V Safety features and equipment for biogas plants

Professor Dr.-Ing. Gerhard Rettenberger

FH Trier, Ingenieurgruppe RUK

1. Introduction

Safety technology is often confused with explosion protection. However, it includes far more than only explosion protection. Basically safety technology can be regarded as the general protection of staff and the neighbourhood from hazards, whether caused by water pollution, collapsing buildings or toxic gases. Safety technology is also often connected to occupational safety. Therefore it covers a very area. The following text can be regarded mainly as safety technology related to explosion protection in view of occupational safety.

2. Basics of safety technology

For an explosion to take place three things are necessary:

a.) An inflammable material having a high degree of dispersion must be available. This is usually given with gases.

b.) An ignitable mixture should be available.

c.) An ignition source of sufficient energy for the existing mixture should be available.

An explosion generating considerable pressure can occur under these given conditions. If a mixture gets ignited under atmospheric conditions then, e.g. in the case with methane explosions, depending on whether the gases produced can escape, pressures of about 7 bar are possible.

If the mixture is not under atmospheric conditions before the ignition, increased pressure or even temperatures develop in the gas causing the pressure to be much higher in the end. Therefore a difference between deflagration and detonation is made in explosion protection.
A safety related assessment should therefore examine whether and what kind of inflammable materials are present and whether their concentrations are such that they can be ignited in air. These concentrations are given a lower and upper limit which can be termed the lower explosion limit and the upper explosion limit.

The inflammable gas in case of biogas is methane. However, one should take into account that other gases could also form especially hydrogen. If on the other hand chemicals or fuels are being stored other gases could also develop. Dust should also be considered. Organic, inflammablle dust develops in almost all biogas plants. An explosion hazard is given if this dust is able to accumulate.

It should furthermore be tested whether the conditions under which the mixture exists is atmospheric. This is the case if the temperature of the mixture is between -20 and 60°C and the absolute pressure between 80kPa and 110 kPa. The quantity of the inflammable mixture is not always large, so there is no impending danger. A general value for such a hazard cannot be given. An estimation will have to be made for every individual case. If the conditions are as specified, a hazardous, explosible atmosphere exists, abbreviated to h.e.A.

In order to determine whether a mixture is ignitable, a graph of three materials as shown in the following diagrame is used.

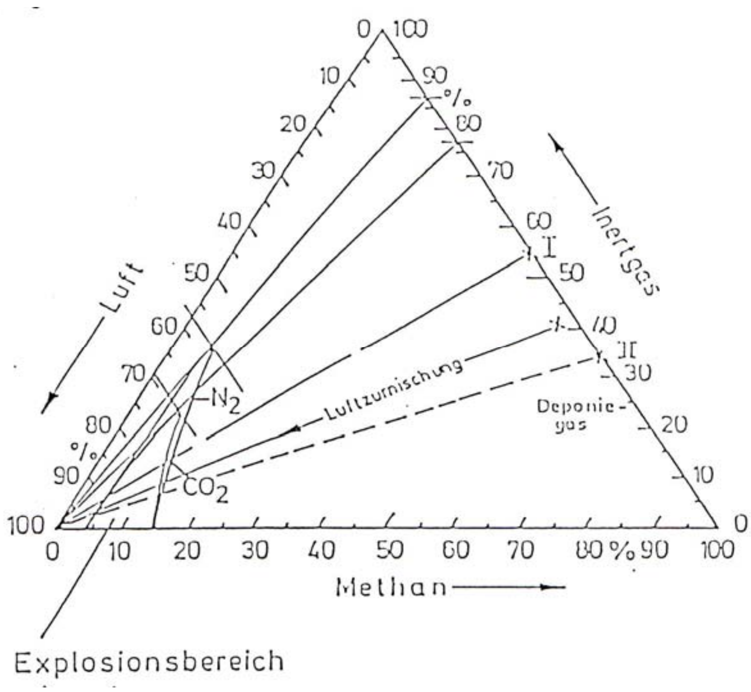

Fig.: 1:Triangular classification chart for evaluating the inflammability of a mixture of methane, air and inert gases (CO_2,N_2)

In order to inflame such a mixture, an ignition source must be available, that will have enough energy to induce an explosion. Not all potential ignition sources are capable of inflaming e.g. methane. Some potential ignition sources are:

- Elektric sparks and arcs,
- Mechanically produced sparks (hammering metal with metal),
- Hot surfaces, these could be e.g. exhaust pipes of block heat and power plant or turbo chargers of gas engines
- Electrostatic charges, that e.g. are produced by synthetic materials on friction (dusters),
- Self ignition of sedimentary depositions
- Lightening striking a plant.

Explosion protection measurs become necessary if it is detected that a hazardous quantity of ignitable material exists and that ignition sources cannot be eliminated. The usual process is to create a diagramm of „safety related concept“.

The safety related concept is subject to a hierarchy, that in explosion protection specifies and demands that primary explosion protection comes first. This is directed towards all measures that help to avoid the formation of a hazardous, explosible atmosphere. **Secondary explosion protection** in which mostly technical measures are taken to ensure that ignition sources do not become effective, is to be listed only in the second position. If these measures too cannot guarantee that hazards cannot be eliminated, **tertiary (constructive) explosion protection** is to be applied.

Mainly, following points have to be taken into account with primary measures:

- Selection of suitable procedures,
- Leak proof pipes and armatures, so that no air can enter or escape from the facility,
- Measuring equipment for monitoring and limiting the concentration
- Inerting mixtures by adding non-inflammable gases, so that the mixture is safely below the explosion limit,
- Supplying air either by natural or technical means, so that inflammable gas is always diluted and not explosible any more.

Fig. 2 shows the difference between primary and tertiary explosion protection on the example of a gas generating plant.

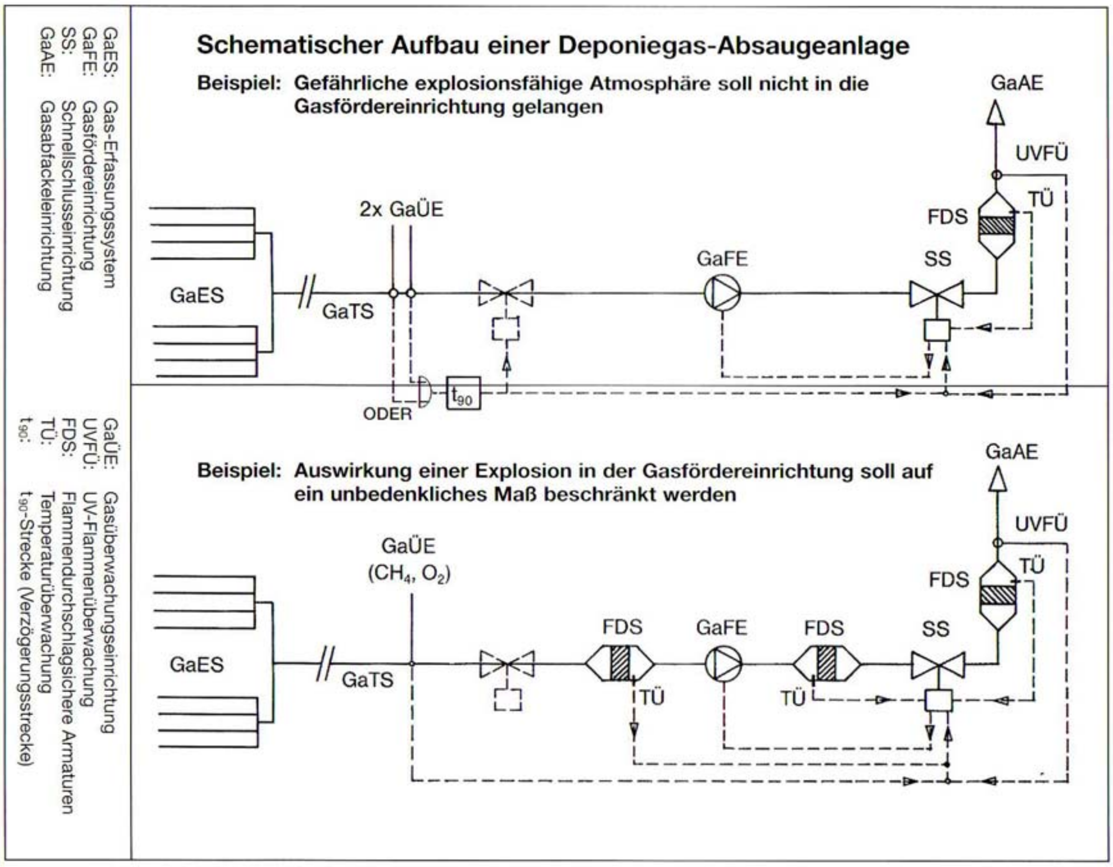

fig.: 2: Landfill gas plant equipped with primary (top) and tertiary (bottom) explosion protection, from „GUV-standard landfills“

In case of „primary explosion protection“ it is first tested whether an ignition source exists. One ignition source is for example the converyor unit shown in fig. 2. Measures should be taken to ensure that no explosible atmosphere reaches the conveyor unit. This can be carried out by monitoring the mixture. A double monitoring is however necessary with suitable measuring equipment permitted in primary explosion protection. These will have to conduct redundant measurements.

In the case of tertiary explosion protection, avoiding an h.e.A. at the conveyor unit is not necessary. On the other hand it should be prevented that an explosion that could possibly occur in the gas conveyor or the surrounding pipes do not have any effects on the plant area. A number of measures are required for this. Firstly, the spreading of the explosion to the surrounding pipes to develop into a detonation should be prevented. This can be safeguarded by employing flame-proof armatures in both directions of flow starting from the conveyor unit. The equipment must be constructed so secure in the area of a possible explosion that it will be able to withstand the pressure caused by an explosion.

Another source of ignition is the excess gas burner, which cannot be safeguarded by primary measures and therefore only tertiary measures are planned.

After primary explosion measures have been defined, it should be determined whether there is any „remaining", hazardous, potentially explosive atmosphere to be reckoned with. Hence, a reassessment is to be done. In order to maintain a certain system, it was proved practical to differentiate between such a hazardous, potentially explosive atmosphere occurring within the plant and outside the plant. Therefore there is a difference between internal explosion protection and external explosion protection.

Estimating whether a potentially explosive, hazardous atmosphere exists even after primary measures is done under two aspects:

a.) Where such a potentially explosive, hazardous atmosphere could occur
b.) The frequency in which such an atmosphere could occur

The frequency is differentiated into three categories which are then defined according to the spreading area. The three areas defined are evaluated as zones. Following zones have been defined for gases:

- Zone 0: includes areas in which a hazardous, potentially explosive atmosphere already exists permanently, long term or very often.
- Zone 1: includes areas in which a hazardous, potentially explosive atmosphere can builds up occasionally.
- Zone 2: includes areas in which one does not reckon with the building up of a hazardous, potentially explosive atmospher but in case it does than in all probability only very rarely and of very short duration.

The evaluation for dust is analogous to gas but the zones are termed zone 20, zone 21 and zone 22.

Since such an evaluation needs experience and these experiences can be basically obtained only from past accidents and damages, it is practical to refer to past reports. These reports can be found especially as a collection of examples in specifications for accident prevention. The set of examples are usually listed by primarily differentiating between specific plant elements and components. Clear descriptions of the components and their method of installation are given here e.g. the requirements on the pipes, the material, the joints and the method by which they are to be installed and tested. These examples also give details on room specifications for the respective zones assuming that primary measures have already been taken e.g. natural or artificial ventilation. Fig. 3 shows a pullout from a set of examples given given in GUV-I 842.

Lfd. Nr.	Beispiel	Merkmale/Bemerkungen	Schutzmaßnahmen nach		
			E1	E2 in den nachstehend aufgeführten (verbleibenden) Zonen	E3
(Sp. 1)	(Sp. 2)	(Sp. 3)	(Sp. 4)	(Sp. 5)	(Sp. 6)
1	**Deponiegasanlagen**	Zu Geltungsbereich und Begriffsbestimmungen siehe GUV-Regel „Deponien" (GUV-R 127, bisher GUV 17.4)			
1.1	**Gaskollektoren und schachtförmige Bauwerke** (z.B. Entwässerungsschächte)	Ausführung entsprechend Abschnitt 5.12 bzw. 5.14 der „Regeln für Sicherheit und Gesundheitsschutz bei der Arbeit auf und in Deponien". Bildung g.e.A. durch unkontrolliertes Eindringen von Luft (z.B. bei Beschädigungen, Störungen) möglich Unterdruck gegenüber Atmosphäre	E 1.3.4.1	Zone 1: innerhalb Zone 2: außerhalb, 0,5 m um Öffnungen, flexibler Verbindungen und Armaturen	
1.2	**Gasansaugleitungen einschließlich zugehöriger Apparate und Armaturen**				
	– unter Flur			Zone 1: innerhalb der Rohrleitungen	
	– über Flur (frei liegend)	Ausführung entsprechend Abschnitt 5.13.6 der „Regeln für Sicherheit und Gesundheitsschutz bei der Arbeit auf und in Deponien".		Zone 1: innerhalb der Rohrleitungen keine: außerhalb der Rohrleitungen	

Fig. 3: Pullout from a collection of examples (GUV-I 842)

If further measures should be necessary after the remaining zones have been inspected, secondary and tertiary measures will have to be taken.

Secondary explosion protection is given if the materials used in the plant are such that no sparks with sufficient ignition energy can be produced for example by safeguarding electrical equipment. German laws specify that only permitted equipment is to be installed in explosion hazarded areas. Attention should be paid to the category of the device. The explosion group IIA and temperature class T1 should be observed for biogas in a hazardous, potentially explosive atmosphere. Apart from the instruction manual and the EU certificate of conformity, the prototype inspection document should also be available for equipment categorised 1 and 2 installed in the zones.

Such electrical equipment installed in zone 1 is labeled with specific information on the device as shown in fig. 4.

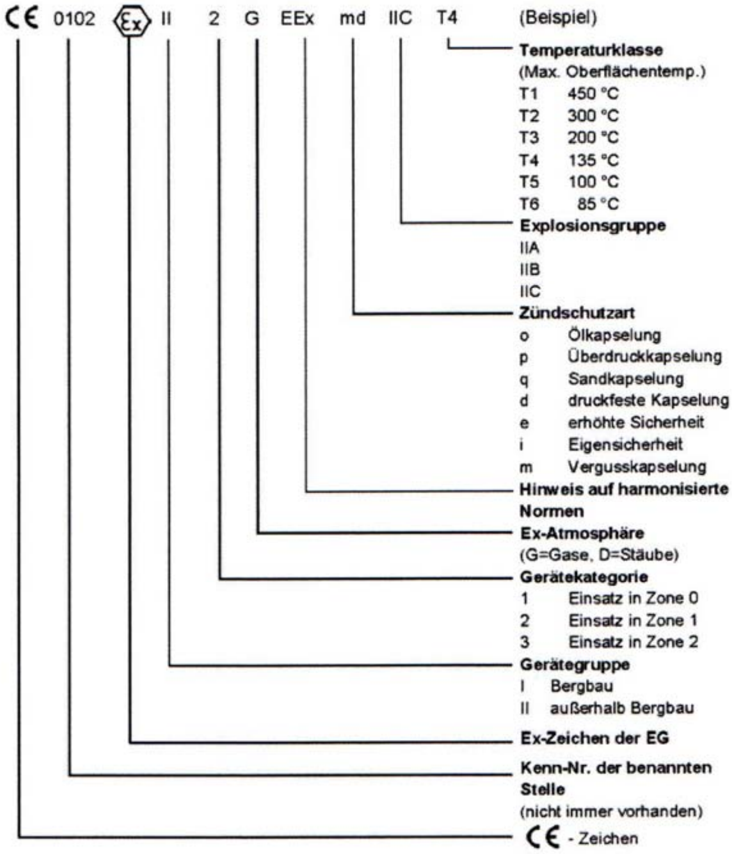

Fig. 4: Label of electric equipment for zone 1 according to EU specifications

3. Safety related concepts

The above mentioned aspects should be systematically worked off while estimating the hazards of a plant. The required procedure of such a „safety related concept," can be given as follows.

1. Determine the existence of a hazardous, potentially explosive atmosphere
2. Inspect whether an ignition source is present

3. Measures for creating a condition in which the building of a potentially explosive, hazardous atmosphere is prevented. The term **primary explosion protection** is given to these measures.
4. Inspection of the plant to determine whether a hazardous, potentially explosive atmosphere is still possible in spite of primary measures.
5. Developing additional measures in order to eliminate remaining hazards (secondary, tertiary explosion protection)
6. Testing whether the safety related concept is complete.
7. Verifying whether the required measures have been implemented correctly after the construction of a specific plant. Such an inspection is usually done prior to starting up the plant.

Fig. 5 gives an exemplary safety related concept.

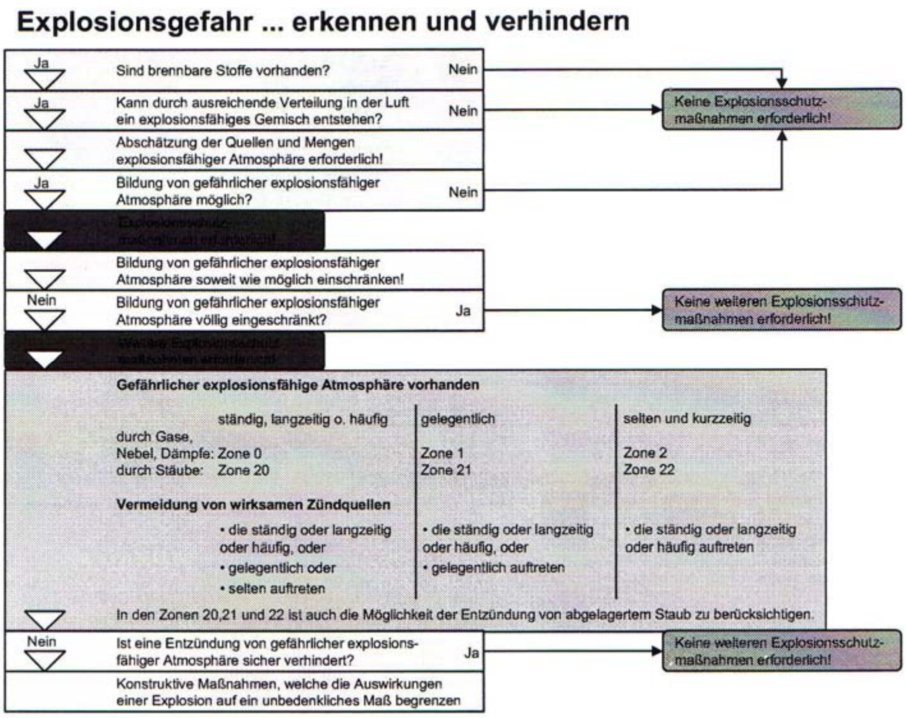

Fig. 5: Safety related concept (specified DWA)

According to this it is inspected first of all whether inflammable materials are present, whether an explosible atmosphere can build up by mixing with air and whether a potentially explosive, hazardous atmosphere is subsequently possible. The next step is to verify whether a hazardous, potentially explosive atmosphere can be limited by primary measures. If this is not possible completely, the remaining zones should be evaluated and graded as zones 0, 1, 2 for gases and zones 20, 21, 22 for dust. Additional measures become necessary. These should include secondary and tertiary explosion protection measures.

4. Responsibilities of the operator according to laws

According to legal requirements and taking the possible formation of a hazardous, potentially explosive atmosphere in a plant into account, specific actions by the operator is demanded. These can be summarized as follows:

- A hazard assessment is to be done to determine where in the plant a hazard is to be reckoned with.
- Specifications should be defined for the equipment made available.
- The explosion hazarded areas should be defined. The points should be recorded in writing in the explosion protection document.
- Specifications on the properties of the working materials should be defined. Further special protection measures should be defined. In addition to this the staff should be briefed.
- Working materials should be inspected regularly.
- All actions of the operator should be recorded.

All the equipment with which an employee works with and is present at the place of work is to be listed under working materials. These include machines e.g. excess gas burners, gas engines, conveyor facilities, armatures and pipes etc.

Equipment that need monitoring are those that are installed in explosion hazarded areas and e.g. include systems of devices and protection systems that can be assumed explosion prone. However, even facilities that guarantee safe functioning should be included so that explosions do not occur at all. Furthermore, all installation devices for joining components should also be included. Facilities that need monitoring should be subjected to very special inspection.

Taking all this into consideration, the responsibilities for operators can be summarised as following:

1. Organisational measures
    - Briefing the staff
    - Written instructions, work clearance, supervision
    - Identification of explosion hazarded areas
    - Prohibiting specified ignition sources in explosion hazarded areas (e.g. smoking).
    - Prohibiting the entry of unauthorised persons in specified areas

2. Personal security measures
    - Installation of protection measures, based on the largest possible danger potential.

- Employment of specifically suitable equipment safety systems. This should be defined in the explosion protection document.
- It should be guaranteed that only such working materials that will make allowance for the aspects of explosion protection will be applied.
- The staff should be warned acoustically and visibly prior to reaching the explosion conditions.
- Ignition sources created by electrostatic charging should be avoided.
- Sufficient escape routes should be provided.
- If necessary a means of escape should be provided.
- Prior to first use, inspections will have to be carried out. These tests should be conducted by qualified persons. Qualified persons are those that have special knowledge especially in the area of explosion protection.
- In case of power-cuts, the safe functioning of the equipment should be guaranteed.

3. Only those devices and protection systems permitted for the particular zone should be installed i.e. only those that conform to the requirements.

Clear regulations are to be specified for the responsibilities. Written instructions should be provided for specific cases. Briefings should be conducted. A written work clearance is to be issued for hazardous areas. All areas in which an explosion hazard is to be reckoned with i.e. all areas that are marked as zones should be specifically identified.

The plant operator should verify this. The deadlines for carrying out the tests should be defined taking safety related aspects, manufacturers data, and general rules into consideration. The maximum term according to German rules is three years. It can be considerably shorter if the manufacturer's data or the technical specifications demand it.

The tests should be carried out by qualified persons or authorized test agencies.

The tests in the areas dealing with safety technology should only be conducted by specially authorized qualified persons.

Tests are required at different points of time:

1. Prior to starting up or after a fundamental change,
2. Prior to reconnection,
3. Subsequent to a maintenance measure on a component that is connected to explosion protection,
4. recurrent.

The operator should establish the test deadlines of the complete plant and its components through a safety related evaluation.
All the points mentioned are to be compiled in an explosion protection document both in the form of a written text and a drawing. The explosion protection document should include the following points:

a.) Description of the workplace and areas e.g. by an allotment plan, a lay-out drawing, marking the escape routes
b.) Description of procedures and actions with the help of a flow chart.
c.) Description of materials involved. Mostly methane with biogas plants.

d.) Depiction of the results of the hazard assessment by naming the explosion hazarded areas within the plant and in the surroundings by identifying the zones with the help of a zone plan. Description of the hazards during standard operation, and also during starting up and shutting down the plant e.g. disruptions, cleaning etc.

e. Depiction of technical protection measures

f. Depiction of organisational explosion protection measures

- A compilation of written operating instructions
- Description of required personal protective equipment

g. Documenting the responsible person

Thus it becomes obvious that the explosion protection document includes all fundamental details of measures that will have to be taken in order to guarantee safety at work in areas with specific equipment.

5. Examples of accidents

- The port hole in a fermentation container was not tight. Pressure increased due to sun-rays, gas was discharged and collected in the technical room. There was an air compressor that produced ignition sparks in the room. No explosion protection measures had been provided..
- The gas storage foil of a two-wythe inflated roof had a leak. Owing to the high production of gas, the pressure of the biogas was higher than that of the back pressure of the bubble inflation air. An ignitible mixture formed in the surrounding rooms. Ignition through switcing operation of the agitator

- Insulating fluid had settled in the condensate chamber, gas streamed out, ignition by a charred electrical wire.
- Insulating fluid had settled in the condensate chamber, gas streamed out, ignition by a charred electrical wire
- Some digestate was left in the fermenter after it was emptied. Gas was formed and ignited by the feed screw which induced sparks on rubbing with the wall. The fermenter cover had been lifted off .
- While leading the heating lines through the container walls, the sealing broke, the container was almost completely drained.
- Liquid manure seeped out through a leak in the container. Gases formed over this manure-lake, a defective 20 kV cable induced ignited the gas when the electricity was switched on.
- Liquid manure drained out of a container in which the ring seal was not tight.
- Gas was released on the leakage of a container, the UEG was transgressed, an explosion occured as the sealing on a sluice valve was defective.
- Intenstinal mucin from the production of heparin came into contact with acidic material in a pit. More than 6000 ppm of H_2S was released. Suction was insufficient (defective) and the running agitator caused the gas to be set free very quickly => 4 dead
- A technician climbed into an empty mixer for reparing it. The residue produced H_2S concentrations of 2200 to 2600 ppm about 30 – 40 minutes after emptying => 1 dead