Explosion Protection
Berghof **high*preactor***

Introduction:
Different applications of Berghof **high***preactor* High Pressure Reactors include potentially explosive conditions inside of the reactor. These conditions can be for instance the use of hydrogen gas or any other flammable gas, as well as vapors of many different organic solvents. The following information includes advice based on good working practices, the DGUV Information sheet for explosion protection documents, ATEX guidelines and the Berghof product portfolio. Following these suggestions does not automatically ensure safe working conditions. Every entity working with Berghof reactors should fulfill their own risk assessment before every use under consideration of locally applicable laws and regulations. According to this risk assessment safety precautions have to be chosen. Wherever explosive atmospheres can exist, there must be an explosion protection document on-site. The Berghof team will supply you with all necessary information about the products to ensure a sufficient risk assessment and explosion protection documentation for your process and system.

Good working practices:
Berghof reactors are designed to ensure safest possible working conditions. In addition to the constructive safety mechanisms, some precautions during the installation of the reactor and some general precautions during usage can help to increase the user safety furthermore.

- The reactors should be installed in a ventilated area, that can be separated from the user. This can be realized by a fume hood, glass walls or by a separate room for example. In case of uncontrolled reactions during opening, emptying, or filling of the reactor the user is able to separate the reactor from himself and others nearby.

- Before starting an application, the reactor and all accessories (including O-rings) have to be checked for damage. In case any damages have been observed the application should not be started.

- After closing the reactor and before starting the heating process the user should check the tightness of the reactor. This can be done by pressurizing the reactor with pressured air, nitrogen or other harmless gasses. In case no significant pressure drop is visible, the reaction can be continued. A small pressure decrease can be observed during the first 5 to 10 minutes for reactors equipped with a PTFE lining. This pressure drop is caused by a slight expansion of the liner within its steel vessel.

- During the time the reactor is under pressure a sufficient tube should connect the rupture disc holder with an exhaust system. In case the rupture disc brakes, this tube can safely remove pressurized, hot and potentially dangerous content to the exhaust system.

- Before opening a reactor, the content should reach room temperature and the pressure has to be fully removed. Although a safe opening key is installed on reactors BR-100 or larger, it is highly recommended to use the vent valve with sufficient tubing to remove the pressure in a safe manner.

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Assessment for explosion protection measures:

Follow this flow diagram to determine if sufficient explosion protection measures have been taken or whether certain measures are still to be taken care of.

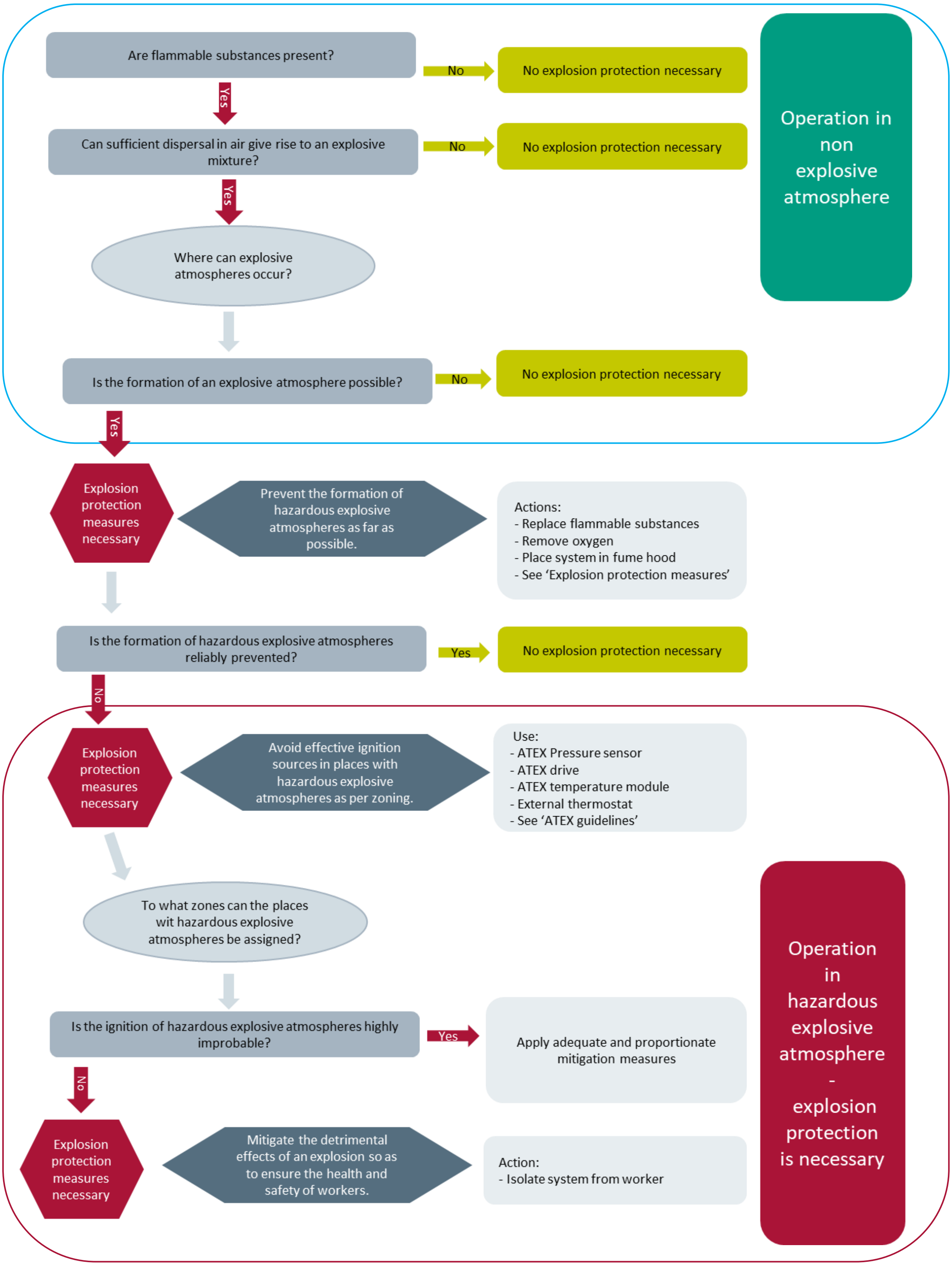

Figure 1: Flow diagram for assessment of explosion protection measures. Based on the "DGUV Information 213-106 Explosionsschutzdokument_06_2021"

Within the large blue outlined box in figure 1 substance properties and process parameters need to be taken into account. The substance properties like upper and lower flammability limits or flash points can be found in substance data bases like the GESTIS database[i] provided by the Institute für Arbeitsschutz from the Deutschen Gesetzlichen Unfallversicherung. With knowledge of process parameters such as temperature or amount of flammable substance the possibility of a formation of an explosive atmosphere can be assessed. For instance, if the process temperature is significantly below the flashpoint of a flammable liquid or if the amount of flammable substance is not allowing the system to reach the lower flammability limit, no explosive atmosphere can occur.

Figure 1 shows what measures can be taken to prevent the formation of a potentially explosive atmosphere. This can be realized with different methods. A general method is to assure if the process allows the replacement of the flammable substance by a less harmful substance. A replacement is not always a possibility. For processes in a reactor system the replacement of oxygen and air by inert gases like nitrogen, argon or carbon dioxide is a sufficient way to prevent explosive atmospheres. When working with conditions below the limiting oxygen concentration the system is not able to form explosive atmospheres. These concentration limits can be reached in reactor systems either by sufficient flushing of the system or by multiple cycles of evacuation and refilling with inert gas. To prevent explosive atmospheres surrounding the reactor, sufficient air circulation is recommended. This ensures that the surrounding stays under the lower flammability limit. Prior to any experiment it is strongly advised to complete a leak test and to reassure that the rupture disc is connected to the exhaust system by a gas house.
The tolerated leaking rate of 0,5 bar/h is the most important source of flammable substances in the surrounding of the reactor. A fume hood with sufficient air flow can prevent the accumulation of an explosive atmosphere around the reactor and can ensure safe working conditions.

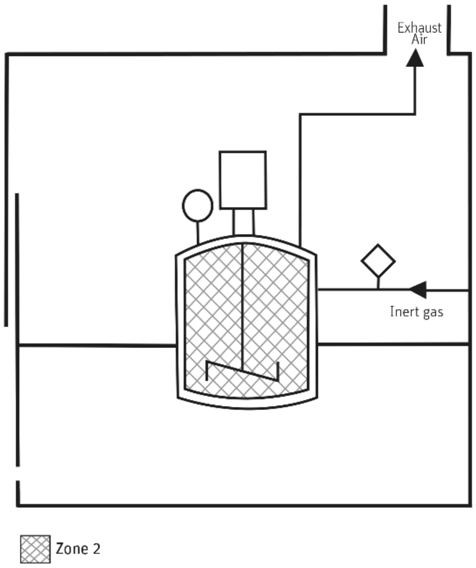

Figure 2: typical setup of a Berghof reactor in a sufficient fume hood.

Marked within the red outlined box in figure 1 are scenarios when ATEX certified devices are being used and an explosion protection document has to be provided. Measures in this area aim to remove ignition sources in areas with potentially explosive atmospheres. In many cases the use of ATEX certified devices and measures from this section can be prevented by proper reaction conditions and setup.

ATEX guideline 2014/34/EU:
To improve workers safety the ATEX (Atmosphères explosibles) guideline 2014/34/EU came into effect in April 2016. The ATEX guideline regulates the use of devices and protection systems in potentially explosive areas. It can only be applied to devices that function as a source of ignition and to protection systems. Sources of ignition can be for example electrical and mechanical sparks, electrostatic discharges, electromagnetic radiation, hot surfaces and flames. Therefore, electrical devices like pressure sensors, motors or electrical heaters need to be certified. Non-electrical devices with fast moving parts, for example a magnetic clutch also need to be certified. The friction during fast movement can heat up parts within the clutch, so that these parts become a possible ignition source. Other non-electrical devices like pressure vessels according to DGRL 2014/68/EU, hand operated valves and tubes do not show ignition sources. Thus, these devices cannot and do not need to be certified

To assess the risk of an explosion the guideline defines three different zones. The different zones vary in the duration of a potentially explosive atmosphere being present during the regular use of the system. Therefore, devices certified for these zones have to fulfill different requirements. For gas, vapor and mist these zones are called 0, 1 and 2, defined as follow:[ii]

Zone 0: A place in which an explosive atmosphere consisting of a mixture of air of flammable substances in the form of gas, vapor or mist is present continuously or for long periods or frequently.
Zone 1: A place in which an explosive atmosphere consisting of a mixture of air or flammable substances in the form of gas, vapor or mist is likely to occur in normal operation occasionally.
Zone 2: A place in which an explosive atmosphere consisting of a mixture of air or flammable substances in the form of gas, vapor or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Different potentially explosive substances have different autoignition temperatures. Therefore, devices are dedicated to different temperature classes and have to be chosen according to the substances used in the experiments. The declaration of different zones and the selection of the installed devices have to be done individually for each setup and type of experiment.

The declaration of zones and selection of possible devices is done by the safety delegates of the operating company or an external commissioned safety delegate. An ATEX code given for all certified devices provides all necessary information as for example the zones the devices can be used in or the temperature class.

The Berghof team is supporting the delegates with all necessary information and is dedicated to help finding the right configuration for the planed experiment.

Measures to prevent explosive atmospheres in reactor systems and resulting zone declaration
For example, the removal of air and oxygen from the reactor prevents the formation of potentially explosive mixtures inside of the reactor. During normal experiments the reactor is tight and does prevent the formation of potentially explosive atmospheres surrounding the reactor. By using a fume hood with sufficient air flow, the gases leaving the reactor caused by the tolerated leaking rate of 0,5 bar/ h cannot accumulate to a potentially explosive atmosphere. A gas house connecting the rupture disc holder with the exhaust system prevents the formation of an explosive atmosphere during an over pressure situation.

Therefore, by following good working practices and preventing oxygen inside of the reactor, the formation of potentially explosive atmospheres can be sufficiently prevented in various experiments.

Berghof product portfolio:
All given parts below are made from stainless steel. Parts made from Hastelloy can be delivered for most of these parts on request.

<u>Manometer / Pressure Sensor</u>:
Pressure gauges are non-electrical parts and do not show an ignition source. Therefore, all of the pressure gauges can be used in potential explosive areas. For electrical or digital pressure sensor Berghof offers different ATEX certified pressure sensors.

Description	Part Nr.	ATEX Code	Suitable for
Digital manometer 30 bar accuracy 0.1 % FS absolute pressure	10001859	II 2G Ex ia IIC T4 Gb	BR-100 ─ BR-4000 NR-1500 ─ NR-10000
Digital manometer 300 bar accuracy 0.1 % FS absolute pressure	10004840	II 2G Ex ia IIC T4 Gb	BR-100 ─ BR-4000

<u>Stirring</u>:

Description	Part Nr.	ATEX Code	Suitable for
RV-GL magnetic clutch 140 Ncm torque	10004534	II2 2G Ex h IIC T6-T1 Gb X	BR-300 ─ BR-4000 NR-1500 ─ NR-10000

<u>Stirrer drive</u>:

Description	Part Nr.	ATEX Code	Suitable for
Compressed air drive	10006734	Ex II 2G Ex h IIC T5 Gb	BR-300 ─ BR-4000 NR-1500 ─ NR-10000

<u>Temperature sensor</u>:
Pt-100 temperature sensor is not viewed as an ignition source as long as the controller does not deliver to high electrical energy. To prevent high electrical energy at the PT100 a Zener barrier can be included between the controller and the temperature sensor.

Description	Part Nr.	ATEX Code	Suitable for
Zener barrier for PT100	5703307		PT100

Heater:
All Berghof electrical heating devices does not meet the ATEX requirements. For the heating of reactors under conditions ATEX devices are required thermostatic mantels should be used. The mantle is no source of ignition, and the circulation thermostat can be placed outside of the potentially explosive atmosphere.

Description	Part Nr.	ATEX Code	Suitable for
BTM-300	5708965	-	BR/DB-300
BTM-500	5708945	-	BR/DB-500
BTM-700	5708964	-	BR/DB-700
BTM-1000	5708955	-	BR/DB-1000 (BR-800)
BTM-1500/2000	5708850	-	BR/DB-1500 / BR/DB-2000
BTM-4000	5745904	-	BR/DB-4000
NR-1500 with double wall jacket	5815100 / 5815065	-	NR-1500
NR-3000 with double wall jacket	5830060 / 5830065	-	NR-3000
NR-6000 with double wall jacket	5860060 / 5860065	-	NR-6000
NR-10000 with double wall jacket	5810060 / 5810065	-	NR-10000

[i] https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp
[ii] Directive 1999/92/EC of the European parliament and of the council of 16 December 1999