction of the at least one outlet opening with the ignition of the explosive gas mixture in the explosion chamber, in particular in the mixing zone can effect the expulsion of explosive gas mixture through the at least one outlet opening, so that a cloud of explosive gas mixture forms or is formed completely.

The impact of the explosion and the surface, e.g. a receptacle wall or pipe wall which is brought into oscillation by the shock waves effect the blasting-away of the wall caking and slagged deposits and thus the cleaning of the surface.

The quantity of the explosive gas mixture which is provided in a cleaning cycle is selected such that an optimal cleaning effect is achieved without however damage to installations arising. Thus for example 220 litres of explosive gas mixture is generated per cleaning cycle in the explosion generator according to the invention.

Similarly to a combustion engine, a cleaning and explosion cycle can be divided into different “strokes”. In a first stroke, the inlet fitting(s) to the explosion chamber is/are opened and the at least one gaseous substance is led under pressure into the explosion chamber of the explosion generator and an explosive gas mixture is provided in the explosion chamber. As the case may be, a cloud is additionally formed outside the explosion generator via the outlet opening.

After introducing the predefined quantity of gaseous substance, the at least one inlet fitting is closed. Subsequently to this, the ignition is activated and the formed total volume of explosive gas mixture is brought to explosion in a second stroke. Subsequently to the explosion, an explosive gas mixture can be generated in the explosion chamber by way of a renewed opening of the at least one inlet fitting.

Preferably, after the explosion has been effected, at least one introduction channel and possibly also the explosion chamber of the explosion generator is rinsed with a scavenging gas.

The rinsing with scavenging gas is to prevent the backflow of exhaust gases into the at least one introduction channel and in particular up to the at least one inlet fitting. The exhaust gases are expelled or driven out of the at least one introduction channel and in particular out of the explosion chamber by way of the scavenging gas.

The cooling, hot exhaust gases could otherwise condense out in the explosion generator and in particular in the at least one introduction channel and lead to corrosion, in particular to corrosion at the at least one inlet fitting.

In particular, the scavenging gas is a non-combustible gas. In particular, the scavenging gas is air or compressed air. The compressed air can be obtained from an existing compressed air supply.

In particular, considered downstream, the scavenging gas is fed in to the introduction channel after the inlet fitting. By way of this, the backflow of exhaust gases to the inlet fitting is prevented.

In particular, considered downstream, the scavenging gas is fed in front of the associated inlet opening.

In particular, the scavenging gas is fed into the introduction channel between the inlet fitting and a non-return device which is arranged further downstream.

In particular, the scavenging gas is fed into the introduction channel for the gaseous oxidant. Alternatively or additionally, the scavenging gas can be fed into the introduction channel for the gaseous combustible.

If the gaseous combustible is led into the explosion chamber transversely to the gaseous oxidant, a scavenging gas feed into the introduction channel of the gaseous oxidant can be

sufficient, in order to prevent the flowing of exhaust gases into the introduction channel for the gaseous combustible.

For this, the explosion generator in particular comprises at least one connection device for connecting a scavenging gas conduit. The connection device can comprise a non-return device in order to shield the scavenging gas conduit from the pressure of the explosion.

The control of the quantity of gaseous substance which is to be introduced, which is to say its metering which e.g. in the case of two or more gaseous substances is to be in a stoichiometric ratio, can be effected in different manners.

Thus the metered introduction of the at least one gaseous substance can be effected according to the principle of the differential pressure method, as is described e.g. in WO 2015/120563. Thus the respective nominal residual pressure or differential pressure can be determined from the quantity of gaseous substance which is to be introduced and on the basis of a known maximal pressure in a metering or storage container with a known storage volume at the beginning of the introduction procedure. The metering fitting(s) via the control device are opened until the nominal residual pressure is measured via the pressure sensor. The pressure sensor is accordingly connected to the control device.

The control of the quantity which is to be introduced and which e.g. in the case of two or more gaseous substances is to be in a stoichiometric ratio can also be effected via the opening time of the metering fittings, thus in a time-controlled manner.

Hence, on the basis of a known maximal pressure at the beginning of the introduction procedure as well as the known filling volume of the storage container, the gas speed or the gas flow through the inlet fitting can be determined by calculation or empirically. From this, one can derive a direct relation between the opening time and the introduced gaseous substance. The predefined opening time of the at least one inlet fitting is controlled via the control device.

In particular, the storage containers have an overpressure of maximally 20 bar or less. Thus an overpressure of 10 to 20 bar can be provided. Since the respectively introduced, gaseous substance has a comparatively low (over)pressure in the explosion chamber, despite this the mentioned pressures in the storage containers permit the introduction of the gaseous substance into the explosion chamber at high speed.

Thus the at least one gaseous substance can be introduced with an average speed of over 50 m/s (metres per second), in particular over 100 m/s, advantageously over 200 m/s. However,

the speed can even locally exceed the speed of sound, e.g. in the region of abrupt cross-sectional widenings. Such abrupt cross-sectional widenings occur e.g. in the region of the valves or of the non-return devices or inlet openings.

Since less strict safety regulations apply to storage containers with a maximal overpressure of 20 bar or less, the service costs or the service expense reduces, e.g. due to the absence of regular inspections.

One can envisage the at least one storage or pressure container not being completely emptied, i.e. down to atmospheric pressure. Thus the residual pressure in particular has an overpressure. The residual pressure can be e.g. 5 bar or more, in particular 10 bar or more, such as e.g. 10 to 15 bar. Thanks to the high residual pressure, one achieves high speeds on introduction. This is the case for example given the introduction according to the differential pressure method.

The installation according to the invention in particular is installed in the region of wall surfaces of combustion chambers or incineration boilers, of heat recovery boilers or empty passes of waste incineration facilities, of thermal power stations, or generally of combustion boilers.

The installation according to the invention and the associated method in particular serve generally for the cleaning of wall surfaces, pipe bundles, heat exchangers in the aforementioned facilities. The installation according to the invention and the associated method can also be applied for cleaning catalysers in flue gas cleaning devices.

The installation according to the invention and the associated method can moreover also serve for the cleaning e.g. for removing adhering deposits and encrustations of hardened cement in interiors of devices for the manufacture, storage and/or transport of flowable cement. Such devices can be e.g. mobile mixers (cement mixers) or cement mixing facilities.

The subject-matter of the invention is hereinafter explained in more detail by way of preferred embodiment examples which are represented in the accompanying drawings. In each case shown schematically are:

Figure 1: a lateral view of an installation according to the invention, with an explosion generator which is installed on a receptacle or facility;

Figure 2: a front elevation of the installation according to Figure 1;

- Figure 3: an enlarged detail of the installation according to the invention according to Figure 1, from the region of the explosion generator;
- Figure 4a: a perspective view of an explosion generator according to the invention,
- Figure 4b: the perspective view according to Figure 4a with a page view;
- Figure 5: a first embodiment of an outlet device;
- Figure 6: a second embodiment of an outlet device;
- Figure 7a: a perspective view of the basic body of the wall outer-side, first component of an explosion generator;
- Figure 7b: a second perspective view of the basic body according to Figure 7a;
- Figure 8: a perspective view of a first embodiment of a pressure transmission conduit of a sensor device according to the invention, according to the second aspect of the invention;
- Figure 9: a perspective view of a second embodiment of a pressure transmission conduit of a sensor device according to the invention, according to the second aspect of the invention;
- Figure 10: a sectioned view of the construction of a flexible pressure transmission conduit;
- Figure 11: a detailed view of the corrugated hose according to Figure 10.

Basically, in the figures the same parts are provided with the same reference numerals

Certain features are not represented in the figures for a better understanding of the invention. The described embodiment examples are exemplary of the subject-matter of the invention.

Figures 1 to 3 schematically show a facility 50 with an interior 51 which is to be cleaned and in which a pipe bundle 52 of a heat exchanger is located. The explosion generator 2 of a installation 1 according to the invention is fixedly installed on the wall 54 of the facility 50 in the region of a through-opening 53 in the wall 54 of the facility 50 via an assembly insert 55 (see also Figure 3).

The explosion generator 2 is described in detail further below by way of a detail view according to Figure 4a and 4b.

Apart from the explosion generator 2 which is fixedly installed on the wall 54 of the facility 50, the installation 1 comprises a supply device 30. The supply device 30 comprises a metering unit 31 with a first and second storage container 34, 35 for the separate supply of the explosion generator 2 which is connected downstream, with a first and second starting material for creating an explosive gas mixture.

The starting materials are fed from the storage containers 34, 35 to the explosion generator 2 via feed conduits 32, 33. Hence a first starting material in the form of a gaseous combustible, such as ethylene or natural gas is fed to the explosion generator 2 via a first feed conduit 32 and is led into the explosion chamber 3 of the explosion generator 2 via a first inlet device 4. A second starting material in the form of a gaseous oxidant, such as oxygen is fed to the explosion generator 2 via a second feed conduit 33 and is led into the explosion chamber 3 of the explosion generator 2 via a second inlet device 5.

The storage containers 34, 35 in turn are supplied with the respective starting components from gas bottles 38, 39 of a gas store via supply conduits 36, 37, said gas store not being integrated into the metering unit 31. The gas store with the gas bottles 38, 39 is not arranged in the direct proximity of the explosion generator 2 or of the metering unit 31 but in contrast at some distance to this.

The metering unit 31 is arranged on the wall 54 of the facility 51 at the outer side in the direct proximity of the explosion generator 2 (see Figure 2). The metering unit 31 is moreover supplied externally with scavenging gas via a supply conduit 43, for scavenging the explosion chamber 3. The scavenging gas is e.g. compressed air which is obtained from an already present compressed air device. Furthermore, the metering unit 31 also comprises an electricity supply lead 40 to an external electricity source for the supply of electricity.

Moreover, the metering unit 31 comprises a control device 41 for the control of the cleaning method. Amongst other things, the leading of the starting components into the explosion chamber 3 of the explosion generator 2, as well as the ignition device 6 are controlled via the control device 41.

The explosion generator 2 according to **Figure 3** as well as **Figure 4a and 4b** comprises a first wall outer-side component 2.1 as well as a second wall inner-side component 2.2 which forms the outlet device 7. Both components 2.1, 2.2 each comprise a connection flange 8, via which these are fastened to the wall 54 or to the assembly insert 55 of the facility 51 by way of screw connections 56. The wall 54 of the facility 51 forms a through-opening in the fastening region. The two components 2.1, 2.2 form a continuous explosion chamber 3 in the assembled state.

The explosion chamber 3 comprises three chamber sections 3.1-3.3. Hence the first component 2.1 forms a first chamber section 3.1 as well as a second chamber section 3.2 which is subsequent to the first chamber section in the process direction or flow direction R and widens

in a funnel-like manner (see Figure 4b). The second component 2.2 forms the third chamber section 3.3 which in the process direction R ends in the outlet opening 7.1 (see Figure 5 and 6).

The first component 2.1 comprises a basic body 9 with an inlet-side, first part-body 9.1 which includes the first chamber section 3.1, as well as with an outlet-side second part-body 9.2 which forms the second chamber section 3.2 with the funnel-like widening. The second part body 9.2 accordingly in the process direction R forms a funnel-like widening 10 which ends in a first connection flange 8 (see also Figure 4a and 4b).

In the installed state the second, outlet-side part-body 9.2 of the first component 2.1 projects outwards perpendicularly from the wall 54 of the facility 51. The two part-bodies 9.1, 9.2 are arranged at an obtuse angle γ to one another. Hence the first component 2.1 comprises a bending in the transition from the first to the second part-body. The bending is designed in a manner such that the first, inlet-side part-body 9.1 leads away obliquely upwards in the installed state.

The explosion generator 2 or the first component 2.1 or the basic body 12 forms an inlet-side physical interface 13 which is represented in the figures in the form of a basic body connection plate 13. The basic body connection plate 13 however is only one possible design of such an inlet-side physical interface. The inlet-side physical interface 13 comprises a first and second feed opening 13.1, 13.2 each for introducing the two starting substances. A first and a second inlet fitting 4.2, 5.2 of a first and second inlet device 4, 5 is connected in each case to the mentioned feed-openings 13.1, 13.2. The leading of the starting substances into the explosion chamber 3 is controlled by way of the control device 41 via inlet fittings 4.2, 5.2.

The inlet fittings 4.2, 5.2 here are connected to the basic body 12 or basic body connection plate 13 via a common fitting connection plate 14. For this, the two connection plates 13, 14 are screwed to one another via screw connections 56. The fitting connection plate 14 however is only one possible design of such an inlet-side physical interface on the part of the inlet fittings 4.2, 5.2.

Coming from the feed openings 13.1, 13.2 at the inlet-side physical interface 13, a first and second introduction channel 4.5, 5.5 leads into the explosion chamber 3 in the inlet-side first part-body 9. The introduction channels 4.5, 5.5 each end in the explosion chamber 3 via an inlet opening 4.1, 5.1 (see Figure 4b). Introduction channels 4.5, 5.5 with the respective inlet openings 4.1, 5.1 are designed such that the two gaseous substances flow into the mixing zone 11 at an angle β of 90° to one another.

The inlet fittings 4.2, 5.2 are each arranged between the feed conduits 32, 33 and the feed opening 13.1, 13.2 or the basic body connection plate 13. The inlet fittings 4.2, 5.2 each comprise a switched magnet valve 4.4, 5.4 with a non-return device 4.3, 5.3 (non-return) which is arranged subsequently in the flow direction. The inlet fittings 4.2, 5.2 accordingly each comprise a valve circuit 17 with magnet coils for switching the inlet valves 4.4, 4.5. The inlet fittings 4.2, 5.3 are connected to the control device 41 via valve control leads 18 via the respective valve circuits 17.

The explosion chamber 3 forms a mixing zone 11 in the first chamber section 3.1 in the region of the inlet openings 4.1, 5.1, in which mixing zone the two starting components or substances which are led in separately and in a stoichiometric ratio to one another are mixed with one another into an explosive gas mixture.

Furthermore, the first component 2.1 comprises an ignition device 6 which is arranged on the inlet-side, first part body 9.1. This is designed in order to ignite into the first chamber section 3.1 and in particular directly into the mixing zone 11. The ignition device 6 is connected to the metering unit 31 or to the associated control device 41 via an ignition lead 42. The ignition device 6 or the ignition procedure is controlled via the control device 41.

Moreover, a scavenging gas connection 15 for feeding a scavenging gas into the first inlet fitting 4.2 is arranged on the first component 2 between the inlet valve and the non-return device 1. For this, the scavenging gas connection 15 is connected to a scavenging gas conduit 43. A non-return device 16 is arranged in the scavenging gas connection 15. This device is to prevent the propagation of the explosion pressure wave into the scavenging gas conduit 43.

Moreover, sensor devices 20 each with a pressure transmitter 20.1 for measuring the pressure in a gas-leading part of the component 2.1 are arranged on the first component 2.1. Such a first sensor device 20 is arranged on the first part-body 9.1 for monitoring the pressure in the explosion chamber 3. A further sensor device 20 is arranged in each case on the inlet fitting 4.2, 5.2 for monitoring the pressure in the inlet fitting 4.2, 5.2. The sensor devices 20 each comprise a pressure transmission conduit 20.2 for transmitting the gas pressure in the gas-leading part of the component onto the pressure transmitter 20.1. Furthermore, the sensor devices 20 or the pressure transmitters 20.1 are each connected to the control device 41 via sensor leads 20.3. The sensor signals are transferred to the control device 41 via the sensor leads 20.3.

The arrangement of the sensor device 20 in particular can be derived by illustration from **Figure 3**. The pressure transmission conduit 20.2 of the sensor device 20 is attached to a connection at the inlet fitting 4.2 via a screw connection. The pressure transmitter 20.1 is

likewise screwed onto the pressure transmission conduit 20.2 via a screw connection at the other, free end of the pressure transmission conduit 20.2. The gas pressure in the gas-leading part of the component, such as here e.g. in the inlet fitting 4.2, is transmitted onto the pressure transmitter 20.1 via the pressure transmission conduit 20.1. A conduit section 21 of the pressure transmission conduit 20.2 is now designed as a flexible hose.

The construction of the pressure transmission conduit 20.2 according to the second aspect of the invention is to be derived from Figures 8 to 11.

Figures 8 and 9 show two different embodiments of pressure transmission conduits 20.2 each comprising a flexible conduit section 21. Furthermore, both ends of the pressure transmission conduits 20.2 are equipped with inner threaded sleeves 20.4, via which the pressure transmission conduits 20.2 can be screwed to a screw connection on the explosion generator 2 or via which the pressure transmitters 20.1 can be screwed to the pressure transmission conduits 20.2.

The pressure transmission conduits 20.2 according to Figure 8 differ from the pressure transmission conduits 20.2 according to Figure 9 by a bent pipe section which deflects the pressure transmission conduits 20.2 at an angle of 90°. In particular, such pressure transmission conduits 20.2 are applied when the screw connection leads perpendicularly away from the explosion generator 2. The bend pipe section ensures that the sensor device 20 with the pressure transmitter 20.1 does not project laterally too much.

The flexible conduit section 21 is an intrinsically stable and self-supporting hose and consists of an outer-lying braided hose 21.2 which in particular serves as a protection, and of an inner-lying, gas-tight corrugated hose 21.1 which is surrounded by the braided hose 21.2. Both hoses are of metal.

Figures 5 and 6 show particular embodiments of outlet devices 7. Common to these is the fact that they comprise a basic body 12 with a tubular gas receiving body 12.1, at whose wall-side end a connection flange 8 is arranged, via which flange the outlet device 7 is fastened to the wall 54 of the facility 51.

The tubular gas receiving body 12.1 extends perpendicular from the wall 54 into the interior 51 of the facility 50. An outlet body 12.2 which forms two outlet openings 7.1 connects at its outlet-side end which is remote from the wall. The gas receiving body 12.1 and the outlet body 12.2 are welded to one another.

According to the embodiment according to Figure 5, the outlet device is designed in a T-shaped manner, wherein coming from the end of the tubular gas receiving body 12.1 which is remote from the wall, two outlet pipes of the outlet body 12.2 lead laterally away in opposite directions via a bending section. The end sections of the outlet pipes herein each lead laterally away at an angle of 90° with respect to the tubular gas receiving body 12.1

The outlet pipes are each designed in a mirror-symmetrical manner to the longitudinal axis A of the tubular gas-receiving body 12.1. An outlet opening 7.1 is arranged at the free end of the outlet pipes. The opening plane of the outlet openings 7.1 in particular runs parallel to the longitudinal axis A of the tubular gas receiving body 12.1.

The flow of explosive gas mixture as well as the pressure wave which is generated in the explosion chamber are divided in the outlet body 12.2 and deflected towards the two lateral outlet openings by 90° (see arrows). The explosive gas mixture forms a cloud 70 outside the outlet openings 7.1.

According to the embodiment according to Figure 6, the outlet device is designed in a Y-shaped manner, wherein coming from the end of the tubular gas receiving body 12.1 which is remote from the wall, two outlet pipes of the outlet body 12.1 lead laterally away in an oblique manner at an acute angle α to the longitudinal axis A of the tubular gas receiving body 12.1. The outlet pipes are each designed in a mirror-symmetrical manner to the longitudinal axis A of the tubular gas receiving body 12.1. An outlet opening 7.1 is arranged at the free end of the outlet pipes. The opening plane of the outlet openings 7.1 runs parallel to the longitudinal axis A of the tubular gas receiving body. 12.1. By way of this, the outlet cross section is enlarged.

The flow of explosive gas mixture as well as the pressure wave which is generated in the explosion chamber are divided in the outlet body 12.2 and deflected laterally and obliquely towards the two outlet openings 7.1 at an acute angle. The explosive gas mixture forms a cloud 70 outside the outlet openings 7.1.

The outlet devices according to Figure 5 and 6 in particular have the advantage that lower or no recoil forces occur thanks to the lateral exit of the explosion pressure waves.

Firstly, the storage containers 34, 35 are filled with the starting components or substances from the gas bottles 38, 39 for carrying out the method.

At the beginning of a cleaning cycle, the inlet fittings 4.2, 5.2 are opened by the control device 41 and the starting components flow in a stoichiometric ratio into the mixing zone 11 of

the explosion chamber 3 and there intermix with one another into the explosive gas mixture. The two gaseous substances are led into the mixing zone 11 in the so-called cross-flow method at an angle β of 90° to one another. As soon as the predefined inlet quantity of starting components is reached, the inlet fittings 4.2, 5.2 are closed by the control device 41.

Since the explosion chamber is not closed to the interior 51 of the receptacle 50 or of the facility 50, the explosive gas mixture before its ignition flows through the at least one outlet opening 7.1 into the interior 51 of the receptacle or of the facility 50 and forms a cloud 70. The formation of the explosive gas mixture in the explosion chamber 3 as well as in the cloud 70 from the explosive gas mixture lasts for example 0.015 to 0.03 seconds.

The explosive gas mixture is ignited by way of the ignition device 6 directly after the closure of the inlet fittings 4.2, 5.2 or after a defined time delay. The ignition device 6 is actuated by the control device 41 via the ignition lead 42. The explosive gas mixture in the explosion chamber 3 and in the generated cloud 70 is detonated. This effects a pressure wave in the interior 51 of the receptacle or of the facility 50.

CLAIMS

1. An **installation** (1) for removing deposits in interiors (51) of receptacles or facilities (50) by way of explosion technology, comprising an explosion generator (2) with:
 - an explosion chamber (3);
 - at least one inlet device (4, 5) with an inlet opening (4.1) for admitting a gaseous substance into the explosion chamber (3) for the purpose of providing an explosive gas mixture in the explosion chamber (3);
 - an ignition device (6) for igniting the explosive gas mixture in the explosion chamber (3);
 - an outlet device (7) with at least one outlet opening (7.1) for letting out a pressure impulse and/or an explosive gas mixture for removing deposits.
2. An installation according to claim 1, characterised in that the at least one outlet opening (7.1) is closure-free.
3. An installation according to one of the claims 1 or 2, characterised in that the explosion generator (2) is designed for the stationary installation on the receptacle or the facility (50), in particular on a wall (54) of the receptacle or of the facility (50), said wall comprising a through-opening (53).
4. An installation according to one of the claims 1 to 3, characterised in that the explosion generator (2) is designed in a multi-part manner and comprises a wall outer-side, first component (2.1) with the at least one inlet device (4, 5) and with the ignition device (6), and a wall inner-side, second component (2.2) with the outlet device (7).
5. An installation according to claim 4, characterised in that the first and the second component (2.1, 2.2) each comprise a fastening flange (8) for the mutual connecting and/or for connecting to the container or to the facility (50).
6. An installation according to one of the claims 4 to 5, characterised in that the first wall outer-side component (2.1) comprises in particular one-part basic body (9) with an inlet-side part-body (9.1), and a wall-side part-body (9.2), and the wall-side part-body (9.2) comprises a funnel-like widening (10).

7. An installation according to claims 6, characterised in that the opening angle (α) of the funnel-like widening (10) is 60° or smaller, in particular 45° or smaller, very particularly 30° or smaller, and 10° or larger, in particular 15° or larger and very particularly 20° or larger.
8. An installation according to one of the claims 1 to 7, characterised in that the explosion chamber (3) comprises a first chamber section (3.1) which in particular forms a mixing zone (11), a second chamber section (3.2) which connects onto the first chamber section (3.1) and widens in a funnel-like manner and a third chamber section (3.3) as part of the outlet device (7), or consists of such.
9. An installation according to one of the claims 4 to 8, characterised in that the wall inner-side component (2.2) comprises an in particular one-part basic body (12) with a tubular gas receiving body (12.1).
10. An installation according to one of the claims 1 to 9, characterised in that the at least one inlet device (4, 5) comprises an inlet fitting (4.2, 5.2) for the controlled inlet of the gaseous substance into the explosion chamber (3).
11. An installation according to claim 10, characterised in that the basic body (9) forms an inlet-side physical interface (13) with at least one feed opening (13.1, 13.2) for connecting the inlet fitting (4.2, 5.2) of the at least one inlet device (4, 5).
12. An installation according to one of the claims 1 to 11, characterised in that the at least one inlet device (4, 5) and in particular the inlet fitting (4.2, 5.2) comprises a non-return device (4.3, 5.3).
13. An installation according to one of the claims 10 to 12, characterised in that the inlet opening (4.1, 5.1) of the at least one inlet device (4, 5) is arranged after the inlet fitting (4.2, 5.2).
14. An installation according to one of the claims 1 to 13, characterised in that the installation (1) comprises at least two inlet devices (4, 5) for admitting at least one first and second gaseous substance into the explosion chamber (3) for generating the explosive gas mixture in the explosion chamber (3), and the explosion chamber (3) forms a mixing zone (11) for mixing the explosive gas mixture.
15. An installation according to claim 14, characterised in that a first and second inlet opening (4.1, 5.1) of the at least two inlet devices (4, 5) have a different inlet cross section and act

as orifices which limit the volume flow of the gaseous substance which flows into the explosion chamber (3).

16. An installation according to one of the claims 14 to 15, characterised in that the introduction channels (4.5, 5.5) and the inlet openings (4.1, 5.1) of the at least two inlet devices (4, 5) are designed and arranged, such that the at least one first and second gaseous substance flow into the explosion chamber (3) at an angle (β), in particular at a right angle to one another.

17. An installation according to one of the claims 14 to 16, characterised in that a first inlet device (4) comprises a first introduction channel (4.5) for leading a first gaseous substance and a second inlet device (5) comprises a second introduction channel (5.5) for leading a second gaseous substance, into the explosion chamber (3), and the end sections of the introduction channels (4.5, 5.5) which each run out into the inlet opening (4.1, 5.1) are arranged in particular at angle (β) to one another.

18. An installation according to one of the claims 1 to 17, characterised in that the installation (1) comprises at least one sensor device (20) with a pressure sensor (20.1) for measuring a gas pressure in a gas-leading part of the installation (1), as well as a pressure transmission conduit (20.2) which connects the pressure sensor (20.2) to the gas-leading part of the installation (1), wherein at least one conduit section (21) of the pressure transmission conduit (20.2) is designed in a flexible manner.

19. An installation according to claims 18, characterised in that the at least one flexible conduit section (21) of the pressure transmission conduit (20.2) is designed as a hose.

20. An installation according to one of the claims 18 to 19, characterised in that the at least one flexible conduit section (21) is constructed in a multi-layered manner and in particular comprises an inner-lying, gas-tight first hose (21.1) such as a corrugated hose, and an outer-lying protective hose (21.2) such as a braided hose, which surrounds the inner-lying gas-tight first hose.

21. An installation according to one of the claims 1 to 20, characterised in that the installation (1) comprises at least one storage container (34, 35) which is connected to the at least one inlet device (4, 5) of the explosion generator (2) via a feed conduit (32, 33) for the purpose of leading the at least one gaseous substance out of the at least one storage container (34, 35) into the explosion chamber (3) of the explosion generator (2).

22. An installation according to claim 21, characterised in that the at least one feed conduit (32, 33) is designed as a multi-layered hose and comprises an inner-lying, gas-tight first hose (32.1, 33.1) and an outer-lying second protective hose (32.2, 33.2) , in particular a braided hose, which surrounds the inner-lying, first hose (32.1, 32.2).

23. An installation according to one of the claims 1 to 22, characterised in that the installation (1) is designed for leading explosive gas mixture into the interior (51) of the receptacle or of the facility (50) and for forming a cloud (70) of the explosive gas mixture in the interior (51) of the receptacle or of the facility (50).

24. A **facility** (50) with an interior (51) and with at least one wall (54) and with an installation (1) according to one of the claims 1 to 23, said installation comprising an explosion generator (2) which is fixedly installed on the facility (50), in particular on a wall (54) of the facility (50).

25. A **method** for removing deposits in interiors (51) of receptacles and facilities (50) by way of explosion technology amid the use of an installation (1) according to claims 1 to 23, with the following steps:

- leading at least one gaseous substance into the explosion chamber (3);
- providing an explosive gas mixture from the at least one gaseous substance in the explosion chamber (3);
- controlled igniting of the explosive gas mixture in the explosion chamber (3) by way of the ignition device (6), wherein the explosive gas mixture is brought to explosion.

26. A method according to claim 25, characterised in that the at least one outlet opening (7.1) is open to the outside during the introduction of the at least one gaseous substance as well as during the ignition and explosion of the explosive gas mixture.

27. A method according to one of the claims 25 to 26, characterised in that a part of the explosive gas mixture which is provided in the explosion chamber (3) flows into the interior (51) of the receptacle or of the facility (50) via the at least one outlet opening (7.1), and a cloud (70) of the explosive gas mixture is formed in the interior (51).

28. A method according to one of the claims 25 to 27, characterised in that the total volume of explosive gas mixture which consists of the explosive gas mixture in the explosion chamber (3) and possibly in the cloud (70) is provided or generated in the explosion chamber and brought to explosion in a controlled manner in a time period of 1 second or less, preferably 0.5 seconds or less, in particular 0.1 seconds or less.

29. A method according to one of the claims 25 to 28, characterised in that at least two gaseous substances are led into the explosion generator (2), and a mixing zone(11) is formed in the explosion chamber (3), in which mixing zone the gaseous substances are mixed into the explosive gas mixture.

30. A method according to one of the claims 25 to 29, characterised in that during the introduction of the at least one gaseous substance up to the ignition of the explosive gas mixture in the explosion chamber (3), a maximal gas overpressure of 100 kPa (1 bar), in particular of 50 kPa (0.5 bar), very particularly of 20 kPa (0.2 bar) is built up.

31. A method according to one of the claims 25 to 30, characterised in that an explosion pressure wave which moves in the direction of the at least one outlet opening (7.1) is generated with the ignition of the explosive gas mixture in the explosion chamber (3), in particular in the mixing zone (11), said explosion pressure wave effecting the expulsion of explosive gas mixture through the at least one outlet opening (7.1), and thus a cloud of explosive gas mixture forms or is formed completely.

32. A method according to one of the claims 25 to 31, characterised in that the explosive gas mixture is ignited in the mixing zone (11).

33. A method according to one of the claims 25 to 32, characterised in that the explosion is effected by way of a detonation of the explosive gas mixture which propagates at supersonic speed and in a manner coupled to a shock wave.