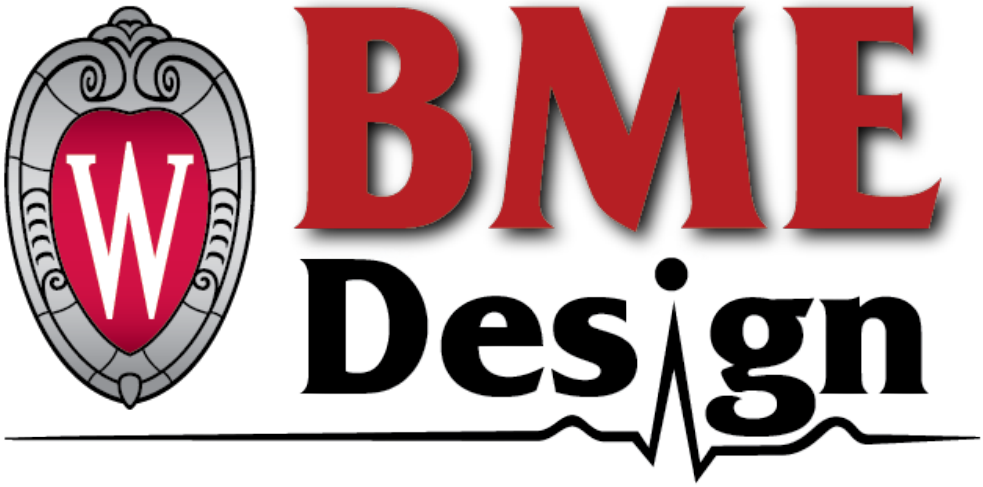


**Remote Euthanasia System**

Team Members:
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Client:
Dr. Marlowe Edgridge & Dr. Aleksey Sobakin

Group Information:
BME 200/300

**Function:**

Due to a new contract with the Navy, Dr. Aleksey Sobakin and Dr. Marlowe Eldridge are testing the Navy's standard operation to rescue sailors in a disabled submarine at the bottom of the ocean. In order to examine their standard operation, our clients will be using sheep and a hyperbaric chamber. This hyperbaric chamber will be putting the sheep through a variety of pressures that can lead to various health risks like pulmonary barotrauma or decompression sickness [1]. In fact, decompression sickness has the capacity to result in neurological injury or even death [1]. In order to avoid these traumatic health complications, IACUC has asked our clients to institute a method to euthanize the sheep humanely prior to a rapid drop-out decompression if necessary. As the sheep are sealed away in a chamber, the client has asked our team to devise a method to remotely euthanize the sheep when they are inside the hyperbaric chamber. In addition to being able to be remotely controlled by bluetooth or RF signalling as requested, this euthanasia system will also have various other subsystems to enable its function. For the housing subsystem, there must be a way to secure the injection system to the sheep and to prevent it from moving. For the needle movement subsystem, there must be a way to inject and to retract the needle into the desired vein. Finally, for the injection subsystem, there must be a way to pump the euthanasia solution out of the needle and into the vein in a timely, complete manner.

**Client requirements:**

- Materials capable of withstanding pressure differential caused by hyperbaric chamber
- Remote-controlled system to allow for activation of the system from outside the hyperbaric chamber
- Adjustable method to affix the injection system onto the neck of the sheep
    - System must be able to be "aimed" toward the jugular vein
- Method required to remotely drive the needle linearly from the injection system in a humane, timely manner
- Method required to expel the euthanasia solution from the needle in a humane, timely manner

**Design requirements:**

1. **Physical and Operational Characteristics**
    a. *Performance requirements:*

        Depending on the number of sheep tested during the experiment, the remote euthanasia system must be ready and usable each time a sheep is placed into the hyperbaric chamber for the experiment. In general, the remote euthanasia system is not expected to have to carry a load larger than the components that

make it up; however, the system must be capable of withstanding and function within the pressure differentials induced by the hyperbaric chamber. In terms of specifics, the remote euthanasia system that is to be developed will need to be able to perform five key tasks repeatedly and without fail.

First, the system must be able to be placed and fixed to sheep of various neck circumferences. Furthermore, the system must not move from its initial position as this will likely result in the failure to inject the correct vein. Second, the system must be able to drive the needle with solution into the jugular vein of the sheep at the correct downward angle without puncturing through the backside of the jugular vein. Third, the system must be capable of expelling the euthanasia solution from the syringe once the needle has been inserted into the jugular vein. This expelling step must be timed properly in order to ensure the sheep is correctly euthanized. Fourth, the syringe must be able to be replaced and "reloaded" after use in order to ensure reusability of the remote euthanasia system. Fifth, the system must be able to be controlled remotely via an RF or Bluetooth signalling system. This will enable researchers to control the system outside of the hyperbaric chamber if any rapid sheep health degradation occurs. These five key tasks will enable the remote euthanasia system to operate and to meet the client's requirements.

b. *Safety:*

This product is being made with the intention of humanely euthanizing animal test subjects; thus, the primary safety considerations are of the researchers handling the device. It is important that the needle system doesn't activate at unexpected times when handling or upon strapping the device onto the sheep. Although meant to dispatch animal test subjects, it is also important that this product euthanizes the animal test subjects in a timely manner in order to prevent them from succumbing to the medical issues of the hyperbaric chamber. This device needs to perform a humane euthanization, and it needs to be able to be activated when the researchers decide the time is right to reduce suffering of the animal.

c. *Accuracy and Reliability:*

Our project requires an injection directly into the jugular vein which is generally done using a 4-cm 20 gauge needle [2]. In a study of 50 sheep, it was found that the jugular vein has an average diameter of 13.34+/- 1.18 mm, at a 95% confidence interval [3]. By subtracting the width of the needle from the width of the vein, and then dividing by two, the team determined that with a

needle of diameter .908 mm (20 gauge), this gives us approximately 5-7 mm of error to work with to assure at least a 95% success rate in injection.

d. *Life in Service:*
The device must last as long as the hyperbaric sheep experiment lasts. The experiments will most likely occur during the day and need to be reloaded after each sheep experiment. Our product must be able to function in pressures ranging from 27 to 41 psi from the hyperbaric chamber [4].

e. *Shelf Life:*
Euthanasia will likely be performed using sodium pentobarbital. Typically, a dosage of 100 mg per kilogram of body mass of the sheep is required to adequately dispatch a sheep [5]. The shelf life of sodium pentobarbital is rated at 3 years when unopened, and 28 days after opening the package [5].

Batteries will need to be utilized in our project, as the device must be fully self-contained, and thus must rely on batteries within the device housing. Small, lightweight batteries must be used, in order to minimize weight, since this device will likely be attached to the ventral side of the sheep's neck, tapping into the jugular vein. Batteries are labeled with an expiration date on the packaging.

f. *Operating Environment:*
This device is going to be subjected to very high pressures due to the hyperbaric chamber environment [4]; thus, all components of the device, including the housing material, the needle, as well as the containers of the medications will have to be able to withstand large pressures. There are likely to be other concerns to take into the consideration that the team has not been notified of yet.

g. *Ergonomics:*
The product must fit comfortably on the sheep and not interfere with the sheep's mobility. There will need to be a method to tighten the device around the sheep's neck and prevent the device from loosening when secured to the sheep's neck. The device must be adjustable in order to account for a range of neck circumferences. The average girth of a sheep neck is measured from the posterior portion of the last cervical vertebra to the anterior center portion of atlas joint, and varies among sheep [6]. As a result, we need to create a device that is able to cinch in order to be customizable and comfortable, while also being lightweight enough to rest securely on the sheep.

h. *Size:*

The device must be compact and personalized to fit on each sheep. The device must adhere to the circumference of various sheep's necks. The product must be large enough to fit a 4-cm 20 gauge needle, a small device to drive the needle into the sheep's jugular vein, and a small device to control the injection rate of the needle [2]. This device will consist of electrical components, the injection system housing, and motorized components, so the device must contain these elements while still remaining small enough to fit comfortably attached to the sheep. It will be important that the device does not limit the mobility of the sheep.

i. *Weight:*

The device must be light enough to not be a burden on the sheep test subject's neck. Also, it is important that the device does not hinder a sheep's head movement or behaviors, as it may alter experiment data and skew observations. Throughout the design process, the weight of components will be considered and kept to a minimum.

j. *Materials:*

It will be very important to choose materials that can withstand the pressure differentials induced by the hyperbaric chamber that is to be used in the experiment. Outside of the closed system of the syringe, the pressure changes will need to be considered in terms of the electrical components of the PCB, the injection system housing, and the motorized components. When possible, it will be important to avoid closed systems as this will mitigate the risk of having a closed system failing under pressure changes. Next, it will be important to choose a belt material that will not cause unnecessary discomfort to the neck of the sheep. As this belt material will be used to secure the injection system to the neck of the sheep, the belt material mustn't cause a rash, irritation, or alter the behavior of the sheep in any way in order to prevent adding in confounding variables into the experimental system.

The materials utilized in this design should facilitate the creation of a lightweight, sturdy system that is capable of repeated use without disrupting the experimental design of the clients. When materials are chosen, it will be important to keep the pressure, the sheep's health, the overall structural integrity of the system, and the weight of the system in mind.

k. *Aesthetics, Appearance, and Finish:*

As the device's function is most important in the project, the device can have a very simple appearance. The client has not specified a specific color or type of finish; however, the device will be designed to be as professional and compact as possible while still functioning efficiently and effectively.

**2. Production Characteristics**

a. *Quantity:*

The quantity of the product is currently not defined as it is unknown how many sheep will be in the chamber at a time during experimentation. The upcoming client meeting should clear this up.

b. *Target Product Cost:*

The target product cost must be within the client's budget. The team's goal is to remain under $250 per collar.

**3. Miscellaneous**

a. *Standards and Specifications:*

Governmental approval will likely be required, as this device is being used on live animals to aid in research. More information about the regulations governing our device will be known after discussing the specifics of the project with the client.

b. *Customer:*

The design team has not met with the client, so the team is unaware of any preferences regarding the device. Ergonomics and the anatomy of sheep will need to play a major role in the design of the device in order to maximize the effectiveness.

c. *Patient-related concerns:*

The most important part of a humane euthanasia is a quick and relatively painless death. Assuring death is very important, and is if the animal doesn't die, the decompression sickness, and the side effects of the injected medication cause the animal to suffer, which is contrary to the purpose of the project. The device will need to be removed from the subject between trials, sterilized, refilled with anasthesia and euthanasia medications, and then refitted to a new subject before the next test begins.

d. *Competition:*

There are similar items/patents that will compete with the design. A competing design for fluid injection in human patients was patented in the European Patent Office in 2016 [7][Appendix A]. This device injects insulin into the patient by leaving a permanent needle in the patient and using a pump to inject insulin into the patient.

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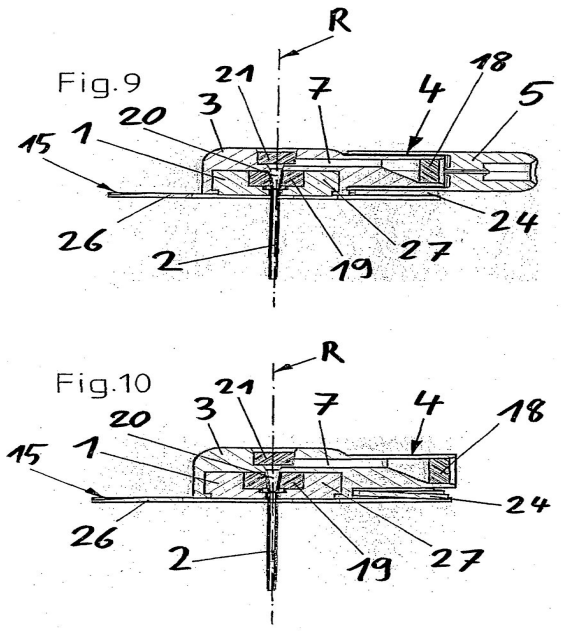
# Appendices

## Appendix A







This figure shows the competing injecting design where a needle is permanently inserted into a patient and the pump pushes fluid into the patient [8].