Pork CRC

Bioenergy Support Program

Talking Topic 2

Biogas Safety – the essentials

Safely enjoying biogas benefits

Biogas produced in piggery effluent lagoons usually bubbles to the water surface and escapes into the atmosphere. Instead, this biogas can be captured and used as a fuel on-farm for heating and/or electricity generation. Doing this also has benefits for the environment, including odour reduction and potential buffers.

On-farm use of biogas as a fuel introduces unique health and safety precautions which are highlighted in this Talking Topic. Readers are also encouraged to refer to The Code of Practice for On-farm Biogas Production and Use (Piggeries) (APL 2014) (available from the author) for an excellent overview of safety considerations and ways to reduce safety risk relevant to Australia.

Relevant safety risks are of a generic nature (such as falls, noise or entanglement) or are specifically related to biogas as a chemical substance (a gas).

Australian Standard AS3000 addresses general electrical installations. Other generic risks are addressed in Codes of Practice published by Safe Work Australia at http://www.safeworkaustralia.gov.au/sites/swa/model-whs-laws/model-cop/

Biogas as a substance can cause:

1. Flash fires or explosions, and
2. Poisoning by hydrogen sulphide in raw piggery biogas.

Australian Standards AS5601 and AS3814 set out the minimum requirements for gas installations which deal with the fire/explosion risk. All Australian states require that biogas installations comply with these and other relevant standards, albeit that biogas is not yet a legislated fuel gas in all Australian states.

IMPORTANT

AS5601 and AS3814 do not address hydrogen sulphide and so gas fitters may not be aware. Further information on hydrogen sulphide is provided below and in the APL Code of Practice (2014) publication.

Real case studies are also presented throughout this Talking Topic to provide context.

Biogas Safety

BIOGAS

Biogas is a gas mixture of mainly methane and carbon dioxide and is produced by the natural microbial breakdown of pig manure in parts of an effluent lagoon where dissolved oxygen is absent.

Methane is the flammable ingredient in biogas, but only when biogas is mixed with sufficient air as an oxygen source and a viable ignition source such as a flame, spark or other is present. As with other fuels, there is a range of biogas-air proportions over which the biogas-air mixture is flammable. This range (commonly the explosive or flammable range) contains enough methane fuel and oxygen to support a flash fire. This is important because, provided that biogas concentrations remain high (e.g. by actively excluding air from pipework carrying biogas) or biogas concentrations remain low (e.g. in well-ventilated areas), a flammable mixture can be prevented from forming.

According to Table 1, a flammable biogas-air mixture contains biogas at 5-24% of the total volume of the mixture.

PURGING (Getting air out)

During start-up of a biogas system, the previously dormant equipment and biogas pipework may contain air. As biogas begins to flow through this equipment and pipework, the air is progressively displaced and a flammable gas mixture may form. For this reason, a biogas system must first be adequately purged with biogas before a downstream blower, flare or biogas appliance can be turned on. This is to prevent ignition and burn-back of flammable gas mixtures contained in equipment or pipework.

PREVENTING AIR INGRESS

It is also important to keep air out of operational biogas equipment and pipework to prevent a flammable mixture from forming with the biogas inside the equipment or pipework. Having multiple appliances fired on biogas at the same time can increase the risk of air ingress. This is especially the case with vents or flare stacks without backflow prevention, where another appliance drawing biogas from the pipework can create a negative pressure at the vent or flare and draw air back into it. This has previously occurred in Australia, but not at a piggery. Air ingress can be simply prevented by installing backflow prevention, by providing a dedicated blower for each biogas appliance to prevent negative pressures, and by operating biogas pipework and equipment under a slight positive pressure (not under vacuum).

During maintenance, when the biogas system is taken offline, air ingress should also be actively minimised, for instance, by not removing excessive amounts of digester or covered lagoon liquid contents which could lead to a negative pressure inside a digester or covered lagoon.

TABLE 1 Typical properties of raw piggery biogas in Australia

PROPERTY	VALUE
Methane content of piggery biogas (CH_4) by volume	60-70% [a]
Hydrogen sulphide content of piggery biogas (H_2S)	700-3000 ppm [b]
Explosive range (volume % biogas in biogas-air mixture)	5-24 [c]
Raw biogas temperatures	10-65°C [a]

(a) From under a dark plastic cover on a covered lagoon – Skerman and Collman (2012)
(b) Skerman et al. (2012)
(c) Ross and Walsh (1996). Influenced by moisture and methane content. The lower explosive limit (LEL) of 5% by volume in air is that of pure methane in air mixtures, taken as a conservative LEL estimate for biogas. The upper explosive limit (UEL) of 24% by volume reflects dilution by carbon dioxide and corresponds to raw biogas with 40% CH_4 (much lower than typical piggery biogas and thus is a conservative UEL).

CASE STUDY 1

Not the murderer we suspected

The notorious Lane Cove River 'murder' was revisited in 2006 and an alternative suspect was revealed. It is now strongly suspected that a large release of hydrogen sulphide gas (same as in biogas) from the river-bed overcame the couple and the rest was history. The hydrogen sulphide formed as microbes, broke down organics and converted sulphur into hydrogen sulphide in a very similar way to a covered piggery lagoon.

Source: ABC Catalyst, November 23, 2006.

A biogas flame burns clear and may only be visible at night (Figure 1). Consequently, for a flare with malfunctioned spark ignition, a considerable amount of unburnt biogas may vent before an operator is made aware of it. Because methane is lighter than air, it usually dissipates rapidly and would not likely cause a fire hazard. However, peripheral initiatives such as carbon trading (participation is voluntary), already require close monitoring and record keeping to prove that biogas sent to a flare was actually burnt. So, it is beneficial to have a flare monitoring device such as a thermocouple or UV eye in place to confirm that a flare is burning.

IGNITION SOURCES

The third option to prevent flash fires is to exclude viable ignition sources from areas where flammable biogas-air mixtures may exist. There is an established method under Australian Standard *AS/NZS 60079.10.1: Classification of hazardous areas – explosive gas atmospheres* whereby spaces in close proximity to biogas pipework and equipment are zoned in terms of the likelihood of there being an explosive biogas-air mixture present in those spaces. Specifically, electrical equipment is then selected according to the zoning to keep potential ignition sources well-distanced from danger zones. Figure 2 shows an example of spark-proof electrical equipment selected for safe operation in ZONE 1 (a space where an explosive gas atmosphere can be expected to occur periodically or occasionally during normal operation – more than 10 hours but less than 1000 hours per year). Although AS/NZS 60079.10 remains the official standard for compliance in Australia, the Safety Rules for Biogas Systems by the German Agricultural Occupational Health and Safety Agency (2008) (a German equivalent AS/NZS 60079.10) is also noted as a useful guidance document, which is more stringent but can be easier to apply in a farming context.

FIGURE 2 Example of a biogas fan blower at an Australian piggery rated to Zone 1 in accordance with *AS/NZS 60079.10.1: Classification of hazardous areas – explosive gas atmospheres*.

FIGURE 1 Biogas flares at a piggery in Australia. Note the shrouding on the top of some of the flares, which can provide some protection and may reduce fire risk. Note also that vegetation has been cleared around the flare to reduce fire risk.

HYDROGEN SULPHIDE, a minor gas ingredient in raw piggery biogas, is highly toxic if inhaled (Table 2). Raw piggery biogas contains enough hydrogen sulphide to instantly kill a person through nervous system failure. At low concentrations, hydrogen sulphide is very odorous with a characteristic rotten egg smell that blends with other piggery odours.

Hydrogen sulphide is particularly dangerous because although it can be smelt at lower concentrations, it numbs the sense of smell at moderate concentrations and therefore an exposed individual is no longer aware of the imminent danger (Table 2). For this reason, the use of detectors for hydrogen sulphide and/or flammable gas is highly recommended. Portable gas detectors (Figure 3) can be comfortably carried or worn by a person walking around a biogas system.

Another danger of hydrogen sulphide gas is that, being heavier than air, it can settle and may not readily dissipate in poorly ventilated areas. This means that hydrogen sulphide can collect or remain in low-lying areas or even in open-top tanks (see case study 1 and 2).

TABLE 2 Potential human health effects from short-term exposure to hydrogen sulphide gas at various concentrations in inhaled gas mixtures.

HYDROGEN SULPHIDE CONTENT OF GAS MIXTURE BEING INHALED (PPMV)#	HUMAN HEALTH EFFECTS AFTER SHORT TERM INHALATION
700–3000	typical concentration in piggery biogas
1000	causes nervous system failure and death
500–1000	causes rapid breathing, then loss of breath and potentially death
320–530	causes fluid accumulation in lungs, risk of death
100	causes loss of sense of smell, person no longer aware of the imminent danger
10*	causes eye irritation and chemical changes to blood and muscle tissue
0.003–0.02	detectable “rotten egg” odour

Department of Health NY USA; Skrtic (2006).
#Parts per million by volume
* Many handheld gas safety detectors will sound an alarm at 10 parts per million by volume, signifying that safe short-term working levels have been exceeded.

SAFE VENTING OF UNBURNT BIOGAS

It is common, especially during maintenance, to have biogas-fired appliances offline and switched off. Under such circumstances, it may be necessary to safely vent unburnt biogas from a covered lagoon or digester. A **good** vent design allows the operator to intervene and force safe venting when there is a need to do so (Figure 4). **Poor** vent designs rely on the bloat of a cover or a large positive pressure to force venting (Figure 4). **Any vent stack should be at a safe height/location so as to not expose persons walking around the perimeter of a biogas system to any unburnt biogas being vented.**

It is also important to understand that the gas mixture under an inflated cover of a piggery lagoon contains raw piggery biogas, including lethal hydrogen sulphide. If a person walks on and falls through a compromised cover, they are likely to die from the toxic hydrogen sulphide in the biogas, rather than by drowning. **For this reason, walking on lagoon covers is strongly discouraged.**

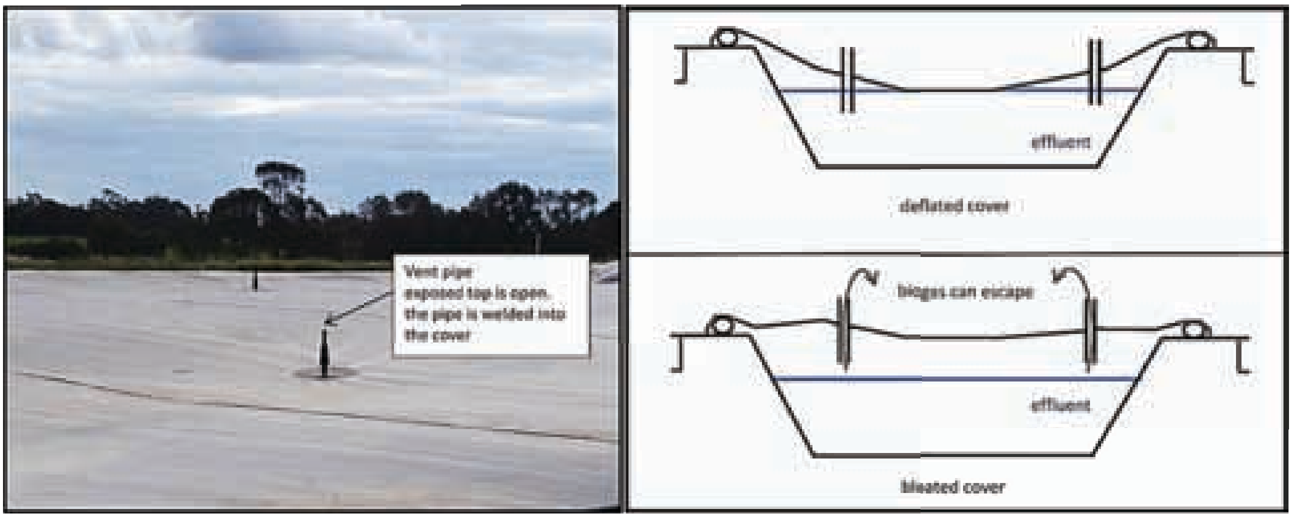
Table 3 summarises some more specific safety activities around piggery biogas. For further safer practices, see The Code of Practice for On-farm Biogas Production and Use (Piggeries) (APL 2014).

FIGURE 3 Typical portable biogas/hydrogen sulphide safety detectors (Google images)

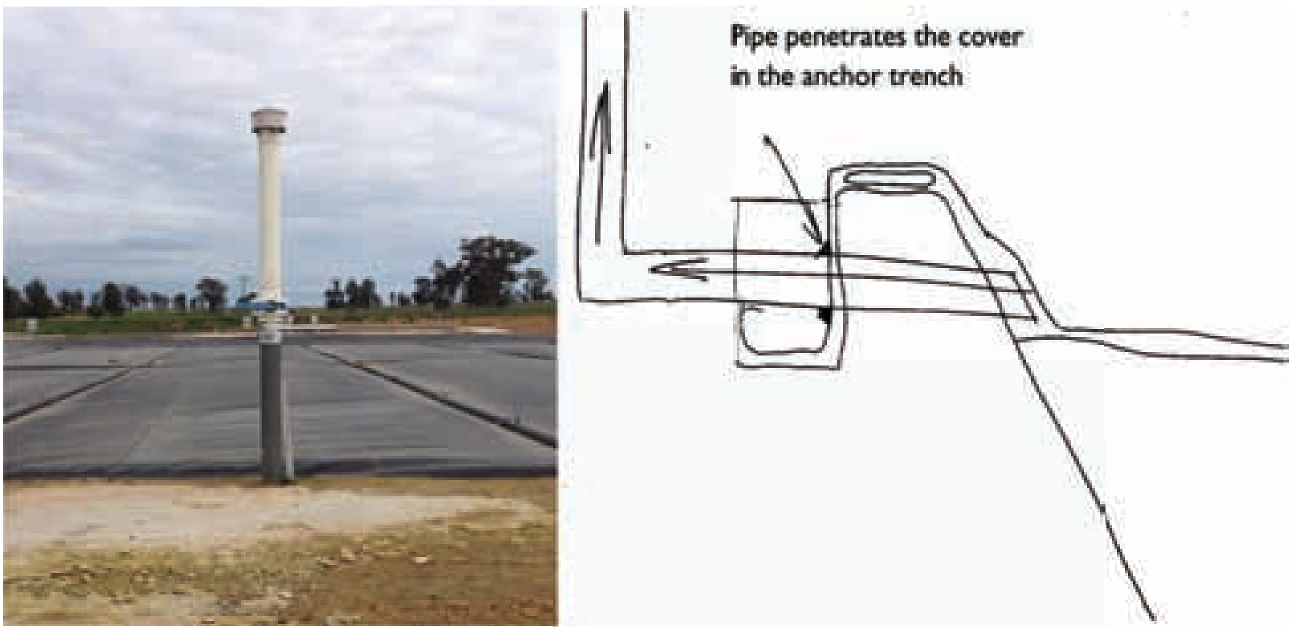
Biogas Safety

FIGURE 4 Biogas pond safety vent. Poor design (top) and good design (bottom)

POOR VENT DESIGN - RELIES ON SUBSTANTIAL POSITIVE PRESSURE FOR VENT TO WORK



GOOD VENT DESIGN - THE VENT OPERATES INDEPENDENTLY OF THE COVER PRESSURE AND THE COVER DOES NOT NEED TO BE HIGHLY PRESSURISED/BLOATED IN ORDER TO VENT BIOGAS



Piggery biogas can be made safer by:

1. preventing leaks of biogas (excludes safe and purposed venting)
2. preventing people being exposed to raw biogas
3. preventing unwanted flammable biogas-air mixtures from forming
4. keeping ignition sources well-distanced from areas where flammable biogas-air mixtures may be present (this includes bushfires)
5. minimising the amount of biogas present on-site
6. providing adequate safety signage, equipment for those working in close proximity to a biogas system.

CASE STUDY 2

Real Piggery Case Study

Death by inhalation of hydrogen sulphide suspected on Polish pig farm.

Seven family members died in Western Poland. A person drove a tractor onto a tank's cover (presumably a below-ground tank) which gave way and seven family members who tried to rescue her were overcome by noxious gases, fell into the tank and died at the scene.

Source: News Corp Australia, July 18, 2014.

Biogas Safety

TABLE 3 Practical actions for making piggery biogas safer

OBJECTIVE	ACTION
Preventing leaks of biogas	▪ Construct biogas system from compatible materials [(a)] ▪ Provide safety flare to burn off excess biogas [(b)] ▪ Perform regular checks for cracks, tears, damage, odour or significant gas detector readings ▪ Provide back-up power for essential services, such as a biogas blower to a safety flare ▪ Install appropriate ballast weight pipes to balance biogas volumes under a cover and to minimise adverse wind exposure of a cover [(c)] ▪ Operate biogas pipelines and equipment at pressures below 50kPa ▪ Allow for the thermal expansion and contraction in the length of buried plastic pipework ▪ Do preventative maintenance as per manufacturer's specifications
Preventing personal exposure to raw biogas	▪ Adequately train piggery staff and contractors, including how to distinguish odours of piggery biogas ▪ Restrict access to biogas system to authorised persons (fencing can be useful, See Figure 5) ▪ DO NOT enter manure pits, covered lagoons, digesters, other confined spaces, even in an attempt to save life (See Case Study 2) ▪ Fix gas detectors in poorly ventilated areas (such as sheds containing biogas equipment), preferably with external alarms to warn persons before entering the area ▪ Wear or carry portable gas detectors when walking around a biogas site (within marked fencing area, where relevant) ▪ Position condensate drains and biogas vents at a safe height and location to prevent direct exposure to raw biogas [(d)] ▪ Refrain from working alone at the biogas plant ▪ Thoroughly isolate biogas and effluent during maintenance with a lock-out procedure, and consider the risk of backflow
Preventing unwanted flammable biogas-air mixtures	▪ Locate biogas equipment and above-ground pipework in well-ventilated areas, where possible ▪ Provide a dedicated blower to each individual biogas-fired appliance, including flares, to minimise risk of air ingress ▪ With initial start-up/commissioning, thoroughly flush all biogas pipework and equipment with the biogas that is being produced, before switching on any biogas-fired appliances such as flares, boilers or engines ▪ Provide backflow prevention in the biogas pipework, especially to vent stacks and flares ▪ Minimise air ingress when biogas equipment and pipework is taken offline
Keeping ignition sources out of explosive areas	▪ Install flame arrestor upstream of each significant ignition source (flare) ▪ Electrical equipment should be appropriately selected according to hazardous area zoning under AS/NZS60079.10 and installed in accordance with AS3000 ▪ Install clear-explicit signage to warn of fire danger and notify of the need to keep viable ignition sources (e.g. mobile phones, cigarettes) well away from a biogas system
Minimizing the amount of biogas fuel onsite	▪ Install a safety vent which allows the operator to vent biogas safely at will and with a safely-located vent stack (e.g. above head-height) to prevent direct exposure to vented raw biogas [(e)]
Warning persons working around a biogas system of any imminent dangers	▪ Clear/explicit safety signage ▪ Use fencing to clearly demarcate a danger area, where appropriate ▪ Adequately train and advise piggery staff and contractors ▪ NOTE: gas fitters may not be aware of the unique dangers of hydrogen sulphide in biogas ▪ Fix gas detectors in poorly ventilated areas, preferably with external alarms ▪ Wear or carry portable gas detectors when walking around a biogas site

(a) Which are compatible with biogas and tolerant to exposure temperatures and UV where appropriate. Biogas can be corrosive to many metals. NOTE: Section 4 of AS5601 does not allow plastic pipework or components above-ground. Plastic pipework may only be used above ground if section 2 of AS5601 is appropriately enacted.

(b) A safety flare should be appropriately sized to evacuate a cover on a piggery lagoon within a reasonable period (at least 1.2-1.6 times the maximum expected rate at which biogas is produced by the lagoon or digester).

(c) Water filling of ballast pipes can provide adequate weight and gives greater operational flexibility than concrete or sand-filled weight pipes, because the level of water in the ballasts can be adjusted to alter the weight as necessary. NOTE: The only major biogas-related fire to date at an Australian piggery was caused by the ripping of a cover when a concrete-filled ballast pipe was dragged across the cover to be re-positioned.

(d) Vents or drains should NOT be placed in poorly ventilated areas, low lying areas or underground pits, because hydrogen sulphide may accumulate to dangerous concentrations.

(e) Note that a flare can be a safe vent option.

Biogas Safety

FIGURE 5 Fence exclusion can clearly mark restricted access areas and related hazards

General Safety Issues

In general, producers in Australia are required to achieve the standards of health, safety and welfare under the Work Health and Safety (WHS) Act and the WHS Regulations in the respective jurisdiction.

This is required, irrespective of whether or not biogas is being captured and used on-farm. Safe Work Australia has published a number of Model Codes of Practice which can help to deal with relevant generic safety precautions such as:

- Confined spaces (particularly relevant to biogas-filled spaces)
- Electrical risks
- Excavation work
- First aid
- Fall prevention
- Hazardous manual tasks
- Noise
- Plant such as machinery (including risk of entanglement and others).

These Model Codes of Practice are located at http://www.safeworkaustralia.gov.au/sites/swa/model-whs-laws/model-cop/

ELECTRICITY

A biogas system uses electricity for motors and instruments and can also produce electricity from biogas-fired generators. Electrical work must only be performed by a licensed person in accordance with relevant standards and regulations.

Live electricity must not be generally accessible and electrical circuitry must have appropriate leak detection and tripping mechanisms. When maintenance work is performed, electrical supply must be isolated and locked out to prevent accidental energising. Clear/explicit and visible signs must warn of a live electrical supply (Figure 6).

FIGURE 6 Guarded electrical supply with warning signage on a shipping container with a biogas-fired generator inside. Also note the illuminated emergency switches which are located outside the shipping container.

General Safety Issues

HAZARDOUS CHEMICALS

Some hazardous chemicals are used to clean hydrogen sulphide from raw piggery biogas and require tailored handling and disposal. Examples may include caustic soda, hypochlorite and iron(III)chloride. The relevant material safety data sheets (MSDSs) for chemicals that are in use, outline appropriate precautions and are best kept on-hand for easy reference.

Porous solid media containing iron (rust) is often used to remove hydrogen sulphide from raw biogas by contacting the biogas with the media in a vessel. Commercially available media is typically not a hazardous substance in its purchased form. However, when the media has become spent (can't absorb any more hydrogen sulphide) it may be regenerated by passing air through it. The chemical reactions that take place between the regenerating solid media and the air, releases large amounts of heat which can melt plastic equipment.

DROWNING

Drowning in covered lagoons or digesters is more likely to be an indirect consequence of being overcome by noxious gases such as hydrogen sulphide. However, where drowning is the obvious direct risk (e.g. open lagoons), retrieval or floating apparatus should be available.

MACHINERY

As with other machinery, engines and motors used with biogas equipment pose a risk of entanglement, unless appropriately guarded. Loose clothing and jewellery should not be worn when operating mechanical equipment and long hair should be tied back. Machinery must be appropriately isolated during maintenance and locked out to prevent accidental energising when being worked on. Safety signage should warn of the risk of entanglement where appropriate (Figure 7).

HOT SURFACES

Surfaces of biogas-fired boilers/ engine generators can be hot and appropriate signage should warn workers about uninsulated hot surfaces.

HEIGHTS

Wherever possible, work should be performed at ground level, or fall prevention should be in place where there is a risk of a fall that is reasonably likely to cause an injury. Signage should warn workers of a risk of a fall, where appropriate.

NOISE

Biogas-fired engine generators require muffling and housing to reduce noise (Figure 6). There have been cases of noise complaints from biogas-fired generators at piggeries. Ear protection should be made available and worn where appropriate in close vicinity to engine generators. The location of engine generators should consider noise. Unfortunately, because the transport of electricity is much more expensive than the transport of biogas, a generator skid will generally be located close to connecting circuitry and grid infrastructure (in the case of grid electricity exports) which may not be the most ideal location to reduce noise.

PPE AND SIGNAGE

As a last line of protection, workers should be provided with appropriate personal protective equipment (PPE). Examples of relevant personal protective equipment include hearing protection and gas detectors. Warning signs and tags should also identify hazards and any required PPE, and should be clearly visible and unambiguous (diagrams can be useful for non-English speaking or illiterate persons).

General Safety Issues

FIGURE 7 Typical safety signage around an on-farm biogas system.

Other Talking Topics

Talking Topic 1
Collecting the biogas benefits of pig manure.

Talking Topic 2
Biogas safety – the essentials.

Talking Topic 3
Looks at designing a covered lagoon for biogas… What are the unique features of covered lagoons over conventional piggery lagoons?

Talking Topic 4
Reviews the uses of piggery biogas: Power generation and heating options… How is piggery biogas used for energy?

Talking Topic 5
Deals with biogas cleaning... Why clean biogas before using it and how?

Talking Topic 6
Looks at Carbon Farming with pig manure... How does it work?

Talking Topic 7
List of biogas suppliers.

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