Development and Extension of Industry Best Practice for On-Farm Euthanasia of Spent Layer Hens

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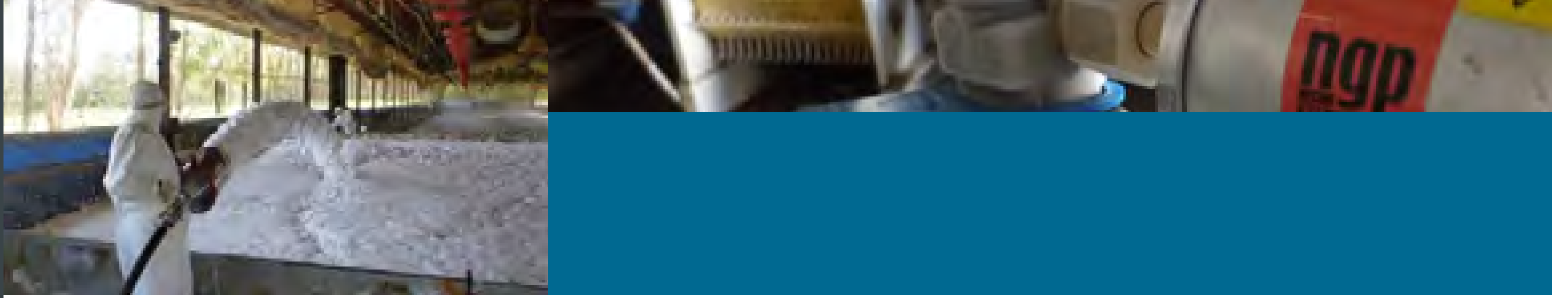

Best Practice for On-farm Euthanasia of Spent Layer Hens

POULTRY PRODUCTION
Sub-Project No. 1.5.3

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EXECUTIVE SUMMARY

At depopulation, spent layers have historically been caught, crated and transported to various poultry processing plants where they are slaughtered and processed as whole birds or further processed for use in a variety of human food products. Due to the reduced commercial value of spent hen meat and the imposed charges applied to collecting spent layers, egg producers are looking for alternative ways of removing spent layer hens.

On-farm mass destruction of spent hens, coupled with a disposal method, has become a viable option and has already been taken up by many egg producers. With the need for the egg industry to have an alternative to processing spent layers in the form of on-farm euthanasia, it is essential for individual layer farms to establish standard operating procedures to ensure that this activity is undertaken in a sustainable and welfare compliant manner. It is also necessary that the disposal of these birds is carried out in accordance with environmental protection guidelines.

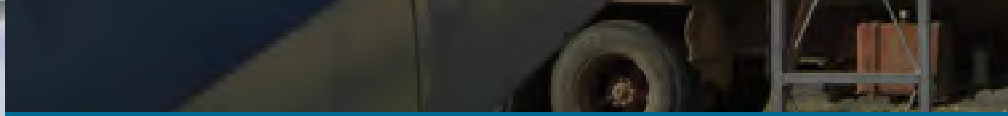
An extensive literature review of the methods of destruction of commercial poultry has been undertaken, covering individual bird killing to mass destruction methods.

The advantages and disadvantages of on-farm killing were compared and discussed and the practical options considered. Mass destruction by the utilisation of gaseous carbon dioxide (CO_2) or Modified Atmosphere Killing (MAK) was considered to be the most feasible and acceptable methodology to be used by the Australian layer industry.

On-farm mass MAK was evaluated by observing field operations, with both positive and negative aspects of the process being observed and recorded. More formalised field trials were undertaken with extensive recording and monitoring. From this, improvements in the methodology were developed, involving container design, the objective recording of CO_2 concentrations and the improved delivery of gaseous CO_2.

Other areas including costings, bird welfare, WH&S and bird disposal methods were considered for their importance in the process of mass destruction of spent layers.

The studies have allowed the development of a case study that may assist the Australian poultry industry to undertake efficient and welfare-sensitive mass destruction of spent layer hens (Appendix 1).

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ABBREVIATIONS

AI	Avian influenza
AVMA	American Veterinary Medical Association
BOC	British Oxygen Company
DEPI	Department of Environment and Primary Industries
EAD	Emergency Animal Disease
ECG	Electrocardiogram
EEG	Electroencephalogram
MAK	Modified Atmosphere Killing
WH&S	Workplace Health and Safety
OIE	World Organization of Animal Health
RPM	Rotation per minute
SOP	Standard Operating Procedure
USDA	United States Department of Agriculture
WHG	Whole House Gassing

1. INTRODUCTION

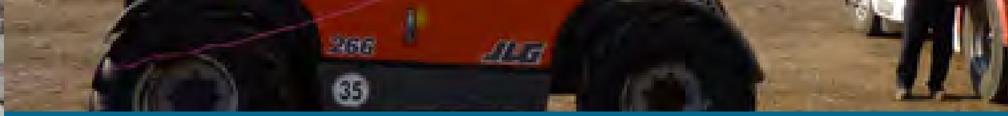
In 2014 the Australian commercial egg industry has approximately 17 million laying hens (layers) in production, producing over 400 million dozen eggs. Annual per capita consumption in Australia exceeds 220 eggs.

Historically, based on achieving best returns per hen housed, layers have been depopulated after a lay period of approximately one year. A spent hen is a term used for a hen that has passed its prime egg laying period. Spent hen flocks are depopulated to accommodate more productive flocks.

Today, in most commercial egg production systems, hens are considered spent at around 72 weeks of age (although some now run to 80 weeks of age). At depopulation, spent layers have historically been caught, crated and transported to various poultry processing plants. The layers are then slaughtered and processed as whole birds, or further processed to recover the breast and leg meat for use in a variety of human food products. Carcasses and soft offal are sent for rendering, as are the feathers. Currently, approximately 75% of the spent layer hens in Australia are processed in processing plants, but this number varies from state to state and largely depends on the availability of processing facilities and their distance from the farm. The remaining 25% are euthanised on-farm, but this is expected to increase in the coming years. Broiler breeder hens, on the other hand, are typically depopulated at about 64 weeks of age. Spent broiler breeders have a significantly higher commercial value than spent layers because of their relatively high meat content and are likely to continue to be commercially processed.

Previously, all spent hens, meat and products, had a commercial value and egg producers were able to recover some monies for their spent layers, which were usually transported at nil cost by the processing plant. In more recent years, a number of factors have contributed to the reduction in value of spent layer hen meat, to the extent that the activities of catching, transporting and processing have made the viability of processing spent layers marginal. This situation has also been reported in the Canadian egg industry (Montgomery, 2005). The factors that have contributed to this include:

- The relative low cost of quality broiler meat, making it a more preferable option to use in food manufacturing.
- The lower meat yields of modern processed spent layers compared to the older, heavier style of layers, this being particularly so for birds housed under extensive systems (Montgomery, 2005).
- The relatively high transportation and labour costs for the net kilogram yield of boned out hen meat.
- Increased compliance costs for the handling, transportation and processing of spent layer hens.
- The higher Australian dollar limiting export markets.
- Increased frozen storage costs.
- The lower price offered for rendered poultry meal that contains feather material. Removing the feathers at the processing plant where the carcass is solely used for rendered material is another cost impediment.



Poultry processing plants that are regularly processing broilers have found that the incorporation of the relatively erratic runs of spent layers into the processing plant is not compatible with their efficient programming; the processing equipment is not always suitable and the overall processing efficiencies for the products achieved does not meet sound economic targets. Biosecurity is also an issue as there is generally less control and knowledge of the health status of the longer lived layers, which is of a concern where there is a crossover of horizontal contacts such as transportation vehicles, crates and staff.

A number of the smaller specialist plants processing spent layers hens found that the current arrangements affected the sustainability of their businesses. What followed on from this was an attempt by the processors to recover some monies by charging for the collection and transportation of the spent layers. This applied particularly to cage layers, where there was no demand for this processed meat that was relatively costly to produce. Free range layer meat still obtained a premium price, but this also was compromised due to the increasing level of free range broiler (chicken meat) production. For the first time, egg producers found that spent hens were no longer a small profit centre but were a significant cost component. Egg producers looked at alternative strategies to deal with spent layer hen disposal. The sale of spent hens to back yard producers only absorbed a very small, insignificant number of birds from depopulation.

On-farm mass euthanasia of spent hens became a viable option and was immediately taken up by many egg producers. The absence of a reliable continuum of spent layer hens further compounded the plight of some processors resulting in the closure of their businesses.

The closure of these facilities resulted in a rebound problem for egg producers who were still able to and wanted to have their spent layers processed. Other existing and more distant processors could not be used because of the domestic poultry code conditions requiring commercial poultry having to be slaughtered within 24 hours of catch out.

Currently, the egg industry utilises both processing plants and mass euthanasia to dispose of spent layer hens. The number of spent layer hens to be depopulated is influenced not just by the increasing per capita consumption of eggs, but also by a number of factors which include:

- The increased hen house production figures of the modern layer.
- The increased mortalities of free range birds compared to cage, which is significant.
- The depopulation age of spent hens increasing to over 80 weeks and predicted to go to 100 weeks with future layer genetics having better sustainability and improved shell quality.

With the need for the egg industry to have an alternative to processing spent layers in the form of on-farm euthanasia, there is a requirement for individual layer farms to establish standard operating procedures to ensure that this activity is undertaken in a sustainable and welfare compliant manner. It is essential that the disposal of these birds be carried out in accordance with environmental protection guidelines.

This report aims to provide a foundation for the commercial egg producer in the facilities, requirements and methodologies that guarantee that spent layer hens will be depopulated and euthanised in an appropriate manner with regard to welfare and environmental management. Associated with this will be the consideration that the procedures are economically sound, meet the expectations of the public and regulatory authorities, and are undertaken with WH&S responsibilities for those personnel involved.

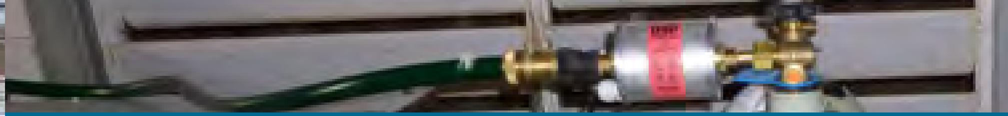
This report does not specifically cover the situation of mass euthanasia as a consequence of an Emergency Animal Disease (EAD) mandated slaughter out and eradication policy. However, the underlying principles are the same when it involves the mass euthanasia of poultry.

2. LITERATURE REVIEW

In undertaking the literature review it was noted that most of the material studied was produced around the need for or experience from mass euthanasia of poultry as a consequence of an EAD.

This situation is somewhat different from the pre-planned and hopefully orderly fashion in which a routine spent layer hen depopulation is undertaken. In an EAD situation, rarely are birds from infected properties and restricted zones sent for processing, and invariably there are restrictive movements for biosecurity reasons. The other difference is the possibility of a zoonosis, particularly with avian influenza, where mass euthanasia procedures must ensure that no health risks are imposed on the workers. It was also noted that prescriptive detail on the facilitation and methods employed were limited. Below is a synopsis of the current literature on the mass euthanasia of commercial poultry for the reader to consider the different approaches used to the mass killing of poultry as well as the different values and considerations placed on the real and perceived welfare of the birds.

In their first trial, Webster and Daniel (1996) used a renderer's offal trailer covered with a heavy plastic sheet. A series of 50 lb carbon dioxide (CO_2) cylinders was set up on the loading dock of the hen house to dispense CO_2 into the trailer as needed. The hens were rolled out of the house on hanging carts according to typical practice for fowl removal, and were loaded through 3' x 3' holes cut into the plastic sheet over the front and rear halves of the trailer. However, after a few hundred hens had been placed into the trailer, it became obvious that the atmosphere inside was no longer able to render the hens unconscious. CO_2 had to be added to the trailer after successive batches of 500-600 hens were loaded and when the trailer was full, it was not possible to kill all the hens in the top layer regardless of how much CO_2 was added. In the second trial, a modified atmospheric killing (MAK) unit built of 3/4 inch plywood with an interior capacity of about 21 ft^3 (0.6 m^3) was used. Later the MAK unit was refitted with two plywood boxes on top of the cart with spring-loaded plexiglass doors opening inward on the side of each box to eliminating the problem of hens going in one door and out the other when the two catchers had the doors open simultaneously. A 20 lb CO_2 cylinder was mounted on one end of the unit and connected to a system to permit gas to be delivered through a regulator to two levels within the box. The unit worked successfully in an on-farm trial, allowing hens to be killed directly after being removed from their cages. CO_2 was added when the hens' activity in



the container warranted. In this trial it was possible to kill 1,500 hens per 20 lb cylinder. The author noted that gas cylinders in the upright position can dispense only 2/3 of the gas because of rapid pressure drop and recommended that gas cylinders be fitted with interior siphon tubes to get around the need to install cylinders upside down.

In another trial, Webster and Collett (2012) tested a MAK system for the purpose of humanely depopulating backyard or small flock poultry. The MAK container was built on a 12 foot tandem-wheeled trailer and was placed with a slight overhang to allow for unloading. The loading doors were made of clear lexan to additionally serve as an observation port. Separate gas delivery systems were installed for the CO_2 and nitrogen (N_2). Each sensor controlled a solenoid valve, triggering it to release gas to modify the internal atmosphere according to a target gas concentration. A small in-line block heater was mounted in the CO_2 cylinder ahead of the pressure regulator to reduce chilling of the regulator and gas line. The target CO_2 concentration was set at 50% for trial with poultry and for N_2 2% residual O_2 was set as a target. With CO_2, it took an average 4.2±0.2 min to prefill the container with CO_2 to a concentration of 50% before loading, and thereafter the time required to obtain a full load was primarily a function of distance and number of individuals available. However, with N_2, continuous loading was not possible as the very low levels of residual CO_2 necessary to cause death could not be maintained during loading, so consequently birds had to be killed in batches. Therefore, automated control of the gas delivery system was helpful to hold CO_2 at a pre-set level, ensuring a quick kill of the birds while minimising gas consumption. The author concluded that in warm weather CO_2 gives the fastest loading time and quickest kill of the individual birds but in cold weather, N_2 could be preferred as chilling of the cylinder during gas release is not problematic.

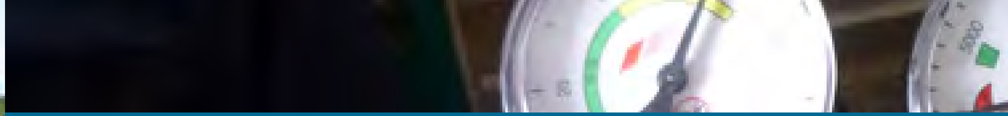
In an attempt to search for a gas that could either stun the chicken through its own action or replace oxygen and thus stun the birds through anoxia/hypoxia, Duncan (1997) had discussions with the British Oxygen Company (BOC), the largest producer of industrial gas in the UK and worldwide. The BOC group narrowed the field of potential gases down to CO_2 and Argon. Both of these gases are considerably heavier than air and so are reasonably easier to contain. In addition, these gases, particularly CO_2, is relatively low cost.

The effect of different rates of induction of carbon dioxide anaesthesia on the time to loss of consciousness was investigated in broilers and laying hens by Raj and Gregory (1990). In their first experiment, 24 and 17 broilers respectively, were exposed to 45% carbon dioxide within 8 or 18 seconds (accession time). In the second experiment, 18 to 20 broilers and hens were exposed to 35, 45, 55 or 65% carbon dioxide within 8 seconds. The results indicated that in general, the rate of accession is more critical than the final concentration of carbon dioxide; however, in 35% carbon dioxide, an exposure time of longer than 5 minutes was required to kill the birds. The time to sustained eye closure, time to onset of clonic and tonic convulsions and the duration of convulsive episodes were shorter in broilers than in hens. The authors suggested that under commercial situations, a final concentration of 55% carbon dioxide would be suitable for killing broilers and hens.

The efficacy for the euthanasia of day-old chicks of mixtures of CO_2 and air, or CO_2 and argon containing 1, 2 or 5% residual oxygen, or argon containing 1 or 2% residual oxygen was tested in three experiments by Raj and Whittington (1995). The time to the onset of unconsciousness of individual chicks, determined from the time to loss of posture, was similar during their exposure to 2% oxygen in argon, 20, 30 or 40% CO_2 in argon with 2% residual oxygen, or 90% CO_2 in air. The exposure of chicks in batches of 20 to a mixture of 20, 30 or 40% CO_2 in argon resulted in the death of all the chicks within two minutes. However, a residual oxygen level of 5% in these mixtures resulted in the survival of some chicks for longer than two minutes. With argon alone the level of residual oxygen (O_2) was critical; less than 2% was essential to achieve 100% mortality within three minutes, and a rise from 2 to about 3% resulted in up to 20% of the chicks surviving for seven minutes.

A mixture of gas containing up to 20% by volume CO_2 in argon is universally available as welding gas mixture at affordable prices. In their earlier study, Raj et al., (2008) revealed that a mixture containing a low concentration of CO_2 and inert gas is less aversive than high concentration of CO_2 (50% by volume). It also revealed that 20% CO_2 in argon with 5% residual O_2 would be sufficient to kill poultry in 2 minutes. Furthermore, ducks could be killed within 3 minutes exposure to the same mixture with 2% by volume of residual O_2. To assess and develop a large compartmentalised killing system to minimise the welfare concerns of smothering, and enhance monitoring and flexibility of use, Raj et al., (2008) designed a 6.75 m^3 front loading container with 2 ventilation holes at the top, high pressure tubing and silencer and duplicate gas fittings as a backup. Every time 300 crated chickens were placed in each container using a forklift, and after locking the door, they allowed 2 minutes for the gas concentration to reach to the ideal level (which was monitored from outside) and then allowed half a minute for exposure. The result revealed that 4 out of 4,000 birds in 3 modules survived, mainly due to an inadequate gas supply towards the door, and this was fixed later using two extra diffusers.

A field trial of whole house gassing with CO_2 as part of the Emergency Disease Response Plan was conducted at Peats Ridge, NSW (2006). The main objectives of this trial were to assess the practical issues involved in using CO_2 gas for the mass euthanasia of poultry in an EAD response and to evaluate the likely effectiveness of this method. The target was to fill the shed to about 0.9 m height with CO_2 concentrations of between 40 and 70% within 30 minutes and to maintain concentrations at that level for 30 minutes. CO_2 was injected into the sheds as rapidly as possible to reach the initial target concentration of 20%, which induces anaesthesia in poultry. After 17 minutes, 4 tonnes of CO_2 had been pumped into the shed and the concentration was measured as greater than 40% at more than one sensor. When the flow was stopped, the sensors at the far end of the shed indicated concentrations of greater than 33%. At 'bird level', 20% CO_2, the concentration at which narcolepsy occurs (Gerritsen, 2006), was reached at the end closest to the lance after 2-5 minutes and at the far end after 12 minutes. The steady rise in CO_2 concentration with time indicates that if gas was infused at the same rate, the target concentrations would be reached after 26 minutes.



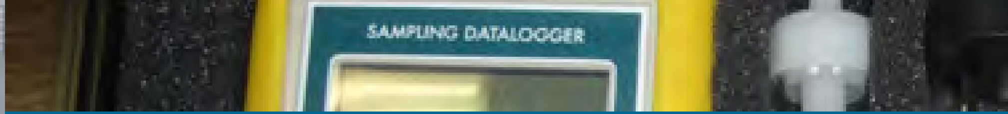
Wiebe van der Sluis (2008) developed an entire system called the 'Slaughter Mobile', consisting of a CO_2 gas stunner that kills the birds humanely within two minutes at a capacity of 5,000 birds per hour. The dead birds are immediately conveyed to a 12 mm grinder where, at the end, three independent perforated cutters mince the material to a mesh size of 12 mm, depending on the requirement, and a 2 m^3 storage tank on board of the mobile machine. In the storage tank the pulp is mixed with acids to further disintegrate the feathers and bones at a pH of 2. This will kill all possible bacteria and viruses. After completing the mixing process, the pulp can be pumped into a trailer tank of up to 20,000 birds for transportation to the feed manufacturing plant. Meanwhile, the pH value of the pulp will, due to the disintegration process, be increased to an acceptable level for further processing to be used as feed. A significant number of spent hens in Denmark are processed on-farm to be used as mink feed. The pulp derived from the process can also be used for the production of bio-energy, as well as meat and bonemeal in a feed ration.

Wepruk (2013) looked at the use of a macerator. Maceration, a less commonly used method, has been described as very humane, with birds being killed quickly upon entry into the vacuum tube. A macerator for use on-farm has been developed by Oleet Processors in Regina, Saskatchewan. Their unit "vacuums" birds down a 20 foot long tube, to a grinder that kills the birds upon impact with its blades. While the system shows potential, some questions remain to be answered regarding its humaneness. Research is needed into the exact length of time it takes for a hen to pass from the vacuum tube to the grinder. It would appear that the macerator holds potential as a humane option for on-site euthanasia of spent laying hens, however, use of the macerator is unsightly and the public's aesthetic perception of this technology may be difficult to overcome.

The paper by Bud Malone and his colleagues (2007) explains different systems of mass depopulation and compares relative advantages of gas killing vs. water based foam killing. It includes four CO_2 methods which have been used in previous avian influenza (AI) events. These are whole house, containerised, poly tent and mobile gassing systems. All of these methods have some advantages and disadvantages and some require manual handling which poses a risk of contamination during an event of zoonotic infectious diseases. On the other hand, submerging the birds in the proper consistency of foam has many potential advantages over current depopulation methods. Benson et al., (2007) found that the time to death in small groups was similar for CO_2 and foam, yet foam was faster as group size increased. Adding CO_2 gas to foam did not enhance efficacy, and based on blood corticosterone concentrations, the foam was no more stressful than CO_2 depopulation. Necropsy and histological examination of birds subjected to both foam and CO_2 showed lesions consistent with hypoxia as the cause of death. To date, compressed air foam, aerated foam nozzles and modified high expansion foam generator systems have been used successfully. Some of the key advantages of this system are that it takes one half to one third less time to depopulate farms, gives significant reduction in the number of workers and their potential exposure to a zoonotic disease. It also requires less physical activity, which can be a major issue when having to comply with personal protection equipment required in a disease situation, suppresses airborne particulates when the house is blanketed with a layer of foam, potentially enhances carcass disposal using in-house composting, and provides greater flexibility of use in various style houses and those structurally damaged. This method does require a significant quantity of water, a supply of foam concentrate, and an investment in foam equipment that is dedicated for this purpose.

In his paper, Raj (2008) gives a brief outline of different mass in-house killing systems and discusses their advantages and disadvantages. It is known that poultry consider humans to be predators; therefore, manual catching and handling can induce avoidable fear and distress. For this reason, overdose via intravenous anaesthesia—which is considered the most humane killing method—could not be achieved without the potential risk of compromising bird welfare. In addition to the stress associated with catching and shackling, it has been reported that electrocution of poultry involving water baths, supplied with 220 to 400 V and closed-loop shackle lines, failed to induce death in all the birds because a considerable proportion of birds hung on shackle lines flapped their wings, leading them to completely miss the electrified water bath. Raj (2008) considered that the main advantage of whole house gassing (WHG) was that that the method is relatively fast, as gas injection can be completed within minutes without entering the house. About 2 kg of liquid CO_2 is required for every 1m^3 of poultry house to achieve a concentration of 45% by volume in air at head level of birds kept on deep litter. In some countries, killing poultry in houses has also been tried by manually sprinkling or spreading crushed dry ice over the floor or laying cylinders of CO_2 gas on the floor and opening the valves. Nitrogen (N_2) gas is inexpensive, readily available, and non-aversive to poultry. N_2 has been evaluated in Denmark for killing layer hens in battery cages. The cold N_2 gas, which is denser than air, was infused into the house using hoses inserted through ventilation holes on the roof. Under this situation, hypoxia (less than 2% residual oxygen) was successfully created, and all the birds were killed within 20 min of administering the gas. Recently, researchers and commercial poultry companies established that non-toxic, water-based foam with a certain bubble size presents a practical, effective, and humane method for mass depopulation. Foam of the right bubble size creates an occlusion in the trachea of birds, causing a rapid onset of hypoxia. The foam that blankets the broiler house induces physical hypoxia—the same cause of death as the approved method using CO_2 gas.

In his PhD dissertation, Gerritzen (2006) assessed behavioural and physiological animal welfare aspects and efficacy aspects of gas killing for individual birds and groups of poultry. In these experiments, blood gas values, EEGs and ECGs confirmed that both ducks and turkeys are equally as sensitive as chickens to increasing carbon dioxide concentrations. The results found that all farmed poultry species can be killed by increasing the carbon dioxide concentration up to 40-45%. However, it was noted that before loss of consciousness, all animals expressed heavy breathing (gasping) and headshaking for a period of 2 to 3 minutes. Therefore, it was concluded that the period of compromised animal welfare is no longer than 3 minutes. This period of compromised animal welfare, however, is shorter than when animals are caught and handled using mobile gas containers or mobile electrocution lines. In another study Gerritzen found that exposure of broilers to 70% argon and 30% CO_2 mixture resulted in the fastest loss of posture. The number of broilers exhibiting headshaking and gasping was least in the greater than 90% argon in air mixture. Convulsions were rarely seen in the 40% CO_2 and 30% O_2 mixture. The experiment did not indicate that broilers could detect or avoid increased CO_2 or decreased O_2 levels when they come into contact with such atmospheres for the first time.



At the APINCO conference, Malone (2006) discussed four CO_2 mass depopulation methods which have been used in previous AI events; whole house, live haul cage cabinet, poly tent and mobile systems. According to the author, to achieve a desired goal of 70% CO_2 concentration with these methods, the kilograms of CO_2 required can be calculated by multiplying the cubic meters of space in the enclosure by a factor of 1.283 kg. Specially constructed steel cabinets, designed to fit over live haul cages, have been used in a previous AI event which greatly reduces the volume of space required to gas birds. Broilers are caught, placed in live haul cages and moved to an outside work area where a cabinet is placed over the cage, the bottom sealed to minimise leakage and gas injected using a single CO_2 cylinder tank per cabinet. While this method resulted in rapid death, it is labour intensive for catching birds, placing cabinets over cages and removing dead birds from the cages. One US company offers a mobile conveyor system that can gas birds with CO_2 or electrocute animals using an electrical contact pad mechanism. The procedure requires catching birds and placing them into the unit or driving birds onto a conveyor. Discussions have suggested that hand mass depopulation using fire fighter foam may have numerous poultry welfare, human health and biosecurity advantages over current methods. Prototype systems have been constructed and are being tested for broilers in the US. There is growing worldwide interest in this technology.

The operational procedures manual for the euthanasia of animals by Animal Health Australia (2010) describes management considerations and best-practice procedures for achieving euthanasia of various animal species. The procedures in the manual were approved by the Primary Industries Ministerial Council out-of-session on 15 June 2006 for use in an animal health emergency. The manual incorporates best-practice techniques from around the country and internationally. According to the manual, CO_2 gassing or barbiturate overdose are the methods of choice for euthanasia of birds. For the euthanasia of small numbers of birds (e.g. fancy breeds and pigeons), the preferred methods are dislocation of the neck (using Burdizzo, forceps or bare hands), or intravenous, intracardiac or intrahepatic injection of sodium pentobarbitone, however for large numbers of birds in commercial poultry units, the preferred, available method is gassing with CO_2. The use of foam for mass depopulation of poultry in an emergency animal disease event has also been discussed in the manual. The author has agreed that the use of type A (Class A) wet foam for depopulation of poultry sheds for emergency euthanasia where birds are confined to floors can be justified and not considered cruel.

The National Animal Health Emergency Management system Guidelines: Mass Depopulation and Euthanasia (2011) have been prepared by USDA, Animal and Plant Health Inspection Services (APHIS) and Iowa State University. It states that CO_2, N_2, and argon can be used to euthanise avian species. When very large numbers of poultry must be euthanised, large roll-off dumpsters can be positioned outside the poultry house, covered with plastic or tarpaulins, filled with greater than 70% CO_2, and loaded with poultry. Tenting with plastic sheeting can be used to efficiently administer CO_2 in floor-housed birds. Whole-house gassing decreases the exposure of people to live birds. Caged birds must be removed from the cage and placed on the floor since higher CO_2 concentrations exist near the floor. An area near the roof of the buildings needs to remain open in order for atmospheric air in the building to escape while CO_2 is pumped in. In the United States, whole-house gassing is not a practical approach for mass depopulation of avian species. When tested in typical US poultry management systems, it is excessively expensive, and euthanasia goals are not readily achieved. Again when compared to CO_2, the use of N_2 or argon is somewhat more problematic as the specific gravity of these gasses is very near that of atmospheric air. On the other hand, water-based foam is a newer method being employed for emergency depopulation of land-based poultry and waterfowl. Although water-based foam has not been officially approved as a euthanasia tool, it is used and approved for poultry mass depopulation under APHIS specified emergency response conditions. Electrocution and ventilation shut down are two other techniques which are under discussion for mass depopulation. Mobile electrical water bath systems have been designed for on-farm stunning and euthanasia of poultry and have proved useful in AI outbreaks. The voltage on these machines is set at sufficient levels for birds to be killed without the need for exsanguination as an adjunct method. Ventilation shutdown is defined as the cessation of natural or mechanical ventilation of atmospheric air in a building where birds are housed, with or without action to increase the ambient temperature. Although this method has not yet been addressed by the American Veterinary Medical Association (AVMA), it is approved in the United Kingdom as a killing method for poultry in certain disease control situations.

In his article at The Poultry Site, Webster (2007) outlined all the available options for on-farm killing of spent hens and included cervical dislocation, water based foam, avicides, electrocution, high speed maceration and gas killing. Of the mass depopulation methods considered so far, foam suffocation was considered to be the best option for a floor-housed flock with no structures for hens to climb on to escape the foam. Relative to other methods, avicide would be slow because birds would have to consume enough poison to kill them. Hens having taken non-lethal doses might stop drinking or eating due to malaise from the effects of the avicide. Webster referred to a preliminary trial to evaluate water-borne avicide for flock depopulation in another part of the world, which was reportedly less successful than hoped for, even when the flock was deprived of water before administration of the avicide. Instantaneous maceration can be humane if conducted properly, but is aesthetically displeasing to the public. It also creates a potential to release bits of tissue, blood and bodily fluids into the environment around the macerator, and the mass of ground birds would have to be carefully managed to prevent spills or seepage. While poisonous gases such as carbon monoxide and cyanide gas have been tried in various nations to depopulate poultry flocks, CO_2 a non-poisonous gas, has been the preponderant choice. CO_2 is relatively inexpensive and is normally readily available. Given enough exposure time, 40% CO_2 in air is sufficient to kill chickens (Gerritzen et al., 2004). Concentrations above 55% will kill birds quickly (Raj and Gregory, 1990). Gas killing requires the gas mixture to be contained. This can be done using portable containers, containers assembled on site (tenting method), or by using the interior of the building in which the flock is housed.

M Scott (2008) of the Department of Environment and Primary Industries, Victoria summarised the findings and available options for the use of firefighting foam in large scale poultry depopulation in his departmental internal report (unpublished). The system essentially relies upon a pump shifting water from an appropriate water source into a foam generating system, whereby foam concentrate is inducted into the water flow and forced through a mesh screen. The combination of this foam solution and air produces finished foam which floods into a poultry house immersing birds in the

process. The paper outlined many advantages of foam depopulation in an emergency disease response such as enhanced operator safety and efficiency, proven efficacy, minimal requirements to seal shed, high capacity, compatibility with in-house composting and most humane method. However, the author acknowledged that the technology has only been applied to floor-reared broiler operations and has limitations for use in caged or slatted floor bird houses.

3. ON-FARM EUTHANASIA OF SPENT HENS

To undertake on-farm euthanasia of spent hens an operator must consider a variety of factors, including the technical and operational advantages, the resources available and required expertise, personal and emotive reasons, contracted agreements and options, locality of the farm and the use of the final product.

3.1 On-farm Advantages

The decision to undertake on-farm euthanasia can be influenced by a number of factors which may include some of the following advantages:

- Reduced overall cost compared to utilising the services of a processor. The overall cost of the method of euthanasia, utilisation of on-farm labour and/or vaccination crews, and use of in-house vehicles have cumulative costs and opportunity costs which can be advantageous over using the processing contractor.
- Proximity to compost or other form of disposal site.
- Distance to processor where the duration of the travel and holding time exceeds the 24 hours allowed under the Domestic Poultry Welfare code, restricting the transportation of the birds.
- Timing of depopulation of an end of lay flock. The use of a processor often means that the time of depopulation and the rate of depopulation are predetermined by the processor. This may mean an egg producer may not be able to depopulate at the opportune time. This affects the programmed production of egg numbers and also the placement schedule of point of lay pullets, and can result in significant consequential losses.
- Minimal negative welfare impact on birds when compared to transportation time and other live bird handling aspects.
- Improved efficiency of labour. Depopulation by processors means the crating of birds and the usual depopulation of a large poultry shed occurs over 2 to 3, or even more days. This means that staffing requirements may be variable for this entire period. With mass euthanasia on-farm, a team of workers can usually have a shed depopulated in less than one day.
- Speed and ease of work.
- Value of the compost.

3.2 On-farm Disadvantages

The decision to destroy birds on-farm does require particular procedures, expertise and facilities to be put in place. These include:

- The need for equipment to either be made or purchased for the purpose of containment and euthanasia of the spent layers. There is no such commercial equipment currently manufactured in Australia. The equipment has to be specifically designed for the physical requirements of the particular farming operation and meet WH&S requirements. This is a capital investment that needs to be considered in the costing model of in-house mass euthanasia of spent layer hens.
- The pivotal requirement that staff and contractors are trained in the correct procedures for handling spent layers and are familiar with the welfare codes of practice. Standard Operating Procedures (SOP) specific to the farm need to developed and implemented under the supervision of a responsible entity such as a senior manager or veterinarian.
- Resources are required to be available on demand and this includes suitable people, equipment, on-farm handling vehicles such as fork lifts and licenced drivers, load out trucks with a nominated destination and disposables including CO_2.
- Welfare considerations are of paramount importance. The procedures for mass hen euthanasia must ensure that they can be monitored with measurable criteria including such things as CO_2 concentration, time period in which the bird is rendered insensible, and the irreversible outcome with the death of the spent layer.

4. KILLING METHODS FOR SPENT LAYING HENS

Though there are no specific published guidelines for the mass euthanasia and disposal of spent layer hens in Australia, various methods of stunning or killing animals, including those used for the purpose of disease control, have been described in several scientific reports, guidelines, and directives published by Animal Health Australia and other international institutions, for example, European Community (EC, 1993), American Veterinary Medical Association (AVMA, 2000), European Food Safety Authority (EFSA, 2004, 2005), and the World Organization for Animal Health (OIE, 2005). The methods that induce immediate death are preferred for spent layer euthanasia. The established or known stunning and killing methods for poultry include the following:

- Cervical (neck) dislocation or decapitation.
- Penetrating and non-penetrating captive bolts, using blank cartridges or compressed air.
- Electrical methods, involving application of currents as head-only and water baths.
- Gas mixtures, consisting of CO_2, carbon monoxide, argon, or N_2, and mixtures of CO_2 and N_2.
  - Undertaken in specially designed containers.
  - Whole shed gassing.
- Lethal injection or oral over-dosing of an anaesthetic drug.
- Maceration of live or unconscious poultry.
- Various types of foam and foam application.

4.1 On-Farm Killing Systems

Spent laying hens are of special concern because of their potential for increased bone fragility. On-farm mass euthanasia when compared to catching, crating and transportation can have welfare advantages provided the birds are handled correctly during removal from the cage or catching from a floor based system and killed humanely on site. The egg industry supports initiatives by researchers to develop viable on-farm slaughter methods. On-farm euthanasia is an alternative procedure for the mass euthanasia of spent layers and the methods and technology applied need to ensure that the welfare of the bird is of the highest consideration. Concurrently the procedure must be cost effective, sustainable and meet the necessary WH&S standards.

4.2 Available practical options

Almost all the humane killing methods act by first causing loss of consciousness (rendering the bird insensible), followed by cardiac and/or respiratory arrest, and death. There are different methods of disposing spent hens but not all of them are economically feasible or potentially environmentally sustainable. Having a range of available options would benefit producers, enabling the flexibility to choose a practical and economic disposal option for the size and type of their operation.

4.2.1 Cervical Dislocation

'Cervical dislocation', 'breaking the neck' or simply 'necking' are terms used to describe a simple, quick killing method. It is normally done by applying stretching pressure to the head and dislocating the spinal column at the junction with the head resulting in both the separation of the spinal column and the major vessels in the neck. It can be done by hand or using a Burdizzo clamp (Photographs 1 and 2) or equivalent. Burdizzo clamps are particularly useful for larger poultry with strong necks (geese, ducks etc.). Neck dislocation without prior stunning is an approved method of killing poultry under the Australian domestic poultry welfare code. It must induce immediate unconsciousness without causing pain or suffering and this is achieved by the rupture of the carotid arteries during the cervical dislocation procedure interrupting the blood supply to the brain causing a loss of consciousness and rendering the bird insensible to external stimuli. This is not achievable in all species, cattle have a vertebral artery supplying the base of the brain, and thus interruption of the carotid arteries will not deprive the brain of blood flow (Barnett et. al, 2007). While cervical dislocation is an effective and humane method of killing poultry, the operator needs to be experienced and competent to ensure that the outcome is reliable and sustainable. The Burdizzo clamp, or other mechanical bird killers, are a mechanical alternative which removes some of the manual skill required by operators. Cervical dislocation is recommended when there is very small number of birds being culled. It is reasonable to use in smaller birds and should only be performed by trained individuals.

Cervical dislocation has been used historically in Australia for large depopulation of poultry during an Emergency Animal Disease (EAD) outbreak. Issues arose with the need for large people resources, repetitive strain injuries to the workers, extended periods to depopulate the flock and also emotive issues affecting some workers. This method of killing also has limitations when involved in potential zoonotic disease outbreaks such as AI.

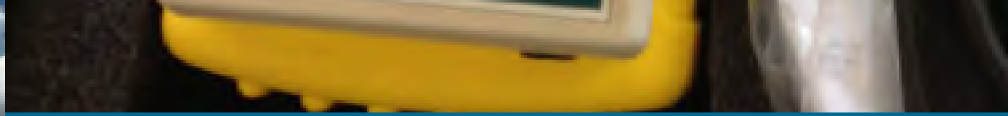
Photographs 1 and 2: Burdizzo Clamp

4.2.2 Captive Bolt

The principle behind captive bolt (Photograph 3) stunning is a forceful strike on the skull using a bolt which usually penetrates into the brain cavity and induces unconsciousness. Captive-bolt guns designed specifically for poultry are commercially available. Depending on what species is involved, a flat or a cone-shaped bolt head can be used. Captive bolt is recommended for use in culling small numbers of large poultry species, especially turkey and duck breeders.

Raj and O'Callaghan (2001) of University of Bristol have engineered a pneumatically operated captive bolt gun using compressed air for on-site killing of hens. They tested the device with two bolt diameters (3 and 6 mm) and two airline pressures (620 and 827 kPa). Captive bolt stunning of broilers with a 6 mm bolt and airline pressure of 827 kPa resulted in an immediate stun leading to death in all 6 broilers tested. But the gun must be held firmly against the head of the bird, firing at a right angle to the skull. This can be achieved by holding the bird's head with one hand and discharging with the other.

Captive bolt stunning is time consuming and is not feasible for large numbers of birds. It is a practical method for euthanising normal daily culls.



Photograph 3: Captive Bolt

4.2.3 Lethal Injection or Overdosing of Anaesthetic in Feed/Water

Killing birds by intra-venous injection of sodium pentobarbital is very time consuming and is only recommended for a very small group of poultry. This procedure requires considerable skill of the operator to be able to locate and inject into a suitable vein in the bird (jugular or wing vein) and thus it is unlikely that adequate suitable resources could be found for a mass culling. The actual procedure can be stressful to the bird while restraining and attempting to inject the bird, particularly where operators are inexperienced. There are also significant potential WH&S risks from needle stick injury. The cost of materials is high, the procedure slow, and the same physical and emotional impacts on workers are likely to arise as seen with cervical dislocation. Finally, the dead bird product is only suitable for burial, composting or possibly rendering. Direct intra cardiac puncture is another method for accessing the vasculature system, but it must be done by an experienced operator.

Poisoning animals by addition of a killing drug to the feed or drinking water is has limited potential due to the uncertain intake of food or water and thus the completeness of the procedure. The type of the killing drug used may also be limited by other aspects such as user safety, ability to dispose of the birds safely, residues and welfare. Alpha-Chloralose can be used in feed or water to sedate birds kept under free-range or semi-intensive husbandry systems, so that the stress of handling during the application of a killing procedure could be minimised or eliminated.

4.2.4 Electrocution

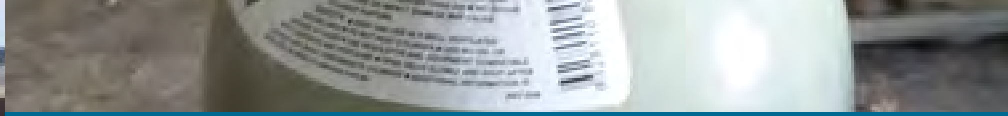
Electrocution has been tried in different countries as a method of flock depopulation. Small, handheld electrical stunners are commercially available. They are used for small scale poultry slaughter and are relatively easy to use on all poultry species. Mobile electrocution lines work along the same principles as the electrical water bath stunner used in processing plants. The major difference is the higher voltage on the water bath to kill all the birds. The capacity of a mobile electrocution device depends on the length of closed-loop shackling line. An arm of the line with an automatic tipoff could be used for loading trucks to remove dead birds from farm premises. Electrical conductivity is an issue in these systems but this can be improved by using salt in the water.

In Australia there has been discussion regarding the development of water bath and stunner equipment that could be brought to a layer farm. The capital aspects of this equipment and having it available in a timely manner at a particular site have been the considered limitations. Having water bath stunning equipment at a rendering plant also offers no advantage to the producer, as the birds still have to be caught and crated in a timely controlled manner, just as occurs when birds are sent for processing.

There are also biosecurity concerns surrounding moving killing equipment between poultry sites.

Different types of mobile modified electrocution methods have been developed in Canada. One of these is mobile electrical stunner (Photograph 4.) which is based on conventional slaughter lines. In this system birds are caught and walked to killing unit where they are electrocuted in a water bath. This system is applicable in many situations but it has limited capacity and requires extensive animal handling and most importantly shackling. In another method birds are placed into a hopper, whereupon they are dispatched by an electric current. Birds are killed immediately and within one second they are dropped onto a conveyor belt leading to a rendering bin. It also incorporates an alternative Modified Atmosphere Killing (MAK) backup. This unit can reportedly kill 4,000-4,500 birds per hour and is reported to be accepted by the Alberta Society for the Prevention of Cruelty to Animals and Alberta Agriculture as a humane mean of disposing of spent hens. There are WH&S considerations when working with electrical devices that are developed to kill animals. High safety regulations and the presence of qualified personnel is therefore a precondition.

Photograph 4: Mobile Modified Electrical Stunner



4.2.5 Macerator and Grinder

A macerator has been tried in Canada as a humane means of mass euthanasia. This unit uses strong negative air pressure to vacuum the birds into a grinder that kills them upon impact with the blade. In some other macerators, birds are manually placed in a hopper leading to a grinder. Only grinders specifically designed for disposal of poultry, which have blades that turn at 5,000 or more RPM, should be used for mass depopulation of aged poultry. This system kills the bird very quickly but is aesthetically displeasing to the public and some questions remain to be answered regarding its humaneness.

4.2.6 Foam Killing

Foam of the right bubble size creates an occlusion in the trachea of birds, causing a rapid onset of hypoxia. Water-based foam, as well as other foam types, has been used for submerging the birds in the United States, Australia and other countries during avian influenza outbreaks. Birds die from physical asphyxiation (as opposed to chemical asphyxiation as seen with CO_2 euthanasia) and studies have shown that asphyxiation by foam occurs more quickly than with CO_2 tenting (Benson et al., 2007). The effectiveness of this method depends on proper consistency and bubble size of the foam. In some cases, CO_2 or N_2 is used to fill foam bubble, but Benson et al., (2007) found that adding CO_2 gas to foam did not enhance efficacy. To date, compressed air foam, aerated foam nozzles and modified high expansion foam generator systems have been used successfully. Though it has been reported that foam technology has advantages of lower labour and time, less physical and mental distress for workers, and is compatible with in-house composting, it has been used in Australia with limited success. Victoria Department of Environment and Primary Industries (DEPI) possesses one Foam Depopulation Unit which has been used in AI outbreaks (Photograph 5). The preliminary result of its use in a mass depopulation of about 50,000 free range layers demonstrated that the foam can effectively kill the birds in 5-7 minutes, however it is not practical to use in slatted floor and cage layer facilities. In the case of the slatted floors, birds had to be moved (outside) to a solid floor base before the foam could be effectively applied (Photograph 6). The movement of birds itself is a welfare issue and in the case of an AI outbreak requires intimate handling of the birds by the operators and thus there is no reduction in the potential zoonotic risks. After the foaming euthanasia of the birds, the removal of the birds manually can be limited due to the rapid onset of autolysis. In the case of non-slatted barn sheds the birds can be left *in situ* and composted. In the case of cages, the ability to remove dead birds from cages can be difficult if not undertaken in a timely manner, due to the rapid decomposition of the birds. It also requires enough space to move both the birds and the machine together, otherwise it may cause smothering.

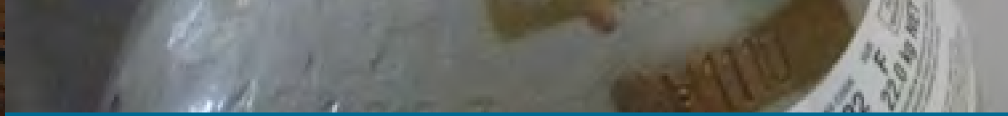
Photograph 5: Foam inside a deep litter shed Photograph 6: Foam outside shed

Images courtesy DEPI, Victoria (personal communications)

Photographs 7 and 8: Kifco Model AV ST3

Foaming is expensive from an initial capital aspect (approximately AUD$85,000 Kifco Model AV-ST3) (Figures 1 and 2) and it requires highly trained personnel.

Foaming has some operational cost advantages over CO_2 gassing, and unlike whole shed gassing, foaming can be used in all types of floor system sheds even if they cannot be made air tight.



4.2.7 Gas Killing

Different types of inert, non-toxic gases such as CO_2, N_2 or Argon can be used to displace oxygen from the ambient air, thus inducing death by hypoxemia. Several investigators have suggested that inhalation of high concentrations of CO_2 may be distressing to the birds. Alternatively, anoxia, through a mixture of argon and CO_2, seems to alleviate respiratory distress. Recommended mixtures of 60% argon and 30% CO_2 can produce very satisfactory results in terms of speed of unconsciousness, minimising distress and cost considerations. A mixture of gas containing up to 20% by volume CO_2 in Argon are universally available as welding gas mixture at affordable prices. Raj et al (2008) revealed that 20% CO_2 in argon with 5% residual oxygen would be sufficient to kill poultry in 2 minutes and ducks could be killed within 3 minutes exposure to the same mixture with 2% by volume of residual oxygen. While potentially considered more humane, the use of Argon+CO_2 gas mixtures require high overall concentrations, are potentially more hazardous for the operator and require more rigid control of the gas concentrations.

The readily available access to pure CO_2 in cylinders or tankers makes CO_2 the preferable choice of gas to carry out mass euthanasia of layers. A concentration of 45% CO_2 renders layers unconscious within 20-30 seconds and induces death within 2 minutes (Webster et al, 1996). Different research has indicated that 40% CO_2 in air is sufficient to kill chickens (Gerritzen et al., 2004) and concentrations above 55% will kill birds quickly (Raj and Gregory, 1990). Unlike N_2 and Argon, CO_2 can induce hypoxemia at higher levels of residual oxygen. CO_2 is also heavier than air, which makes it easier to contain and it is relatively inexpensive and readily available. For all of these reasons, CO_2 has been the preponderant choice. However, the use of CO_2 on waterfowl is controversial. Some reports indicate that the time taken to achieve unconsciousness and death is considerably longer in these species than in hens and turkeys, which raises questions from an animal welfare point of view.

Gas killing requires the gas mixture to be contained. This can be achieved by using portable containers, tenting within the shed or using the whole house as a gas container.

4.2.7.1 Portable Gas Container/ Modified Atmosphere Killing (MAK) unit

Producers throughout the world are trying different types of MAK units for on-farm killing of spent hens. Some of them are designed as carts, to roll into the shed like a wheelie bin. The unit can be pushed down the aisles of the shed, with 200-250 hens per load being placed inside a CO_2 enriched container. The dead birds are then emptied from the bin and loaded onto a truck using the manure belt. Another type of comparatively bigger bin/container has been developed with a higher capacity. It works in the same way as the small mobile bin, except for the fact that the container is placed outside the poultry house, and the birds are carried manually to it. With the bigger container, birds are always placed in layers to avoid smothering and a forklift is required to lift the container up and tip it into the truck. MAK units use very little CO_2 compared to other methods e.g., only 108 ft^3 or 13 lb/1000 hens (Webster et al., 1996).

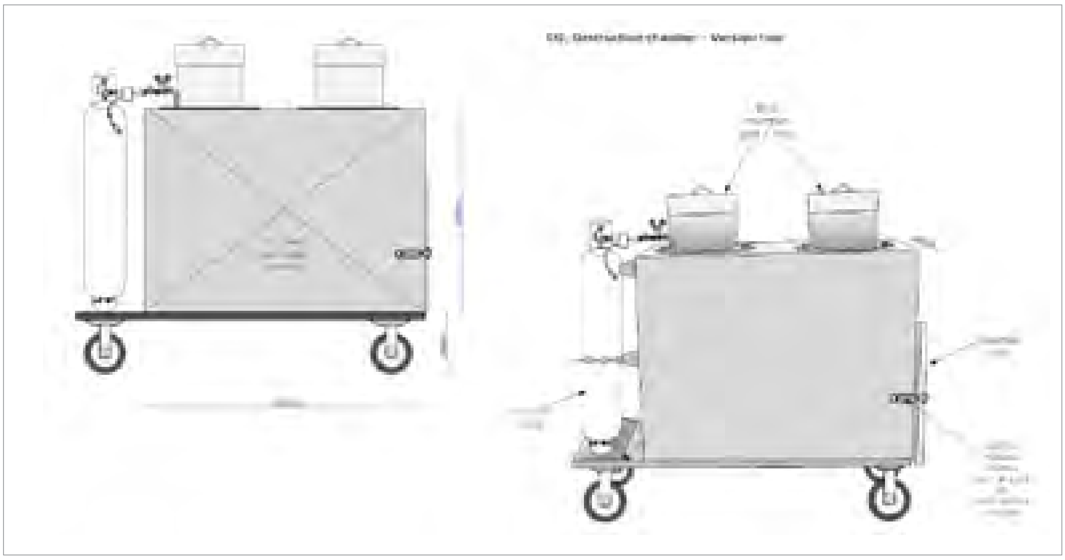


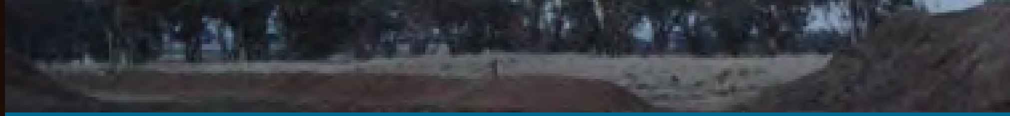
Diagram 1: CO_2 Modified Atmosphere Killing Small Container, Cart Type

4.2.7.2 Containerised Gas Killing

Various forms of containerised gassing have been used to kill crated birds. With this system, birds are caught and placed in live haul cages. Carted birds are placed in a front loading container using a forklift. Gas is then injected into the container to reach a pre-set concentration and maintain the concentration for a specific time. In some cases, a specially designed and constructed steel cabinet is placed over the live haul cages to contain the gas. This method results in rapid death and reduces the risk of smothering, but is labour intensive in catching birds and putting them in the container, or alternatively placing cabinets over cages and removing dead birds from the cages.

4.2.7.3 CO_2 in flow container

A Finnish company has engineered a mobile slaughter unit called 'Slaughter Mobile" which is being marketed internationally by German specialist ProAn®. The birds are carried from the laying facility and are placed on the conveyor belt. The belt first takes the birds through a slightly lower concentration of CO_2 which renders them unconscious, and then on to the lower parts of the container where the gas concentration is higher and the bird is killed. The difference in concentration is a result of the fact that CO_2 is a heavy gas, and the concentration will thus be higher at the lower part of the container. Depending on the design of the conveyor belt, between 5,000 and 12,000 birds an hour can be processed. The birds are then moved from the conveyor belt into the masher. The resulting pulp can then easily be evacuated into a closed bulk transport vehicle and transported away. This unit is very efficient and welfare friendly but it requires high initial capital investment and it may compromise the bio-security as it moves from farm to farm.



4.2.7.4 Tents/Container Assembled on-farm

This method is suitable for floor housed birds. It can be done by setting up an enclosure in the house and pushing the birds into it. CO_2 is then injected into the enclosed area. In most cases a big plastic/polyethylene sheet is anchored with the litter and workers then pull the other edge of the sheet for the entire length of the house towards the middle of the shed. The same process is repeated for the other end of the shed and CO_2 is then injected under the overlapping layer of polyethylene sheet. In most cases the CO_2 cylinders are placed in the middle of the shed before tenting. This is procedure is moderately labour intensive and not suitable for caged birds. However, the materials required for this method are readily available and the procedure can be implemented with short notice.

4.2.7.5 Whole House Gassing

In recent years, many countries have utilised whole house gassing with CO_2 and trials have been conducted in Australia to assess the procedure. It is mainly considered a useful option in an EAD outbreak since this method does not have a large manpower requirement and reduces the exposure of people to live birds where there is the concern about a potential zoonosis. This method requires totally enclosed environmental houses and the sealing of all openings, which is relatively easy to achieve in a modern environment controlled commercial layer house. The fans and air inlets would be the major sites of gas leakage and need to be covered. Some openings at the upper part of the house are required for the inner air to escape as gas is introduced.

The whole house gassing protocol can be varied according to the housing system and species of poultry. Based on the Australian trial report, for a modern commercial layer house that has the dimensions 150 metres by 16 metres, to achieve a 40% concentration throughout would require 8,375 kg of CO_2 to be delivered and it would take at least 26 minutes to fill the house with gas. The method chosen in this trial was to use liquid CO_2 dispersed into the sheds from a tanker, where it immediately vaporised, via a bifurcated lance. Based on this trial, a single semitrailer which contains approximately 18 tonnes of gas would be enough for two standard sheds. But using liquid CO_2 can create extremely low temperatures, and therefore, the possibility of inducing cold shock could not be excluded. This can be avoided by using an electrically heated vaporiser and birds could also be moved back about 15-20 m from the lance by a temporary fence.

Whole house gassing, while an effective method and requiring minimal human intervention in regard to contact with the birds, has logistical issues in regard to removal of the dead birds from the shed. In the case of cages, the method is near impractical as the dead birds rapidly decompose and are extremely difficult to remove from the cages. Also if there is concern regarding an EAD and a zoonosis, then the need for human intervention to remove the birds does not eliminate this horizontal contact. For deep litter based systems the birds can be left *in situ* in the sheds and piled up and composted with the litter. The temperatures achieved in this process are effective in inactivating viruses such as AI and Newcastle Disease (NDV) and thus after a period of time allow the safe handling and removal of the material. For further detail the reader is referred to the Animal Health Australia report, *Humane destruction of poultry in an emergency disease response – use of carbon dioxide.* This report describes a field trial held at Peats Ridge, NSW, 30 October – 1 November, 2006.

In general, for whole house gassing, achieving CO_2 levels approaching 40% is difficult and the period before birds start dying can extend to over 30 minutes. The procedure is also costly. From a biosecurity point of view during an EAD, the insertion of the gas mixture causes the displacement of potentially contaminated air outside.

5. PORTABLE CONTAINER/ MODIFIED ATMOSPHERE KILLING - Preferred Method

For the Australian poultry industry, the portable container or MAK unit is the most feasible alternative for depopulating spent layer flocks using mass euthanasia. For barn and free range systems, the birds can be confined to the shed in preparation for depopulation. Generally, the depopulation of alternate systems can be done more expediently and efficiently than with a cage facility. In a cage facility, there is still the need to remove birds from cages and then either kill them in the sheds using smaller portable killing containers or remove the birds from the cage shed and kill them using a larger container external to the shed. The time at which depopulation is done can be entirely determined by the producer to suit the site's planning schedule to optimise layer placement efficiency, staff utilisation and coordination with other farming operational activities. There will need to be some coordination of transport vehicles if the birds are being sent for rendering, but if they are being composted, then the timing is at the discretion of the producer. Under most MAK methods, birds are taken directly from the cages or from the sheds, and are then put into a container where MAK occurs using CO_2.

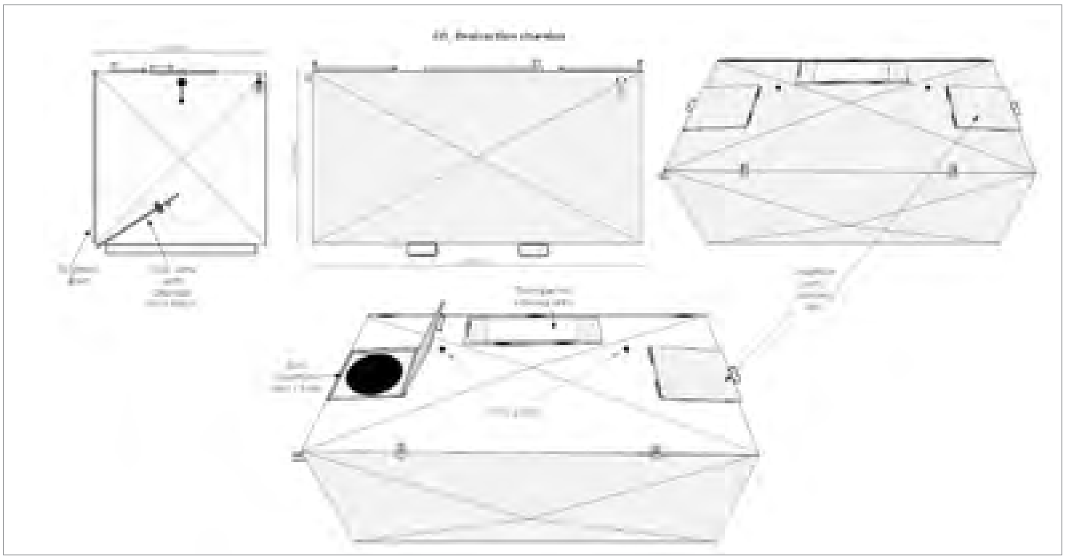
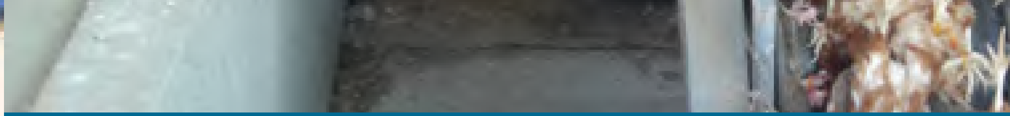


Diagram 2: CO_2 Modified Atmosphere Killing Large Container



5.1 Particulars on using CO_2 for mass euthanasia of laying hens.

5.1.1 Required CO_2 concentration

While the information on the adequate level of CO_2 to render unconsciousness is inconsistent, 20% CO_2 has been reported as anaesthetic for chicken (Gerritzen et al., 2006; Ryan et al, 2006) and 40% has been reported as a lethal concentration (Gerritzen, 2006). Under experimental conditions, broilers lost consciousness at 15% CO_2, and concentrations of 35 to 40%, maintained for 30 minutes led to 100% mortality (Gerritzen et al., 2004). Leghorn chickens collapsed in 12 seconds after exposure to 97% CO_2 (Blackshaw et al., 1988) while 5 week old chickens collapsed on an average of 17 seconds after entering a tunnel filled with 60% CO_2 (Gerritzen et al., 2000). In experimental cases, head shaking, gasping and convulsion were observed before loss of posture, but loss of posture and suppression of brain electrical activity occurred almost simultaneously (Gerritzen et al., 2004).

5.1.2 High CO_2 Concentrations and Bird Welfare

Although high CO_2 exposure can be distressing by causing pain due to the production of carbonic acid in the respiratory and ocular membrane, production of so called air-hunger and direct stimulation on the ion channel, the interpretation of subjective experiences of animals is complicated. While some studies have reported some signs of distress, others have not consistently observed these effects. This may be due to variations in methods of gas exposure and types of behaviours assessed, as well as strain variability. Using preference and approach-avoidance testing, in contrast to other species, a large proportion of chickens and turkeys entered a container containing moderate concentrations of CO_2 (60%) to gain access to food or social contact (Gerritzen et al., 2000). Prior to loss of consciousness, birds in these studies showed behaviours such as open-beak breathing and head-shaking; these behaviours, however, may not necessarily be associated with distress because birds did not withdraw from CO_2 when these behaviours occurred (McKeegan et al., 2006). Thus, it appears that birds are more willing than rodents and mink to tolerate CO_2 at concentrations that are sufficient to induce loss of posture, and that loss of consciousness follows shortly afterwards. While immersion of any conscious animal into a container pre-filled with 100% CO_2 has been labelled as unacceptable by the American Veterinary Medical Association (AVMA), immersion of poultry in a lesser concentration is considered acceptable by the AVMA as it does not appear to be distressing for the birds.

While rats do not lose consciousness prior to aversive responses to CO_2, chickens become unconscious very quickly in high concentrations of CO_2 and somatosensory neuronal potentials are not evoked until several seconds after the birds are unconscious (Raj et al., 1990). Additionally, the time to eye closure, which follows loss of somatosensory potentials in birds, occurred more rapidly in 35% CO_2 administered in an 8 second accession than when 45% CO_2 was administered in an accession of 18 seconds. Raj and Gregory (1990) concluded that the rate of accession is more important in the time to unconsciousness than the final concentration and that a faster rate of exposure would minimise any unpleasantness associated with CO_2 inhalation.

The Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010) addresses the use of CO_2 for euthanasia in poultry (page 121):

"Atmospheres containing a significant amount of carbon dioxide, with or without the presence of oxygen, cause birds to head shake and breathe deeply, but scientific evidence indicates that these behaviours are not associated with distress."

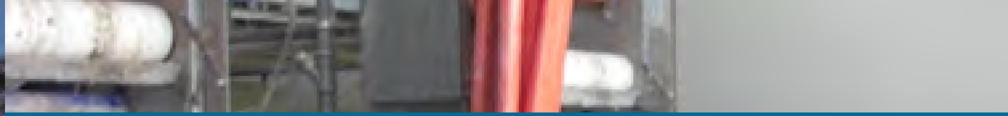
"Furthermore...most chickens and turkeys will voluntarily enter carbon dioxide concentrations as high as 60-80%."

"Because poultry can be rendered unconscious with 30% carbon dioxide in air, or less if enough time is allowed, and concentrations of carbon dioxide above 50% quickly kill adult birds, it is not necessary to measure the carbon dioxide concentration closely when performing euthanasia. However it is important that the process be observed and carbon dioxide added if necessary to ensure that death is attained without undue delay."

Some authors have suggested N_2 and argon as the most suitable gas for humane killing of poultry species. But both N_2 and argon require very tight/strict concentrations for effective euthanasia, whereas CO_2 can render poultry unconsciousness and kill over a wide range of concentrations. In an experiment, broiler and mature hens collapsed in 19 to 21 seconds at 65% CO_2 and in 25-28 seconds at 35% CO_2 (Raj et al., 1990). Ducks and turkeys lose consciousness before a level of 25% CO_2 inhaled air is reached and die within 13 minutes in an environment of 45% CO_2 in inhaled air (Gerritzen et al., 2006).

5.1.3 Findings

After reviewing the literature, it can be concluded that given adequate exposure time, 40% CO_2 in air is sufficient to kill chickens (Gerritzen et al., 2004) but concentrations above 55% will kill birds quickly (Raj and Gregory, 1990). It should be standard practice in all cases to assure that adequate quantities of CO_2 are available and that all equipment is functioning properly prior to beginning euthanasia procedures. Prefilling of the container prior to introducing the birds is recommended, followed by supplementation of CO_2 until death is confirmed. Although the actual percentage of CO_2 in the container will not reach theoretical values of 100%, immersion in high concentrations of CO_2 for poultry is preferred as it induces rapid loss of consciousness followed by death. While it could be argued that there is not the requirement for precise metering of the concentration of CO_2 into the container, it is considered preferable that the CO_2 concentration exceeds a minimum of 40%. This ensures that the spent layer is rendered to a state of unconsciousness and insensible to external stimuli in a relatively short time (approximately 20 seconds) with the death of the birds within 2 minutes.

5.2 Field Trial Results

After an initial number of casual observations of mass euthanasia by CO_2 in the field, a number of findings were noted that required corrective actions:

- There was often inadequate pre-planning in regard to people resources and uncertainty about the quantity of CO_2 required.
- Inadequate pre-training of staff and familiarisation with the correct procedures, and in particular welfare requirements, and obligations was noted.
- Absence of a formal protocol.
- Limited formal evaluation of practices in regard to WH&S.
- Inadequate supervision for the entire duration of the process by a competent person.
- Inability to physically observe the birds to ensure that the correct parameters of time to unconsciousness and death are being achieved.
- Birds were placed in the euthanasia container before adequate concentrations of CO_2 had been established.
- Birds were added at a rate exceeding confirmation of the birds being rendered unconscious before more birds were placed in the container.
- The failure to maintain adequate concentrations of CO_2 during the process.
- The freezing of the gas cylinders resulting in low or nil gas flow.
- The observation of live birds at the destination point indicating a failure in procedure to kill all the birds.

As a consequence of these findings, more formal observations were commenced in conjunction with the implementations of procedural guidelines and facilitation changes to improve the overall outcomes. Some of the field trails, but not all are detailed below.

5.2.1 Trial 1 – Cage Layer Facility.

The container used to kill the birds was 1.8 m by 0.9 m by 0.9m. These containers were originally bought from metal scrapper for $200.00 each and were modified in their workshop with manure belt and with some other farm material. The killing capacity of these containers was 350-400 birds each. There was no viewing window in the containers which limited observation of the behaviour of the birds and the ability to predict the adequacy of the CO_2 concentration (particularly in the absence of a monitoring device).

A CO_2 meter was used, and found to be very effective in determining the CO_2 concentration in the container, time to prefill, and time to pause the operation. The only drawback was that the micro pump inside the CO_2 meter can pump only a small amount of air to analyse. So if the sample collection hose is too long, then it will take several pumping cycles to flush the air already inside the pipe/hose. That means it will take about 10-20 seconds to assess the most recent samples from the container and by this time the actual concentration may have changed. With medium flow, it took approximately 2.5-3 minutes to reach 40% concentration and about 4 minutes to reach 60%

concentration at the hens' level. In the most recent trial, a concentration of 45-60 % was constantly achieved in less than one minute using a centralised gas delivery system.

As the exposure time in a MAK unit (container) is very short, and the CO_2 concentration drops very quickly due to physical displacement by the birds and/or due to wing flapping, the target concentration was set at 60% to start the operation and to maintain a minimum of 40% throughout the operation (for the batch). In an attempt to conserve the high use of CO_2 that occurred in the first operation period, the initial concentration of CO_2 was reduced to 50%. But as the subsequent concentrations dropped very quickly to under 40%, it was noticed that there were a number of survivals in each batch. The limitation was maintaining the required minimum concentration due to variable flow rate. Difficulties were experienced in establishing a higher flow rate, as the regulator was unable to dispense the required amount of CO_2. A different type of regulator was considered. With a newly opened gas cylinder, the pressure remained high and the operator could maintain the minimum concentration for a longer time and there were no bird survivals. After about 10 minutes, the cylinder contents started to freeze and the flow of CO_2 dropped. Required concentrations could not be maintained without halting the operation. Once the minimum concentration of 40% was re-established the procedure re-commenced and there was no survival. A heating blanket was utilised, and was observed to work at a certain level, but could not completely stop the freezing problem. Once again, there was the need to swap the cylinder several times. The technical department of the gas supplier (BOC) confirmed that these blankets would have a minimum effect on the freezing problem. According to BOC, even though the cylinders are freezing; they are freezing only on the outside, not the inside. It is the tiny valve inside the cylinder which is freezing, and this ice was blocking the flow temporarily. This was mainly due to the high flow rate, and a heating blanket will do nothing to solve the problem. According to BOC, this can be solved by setting up a vessel of CO_2 on site, but this is not mobile. BOC recommended using gas pre-heater with regulator, which was tried and found to be effective, especially in reducing the freezing problem of the delivery hose. According to BOC, there are two types of CO_2 - food grade and industrial. The 22 kg cylinder is a food grade cylinder and the 31kg one is the industrial CO_2 which is 2 cents per kilogram lower cost than the food grade one and also ideal for euthanasia. Using the industrial cylinders gives a minimal saving on price and requires fewer cylinders. Consideration needs to be given to the fact that the 31 kg cylinder is too heavy to be moved by a single person. Observationally, there was found to be no significant difference in respect to the time required for induction of unconsciousness between 40-60% particularly between 40-50% CO_2 and it was between 15 to 20 seconds for 40-50% and 10-15 seconds for 60%. Interestingly, sometimes the time to unconsciousness was shorter at 40% than 50%. The reason for this is unclear but may be related to the tendency of the birds to reduce breathing at higher concentrations. The continuous flow of CO_2 is very important, otherwise the concentration will decrease rapidly, and in such cases the birds are not rendered unconscious and while the operational procedure may be viewed as satisfactory, actual smothering of birds is the predominant way the birds are killed. Trials tried both one-off fill and intermittent flow. After putting the last bird in the container it is essential to ensure that the concentration inside the container is at least 40% and to wait for at least 2-3 minutes before tipping out the container.

5.2.1.1 Costings for Trial 1

Number of birds	87,400
Total man hours = 576 hours @ $25.00	$14,400.00
CO_2 cost	$5,366.00
Removal of deceased birds to compost	$12,000.00
Total cost:	$31,766.00
Cost per bird	**$ 0.36**
Additional cost x 4 containers manufacture	$1,200.00

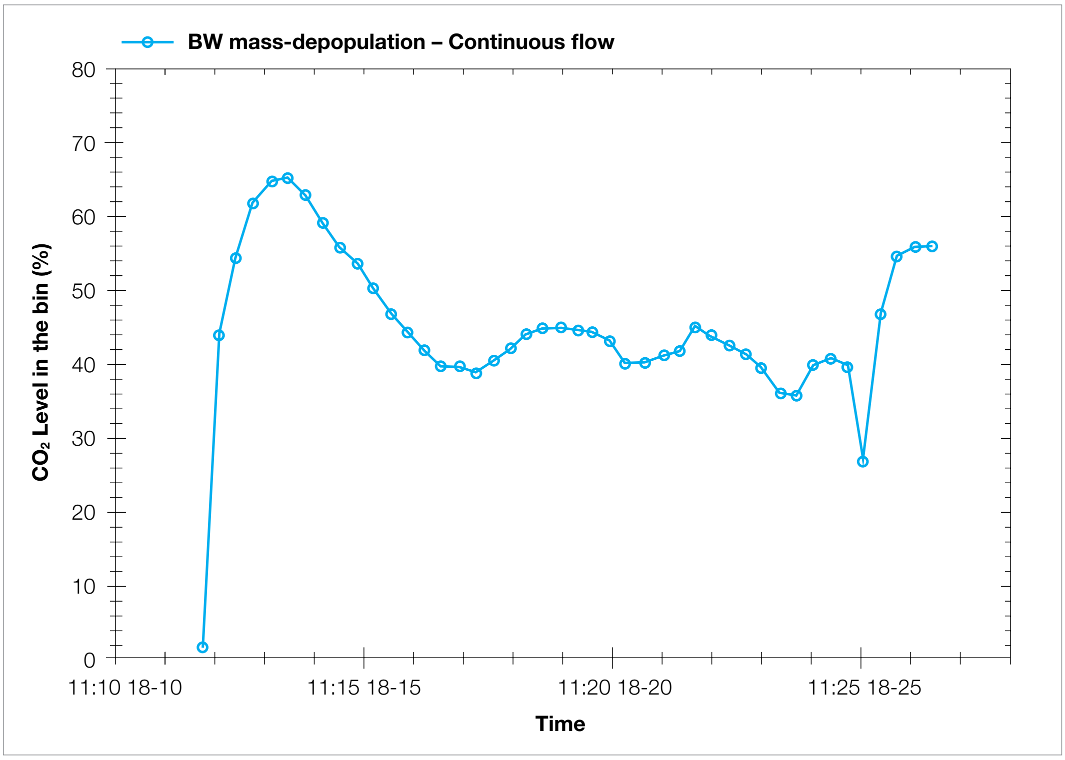


Figure 1: CO_2 concentration in the container during the process of killing birds with continuous flow of gas.

5.2.2 Trial 2 – Free Range Sheds

Shed 1. Total number of birds in this trial was 8,000. The number of personnel involved was18, plus 1 who was supervising the entire operation and was also operating the gas cylinder and the forklift.

There was no effective monitoring of the CO_2 concentration. Prefilling time varied from 1 to 8 minutes depending on the preparation of the catching crew. The specific killing containers were large and delivering gas through one hose was inadequate to keep the required gas concentration throughout the container. Birds were continuously added to the container without any pause unless there was a need to push the birds or adjusting the fences. Birds took 30 seconds to almost one minute to be rendered unconsciousness. Unconsciousness was preceded by a deep breath followed by coughing and wing flapping.

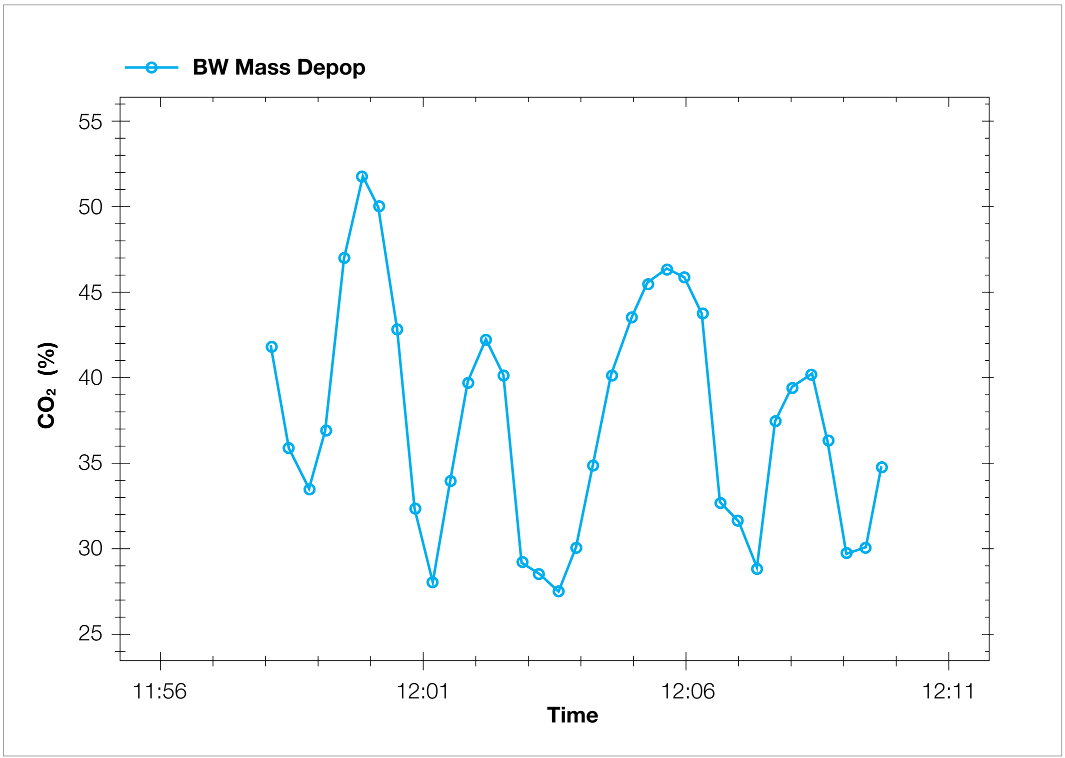
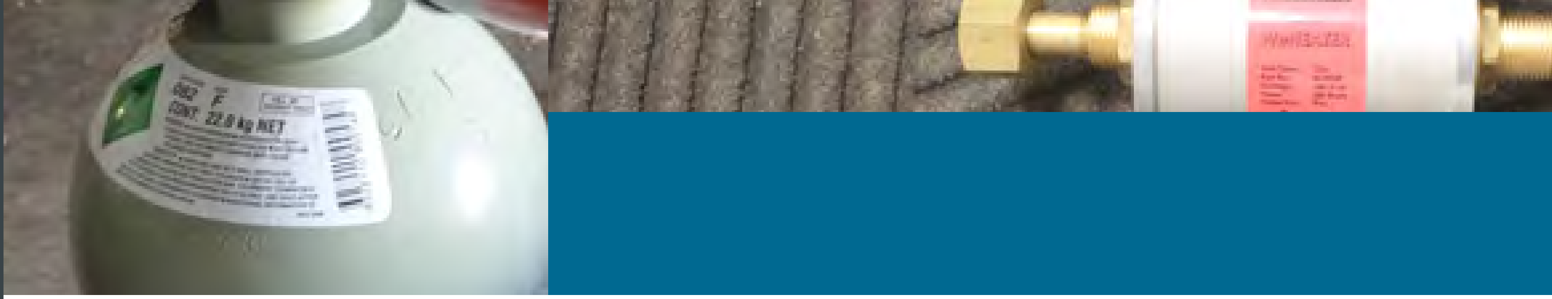


Figure 2: CO_2 **concentration in the container during the process of killing with intermittent flow based on observations.**

A total of four cylinders of CO_2 gas were used (residual gas left in all cylinders) in killing the 8,000 birds. This equated to 10 kg CO_2 to kill every 1,000 birds. In this trial the container held 1,450 birds. Labour cost was covered by hiring 15 workers from a hiring company at $30/hour. Labour hours were staggered, with 6 out of 18 personnel started at 5 am to prepare the shed. The rest of the workers joined the crew at 6 am. After pushing the birds to one side of the shed, 6 workers started removing



the slats from other side, while the rest were catching and carrying the birds to the containers. Euthanasia was completed by 8:30 am and by this time the crew were able to remove ¼ of the slats of the shed. So total labour hours required was 53.5 hours, but if we exclude the slat operation, it would have been 38.5 hours. This resulted in a rate of 207 hens killed per labour hour.

Shed 2. The total number of birds in this shed was 10,000. In this shed, a decision was made to use two gas hoses at a time, one through the normal gas delivery hole and another one through the observation window. The container was prefilled for at least five minutes and the gas level estimated by touching the container (to find the cool point). This significantly reduced the lag time of the birds before unconsciousness from almost one minute to less than 20 seconds. Cylinders were also swapped more frequently to improve the utilisation and flow of gas.

A total of 8 cylinders of CO_2 gas were used in this shed. This means it required 17.6 kg CO_2 to kill every thousand birds. This amount was much higher than in the previous shed. Overall, in regard to the humane killing of the spent layer hens, the process was much improved and afforded better welfare outcomes. It is estimated, depending on the container and delivery system, that around 10-15 kg per 1,000 birds is required to ensure an adequate 40% concentration for humane killing of spent layer hens without death by smothering.

5.2.3 Concluding observations from Trial 2.

1. A CO_2 monitoring system should be used as this capital investment is essential to ensure an objective assessment of the minimum concentration of CO_2.
2. There should be a minimum pre-filling time before putting the birds in the container and a minimum concentration of CO_2 of 40% should be achieved and sustained throughout the killing process. This is estimated to equate to a usage rate of around 10-15 kg per 1,000 birds.
3. It is mandatory that the crews should be adequately trained in the mass euthanasia procedure and that management ensure that the workers have empathy for the birds.
4. Moving the gas cylinder may present a WH&S issue as it is heavy for one person to carry.

Different types of locally made containers for on-farm killing of their spent hens can be used. These include:

- Wheelie bins
- Waste skips
- Various containers on wheels (150-200 hen capacity)
- Placing modules of crates in a gassing container
- Stock watering troughs (1,200 hens capacity)
- Front end loader bucket
- Purpose built container (1,200-1500 bird capacity)

5.3 Major advantage of MAK unit

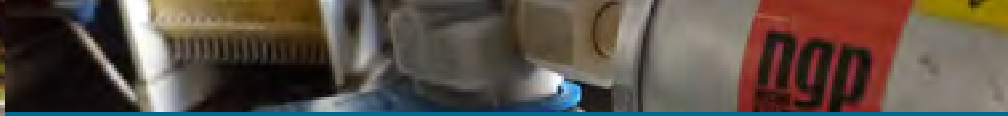
- Easy to make the unit with locally available materials.
- Requires comparatively little CO_2 to euthanise the birds.
- Is an effective and welfare compliant tool for mass euthanasia of spent layer hens.
- Easy to operate and does not require highly skilled personnel when under the appropriate supervision of a trained and experienced operator.
- With the MAK unit used on-farm, welfare concerns over transportation are eliminated.
- Easy to monitor the gas concentration and effective control of gas delivery system.
- Better flexibility - able to perform in variety of situations, such as different flock sizes, housing systems, extreme weather conditions, and at the time chosen by the producer.

5.4 Special Considerations (Design)

According to Raj et al, (2008) the containers should be designed and constructed at least to:

- Be gas tight.
- Facilitate easy transport and storage.
- Be strong enough to withstand extensive handling and use under field conditions.
- Facilitate easy loading and unloading.
- Withstand cleansing and disinfection procedures necessary to ensure bio-security.
- Be user friendly and provide a safe working environment.
- Safeguard the welfare of birds and to facilitate a visual assessment of birds during killing.

With large top loading containers, two loading doors and one viewing window are preferable which should be located on the top/front corners of the containers. The container design should allow the emptying of the container at the front opposite to the lifting machine. A locking mechanism on the side should allow the container to be locked during the filling process and released prior to emptying in the transport trailer. Container opening devices need to be situated so the forklift/tractor operator can open the container when in the air over the truck without getting out of his vehicle. The gas should be distributed from the centre of the container or else there should be at least two CO_2 inlets, preferably on two sides of the container. At least 3 mm thick steel should be used and the container made gas tight. To keep the functional logistics feasible, the dimensions of the container should be carefully chosen to allow access to and around the shedding facilities and transportation. The size of the container should also be capable of accommodating a commercially used transport module for easy movement from one farm to another.



5.5 Cost of the Unit/Start-Up Cost

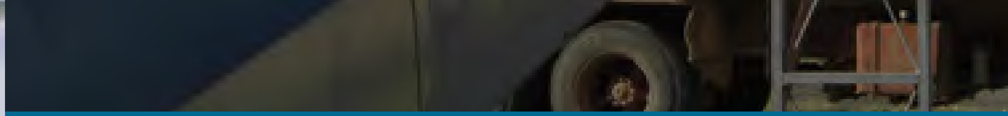
Estimates of the cost of construction of a standard size container range from between $1,000 to $2,000 depending on the capacity of the container. For floor reared or free range birds, a large container of a dimension of 1.2 m (height) by 1.2 m (width) by 2.4m (length) can be operated from outside the shed, but it requires an adequately sized forklift to lift these containers up and tip them into the truck if birds are to be transported off site. The construction costs of small movable containers of 200-300 bird capacity are variable depending on the material and degree of sophistication.

5.6 Operating Costs based on a multiple Farms

The estimated operating cost of a MAK unit with CO_2 costed at $3.71 per kg and labour costed at $24.50 per hour, is between 9 to 25 cents per bird. In general, 10-11 kg CO_2 is required per 1,000 birds, but there are large differences in capacity and labour costs mainly due to different type and sizes of husbandry systems. The capacity of the devices depends not only on the technology but also on the capacity of the operators to catch and transport the birds from their houses to the containers.

Table 1 details some actual costs that have been accumulated from field observations. These were all multi-tiered cage facilities and thus the costings could be considered to be on the high side for depopulation from barn systems. The containers included wheelie type bins or variations of, skips, placing crates in containers, front end loader buckets, and purpose built containers. In all these cases there was no monitoring equipment used to determine if CO_2 levels were optimal and the assessment of the killing of the birds was subjective based on observation of bird behaviour. However most birds were reported to have lost consciousness within about 20 seconds.

Table 1: Costings for Modified Atmosphere Killing of Birds Using Carbon Dioxide							
Costs cents / hen							
Farm ID	A	B	C1	C2	D	F	G
Carbon dioxide	7.80	4.19	3.90	3.90	3.92	4.03	3.35
Labour	12.25	10.35	5.05	7.30	10.73	21.11	14.23
Total	20.05	14.54	8.95	11.20	14.65	25.14	17.58
Efficiency measure							
Hens per 1 hours labour	200.0	236.7	484.8	335.7	228.4	116.1	172.2
kg gas/1000 birds	21.0	11.3	10.5	10.5	10.6	10.8	9.0
Other information							
Production system	cage	cage	cage	cage	cage	barn	cage
Killing container type	purpose built to hold 8 crates (25 birds each)	1,200l stock water troughs	modified waste collection bin	modified waste collection bin	purpose built to hold 150 birds	purpose built to hold 1,200 birds	15m^3 skip
Tasks performed	catching killing remove crates	catching, killing, empty, loading	catching, killing, empty, loading	catching, killing, empty, loading	catching, killing, empty, loading	penning catching killing, empty, loading	catching, killing
Caught, placed into	hand into crates	hand & walk	hand into bin	hand into bin	hand into bin	hand into bin	leg rope & trolley
Truck loading	elevator	elevator	fork lift	fork lift	elevator	fork lift	skip



5.7 Operational Aspect of Modified Atmosphere Killing (MAK) Method

Consideration of the efficient use of the MAK method should not only be based on the equipment and its correct use but the total procedure of killing, including the catching and handling of live birds (Diagram 3). Effective MAK process requires:

- Prefilling of the container
- Maintaining adequate gas level
- Proper handling of live birds
- Proper monitoring of the gas concentration and birds behaviour
- Disposal of the killed birds.

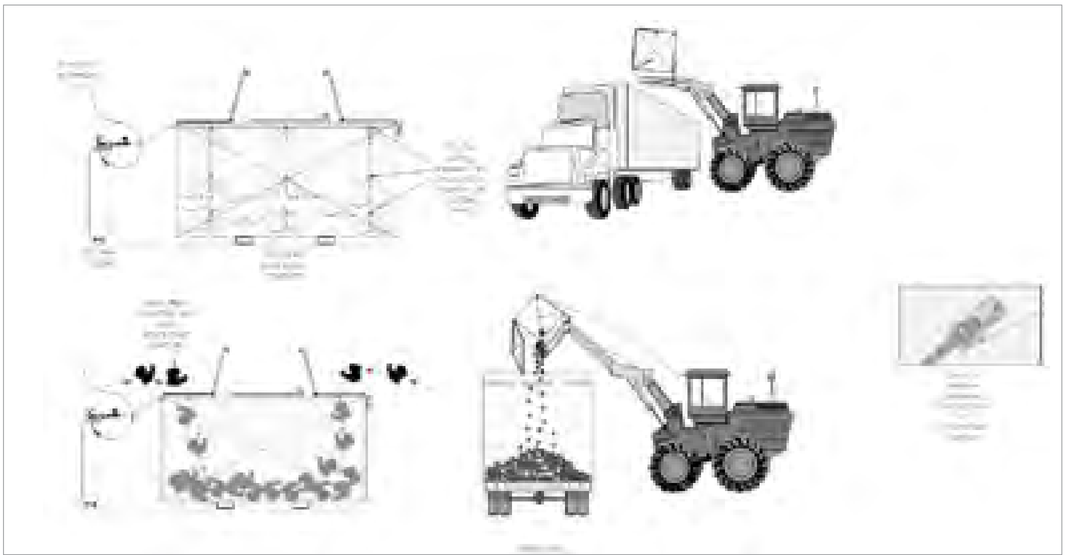


Diagram 3: **Modified Atmosphere Killing Container Operations**

5.7.1 Pre-filling

According to OIE (2005) guideline, birds should be lowered into a container holding the predetermined gas mixture. Therefore, prefilling the container with CO_2 is essential and once the desired gas level and concentration is reached, the addition of the birds to the container can commence. The required gas concentration can be monitored using a CO_2 sensor. Despite the capital cost of the sensors, it is important that these are used to ensure the operational process is undertaken in a satisfactory manner for the welfare of the spent layers by having the optimal CO_2 level monitored throughout the process. Without the proper sensor, monitoring bird behaviour to determine the adequacy of the gas level is subjective. Under the optimal gas concentration, birds should be unconscious in less than 30 seconds. If not, gas concentration should be considered inadequate and addition of birds should be halted until gas level is adequate.

5.7.2 Maintaining Adequate Gas Level

Maintaining the correct CO_2 level during all stages of the killing process is the most critical part of the MAK method.

The container must be prefilled prior to introducing the birds and then supplementation of CO_2 continued to maintain the atmosphere until death is confirmed. From field experiments it became obvious that hens were not rendered unconscious in a timely fashion without the continuous supplement of CO_2. Although CO_2 is heavier than air, body heat of the birds makes the atmosphere within the container buoyant relative to the air outside, and then wing flapping and wind action against the loading door ventilate the container. As a result, the atmosphere inside the container dilutes with air as loading proceeds. The principle here is to maintain an adequate gas concentration throughout the operation to quickly stun and kill the birds, so that there will be no danger of conscious birds being overlain and smothered by hens loaded after them. This can also be done by careful monitoring of the birds during the loading process, and adding CO_2 when the hens' activity in the container warrants, with a final flush at the end of loading. The killing process will continue as the cart is being rolled out of the house.

5.7.2.1 Deficiencies in maintaining adequate CO_2 levels.

Maintaining adequate gas levels consistently in both formal and informal observations was an ongoing issue due to a number of factors:

- Lack of need, as considered by the operator, to observe the adequacy of the CO_2 level in the container, as would be indicated by the timely and effective progression to unconsciousness of the layer.
- Inability to view the inside of the container because of design reasons and the lack of a viewing portal.
- Inadequate supply of gas for the entire euthanasia procedure.
- Inadequate volume of gas supply.
  - Inadequate number of cylinders or cylinder size for the killing container.
  - Freezing of the cylinder valve head or delivery pipe reducing the flow of gas.
  - Poor sealing of the container or loss of CO_2 through the activity of bird placement.
- Low skill level of the operators who were inadequately trained and unfamiliar with the criteria that demonstrated when the birds were being correctly rendered insensible within the appropriate time period.
- Placement of the gas delivery tube not allowing for uniform distribution of gas as birds were being added to the container.
- No monitoring equipment to precisely measure and ascertain the continuum of the optimal level of CO_2 in the container.

5.7.2.2 Operational procedures to ensure that adequate levels of CO_2 are maintained to achieve the required outcomes

1. Manual observation of bird behaviour.

To solely depend on monitoring bird behaviour to ensure that the gassing process is humane, it is essential that all personnel involved in the direct killing procedure are trained in the criteria that demonstrate that birds are being rendered unconscious and insensible to external stimuli in a short period of time. Importantly, personnel need to be recognised by management to have the ethos and compassion necessary for such a procedure.

The container needs to constructed with viewing ports or other types of fabrication that allow continual observation of the birds during all stages of the killing process and monitoring of the progress of the procedure. Containers that do not allow visual monitoring of the birds are unsuitable and, while the final outcome of dead birds may be considered adequate, the assumption that the birds have all died humanely is not valid. For the model requirements for a suitable container design refer to Diagram 2 and 3.

2. Pre-planning the quantity of CO_2 required.

As with any farming task, it is important that advance planning is done to acquire the necessary equipment to undertake a procedure. In some localities, obtaining large quantities of CO_2 cylinders will require advance notice to be given to the supplier, and contingencies need to be in place for a 7 day available supply. For estimated quantities in kilograms of CO_2 per thousand layers the reader is referred to Table 1.

3. Inadequate gas flow from the cylinder.

This can be a simple volumetric problem where the size of the cylinder is not adequate for the size of the MAK container. By matching up the capacity of the container, the rate of kill and the quantity of CO_2 required for the number of birds, the operator is able to ensure the cylinder's flow capacities are adequate.

More commonly, the problem is not related to the size and number of cylinders available, but to the problem of restricted flow or total loss of flow because of the freezing of the cylinder valve head or distribution hose. This invariably requires the ongoing rotation of more cylinders than would normally be required, increased labour input and potentially a decrease in the reliability of the killing process. During the development of procedures to overcome this problem a number of methodologies were tried. The first involved wrap around electrically heated cylinder jackets (Photograph 9).

This proved to not be a suitable solution to the freezing of the cylinders, with most of the restriction occurring at the head of the cylinder and the control valve. To resolve the problem of freezing, an electric CO_2 gas heater unit (Photograph 10 and Diagram 4) was used. In conjunction with the heater unit, the flow of gas using the cylinder valve must be manually regulated, and the valve not fully opened. Despite the use of the heater unit, sustained operation of a single CO_2 cylinder will require rotation with a replacement cylinder.

Photograph 9: Gas Heating Blanket

Photograph 10: CO_2 In-Line Heater Unit

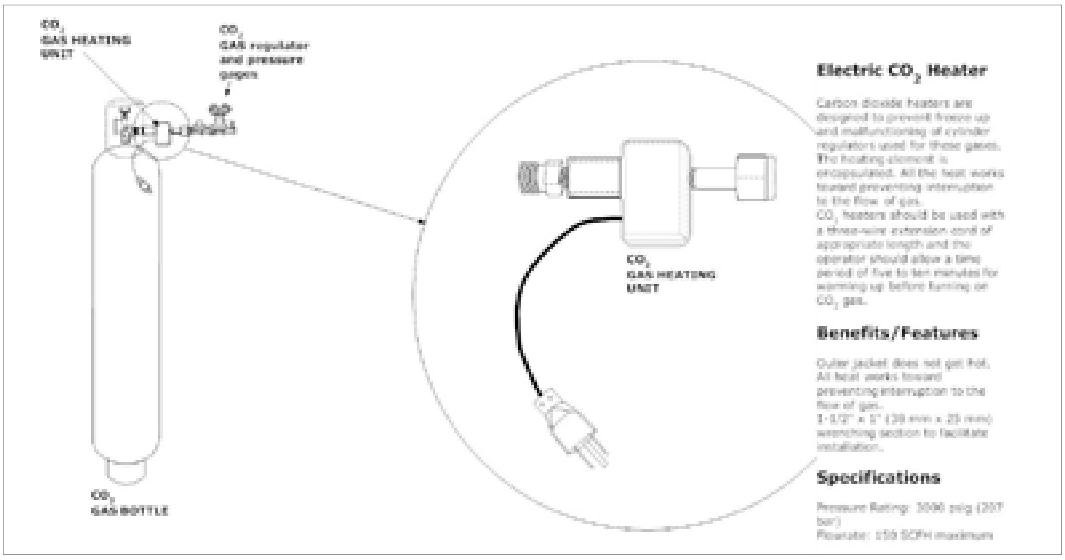
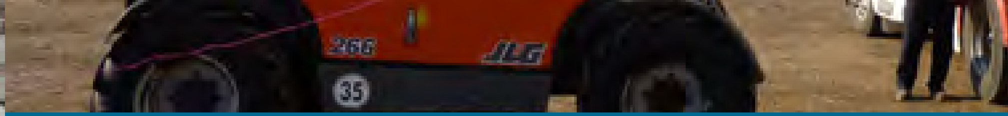


Diagram 4: CO_2 Gas Heater Unit



A major limiting factor in using CO_2 cylinders is the frosting of the whole cylinder that blocks or reduces the flow of CO_2. Dr Mohan Raj, in a personal communication, explained the special property of CO_2 which turns it from liquid to solid and thus blocks the system's gas flow. Normal gas turns into liquid when compressed inside the cylinders, and when drawn, quickly vaporizes into gas again using the heat from atmospheric air. But according to Dr Raj, this is not the case with carbon dioxide, as it can go from liquid state to solid (dry ice) and then to a gaseous state. Owing to this physical property of this gas, it requires an external source of heat to vaporize the gas, especially when the rate of withdrawal from the cylinder is too rapid or the ambient temperature is too cold.

Different types of custom made electric blankets from both the US and China were tried with limited success (Photograph 11). Although these blankets were able to slow down the frosting process, this was not enough to maintain a continuous flow of CO_2.

Photograph 11: **Types of Gas Heating Blankets**

The use of an electrically heated regulator to overcome the problem of frosting was also tried, however, the operators concluded that it would be difficult to procure electrically heated regulators capable of delivering the gas mixture at the rate required to fill the container at a speed necessary to maintain the required gas concentration. The use of an electrically heated gas pre-heater (Photograph 10 and Diagram 4), without the regulator, has some advantages as it was able to stop the frosting of the gas delivery pipe to the MAK unit. Dr Raj identified a number of solutions to this problem:

- Deliver the gas mixture at lower pressure e.g. 3 bar (43.5 psi) rather than 5 (72.5 psi) or 6 bar (87 psi), using a high throughput regulator, which would take longer to fill the container.
- Use gas supply from two regulators connected to two different cylinders delivering 3 bar each to meet the demand of 6 bar delivery pressure.
- Use a manifold of gas cylinders such that the rate of vaporization demanded is distributed across the batch of cylinders.
- Use a combination of two manifolds and two regulators.

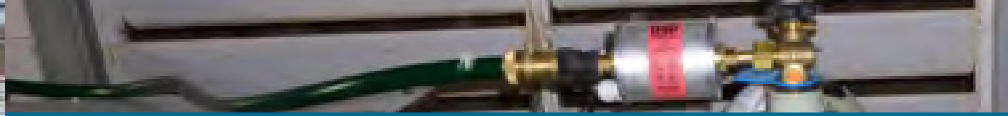
Further consultation with BOC identified that despite all the efforts to provide an external heat source, a tiny valve inside the cylinder will still block with dry ice when the flow rate is very high. According to a BOC expert, the only solution is to slow down the individual cylinder flow rate by the use of multiple cylinders at the same time, or quickly swap the cylinders to avoid ice building up in the valve. To balance the flow rate while maintaining required gas concentration, a centralised gas delivery system was tried with some success (see section 5.7.4). In this trial, a blind ended PVC pipe was connected to the gas delivery hose with a CO_2 pre-heater. The PVC pipe was drilled in a circular manner to stream the gas in all directions, the principle being that during the operation the dead birds will block the holes from the bottom, allowing the gas to flow only at the bird's level. It was observed that under this method a medium size container with a capacity of about 400-500 birds can be prefilled to 60% CO_2 within a minute compared to 3-4 minutes with a normal hose. Most significantly, the required gas concentration during the operation can be consistently maintained at a very low flow rate and thus freezing of the whole gas cylinder can be avoided.

5.7.3 Proper handling of the birds

With the portable gas killing method, birds must be caught and walked to the killing device. It is well known that catching and handling live birds can induce fear (Boissy, 1995) and cause pain as a result of bruising and broken bones (Knowles and Broom, 1990), particularly if the procedures are carried out by poorly trained staff. Therefore, the process of catching and handling of live birds and moving them to the killing device must be carefully considered to minimise both damage to the birds and the labour hours involved.

5.7.4 Monitoring

While the observational monitoring of the birds allows for ongoing assessment if the CO_2 gassing process is adequate, it does result in inconsistency of kill, and even a need to stop the operational activity where it is observed that birds are not being killed in the expected manner. This results in a number of birds not experiencing the required welfare and humane treatment. Observational monitoring also requires a very experienced operator present and constant observation of the birds, which is often neither feasible nor practical. The criteria used to evaluate effective and humane killing may also vary between supervisors. This subjective approach to killing birds is not ideal on welfare grounds and should be supplemented with methods that are more objective. This was achieved by the use of a commercial CO_2 monitoring meter (Photograph 12) and the use of the well-researched figure of a CO_2 concentration around 40%.



Photograph 12: CO_2 Meter

Photograph 13: Centralised Gas Delivery System

A commercial layer farmer designed an effective gas delivery system to use in the medium size MAK unit. The system for CO_2 delivery was described in the following manner: "The distribution of the gas is through a 25mm PVC pipe which is fitted down the very centre of the top of the container. The pipe is capped at one end, and has an elbow and connection for ¾" garden hose at inlet end. The pipe has one (1) 6mm hole at the end of the cap and holes every 100mm from the cap to the elbow. These holes are drill opposing to each other. Meaning there are holes on each side of the pipe 180 degrees from each. The other end of the hose has a poly connection, which is modified to fit the thread of the gas heater. The gas heater is connected direct to the CO_2 bottle. The regulating of the gas is controlled by the gas bottle tap, which does not need to be fully opened. The level of gas in the container is regulated using a CO_2 meter, working in ranges from 45% to 60% concentrate of gas in the container. This level is achieved in no more than 45 seconds. Careful ongoing repositioning of the CO_2 meter inlet hose to be about 100mm from the level of deceased birds is required for an accurate reading. The distribution of birds must be uniform and a steady input of birds into the container" (G Dimech, unpublished data).

5.7.5 Proper Disposal

While mass euthanasia of birds resolved the issue of the inability to depopulate birds in a timely manner, it does create the problem of what to do with the dead birds. The mass quantity of dead birds normally ranges from 20 to 100 MT. Current methods of carcass disposal in Australia include rendering, composting and in some cases burying. Other potential methods include bio-digestion, incineration and use of the carcass for energy production. Consideration of the cost and potential income from the product is important but environmental and biological ramifications should also be taken into account before selecting a disposal method. The following alternatives are considered.

5.7.5.1 Rendering

This is a heating process that extracts usable ingredients such as protein meals and fats from mortalities. Rendering is recommended as the best choice for disposal of mortalities where farms are within a practical radius of a rendering facility that handles feathered poultry. It is a simple, low-cost solution to the disposal problem. Numbers of rendering facilities that will take whole birds with feathers in Australia are limited. The by-product is a protein meal, which has commercial value, however the operator has to depend on the rendering plant and bear the additional cost involved in transporting the killed birds from the farm to a facility. Proper bio-security measures must be implemented to prevent the spread of disease by the rendering truck.

5.7.5.2 Composting

Composting is a viable alternative to disposing of spent layer hens. Composting is a natural, biological process by which organic material is broken down and decomposed. Composting has long been used as a suitable management tool for handling the solid wastes produced in layer hen facilities, and is now becoming a more common practice for managing spent hens and mortalities. Composting is convenient, relatively cost effective and an environmentally safe way to dispose of spent layers; however, building a composting windrow can be labour intensive. It involves equipment, time, and requires an adequate land base for both the windrow and subsequent compost application.

A permit is required to undertake composting, which is considered by the EPA to be distinct from the temporary storage of waste like poultry litter. In order to obtain new permits for the prescribed activity of composting, an operator must submit procedural documentation to the responsible authority, who will consult with the EPA for technical advice, describing how the facility will be constructed and operated, as well as an environmental risk assessment. The pivotal consideration of the EPA will include the following:

- The construction of a pad that will have a base that has an ingress coefficient of 10^{-9} m/sec. This is to ensure leachate does not get into underground water.
- The area is to be bunded to ensure that there is no runoff contamination from the composting area.
- Assurance, possibly based on odour modelling, that no odours offensive to the senses of humans will be detected at the nearest sensitive use site (residential houses, schools, etc.).
- Ensure that barriers are in place to prevent vermin from removing and spreading dead birds from the area.

A number of research projects are currently underway to identify the most effective way to compost commercial chickens. The key is proper windrow construction and site selection. Sites should be flat, well-drained, and away from groundwater sources. A good carbon source, such as wood chips, sawdust or straw is needed to make a one-foot deep windrow base. Key elements to successful composting include a good carbon source, along with nitrogen (in this case, bird carcasses), oxygen, and moisture. Assembled properly, these elements produce the high temperature environment that supports microbial activity.


5.7.5.3 Burying

The burying of birds on a property first requires an existing permit for such activity or the application for a new permit from the responsible authority. Invariably, the latter is becoming increasingly difficult to obtain, requiring an environmental impact investigation to be undertaken for the Environmental Protection Agency (EPA), the state agricultural and environment departments and catchment management authorities. Permits to bury on site are less commonly being granted, with this even being the case for one-off approvals required during an Emergency Animal Disease (EAD) outbreak. Where permits do exist, access is required for heavy earthmoving equipment as well as appropriately trained staff to operate vehicles.

Burial is a common method of handling dead animals. A pit is excavated and is filled with the carcasses. Over time the carcasses will decompose. Burial is a simple and relatively inexpensive means of disposal. There are no or very limited capital costs associated with this method. However, disposal of spent layers by pits/burial is inadequate and a concern for groundwater contamination. The increasing size of poultry flocks will require careful planning to use this method safely. The location of a burial pit is subject to several restrictions which have to be addressed in the decision making tree.

5.7.5.4 Landfill (Rubbish Tip)

Access to landfill for the disposal of large volumes of dead birds is difficult to obtain and most now do not allow such use. Each landfill operates by its own approved processes; therefore, it is advisable to have pre-approval from the landfill operator before considering this option. Where such dumping is allowed, the costings charged are usually considered prohibitive. Access hours may also be restricted and there is the need for heavy haulage equipment.

5.7.6 Common Concerns with On-Farm killing using Gas

5.7.6.1 Bird Welfare

In most of the killing methods, birds must be caught and brought to the killing device. The catching and removing of spent hens from the layer house and their subsequent disposal must be undertaken in a manner that ensures humane treatment. Laying hens at the end of the laying cycle can be prone to skeletal damage. Therefore, consideration of welfare aspects should not only be based on the killing process but on the total procedure including the catching and handling of live birds. In case of gas killing method, attention to the speed of introducing birds in gas containers is of major importance to minimise the stress of bird handling.

Consumers today are concerned about animal production husbandry practises and welfare issues. The poultry industry is required to utilise procedures to depopulate spent hens in a manner which meets consumer expectations, satisfies environmental regulations, and minimizes cost. Essential to the fulfilment of these objectives are the careful selection of the quickest, most humane method and the skilful use of the method.

5.7.6.2 WH&S Issues

Risks to human safety can arise from the gaseous agent used, the killing method, and on-farm hazards, where personnel are working in an unfamiliar environment. Farm management should review the hazards associated with the depopulation method likely to be used. The management should confirm that all personnel associated with the killing process have been briefed with the procedure and any hazards associated with the process. It is essential to ensure that personnel involved in the killing of animals have appropriate skills, training and competencies and that all operations are constantly monitored. Equipment used should be in well maintained working order. Back-up equipment should be provided. Care must be taken to monitor possible psychological effects on staff.

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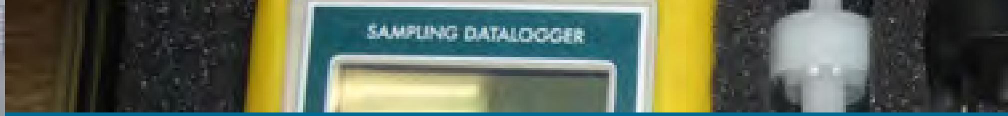
APPENDIX 1 – Case Study for Modified Atmosphere Killing of Spent Layer Hens

Euthanasia can be defined as a humane death that occurs with minimum pain, fear and distress. This means the euthanasia procedure should be conducted with the highest degree of respect for that animal with an emphasis on making that death as painless and easy as possible. Carbon dioxide (CO_2) causes swift onset of anaesthesia with subsequent death due to respiratory arrest. Poultry can be euthanised using CO_2 gas by being placed in containers that are sufficiently airtight to maintain CO_2 at desired levels. To meet the criteria for humane euthanasia, birds already in the container must be unconscious before being overlain by other birds loaded after them, and unconsciousness must be maintained until death occurs.

Materials and Equipment required:

1. Appropriate size container fitted with viewing windows. The capacity of the container may vary from 200 to 1,500 birds.
2. Forklift / tractor to lift and move the containers.
3. Divider pens for floor system and carts for cage system.
4. Appropriate number of CO_2 cylinders.
5. Gas delivery hose preferably made of non-freeze flexible hose.
6. CO_2 pre-heater to heat the gas at the regulator to avoid freezing the gas delivery system.
7. Proper monitoring device, preferably electronic CO_2 meter with or without data logging.



8. Materials for wash down and sanitation of the equipment.

Personnel Required:

- Farm staff familiar with the handling of domestic poultry and with an awareness of sound animal welfare practises. Staff should wear protective clothing and footwear. Proper training of personnel is essential to ensure poultry are euthanised appropriately.
- Farming senior management acting in a supervisory role.

Basic Design of Container:

- The basic criteria for the container are that it should:
- be easy to load,
- ensure fast and effective euthanasia,
- allow easy carcass removal at the disposal location, and
- be easy to wash down and sanitize inside and out.

With a large top loading container, two loading doors and (at least) one viewing window are preferable. These should be located on the top/front corners of the container. The container design should allow for the emptying of the container at the front side opposite the lifting machine. A locking mechanism on the side should allow for the container to be locked during the filling process and released before emptying into the transport trailer. Ideally, container opening devices should be situated on the left hand side of the container, so a forklift / tractor operator can open the container when it is in the air over the truck, without getting out of the vehicle. The gas should be distributed from the centre of the container, or alternatively there should be at least two CO_2 inlets on two sides of the container.

At least 3mm thick steel should be used and the container made gas tight. To keep the functional logistics feasible, the dimensions of the container should be carefully chosen to allow access to and around shed facilities. The size of the container should also accommodate a commercially available transport module for easy movement.

The required CO_2 gas concentration can be sustainably maintained during the operation using a well-sealed container with two layers of protection in the loading window. The first entry layer (top) should be a rubber flap to stop the escape of CO_2 gases, the second under the rubber, is a split flap to prevent birds escaping. A centralised gas delivery system is always recommended, using PVC pipe which should be fitted down the very centre of the top of the container. The pipe should be capped at one end, and should have an elbow and connection for a ¾" garden hose at the inlet end. The pipe should have one 6mm hole drilled at the end of the cap and holes every 100mm from the cap to the elbow. These holes are drilled opposite each other, producing holes on each side of the pipe.

Cost of the unit/ Start-Up Cost:

The cost of construction of containers varies from $1,000 to $2,000, depending on the capacity of the container. For floor reared or free range birds, a large container with dimensions of 1.2 m (height) by 1.2 m (width) by 2.4m (length) can be operated from outside the shed, however an adequately sized forklift must be available to lift this large container up and tip it into a truck for transport. The construction cost of small movable containers of 200-300 bird capacity also varies, depending on the material used and degree of sophistication. A good quality CO_2 meter is around $1,000-$1,500 and a gas pre-heater is around $300.

Operating Cost:

The estimated operating cost of a MAK unit with CO_2 costed at $3.71 per kg and labour costed at $24.50 per hour, is between 9 to 25 cents per bird depending on the container design, gas delivery system and type of operation. The capacity of the devices and cost of the operation depends not only on the technology but also the capacity of the operators to catch and transport the birds from their houses to the containers. In general, 10 kg CO_2 is required per 1,000 birds (although up to 15 kg CO_2 may be needed) but there are large differences in capacity and labour costs mainly due to different types and sizes of husbandry systems.

Procedural Outline:

- Observe and record all Workplace Health and Safety issues.
- Organise logistics so that the correct number of containers and associated transport are available. Containers are to be placed in close proximity to sheds to allow both easy access of staff to sheds and containers, and transport vehicles to containers.
- Place two cylinders of CO_2 beside each container with a gas delivery system positioned inside the container.
- Turn one cylinder on and fill the container with CO_2 until it reaches approximately 60% CO_2 in the container. This level can be observed by carefully positioning the CO_2 meter inlet hose to about 100mm from the level of deceased birds. Alternatively, it can be observed by placing a very thinly inflated party balloon in the container and allowing it to float on the surface of the CO_2. If the gas cylinder begins to ice up, discontinue use of this cylinder and use the second cylinder.
- Birds can then be removed from the shed and placed in the container, submerging them in the CO_2. Birds will take several depth breaths and then become comatose. Birds are to be continually added to the container ensuring that the level of CO_2 is always adequate by the addition of more CO_2.
- Birds should be monitored and confirmed to be unconscious and insensible to external stimuli before other birds are added on top.
- When the quantity of birds approaches a depth where the layer of CO_2 is just in excess of an adequate amount to cover the birds, the addition of birds should cease. At this point after a final inspection by a person in a supervisory category to check that all welfare aspects are being met, the lids should be closed and secured.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