RASCHKA

NEWSLETTER

December 2015

Off-gas collection and treatment

In most chemical, pharmaceutical and petrochemical production, off-gas is an inevitable issue. Off-gases usually vary in temperature, flow rate, content and concentration, sometimes they are even very toxic, and some come with high or low pH and often have a strong smell. It is difficult to indentify a generic solution which would solve all off-gas emission issues. Direct ventilation and/or dilution with air is clearly a violation of laws and regulations which are set to protect people and environment, therefore appropriate measures have to be implemented.
Sometimes solvents in off-gas streams can be recovered, however for pharmaceutical production plants GMP requirements sometimes restrict the possibility of a recovery process or make it economically not viable. Sometimes simple treatment like direct burning is sufficient, but may not be the best economic solution. There is no standard solution and each case requires a careful analysis with regards to safe operation and best possible economical set-up. Reliable and safe off-gas systems must include several aspects during the design phase such as compliance with law & regulation, physical properties of individual gases and gas mixtures, explosion class, corrosion, temperature and pressure range. All condition and operation limits must be discussed, reviewed and confirmed during a thoroughly conducted risk analysis.
A state of the art design applying western safety and emission standards at the same time incorporating Chinese regulation using local products wherever possible to achieve a low cost investment must be the main target.
Inappropriate or substandard systems represent a risk for people and environment and increase the risk for enterprises to be forced to shut down their production facilities.

Design personnel's qualification and experience is of utmost importance, off-gas system design requires multi-discipline cooperation between regulatory know-how as well as competence from process, mechanical and instrument and controls engineering

Regulatory requirements

With an increasing awareness for the need to ramp up environment protection, the Chinese government has stringent off-gas emission control limits. As an example Guangdong province, who issued more rigid regulation in 2002. The following table compares emission limits with the previous edition.

	GD provincial standard（Before 2002.01.01）			GD provincial standard（After 2002.01.01）		
	Maximum Amount（Kg/h）			Maximum Amount（Kg/h）		
Off-gas Cat.	Level one	Level two	Level three	Level one	Level two	Level three
SO_2	2.2	4.3	6.6	forbidden	3.6	5.4
NOx	0.65	1.3	2	forbidden	1	1.6
HCl	forbidden	0.43	0.65	forbidden	0.36	0.54
Methanol	forbidden	8.6	13	forbidden	7	10
Xylene	forbidden	1.7	2.6	forbidden	1.4	2.2

Note: Level one, two and three classification can be referred to Chinese standard GB3095.

From the comparison between the old and new standard of Guangdong, it can be concluded that emission limits become progressively stringent in China and inspections will be conducted more frequently without prior notice. Except for different level of EIA (environmental impact assessment), all individual new projects are required to submit the EIA report for authority approval, during this phase, off gases and waste treatment design will become an increasingly important criteria for the approving body especially for petrochemical, chemical and pharmaceutical production facilities. Several plants have recently been imposed with penalties (including months of imposed shut down) due to the release of hazardous off-gas.

Characteristics of off-gas and risk classification

When designing an off-gas collection and treatment system, the first and foremost task is to identify (specify) individual off-gas which could potentially be emitted by different sources and then list possible components including main & side products, nominal load, max peak load, temperature of the streams, other containing substances like dust, smoke, aerosols or change of physical condition such as evaporation, sublimation, condensation. Identification of low points and potential hold up in equipment as well as transfer distance of pipes is essential as it potentially becomes process and safety relevant.

The Component Cross Matrix Table below provides a simple but explicit instruction for judging the possibility of dangerous conditions in case different off-gas streams are collected in the same transfer lines. Besides, we need to get clarity of the state and condition of the off-gas and need to classify the Ex zone inside and outside of the piping and then define the required classification of the equipment (off-gas category, explosion zone, temperature class, etc). Another important aspect is the specification and design of emergency release (safe distance from any ignition source, none-working area, consider surroundings) and explosion protection of off-gas collection network including transfer line to the incinerator or other off-gas treatment systems (avoid ignition source and specify appropriate flame arrestor or endurance burning devices)

As for highly flammable components, any inadequate design or operation could lead to serious consequences. Therefore, when undertaking off-gas system design, it is of utmost importance to perform an effective and reliable risk analysis method which addresses any safety issues and guarantees a safe and stable operation.

Component cross matrix which will help to identify dangerous reactions between chemicals

	Chemical	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Acetone		–	–	–	–	(+)	–	(+)	+	–	–	+	–	+	–	(+)
2	Ethanol			–	–	–	(+)	–	–	(+)	–	–	+	–	–	–	(+)
3	THF				–	–	–	–	–	–	–	–	+	–	(+)	–	–
4	Water					–	(+)	–	–	(+)	–	–	–	–	(+)	(+)	(+)
5	Phenol						–	–	(+)	(+)	–	–	(+)	–	–	–	(+)
6	Chloracetone							–	+	+	–	–	+	–	(+)	(+)	+
7	Hydrogen								–	–	–	–	+	–	(+)	(+)	–
8	Amine									(+)	–	–	+	–	+	+	+
9	NaOH										–	–	+	(+)	+	+	(+)
10	NaCl											–	(+)	–	–	–	–
11	Sodium Sulfate												(+)	–	+	–	–
12	Nitric Acid													–	+	+	+
13	PEG														(+)	(+)	(+)
14	HCl															(+)	+
15	Sulfuric Acid																+
16	$CaCO_3$																

\+ Dangerous product combination

(+) Desired or harmless interactions under reaction conditions

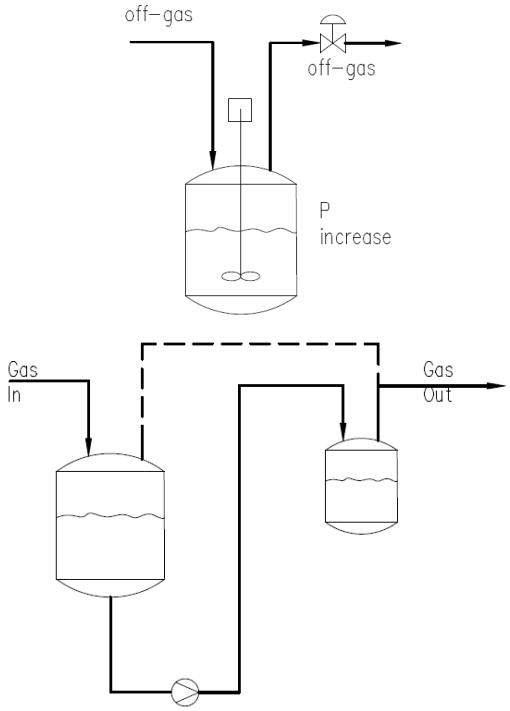
\- Mutual inert behavior

Off-gas system design

Raschka Engineering has vast experience and benefits from operational experience in chemical and pharmaceutical production facilities around the world, the following examples are just some principals which could be considered for certain off-gas applications.

Off-gas release

Off-gas (vapor or gas) is produced either by rising levels in vessels or release of over pressure, both of these cases will create an off gas flow which is eventually controlled by a manual or automated valve. It is advisable to keep the flow as constant and low as possible to minimize the impact on the off-gas treatment plant.



Reduction of off-gas

Reduction of off-gas is an effective approach with a good economical return as it will reduce investment cost for off-gas treatment.

- Balancing

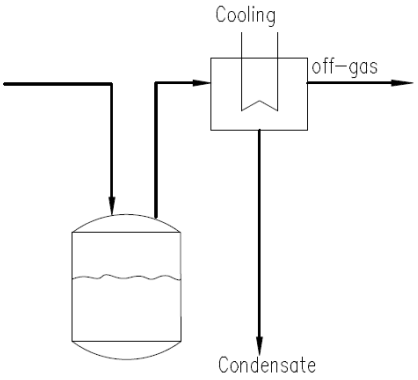
In order to reduce off-gas, the exchange of gas atmosphere between tanks can be a very effective measure. However potential cross contamination issues need to be addressed.

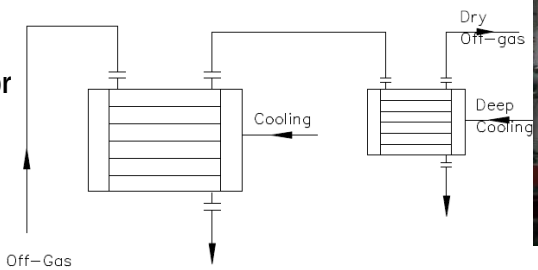
- Condensation / Double Condenser

Condense vapors when ever possible to minimize loss of volatile substances, which has three major aspects:

Environmental
Economical (recovery)
Lower investment cost

Double condenser is advisable for more accurate temperature control (avoid freezing) and to enable partial condensation.

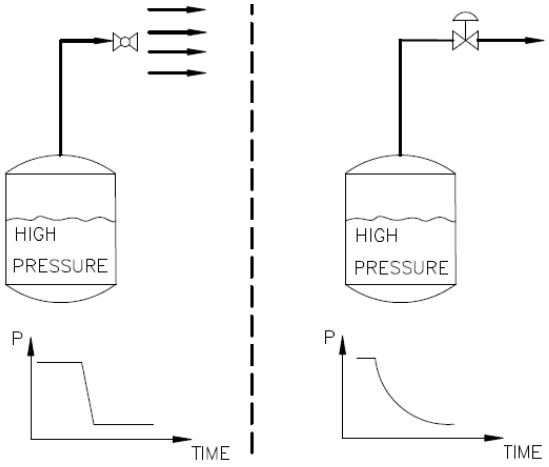




Pressure release

As shown in the picture to the right, pressure release from the vessel should be carried out in a slow but safe way in case of sudden pressure decrease and potential carry over of gas and liquid due to spontaneous evaporation. In addition, we also need to consider:

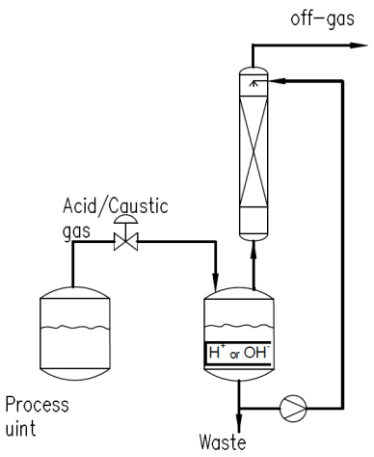
Over the roof emergency release
Disturbance by unpleasant smell
Over-designed off-gas system

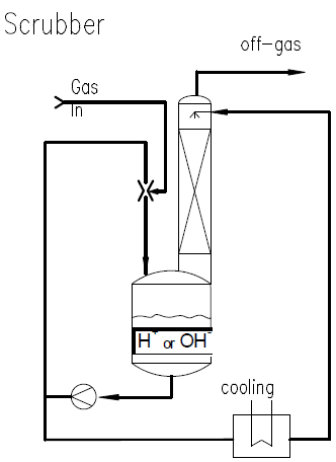


Treatment process steps

Upgrading an existing system can be a cost effective method to resolve an existing off-gas / emission issue. Starting with a **Gap Analysis** which consists of defining the present state, the desired or "target" state and hence the gap between them, summarize the problems and produce an option evaluation and action list. It shall of course not only include the engineering and design aspect but also operational procedures and working habit.

- Absorption / Scrubbing



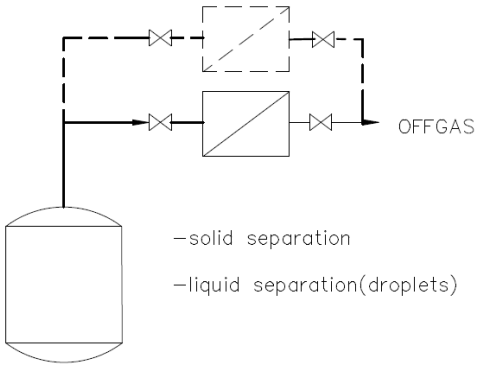


Acid or caustic off gases can lead to unwanted precipitation and heat release and result in exothermic reactions, over-pressurization and explosion. Therefore, potential risks have to be identified and related off gas streams have to be neutralized before sending into off gas collection systems.
For higher efficiency multistage absorption units can be used having several positive side effects such as, slight under pressure in the off gas, better mass transfer due to turbulent mixing while this meanwhile bring about higher through put, higher investment and energy cost.
The picture above shows the popular two stage off-gas scrubbing units available in Lonza plants.

- Additional Separations

Dust containing off gas streams should be treated near the source to avoid accumulation in the collection system and redundant design offers the non-stop operation for continuous off-gas treatment.

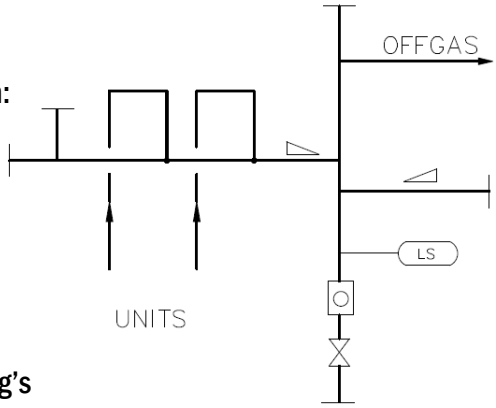
Similar approach for liquid containing off gas streams (aerosols, droplets) meshes, cyclones, demister inside equipment, e.g.



Collection system

Main design considerations when design an off-gas treatment system:

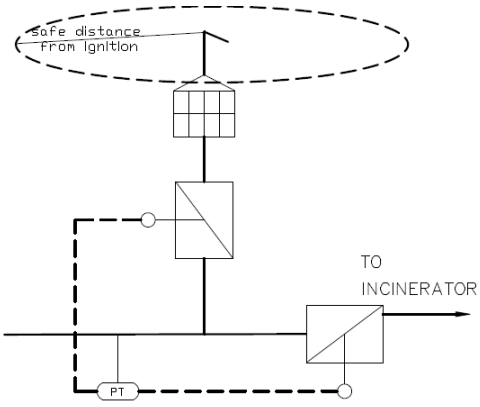
- Cleanability
- Drainability
- Overfill Protection
- Liquid Indication
- Cross Contamination
- Flexibility



The pictures below are practical cases applied in Raschka Engineering's design.

Low point liquid detection

Branches tie-in from above into a main header
Off-gas branches stretch out from upper side of the main pipe, in order to avoid back flow and cross contamination



Transfer line over the roof split

Over the roof / emergency outlet

In case of over pressurization of the collection system, the off-gas has to be immediately directed to the environment to avoid bursting of pipes and uncontrolled release.

The emergency outlet has to be placed at a safe distance from any ignition source (safety) and far from any common working place (health)

The operation over the roof is only allowed in special, abnormal situations (environment)

Flame arrestor to be installed with endurance burning proof design

Hydraulic Flame Arrestor

Advantages: Additional protection from cross contamination
Washing effect/less sensitive to particles in the gas
More obvious principle

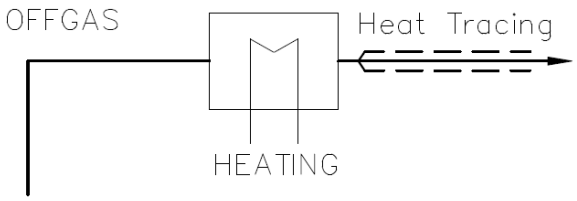
Specification of a hydraulic flame arrestor requires specific know how, it can handle multiple off-gas streams and prevents from back flow, however maximum defined flow rates can not be exceeded otherwise the functionality will be compromised.

Off- gas Condensation

Condensation can lead to dangerous situations in the transfer line:

Corrosion causing damage on the transfer line
Reaction in the transfer line causing damage of the installation
Obstruction / higher pressure drop/ lower flow rate

Whereas, heating and heat tracing for long pipe line can prevent condensation. These heat sources can come from electrical heating, condensate pipes and warm water or other energies.



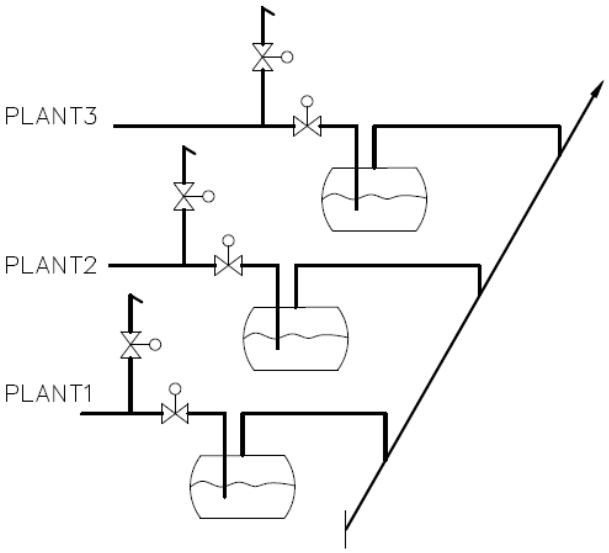
Off- gas transfer line

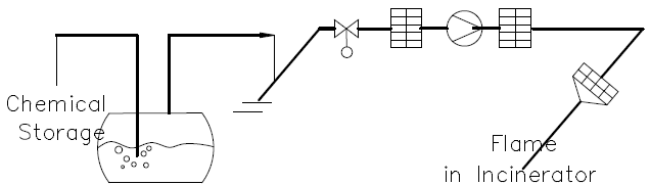
Off-gas from different systems should be transferred via respective lines to the main line then captured in the central collection unit in case of flashback and cross contamination. Three independent protections are normally chosen to realize such a system:

Back flush protection from steady ignition source (flame) inside an incinerator

Detonation flame arrestor around the ventilator as potential ignition source

Flame propagation protection towards the large storage of "fuel"



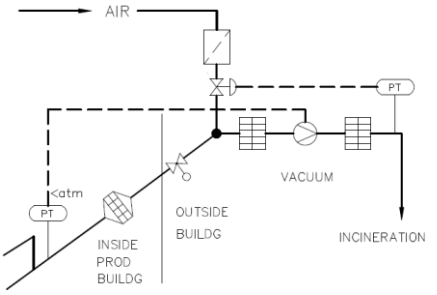


Explosion proof consideration

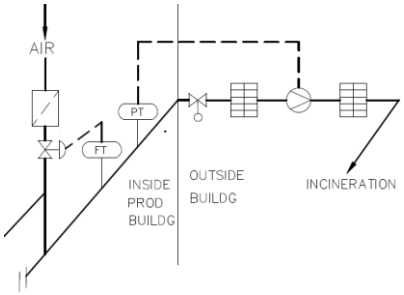
Different strategies to prevent explosion:

- Reduced air
- Introduce more air for dilution
- Avoid ignition (minimize possibilities)

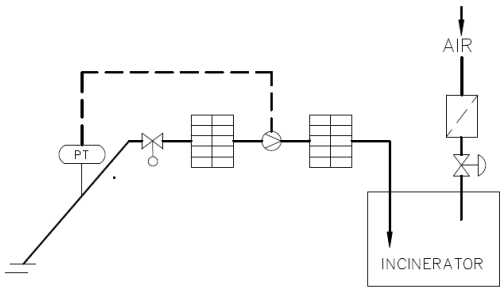
Ventilator is a potential source of ignition and requires special protection. Any explosion or fire has to be contained in smallest possible volume to prevent flame propagation into transfer lines.



Addition of combustion air near ventilator



Addition of combustion air near plant

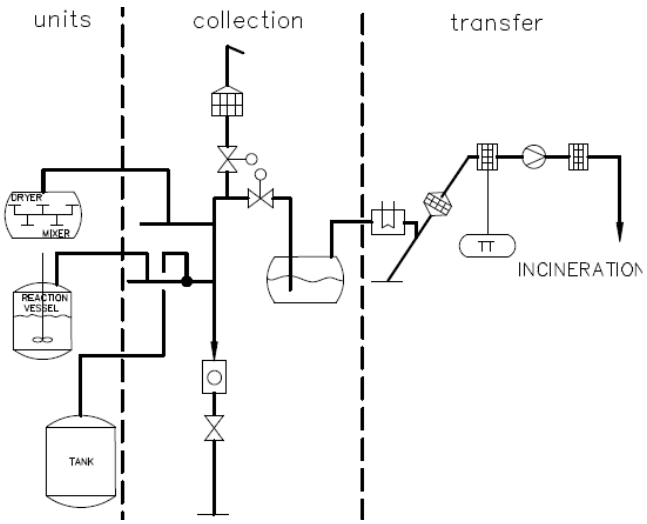


Addition of combustion air directly into incineration

In chemical production facilities, special attention shall be given to its off-gas system, to ensure that we are compliant to the regulation and obtain a better performance of safety and protection of the health of employee and the environment.

Right person shall be involved at the very beginning, from feasibility study, design through risk analysis and installation up to the operation of the plant.

We're ready to help on this end with our vast experience at design, installation, and operation of different off-gas systems.



In this context, Raschka Engineering's service could include:

- Off-gas system and treatment design
- Consultancy, feasibility studies and option evaluation
- Gap analysis and evaluation of existing systems
- Risk analysis
- Energy saving analysis
- Development of an action plan to start a continuous improvement program

Please feel free to contact us in order to discuss your needs with our expert team, we would be very happy to share our experience in off-gas treatment system.

An extensive service list is available on our website: http://www.raschka-engineering.com

Raschka Engineering Ltd

Raschka Engineering Ltd. Liestal, Switzerland (previously be known as Lonza Engineering) now reflects the superior and well known Raschka FBI technology in its name together with its wholly owned subsidiary Raschka Engineering & Consulting Co., Ltd, China provides customer oriented services with a professional, experienced and highly motivated engineering team. We have 20 years of successful project management experience in China which makes us a perfect partner for the chemical, pharmaceutical and biopharmaceutical industry. A board range of services with a project reference list underlining our capabilities is available upon request.

Raschka Engineering has successful managed multiple complex projects such as continuous operating plants for the production of food and feed additives as well as active pharmaceutical ingredient plants including waste gas and liquid waste treatment facilities.

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