

Recommendations for the Depopulation of Swine



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This series of fact sheets provides guidance for veterinarians and producers about available swine depopulation methods, the limitations of each method and how they can be applied under various circumstances, and plan development for how depopulation could be deployed in emergency situations.

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Defining Depopulation and Conditions for its Use



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(Information adapted from AVMA Guidelines for the Depopulation of Animals, 2019)

Depopulation defined

The American Veterinary Medical Association (AVMA) has defined depopulation as the rapid and efficient destruction of a complete population of animals in response to urgent circumstances with as much consideration given to the welfare of the animals as practicable.

The AVMA Guidelines for the Euthanasia of Animals, AASV On-Farm Euthanasia of Swine brochure, or the AVMA Guidelines for the Humane Slaughter of Animals should be referred to in circumstances necessitating prophylactic culling or precautionary killing.

Conditions necessitating depopulation

Urgent circumstances that may require the rapid and efficient destruction of a population of swine include, but are not limited to:

- **Regulatory diseases:** Depopulation may be used by state and federal animal health officials as the first line of defense to quickly eradicate the disease by preventing further disease replication in infected, exposed, or at-risk swine. Stop movements may be implemented in disease control areas and result in the need for depopulation of swine on noninfected farms.
- **Nonregulatory highly pathogenic diseases:** Depopulation of infected and susceptible swine may be required to prevent further agent replication and support herd health stabilization to mitigate further losses.
- **Emerging swine production diseases:** Depopulation may be required to prevent a nonregulated disease from spreading from the index case or early cases to the rest of the national herd.
- **Zoonotic diseases:** Depopulation may be required because of real or perceived public health threats or food safety concerns, such that swine can no longer be moved or marketed. Zoonotic diseases may complicate or increase the burden of accomplishing depopulation owing to the level of personal protection required to prevent human exposure.
- **Intoxications and adulterations:** Depopulation of swine exposed to adulterants or intoxicants (eg, oral exposure to dioxin) may be required to prevent real or perceived threats to food safety or immediate or impending danger to swine welfare from the toxicant exposure (eg, kidney failure).
- **Radiologic exposures:** Depopulation may be required in a radiologic emergency, such as a nuclear power plant incident, to prevent or relieve animal suffering and protect worker and public health.
- **Natural disasters:** Depopulation may be required when swine cannot be removed from harm's way to prevent or relieve animal suffering. Following a natural disaster, farms may be damaged to an extent that is hazardous for workers to enter buildings. Farms may also remain intact but basic services, including animal care and feeding, are unable to be restored in time to prevent suffering.
- **Market disruption:** Any eventuality that reduces or eliminates the marketability of swine could have a negative impact on animal welfare in a short period due to the limited flexibility in the current marketing channel. This puts a high level of importance on the speed at which a decision can be made for swine that cannot be moved or marketed because of regulatory issues, natural or manmade disasters, food safety, and other public health issues.



Depopulation Method Options



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(Information adapted from AVMA Guidelines for the Depopulation of Animals, 2019)

The American Veterinary Medical Association lists possible depopulation methods in three categories (AVMA, 2019):

Preferred	Permitted in Constrained Circumstances	Not Recommended
Gunshot	Ventilation shutdown plus	None listed
Nonpenetrating captive bolt	Sodium nitrite	
Penetrating captive bolt	Compounded or nonpharmaceutical-grade injectable anesthetics and euthanasia agents	
Electrocution		
Manual blunt force trauma		
Movement to slaughter		
Carbon dioxide		
Anesthetic overdose		

Preferred methods are given the highest priority and should be used preferentially when circumstances allow reasonable implementation during emergencies.

Permitted in constrained circumstances methods are permitted only when the circumstances of the emergency are deemed to constrain the ability to reasonably implement a preferred method. Potential constraints include, but are not limited to, constraints on zoonotic disease response time, human safety, depopulation efficiency, deployable resources, equipment, animal access, disruption of infrastructure, and disease transmission risk.

Not recommended methods should be considered only when the circumstances preclude the reasonable implementation of any of the preferred or permitted in constrained circumstances methods and when the risk of doing nothing is deemed likely to have a reasonable chance of resulting in significantly more animal suffering than that associated with the proposed depopulation technique. Examples include, but are not limited to, structural collapse or compromise of buildings housing animals, large-scale radiologic events, complete inability to safely access animals for a prolonged period of time, or any circumstance that poses a severe threat to human life.

The methods listed above have been shown to be appropriate for depopulation based on the available scientific literature and experience. However, this list may not be all-inclusive. The appropriateness of alternative options should be assessed using the following criteria:

- Ability to induce loss of consciousness followed by death in a timely manner with a minimum of pain or distress.
- Reliability and irreversibility of the method to result in death of the animal.
- Compatibility with the safety of humans, other animals, and the environment.
- Potential psychological or emotional impacts on personnel and sensitivity to public sentiment regarding the destruction of large numbers of animals.
- Availability of agents and carcass-processing and disposal venues to handle the volume.
- Ability to maintain equipment needed for depopulation in proper working order.
- Compliance with legal requirements.



Every situation where depopulation is considered will be unique due to the limitations and constraints imposed by the type of the emergency, resource availability, geography, site variation, local regulations, etc. When choosing a depopulation method, the factors highlighted here must be considered. Producers should work with their herd veterinarian to discuss these factors and use the **Depopulation Summary Form** (page 5) to document the details of the situation and justification for choosing the depopulation method used.

Legal requirements

- Become familiar with state laws that may influence the depopulation process. This includes laws related to animal abuse and neglect, firearm usage, mortality management, or restrictions on access to needed resources.

Animal disease characteristics

- The scope of the outbreak will impact the number of animals to be depopulated and resource availability.
- Understand how the epidemiology, transmission route, and pathogenesis of the disease-causing agent will impact the timeline for depopulation, labor needs and worker safety precautions, the physical condition of swine, scope of depopulation, carcass disposal method, and cleaning and disinfection. Information about current pathogens of interest has been published by the Swine Health Information Center (swinehealth.org/fact-sheets/) and the Center for Food Security and Public Health (cfsph.iastate.edu/Species/swine.php).
- Evaluate the current and ongoing disease status (eg, infected, contact, or clean) of the site which will help define the timeline and scope of depopulation.

Time constraints

- Select a method with the ability to achieve the necessary throughput to accomplish depopulation within the established time constraint.
- State or federal regulatory authorities will establish the timeline for depopulation during a regulatory disease outbreak.

Ownership and indemnity

- Depopulation planning and coordination is essential when the owner of the pigs differs from the owner of the barn.
- Approval before depopulation occurs must be factored into any plan where there is an appraisal and indemnity process to offset the financial losses to owners. For example, insurance company or government authority approval may be required.

Personnel availability

- Determine the number of personnel needed and the training required to perform the chosen depopulation method.
- Consider the amount of downtime required if personnel are moving between sites to perform depopulation.
- Create work/shift schedules that allow for some downtime to protect human well-being and safety.

Worker health and safety

- The cause for depopulation will pose varying risks for worker health and safety, which should be a primary consideration when choosing a depopulation method.
- Responders will need to wear appropriate personal protective equipment, which may impact how a depopulation method is performed.
- Designate an individual to address and ensure worker health and safety during all phases of the depopulation process.

Operator and observer impact

- Consider the aesthetics of the chosen depopulation method and the impact the depopulation process will have on observers, operators, and producers.
- Make appropriate social services and mental health support resources available to all participants in the depopulation process, regardless of method used.

Public perception

- The scope of depopulation and the chosen depopulation method should be proportional to the scope and urgency of the of the situation.
- Consider how and where the method can be performed to limit the number of observers and protect public safety.

Animal environment

- Environmental conditions, including weather conditions and temperature, can impact equipment functionality and worker safety.
- Evaluate the facility's infrastructure for safety after a natural disaster or fire before personnel enter. Safety of the barn structure and environment will impact where depopulation can be performed.
- The type and layout of facility or outdoor housing will impact the depopulation procedure including how and where animals can be accessed to apply the depopulation method, which depopulation method can be used, and what type of ancillary equipment may be needed to facilitate animal movement and handling.
- If animals can be moved from the farm, consider developing regional depopulation strategies that use a centralized location and resources to increase throughput and facilitate carcass disposal strategies.

Number of swine and phase of production

- The number of swine to be depopulated will influence the method used for depopulation, as the method throughput should be able to accomplish depopulation within the established time constraint.
- The phases of production housed on a site will impact the depopulation method used and the resources needed to successfully perform the depopulation.
- Multiple phases of production or sizes of pigs on one site may necessitate the use of multiple methods for depopulation.

Animal handling and condition

- Identify the location for depopulation, the route to that location from the area the animals are housed, and who is responsible for gaining access and moving pigs.
- Identify the type of animal restraint needed during the depopulation process.
- If pigs are depopulated in a barn, consider moving pigs closer to egress points to save on the distance a carcass needs to move for extraction from the barn.
- Consider the physical condition of the animals when developing a depopulation plan. Have a plan for how to handle non-ambulatory animals.

Equipment availability

- Identify the key resources needed for each method and calculate how much of the resource is needed, where the resource can be sourced, timeliness of acquisition, limitations on resource availability, and limitations on storage of the resource.
- Identify key ancillary resources needed for animal handling and carcass extraction and movement.
- Understand capacity limitations of equipment such as weight limits, battery life, gas/diesel needs, and durability of equipment.
- Understand and anticipate maintenance requirements of equipment.
- During a regulatory disease outbreak, state or federal regulatory authorities may require specific methods be used and resources may be available through the US Department of Agriculture's National Veterinary Stockpile.

Confirming insensibility and death

- Make every effort to confirm insensibility and death of the animals, provided the effort does not pose a risk to human health or safety.

Carcass removal and disposal

- Ensure that the throughput of the depopulation method does not outpace the ability to remove and dispose of carcasses.
- The cause for depopulation and the method of depopulation will impact the options for carcass disposal. For example, adulterants or intoxicants may limit disposal options to protect environmental health.
- Understand how depopulation and carcass disposal may impact the fallow period required for the site before it can be repopulated.



Depopulation Summary Form



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This form can be used to document the details of the emergency and justification for choosing the depopulation method used.

Premises Identification Number _____ **Date** _____

Cause for depopulation: describe the circumstances necessitating depopulation
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Phase of production:	# Depopulated:	Method used:
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Rationale*:

Phase of production:	# Depopulated:	Method used:
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Rationale*:

Phase of production:	# Depopulated:	Method used:
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Rationale*:

Phase of production:	# Depopulated:	Method used:
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Rationale*:

*If a method classified as “permitted in constrained circumstances” is used, justification must be provided for why none of the preferred methods would have worked in this circumstance.



Method classification:

Preferred.

Suitable for:

All phases of production.

Procedure:

Carbon dioxide (CO₂) replaces oxygen in the body and causes rapid onset of anesthesia with subsequent death due to respiratory arrest. Pigs require a constant exposure of 80% to 90% carbon dioxide concentration for at least 10 minutes. The total time needed to achieve effective concentration is a function of the flow rate and container volume.

Biosecurity risk:

No contamination from blood loss.

Labor needs and throughput estimates:

Labor needs and throughput estimates can be calculated here: ncagr.gov/oep/documents/MultiFarmStartMacro7.xlsm.

Safety considerations:

Carbon dioxide poses a moderate risk to human safety. Personnel should be cautious of CO₂ exposure (fsis.usda.gov/wps/wcm/connect/bf97edac-77be-4442-aea4-9d2b15f37be0/Carbon-Dioxide.pdf?M0D=AJPERES). Risks can be mitigated by using wearable gas monitors and allowing complete ventilation of the container before entry for carcass inspection or removal. Cryogenic gloves and goggles should be worn by personnel working around the vaporizer chamber.

Seasonality impacts:

Extra energy may be needed for the vaporizer and heat exchanger to function properly in cold ambient temperatures.

Carcass disposal restrictions:

None.

Configuration:

Several setup configurations exist for CO₂ administration. Examples of various configurations have been provided by North Carolina State University and are available at ncagr.gov/oep/MassDepop.htm and pork.org/public-health/what-you-need-to-know-about-covid-19/pork-industry-covid-19-webinars/). A schematic of a setup for intermediate-scale depopulation can be found here: aasv.org/shap/issues/v22n5/v22n5p248.html. A schematic of a large-scale depopulation setup can be found here: ncagr.gov/oep/documents/CO2VaporizerHowToV1.pdf.

Required resources:

- **High-pressure CO₂ liquid.**
- **Vaporizer chamber** should be a gas-tight vessel that has a pressure-relief valve and is capable of withstanding 500°F to 600°F. Examples include 55-gallon metal drums, 250-gallon used propane tanks, and polyethylene bags. This chamber can be used to sublimate dry ice accumulation back into gas.
- **Pressure drop valve** rated for pressure and low temperature to prevent dry ice formation in the feed hose or truck valve. Check with your CO₂ supplier to ensure you have the correct connection available for the truck to connect with the vaporizer chamber.
- **Heat enclosure** designed to improve heat transfer to the vaporizer chamber. The heat capacity and number of heaters will be determined by the desired CO₂ flow rate. Heat input can be supplied from several sources including kerosene, torpedo-style heaters.
- **Heat exchanger** to increase the gas temperature to near ambient temperature. Examples include adding a metal heat exchanger coil inside the heat enclosure or a geothermal earth tube.
- **Polyethylene bags (optional)** can be used to store gas onsite and help provide a more consistent flow of gas to the depopulation chamber.
- **Flow regulation** using a field constructed venturi and monometer. A blower can be used to move the gas from the storage bags to the chamber.
- **Airtight container** sized to accommodate the farm needs and the vaporizer capabilities. The floor of the container should be a non-slip surface. The container must be equipped with inlet and outlet valves. Because carbon dioxide is heavier than air, the container's outlet valve should be located at the top. This way, the container can be filled with carbon dioxide while the displaced air can escape. Examples of containers used for depopulation include earthen pits, sealed trailers or dump trucks, shipping containers, roll-off solid waste dumpsters, and temporary corrals constructed of wire fence, plywood, and plastic sheeting.
- **Penning panels** to create temporary corrals, alleyways, or chutes for pig movement out of the barn and into the container.

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Ancillary resources:

- **Animal handling tools** to move pigs from the barn to the container.
- **Adjustable loading chute** may be needed to load pigs into the container.
- **Front end loader** for carcass removal from the container.
- **Backhoe (optional)** to dig earthen pits for CO₂ container or trenches for earthen tubes.



**We want to hear from you! Do you have first-hand experience using this method for depopulation?
Please submit your feedback on the content of this factsheet at aasv@aasv.org.**

Method classification:

Preferred.

Suitable for:

Nursery pigs or older.

Procedure:

Gunshot to the head results in concussion and damage to vital areas of the brain caused by the impact of the penetrating bullet. The ideal target for gunshot is half an inch above eye level, on the midline of the forehead and aiming toward the tail of the pig. An alternative target for gunshot is behind the ear so that the bullet enters the skull from behind the ear aiming toward the opposite eye.

Biosecurity risk:

Potential for contamination due to blood loss through the bullet point of entry.

Labor needs and throughput estimates:

Personnel must be trained in firearm safety and have marksmanship skill. Throughput is estimated to be 1-2 minutes/pig.

Safety considerations:

Gunshot poses a high safety risk to personnel. Additional personnel should always remain behind the shooter. Pigs should be moved outdoors, on soil where the danger of a bullet ricocheting is reduced. Hearing and eye protection should be worn by all personnel.

Seasonality impacts:

None identified.

Carcass disposal restrictions:

None.

Configuration:

Chutes or corrals with removable side panels can be constructed outside of the barn. Chutes can be constructed in an I or Y formation with a width that allows pigs to stand single file and the sides tall enough to prevent pigs jumping over. After pigs are loaded into the chute, shooting can begin with the lead pig and working back through the line. Confirm death and lower one side of the chute to facilitate carcass removal.

Required resources:

- **Rifle or shotgun.** The rifle and ammunition selected must have a minimum muzzle energy of 300 foot pounds to enable the bullet to pass through the skull thickness of grow/finish and mature adult pigs. A 12-, 16-, or 20-gauge shotgun can be used for grow/finish pigs and mature sows and boars. A 28- or 410-gauge shotgun is recommended only for nursery pigs.
- **Ammunition.** Slug ammunition is recommended for shotguns because of its ability for consistent and effective penetration of the skull. Bulleted ammunition should be round-nosed and solid to ensure penetration of the skull. The common type of ammunition known as a “wadcutter” is designed for target shooting and is not suitable. Fragmenting bullets are recommended only for use in nursery and grow/finish pigs as they tend to fragment before fully penetrating the skull thickness of adult animals.
- **Penning panels** to create temporary alleyways or chutes for pig movement out of the barn and into the single file configuration.

Ancillary resources:

- **Animal handling tools** to move pigs from the barn to the chute.
- **Front end loader** for carcass removal.



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Method classification:

Preferred.

Suitable for:

Pigs less than 70 lbs.

Procedure:

The nonpenetrating captive bolt (NPCB) gun typically has a mushroom shaped or flathead bolt that, when applied to the forehead of the pig, causes concussion and severe trauma of the brain. The pig should be restrained by placing the pig so its chin and sternum are supported by a solid surface and holding the back of the pig's head firmly so the pig's chin/neck is pressed firmly flat against the surface. The NPCB gun should be placed firmly against the front of the head.

Biosecurity risk:

Minimal risk for contamination if skin remains intact.

Labor needs and throughput estimates:

Labor needs are estimated to be a 3-person team per NPCB station: one person to handle animals and carcasses at the station, one person to restrain and use the NPCB gun, and one person to manage the equipment. Additional labor will be needed for moving animals from the barn to the station and moving carcasses from the station to the disposal location. Throughput is estimated to be between 30 seconds and 1 minute/pig depending on device used.

Safety considerations:

NPCB poses a low risk to human safety. Operators should be aware of their hand placement when restraining the pig. A customized hand shield can be used to protect the restraining hand when operating the NPCB gun. Hearing and eye protection should be worn by all personnel.

Seasonality impacts:

None identified.

Carcass disposal restrictions:

None.

Configuration:

Identify a location to set up NPCB stations so that pigs can easily be brought to the station by using carts or set up holding pens near the station. The station location should also allow for easy carcass removal.

Required resources:

- **Solid surface** that can be used for restraining pigs for NPCB application. Examples include a table, bench, or PVC restraint trough set at waist height to accommodate operator ergonomics. Larger pigs can be restrained against the floor.
- **Nonpenetrating captive bolt guns** can be cartridge powered or pneumatic.
 - The cartridge-powered guns can be inline or pistol grip. The inline style lends itself to greater comfort and less fatigue for the operator. Nonpenetrating captive bolt guns that achieve a force higher than 120 psi have been shown to be effective as a single-step method for piglets weighing up to 70 lbs. The cartridge-powered guns will become hot after 15-20 minutes of continual use, so it is recommended that the tools be rotated every 15 minutes to allow for cooling. During the cooling period, the breech should be disassembled from the barrel to accelerate cooling and the parts can be inspected for damage.
 - The pneumatic bolt guns are air powered and resemble air-powered nail guns. Nonpenetrating captive bolt guns achieving a force of 120 psi have been shown to be effective as a single-step method for piglets weighing under 20 lbs. Pneumatic bolt guns are air cooled and can be used repeatedly without a cooling period.
- **Powder cartridges or compressed air** depending on the type of NPCB gun used. For cartridge-powered NPCB guns, follow manufacturer's recommendations on proper cartridge loads to use. Operators can use a 2-pouch carpenter's tool belt to hold live and spent power loads. For pneumatic NPCB guns, use a compressor capable of 150 psi output. A 25- to 50-foot air hose is needed to connect the compressor to the gun. Prolonged use of some air compressors can result in water accumulation, so the drain petcock should be opened periodically for draining.
- **Replacement parts and cleaning equipment** will be needed to maintain the guns throughout operation to ensure proper bolt velocity. Refer to manufacturer's recommendations for proper gun cleaning protocols. Cartridge powered NPCB guns should be inspected during cooling periods and worn parts replaced. The pneumatic fitting of the NPCB gun should be oiled every 500 shots.

Ancillary resources:

- **Carts** for movement of small pigs from the barn or movement of carcasses.



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Method classification:

Preferred.

Suitable for:

Pigs over 12 lbs.

Procedure:

The penetrating captive bolt (PCB) gun has a sharp-rimmed, concave bolt that extends and penetrates the skull to cause concussive and physical damage to the skull and brain upon impact. The placement should be directed at the mid-line of the forehead, a half inch above eye level (even with the eyebrows). The PCB gun should be placed very firmly against the skull, aimed at the brain and directed toward the tail.

Biosecurity risk:

Potential for contamination due to blood loss through the bolt point of entry.

Labor needs and throughput estimates:

Labor needs are estimated to be a 4-person team per PCB station: one person to handle animals, one person to use the PCB gun, one person to handle carcasses, and one person to manage the equipment. Additional labor will be needed for moving animals from the barn to the station and moving carcass from the station to the disposal location. Throughput is estimated to be 1-2 minutes/pig.

Safety considerations:

PCB poses a low risk to human safety. Operators be aware of and use the safety features of the PCB gun and use caution to avoid accidental firing causing human injury. Hearing and eye protection should be worn by all personnel.

Seasonality impacts:

None identified.

Carcass disposal restrictions:

None.

Configuration:

Chutes with removable side panels can be constructed at the exit of the barn. Chutes can be constructed in an I or Y formation with a width that allows pigs to stand single file and the sides tall enough to prevent pigs jumping over. After pigs are loaded into the chute, the NPB gun can be applied. Confirm death and lower one side of the chute to facilitate carcass removal. Alternatively, a chute can be constructed at the exit of the barn that leads to a center track or V restrainer. Pigs enter the restrainer where the PCB can be applied and exit onto a conveyor where death can be confirmed before they are loaded into a conveyance for disposal.

Required resources:

- **Penetrating captive bolt guns** can be cartridge powered or pneumatic.
 - The cartridge-powered guns can be inline or pistol grip. The inline style lends itself to greater comfort and less fatigue for the operator. It is important to select the bolt length and cartridge combination appropriate to the age and size of pig being depopulated to ensure that the bolt is long enough to penetrate the pig's skull. The cartridge-powered guns will become hot after 15-20 minutes of continual use, so it is recommended that the tools be rotated every 15 minutes to allow for cooling. During the cooling period, the breech should be disassembled from the barrel to accelerate cooling and the parts can be inspected for damage.
 - The pneumatic bolt guns are powered by an air compressor and can be used repeatedly without a cooling period. The pneumatic PCB guns are heavy and typically have a counter lever that needs to be mounted on or near the chute or restrainer to facilitate correct PCB gun placement to the animals head.
- **Powder cartridges or compressed air** depending on the type of PCB gun used. For cartridge-powered PCB guns, follow manufacturer's recommendations on proper cartridge loads to use for the age and size of pig being depopulated. Operators can use a 2-pouch carpenter's tool belt to hold live and spent power loads. For pneumatic PCB guns, use a compressor capable of 150 psi output. An air hose long enough to span the distance between the compressor and the gun will be needed. Prolonged use of some air compressors can result in water accumulation, so the drain petcock should be opened periodically for draining.

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- **Replacement parts and cleaning equipment** will be needed to maintain the PCB guns throughout operation to ensure proper bolt velocity. Refer to manufacturer's recommendations for proper gun cleaning protocols. Cartridge powered PCB guns should be inspected during cooling periods and worn parts replaced.
- **Penning panels** to create temporary alleyways or chutes for pig movement out of the barn and into the single file configuration or chutes for pig movement into the restrainer.
- **Center track or V restrainer** to facilitate successful application of PCB. Tips to improve animal movement into conveyor restrainers can be found here: grandin.com/restrain/improve.mvmt.html.
- **Conveyor belt system** can be used to move carcasses away from the restrainer. Confirmation of death can be performed once the pig exits onto the conveyor. The conveyor system can be installed at an incline to move pigs into the conveyance used for disposal.

Ancillary resources:

- **Animal handling tools** to move pigs from the barn to the chute.
- **Front end loader** for carcass removal.



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Method classification:

Preferred.

Suitable for:

Pigs over 10 lbs.

Procedure:

Electrocution induces death by insensibility of the brain followed by cardiac fibrillation and cerebral anoxia (no oxygen to the brain). The flow of electricity (the current) should be at least 0.5 amps for pigs up to 6 weeks of age and at least 1.3 amps for pigs 6 weeks of age and older. The force behind the flow of the electric current is the voltage and is recommended to be at least 110 volts for piglets over 3 days of age and up to 6 weeks of age, and 240 volts for pigs 6 weeks of age and older. The current's amperage can be increased by increasing the voltage or decreasing the resistance. Resistance can be affected by the length and gauge of wire delivering the current to the pig, electrode contact with the skin, cleanliness of the electrodes, wetness of the skin, presence of hair, thickness of skin and fat layers, and the thickness of the skull. The frequency of the current delivered should be approximately 60 hertz (U.S. standard) of alternating current (AC). Using an ammeter to measure amperage can be helpful to ensure adequate current flow is being delivered to the pig.

Electricity can be applied in one of two methods. Head only application is achieved by placing electrodes **1)** between the eyes and base of the ears on either side of the head, **2)** below the base of the ears on either side of the head, or **3)** diagonally, below one ear to above the opposite eye and passing electric current through the brain for a minimum of 3 seconds. This method must be followed by a secondary step, such as across the chest electrocution, within 15 seconds of initial stunning.

Head-to-heart application is achieved by placing the front electrode on the head, level with or in front of the brain and the rear electrode placed on the body behind the heart. When applying the front electrode to the ear, the base of the ear is the recommended location. The current should be applied for a minimum of 15 seconds.

For either method, electricity must pass through the brain first. The electrode should be in full contact with the pig prior to applying electricity. The electrodes must stay in contact with the pig for the full time of electricity application.

Biosecurity risk:

No contamination from blood loss.

Labor needs and throughput estimates:

Labor needs are estimated to be a 3-person team per electricity unit: one person to handle animals, one person to apply the electrodes, and one person to confirm death. Additional labor will be needed for moving animals from the barn to the location where electrocution will be performed and moving carcass to the disposal location. Throughput is estimated to be 1-2 minutes/pig.

Safety considerations:

Electrocution poses a moderate risk to human safety. Proper lockout/tagout procedures must be in place to protect human safety. An isolation transformer should be used to improve safety and provide sufficient amperage. The operator should work in a dry location, wear rubber boots, and stand on a non-conductive surface. The restrainer frame and worker walkway structure should be grounded to a perfect ground. The side of the restrainer near the operator should be covered with heavy insulating materials. In a small batch pen setup, only the operator should be in the pen when electrocuting pigs.

Seasonality impacts:

Not a viable option in rainy conditions.

Carcass disposal restrictions:

None.

Configuration:

Alleyways and pens can be constructed outside the barn. Pens should be large enough to hold small groups of pigs. Once pigs are placed in the corral, personnel can approach individual pigs with the electrodes and apply electricity to the animal. After pigs have been electrocuted, death can be confirmed and carcasses removed from the pen. Alternatively, a chute can be constructed at the exit of the barn that leads to a center track or V restrainer. Pigs enter the restrainer where the electrodes can be applied and exit onto a conveyor where death can be confirmed before they are loaded into a conveyance for disposal.

Required resources:

- **Misters or drippers** to wet pig prior to electricity application.
- **Power source** to generate electricity with the proper amperage and voltage.

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- **Electrodes** come in the form of tongs, wands, or saddles. Tong and wand electrodes can be used for head only followed by chest application and wand and saddle electrodes can be used for head-to-heart application. Electrode ends must be kept clean for proper flow of electricity.
- **Penning** to create temporary alleyways for pig movement out of the barn and into a pen or chutes for pig movement into the restrainer. Pen construction should use non-metal materials, such as plastic fencing or plywood.
- **Center track or V restrainer** to facilitate successful application of electrocution. Tips to improve animal movement into conveyor restrainers can be found here: grandin.com/restrain/improve.mvmt.html.
- **Conveyor belt system** can be used to move carcasses away from the restrainer. Confirmation of death can be performed once the pig exits onto the conveyor. The conveyor system can be installed at an incline to move pigs into the conveyance used for disposal.

Ancillary resources:

- **Animal handling tools** to move pigs from the barn to the chute.
- **Front end loader** for carcass removal.



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Method classification:

Permitted in constrained circumstances.

Suitable for:

All phases of production.

Procedure:

Ventilation shutdown (VSD) includes closing up facility openings, shutting inlets, and turning off ventilation fans. This causes the buildup of excessive temperature and moisture from body heat and respiration of the animals and results in death from hyperthermia. Case studies and simulations have found that air temperature and relative humidity increased rapidly within 30 minutes of VSD.^{1,2} VSD should only be used in facilities with the capability to adequately increase air temperature and relative humidity to a level that results in at least a 95% death rate in less than 1 hour. VSD plus uses additional heat sources or the addition of CO₂ to achieve the goal of 100% mortality. After VSD is complete and ventilation resumes in the facility, death can be confirmed and a backup euthanasia method applied to any remaining live animals.

Biosecurity risk:

No contamination from blood loss.

Labor needs and throughput estimates:

Minimal personnel are needed to implement VSD plus. Most labor needs will be associated with carcass removal from the facility. Throughput will be dependent on the size of the animals and time needed for carcass removal.

Safety considerations:

Personnel should not enter the facility while VSD plus is in progress. Allow the facility ventilation to resume before entering the barn to confirm death and remove carcasses.

Seasonality impacts:

Depending on facility design, low ambient temperatures, low relative humidity, and high wind speeds may impact VSD plus application.

Carcass disposal restrictions:

None.

Configuration:

Configuration for VSD plus will be impacted by the age and size of the facility; the insulation of the facility; the ventilation system; the ability to adequately seal fans, louvers, doors, and windows; and the number and size of animals in the facility.

Required resources:

- **Heat sources** used in addition to VSD to increase and maintain elevated temperatures. Existing heat sources in the barn may be used.
- **Carbon dioxide** used in addition to VSD to induce death. Refer to the carbon dioxide factsheet in this series for additional details on CO₂ administration.
- **Plastic sheeting or tarps** can be used with smaller pigs to decrease the head space in the room and assist with elevating temperature and humidity to lethal levels at pig level.
- **Sprayers, foggers, or drip coolers** can be used to increase humidity within the facility during VSD. Additional humidity with no air flow will aid in the development of hyperthermia.

Ancillary resources:

- **Winches or mortality carts** for carcass removal.

References:

1. Bird N. Ventilation failure alarm: 2 case studies. Dicam website. http://www.dicam.co.uk/wp-content/uploads/filebase/research/Case_Study_2_ventilation_failure_incidents.pdf. Published September 2000. Accessed April 30, 2020.
2. Zulovich JM, Bundy DS. Modeling the non-steady state conditions in swine facilities during mechanical ventilation failures. ASAE. 1990:Paper No. 90-4002.



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