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Euthanasia of Dogs and Cats: An Analysis of Experience and Current Knowledge With Recommendation for Research

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The Institute for the Study of Animal Problems

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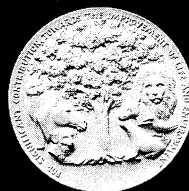
A Division of

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of the United States

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Euthanasia of Dogs and Cats:

An Analysis of Experience and Current Knowledge

With Recommendations for Research

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INTRODUCTION

While it may be regarded by some as inhumane or unethical to take any life, mankind, as responsible stewards of animals, is obliged to do so for many reasons: for food, health, population control, to alleviate incurable suffering, etc. Yet beyond the ironies and ethical dilemmas of the right to life versus the right to take life, lies the necessity to destroy life. This entails an enormous ethical responsibility relevant to the times, and also the moral injunction that the method of killing be humane, in other words, causing the least possible distress, physically and psychologically. This injunction implies, therefore, that there is an obligation (as a final ethical responsibility and demonstration of respect for the life that is to be terminated) to utilize the best available method of euthanasia: to induce a painless death. There are also economic and aesthetic considerations and other situational variables which make this an extremely complex issue. When "euthanasia" must be administered, if it is to be humane, there should ideally be no distress: most authorities agree that many methods are far from this ideal and, to date, at best we have only a hierarchy of more or less distressing methods to choose from.

Distress measured in the eyes of an observer, dispassionate or otherwise, has necessarily been a subjective process until quite recent times. Nevertheless, the tools for evaluating the degree of distress in animals being killed and during the intervening period the refinement method and interpretation of results has progressed. It is remarkable that there has been so little application of these tools, particularly electroencephalographs (EEG) but also electrocardiographs (EKG) and measurement of blood pressure, to determining first of all which agents or methods are inherently capable of causing painless death and which of them, by modification or insistence upon practical but essential precautions, can be safely and economically adapted to invoke a rapid and painless death. Sound clinical, e.g. corneal blink reflex (for non-dissociative anesthetics), and behavioral observations should not, however, be abandoned in the evaluation process for more "sophisticated" methods. It matters little if the dog's heart is still beating and its blood well oxygenated if it is unconscious.

It would be wrong to suppose that the subject of killing dogs and cats has not attracted much attention from scientists. The present contribution, which does not pretend by any means to have exhausted the total available sources, refers to about 70 publications or private reports from 12 countries among which the U.S.A. and Great Britain figure most frequently. While the great bulk of these references relate to work undertaken in the last three decades, it proved necessary to go as far back as the 19th century for the latest (and only?) data relating to one method that had been found capable of effectively killing without great distress up to 100 dogs a day over a period of 50 years. (See Page 24)

Many veterans are of the opinion that there is only one, possibly two, killing methods known to be capable of routinely invoking death without suffering, namely intravenous injection of certain barbituate compounds, and shooting. Of the unknown millions of dogs and cats which are killed each year throughout the world, those which benefit from euthanasia are an insignificant percentage.

The extent of the confusion internationally is amply demonstrated

by the fact that the commonest method used in each of two major English-speaking countries are mutually unacceptable. Decompression chambers used throughout the U.S.A. have not so far been demonstrated in Great Britain while the electrocution chambers widely favoured in British animal shelters have been condemned in principle by American authorities. Differences in the aesthetic appeal of the two methods and the effects of nation-wide publicity campaigns to support one method over others, may account for these differences in opinion. (The implication is that differences in attitudes may be caused by the lack of factual data. Therefore there is a need for more objective research.)

Undoubtedly, one of the most constructive attempts to evaluate killing methods for dogs and cats was the Report of the Panel on Euthanasia of the American Veterinary Medical Association (1963) subsequently up-dated by a fresh panel in 1972. Before and since these initiatives, the most concerted efforts to assess and develop euthanasia methods have been promoted by the Universities Federation for Animal Welfare (UFAW), London (1975). Valuable though these interventions have been, it is clear that the uncertainties and controversies remain unresolved.

It was the desire to reinforce and to overcome the blocks of language and geography which prompted the World Federation for Protection of Animals (WFPA), Zurich, to establish an International Working Group on Euthanasia of Dogs and Cats in 1975. The working group is loosely constituted of persons with practical expertise in killing animals and who also have access to laboratory resources for undertaking further research. This reflects the necessity of not only assessing present knowledge and experience but of pursuing those lines of endeavor which analysis suggests will be most rewarding. The objective of the Group is to make recommendations on the subject which can be accepted with some confidence by those who must decide by which method animals in their charge shall be killed. They should also choose by which methods animals in their charge shall not be killed.

Members of the Group have examined the present work and, although not necessarily agreeing with every detail or particular emphasis, each has been able to suggest modification and improvements in the first draft to the extent where he or she was willing to be identified with the principles of the analysis and the direction of recommendations for further research. Their names are given under the heading of acknowledgements.

In seeking the widest possible audience through publication of this report, the motivation has been less of wishing to instruct or enlighten and more to stimulate response from workers everywhere who have knowledge or experience of the practicalities which could usefully be contributed to the dialogue now in progress. The report, in other words, far from being an end, is merely a fresh beginning.

Further research may provide us with the "ideal" method that satisfies all criteria in all contexts or it may show us that, from the hierarchy of lesser and greater distressful methods, which one is the least distressing and also the most appropriate for a given context/situation. A compromise between humane ethics and the variables of context and available methods should not be regarded, however, as an acceptable solution. The search for a humane solution to animal euthanasia under various conditions is an ethical imperative for all those in whose care or jurisdiction rests the life and well-being of our animal kin. This has reached a critical point today because of the need to destroy on a mass scale, millions of unwanted pets (13-15 million cats and dogs per annum in the U.S. alone). Until the causes of this population explosion can be rectified, mass destruction of pets will continue and so must the search for an optimal method of euthanasia for all concerned.

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EUTHANASIA
Optimal Criteria

Before reviewing various euthanasia methods, some of the more important criteria which must be satisfied in order that a given method be accepted, are as follows:

1. Speed and reliability of inducing unconsciousness and death.
2. Painless: no distressing physiological and/or psychological side-effects (e.g. convulsions or hypoxia and struggling) before unconsciousness.
3. Aesthetic — no disturbing effects on personnel.
4. Safety to personnel, environment.
5. Equipment and efficiency variables — easy to maintain, "fail safe" controls.
6. Ease of application, "fail safe" technique — operator efficiency factor.
7. Cost — of equipment, installation, maintenance, drugs, etc.
8. Time/efficiency of personnel per animal euthanized.
9. Method of restraint (or capture) — evoking minimal distress prior to administration of euthanasia and unconsciousness.
10. Age and species limitations.
11. Health limitations — if animal is sick, pregnant, emaciated.
12. Specific requirements for certain contexts and conditions, e.g. portability for use in the field; problems of capture/restraint of free roaming animals (feral, stray, etc.).
13. Local/national legal restrictions.
14. Minimal handling of animals from holding area to euthanasia point.

All methods considered suitable for euthanasia should be evaluated in relation to the above criteria and variables: no one method may be ideal for all circumstances.

Physical Methods
Shooting

Shooting has long been used for the killing of individual dogs and for the routine killing of small numbers. Where larger numbers have to be killed, the bleeding tends to prove offensive to the staff and there is no known case of the method being used in major pounds or shelters. The method, however, when properly employed is without doubt a quick and painless way to cause death in dogs and cats. Provided the aim is accurate and the animal does not move its head, unconsciousness will immediately result from the brain damage. Breathing stops as a result of the brain damage but the heart continues to beat until it is deprived of oxygen as a result of respiratory arrest.

Carding (1972) has recommended immersion of the animal in water immediately after unconsciousness has been produced by shooting. This procedure not only causes a more rapid death but reduces the unaesthetic effect of the bleeding and would make the method more practical where larger number of dogs are involved. For tropical countries there is the added advantage that leaving the bodies in water slows down decomposition and reduces the consequent odors.

For emergency killing, it is feasible to use shotguns of 12 bore or 20 bore, or calibre .22 rifle or revolver. For regular use the captive bolt stunner as used in the slaughter of meat animals is the weapon of choice, especially one of the smaller, lighter models. With this instrument there is no danger from stray bullets.[1]

In the case of the captive bolt stunner the target is the midpoint between the eyes and the base of the ears but a little off center to avoid the bony ridge. The muzzle of the stunner should be held firmly against the head and pointed in line with the spine and not towards the lower jaw.

When using this method routinely it is convenient to have a ring at, or near, floor level. The leash can then be passed through the ring and gentle, sustained pressure will pull the dog's head to the ground where it can be held firmly while aiming. With practice, one operator can work alone without assistance except with occasional difficult dogs.

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Decompression

Decompression chambers were first introduced for killing dogs about 1950 in the U.S.A. Pioneer work was conducted for the American Humane Association by Dr. Richard Bancroft who utilized his experience in the fields of aviation physiology, including hypoxia and decompression problems in high altitude flying.

The basis for the work on killing dogs was that decompression due to low ambient air pressures without extra oxygen can lead in humans to a painless and rapid loss of consciousness resulting in death if the low pressures were maintained. There is, sometimes, even a sense of euphoria in man as sensory awareness begins to fail (Bancroft, 1960).

The apparatus consists of a chamber, usually cylindrical because of the greater strength of this form, connected with an air vacuum pump similar to those used for petrol/gas pumps.[2] Animals to be killed are placed in a cage which can be wheeled to the chamber and inserted easily. The door is closed and has an air-tight seal.

Recommended procedure for the most commonly used apparatus (Euthanair)[3] is to switch on the motor after adjusting the valves on the chamber. When the pressure has been reduced to the equivalent of 55,000 feet, the pump automatically stops. Instructions are to set the timer to last

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[1]Personnel using such weapons should not only be well trained in the use and safety of firearms, but should also be carefully screened for psychological/emotional health and stability. In some U.S. cities, animal control officers wear firearms for personal protection and undergo rigorous screening and training before being allowed to carry and use any firearm.

[2]Specified as 7½ HP, 3 phase, 60 cycle motor.

[3]Euthanair Company, 5156 Southridge Avenue, Los Angeles, California.

for 10 minutes for adult animals and 20 minutes for aged, sick or young animals. After this period, the pressure may be returned to normal by opening the appropriate valve. Before the animals are removed and checked to ensure they are dead, the pump is to be turned on for one minute to remove odors.

The system is certainly capable of killing animals and sometimes without evidence of distress. Gauges are often inaccurate and seals may leak and should be checked frequently. The person operating it has to be well trained and skilled in using and understanding this equipment. After the costs of purchase and installation, the running costs are negligible. There is no danger to personnel.

In the early days, a number of decompression units were installed in animal shelters in Canada, but within a few years most were withdrawn from use. The method has not been adopted in Europe, but in Japan, the apparatus is being introduced into some city dog pounds. An imported Euthanair apparatus was installed at the shelter of the Japan SPCA, Tokyo, about 1962. Use of an autoclave to kill laboratory animals has been reported from Italy by Barber (1972).

There has been much controversy about the degree of suffering caused by decompression. The two sides have been polarized into those who claim that rapid decompression is a satisfactory way of producing painless death in all animals and those who insist that considerable distress may be caused to a significant proportion of animals killed.

The confusion is well illustrated by the fact that the 1968 report of the AVMA Euthanasia Panel withheld approval of what is termed explosive decompression until definitive studies had been made to determine whether pain was caused during the process. Without apparently any such studies having been made, the 1972 report of another AVMA Euthanasia Panel was satisfied that the same technique (but now referred to more accurately as rapid decompression) was satisfactory.

There are two particular factors of fundamental importance about which no data appear to be available. They are:

1. At what altitude equivalents do cats and dogs lose consciousness and/or pain perception?
2. What is the optimum rate of decompression for dogs and cats?

According to protagonists of the method, it may be assumed that dogs lose consciousness and collapse 40-60 seconds from the start of decompression in an apparatus capable of simulating an altitude of 55,000 feet in 45 seconds. Death will then follow without any painful sensation (AVMA, 1972). No authority is quoted for this conclusion with regard to dogs or cats.

Doubts about the humaneness of rapid decompression have been expressed over many points but those which seem most pertinent include the following:

Effects of hypoxia

There is a wide variation in humans over the effects of hypoxia ranging from the extremes of euphoria to apprehension and very marked hyperventilation. Armstrong (1961) records a case which shows that in some humans hypoxia can cause considerable distress and warns that rapid induction of anoxia can cause the sensation of suffocation.

Young animals are much more resistant to the effects of hypoxia than adults. Loss of consciousness is therefore delayed and also death. Recommended procedure is to hold young animals for a double period at 55,000

feet while newborn puppies and kittens should be placed in a special unit and taken to an altitude equivalent of 65,000 feet or more. The most important sequela is that young animals are more likely to remain conscious of the painful mechanical effects of decompression than adults.

Mechanical Effects of Decompression

Pain in the middle ear

Humans rapidly learn to equalize the pressure inside and outside the middle ear by forcing open the Eustachian tube directly, or by swallowing. Matthews (UFAW) states that laboratory animals undergoing even slow decompression demonstrate their inability to equalize the pressures by scratching at their ears. He adds that when anesthetized cats were decompressed so that no voluntary equalization could take place, the damage to the ears was severe. In an experiment, however, in which two dogs were decompressed and then recompressed, examination of the ears at both stages showed that damage to the middle ear occurred only during recompression (AHA, 1964). Upper respiratory infections often involve the Eustachian tubes to an extent where inflammation prevents adjustments to equalize the pressure in the middle ear. Virus infections involving the upper respiratory tract are very common in cats and are common in dogs. In both species they are a frequent reason for owners to seek destruction of their pets. Stray animals in animal shelters also have a high incidence of such infections which are often overlooked; sick and healthy pets are usually destroyed indiscriminately where there are no alternatives other than decompression.

Pain in the sinuses

With upper respiratory infections blocking off the entrances to the sinuses, pain in these areas could be acute.

Abdominal pain

This would arise in an unknown percentage of cases as a result of expansion of gas trapped in the intestinal tract. (Sudden reduction of the atmospheric pressure to about one-fifth its normal value will result in a sixfold increase in volume of any trapped gases). With this likelihood, and the untold reactions described in the paragraph above, there is growing concern over the humaneness of the decompression method in the U.S. especially since there are less debatable and variable alternatives. If there is less than 1% incidence of painful side effects either demonstrated or suspected, and if it is not practical to separate those animals that are more likely to suffer under rapid decompression — and euthanize them more humanely — this method should not be considered humane. Alternative methods should be instigated until further research has removed all doubt as to the potential inhumaneness of this method.

The "bends"

Pain caused by the nitrogen bubbles forming in the blood and in the body tissues will occur in humans after about 10 minutes at 35,000 feet but sooner at higher altitudes. With the rapid decompression technique this condition is only likely in cases of faulty apparatus or procedure when unconsciousness is delayed.

This effect occurs in humans at about 63,000 feet and pain is likely to result from air embolism and "vapour locks" in blood vessels. The condition is most likely to occur in newborn puppies and kittens, which, it has been recommended by protagonists, should be subjected to the equivalent of about 65,000 feet.

Other factors

There is no evidence to decide whether dogs and cats when they collapse are conscious or not. Neither is it known whether, under the conditions of rapid decompression, there is loss of perception to pain before loss of consciousness.

When dogs collapse, it is not known to what extent they are immobilized and unable to respond to pain. This point becomes of importance if consciousness and perception of pain are maintained beyond the point of collapse.

Vocalization becomes progressively difficult at higher altitudes near the point where the painful mechanical effects of decompression arise (Armstrong, 1961).

Reference has already been made to the variability of the effect of hypoxia on humans. It seems unwise, therefore, to apply human experience directly to other species. Dogs differ not only from the average human, but among themselves, while cats present other differences.

Attention also has to be given to the known and suspected differences in effect of rapid decompression on sick animals (especially those with upper respiratory infections, present or recent) compared with the healthy, and on newborn, young and aged animals compared with the average adult.

Thomsen (1972) in an extensive and objective review of rapid decompression euthanasia concludes that:

(1) Rapid decompression is not the horribly cruel and inhumane method of disposing of surplus dogs and cats that it is frequently pictured as being. But decompression also does not deserve the following description, taken from an actual publication: "Absolutely no suffering . . . there is no pain . . ." Nor the following, taken from a statement by a committee of scientists: ". . . a most humane method . . . produces unconsciousness and death without any painful sensation. The animals are completely unaware of any . . . internal organ changes which may occur." Such categorical statements reflect either ignorance or bias.

(2) Rapid decompression definitely is not a humane method of euthanasia for some animals, nor for any animals if the chamber is not properly constructed and operated. Animals below four months of age, and those that are diseased, particularly in such a way as to make them subject to sinus and inner ear infection or difficulty in clearing the Eustachian tubes, definitely should not be decompressed. Yet, once the chamber is installed, there is a tendency to use it for all animals, and not to have an alternative method readily available for those animals for which the method is definitely unsuitable.

Thomsen also makes some additional cogent observations. Schelkopf's (1958) theses research concluded with the statement that "it is presumptuous to state that animals during decompression do or do not suffer pain." Thomsen states that animals are conscious and capable of feeling pain for 30 seconds-2 minutes. Also with the decompression effect on the lungs, they would be unable to display any distress vocally. Armstrong et al. (1961) noted that some human beings experience distress rather than euphoria, which is commonly believed by proponents of this method, to be experienced by animals undergoing decompression. More important is the fact that human studies are hardly comparable to the high (explosive) rate of decompression (55,000 feet in 60 seconds) used to euthanize animals. The rate of decompression is of critical concern: Thomsen, (op cit) concludes that: "despite all of the experiments that have been performed, nobody really knows what speed would result in the least pain and discomfort for different animals."

Summary

The advantages of simplicity, lack of hazard, and cheap running costs have had an appeal to operators of many pounds and shelters in the U.S.A. and these appear to have outweighed doubts about the humaneness of the method.

There are sufficient grounds for doubt to recommend that no sick dogs or cats, even if there are only mild signs of present or recent upper respiratory infections, and no animals under about four months old should be killed by rapid decompression. Since this recommendation presupposes that an attendant will have the time and normal degree of concern to separate these categories of animals from the normal, and since there may be no alternative arrangements for giving, for example, injections of barbituates, recommendations such as these will not be heeded in many cases.

It seems reasonable to sustain strong doubts about the absence of distress in young, sick and aged animals and to harbour further doubts about normal animals in view of the variability of effects on humans and the lack of data on dogs and cats.

Until reliable data are obtained about the effects of rapid decompression on a significant number of dogs and cats this method cannot be recommended as a form of euthanasia at this state. It is a method of killing which is of proven efficiency, despite occasional reports of alarming defects in apparatus. Faulty valves, gauges and leaking seals necessitate constant monitoring and maintenance. Strict regulations to prevent operators from overloading the chamber with animals and providing separate cages for non-related animals are not always consistently enforced. The main appeal of this method is that the operator simply wheels the caged animals into the chamber, closes the door, sets the timer and pushes a button: the impersonal, mechanical method reduces contact with the animals and indirectly "protects" the operator from seeing the animal die. Such aesthetic and psychological considerations aside, the mechanical "distance" between the operator and the animals may lead to negligence and indifference, which, combined with the high risk of mechanical failure, makes constant supervision a necessary but difficult to enforce imperative.

Research Proposals

1. Does the recommended procedure of rapid decompression cause distress to dogs or cats in any categories?

2. What modifications can be introduced to present procedure to eliminate or reduce distress in any category of animals?

More tests (to add to the AHA study by Fitch et al.) need to be made to obtain electroencephalograms, electrocardiograms and arterial blood pressure readings from a substantial number of animals (and in various states of health) undergoing rapid decompression. Such physiological measures may tell us with some accuracy as to when the animal becomes unconscious, but they can never indicate if and how much the animal is experiencing pain prior to unconsciousness. Since the latency before unconsciousness may be over one minute for some animals and hyperventilation and struggling or "freezing" in a strange, confined place may mask or confound overt behavioral pain and distress reactions to an observer, further research and techniques are needed. There is no clear evidence yet that healthy animals do not suffer under decompression prior to unconsciousness.

The possibility that a two-stage decompression procedure may be more humane, warrants evaluation. Decompression to 40,000 feet in 30 seconds would render the animals unconscious and at this altitude, extreme pressure changes in the body which might cause pain, would be less than at 55,000 feet. Once unconscious, decompression could be raised to this level to insure a painless death.

The following statement from D. J. T. Kalberer is a pertinent conclusion to this review of decompression killing:

"As one versed in the field of decompression sickness, I can say that the pathogenesis of shock is acute dybarism by simulated high altitude still remains controversial. To give an indication of the clinical picture concerning the suffering experienced by animals subjected to "explosive" decompression, I quote from a research paper of mine, which appeared in the journal *Aerospace Medicine*, Vol. 40, page 1071, 1969. "Shortly after decompression, animals exhibit difficulty in breathing ("chokes"), begin scratching, show little motor activity, and, in most instances, die within minutes (up to 15). For a few seconds preceding death, the animals jump about erratically, have severe respiratory distress with hiccough-like spells, twitch, fall on their backs, gasp several times, and expire. In some instances you can even get enlarged abdomens due to gaseous distension of the gastrointestinal tract. These facts are the result of well controlled research experiments which had to be carried out so that this Nation could safely land men on the moon. This work was done also in an effort to make undersea exploits safer. It is evident that these animals are subjected to a painful and grotesque last few seconds of life where in some cases the process can last several minutes. . . . It is not possible for me to agree with the statement that the Euthanair machine or any other high altitude decompression chamber is more "expedient" for destroying large numbers of animals, as too often animals have different responses to simulated high altitude conditions. . . . I am in absolute agreement with members of the Humane Society of the United States, and the many veterinarians who are of the opinion that the injection of a barbiturate, namely sodium pentobarbital, is a far more humane method of euthanasia than is the high altitude chamber method."

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Apart from the sources quoted in this report, this list includes other references useful in obtaining a fuller knowledge of the problems involved.

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Electrocution

Electrocution has been used widely to kill dogs and sometimes cats since about 1920 and, in most cases, the animals were killed singly. The simplest technique was to clip electrodes on the front and back parts of the body and connect them to the domestic power supply.

In Britain there were at least four special electrocution cabinets in use for dogs and cats in 1926 when doubts began to arise about the humaneness of the method. Evidence of severe pain was arising from humans who survived accidental electrocution. In 1928-29 the Nobel laureate, Professor A. V. Hill, reported that the cabinets were likely to cause great pain although this would be masked by muscular paralysis. Principal users of these cabinets ceased to use them by 1930 although some were brought back into use again later (Hume, 1935).

In 1937 the standard CECAM electrocution cabinet gained the approval of the Euthanasia Committee of the then National Veterinary Medical Association (now British Veterinary Association). Many of these units were manufactured for use in Britain and abroad during the course of the next two decades.

The apparatus was effective in killing dogs without causing apparent distress but the results of American research were adding force to those who continued to have doubts. Their fear was that the quiet, relaxed, supposedly unconscious or dead animal was, in fact, fully conscious and in agony for some time before unconsciousness and death supervened.

Pioneer research by Simpson and Derbyshire (1934) and Sugar and Gerard (1938) had demonstrated two important points:

1. A small electric current passing through the body prevents normal respiration and causes death from asphyxiation.

2. A larger electric current passing through the body causes ventricular fibrillation.

It was further suggested that consciousness could remain for 12 to 20 seconds after the onset of extremely painful fibrillation.

Between 1950 and 1954 both the Universities Federation for Animal Welfare and the British Veterinary Association (BVA) sponsored further research, the former by P.G. Croft (1952, 1953 & 1976) and the latter by T.D.M. Roberts (1954).

From this work it became apparent that to avoid pain during electrocution it is essential first to make the animal unconscious by passing a current directly through the brain, from side to side. Only after doing this, and checking that the classical electroplectic fit is produced, should the lethal current be passed through the whole body to bring about death from ventricular fibrillation and circulatory failure.

As a result of their studies the British Veterinary Association in 1954 condemned all existing methods of electrocution. These methods included:

1. Apparatus in which one of the electrodes is a metal collar or chain around the dog's neck.

2. Apparatus where the only electrodes are metal rods forming the floor of an electrocution chamber.

3. Apparatus where the electrodes are connected to the domestic power supply and clipped to an ear or the mouth and to a hind part part of the body.

In 1957 the Euthanasia Committee of the BVA laid down standards to which all electrocution cabinets must conform if they are to be regarded as humane. They include:

1. (a) That the unit be tested adequately to insure that the frequency of the alternating current received from the electrical "mains" be 50 or more cycles per second;

(b) that the unit delivers at least .05 amperes per second across the head to produce unconsciousness.

(c) that it delivers at least .05 amperes for 2 seconds through the thorax to fibrillate the heart; and

(d) that the total time for application of electrical current be limited to 3 seconds by a timing apparatus.

2. A satisfactory continuity tester be built into the circuits of the unit to show in advance that current is alternating and of subsensory strength but still adequate to meet the above requirements.

3. Ammeters be incorporated in each circuit to show that an adequate current is passed in each lead.

4. The unit be used only by a trained operator who would examine each animal immediately after shock to ensure that unconsciousness had occurred and that the heart had stopped. A subsequent examination should be made approximately 30 minutes later.

Electrocution of cats by any method had been condemned in 1954.

Detailed specifications for a cabinet for electrical euthanasia of dogs were drawn up by the British Standards 2909 (1957). Apart from defining the construction of the cabinet and ancillary equipment and a system of checks to be made, the following points were scheduled:

— Voltage should not exceed 250 volts
— Current should be between 0.5 and 5.0 amperes
— Stunning current through the ear electrodes to pass for .05 to 1.5 seconds
— Lethal current through the hind leg electrode to pass for 2 to 4 seconds
— It shall not be possible to apply the current through the leg electrode before the current between the ear electrode has ceased.

The only apparatus allegedly manufactured to these specifications has been the "Electrothanator" of which a considerable number have been sold in the United Kingdom and abroad.

It was widely believed that with a trained and sympathetic operator and with regular competent servicing and maintenance this complicated apparatus was capable of giving a humane death to dogs. However, the Panel on Euthanasia of the American Veterinary Medical Association, reporting in 1963, would not recommend the Electrothanator and made the following criticisms, some of them inherent to the method:

1. It is not a method for mass euthanasia because of the time required to deal with each dog (5 minutes).

2. It is not a method for a vicious, intractable dog.

3. The apparatus examined has not been well designed from a practical standpoint, i.e., the ear electrodes and leads may cross because the dog can turn its head, the salt solution in the shallow floor pan is messy and troublesome, the control switch is poorly designed and has had to be replaced in the test machine; the cabinet is not sturdy in construction.

4. In a general evaluation of electrocution as a method of euthanasia, it must be recognized that the electroplectic fit or convulsion produced by application of electric current will always be visually objectionable. The electroplectic convulsion consists of violent extension and stiffening of all legs with retroflexion of the head and neck plus respiratory arrest.

The Electrothanator was recommended by the leading authorities in Britain who believed that it complied with the standards laid down in BS2909. It was only in 1974 that the manufacturers were forced to admit that their apparatus did not conform to the standards and never had done so. The principal defect was that there was no allowance for a current to be passed directly through the brain to produce an observable electroplectic fit with unconsciousness before the lethal shock was directed through the whole body of the animal. Labeling of the control knobs suggested otherwise since the main control could be set first at the "stun" position and then at the "lethal" position, although current passing along the same routes in both cases.

Defects were also noted in the procedures followed by even the most experienced operators in Britain. As noted by the AVMA Euthanasia Panel in 1963, the electroplectic shock is visually objectionable and operators were not keen to comply with approved procedures and check that

each animal went into shock after stunning and before the lethal shock was given.

A further complaint in the 1974 investigations was that several cabinets had been modified so that no third electrode was clipped to a hind leg. Instead, the dog stood on a metal tray to which water was added and this method defeated the objectives of having the maximum amount of current pass directly through the body to a hind leg.

These disclosures have resulted in assurances from the manufacturers that all apparatus in use, and future models, will be modified to conform with the British Standards 2909, in the most important respects, and operating procedures have been revised to comply with the recommendations. Prospects, however, of having exported units modified are not good in the short term.

This experience tends to support the caution shown by the AVMA Euthanasia Panel in 1963 and 1972. Although electrocution is capable of producing a painless death, the sophisticated apparatus and demands placed on a suitable operator do not allow a general recommendation even of approved apparatus for the electrocution of dogs.

To this day, mass electrocution of dogs by old systems, in which no attempt is made to pass a current first through the brain from side to side before passing a lethal current through the body, is still in daily use. Electrocution apparatus where current is passed from a neck collar to floor bars for killing groups of dogs at a time are still in use, for instance, in the municipal pounds of Kobe and Kyoto in Japan.

Roberts (1954) made two tests which showed the degree of distress caused when dogs are electrocuted without first being made unconscious by a direct brain current. In order to demonstrate the effects he had to avoid the paralysis which in normal circumstances prevents the dog from expressing its feelings. This was achieved in the following ways:

1. One dog was given the usual shock for one second which was sufficient to cause fibrillation but did not produce strong paralysis. When the current was switched off, the dog howled in pain for some 20 seconds before it died.

2. Another dog was given the standard shock but for only 0.5 seconds which was not sufficient to cause fibrillation and did not kill the animal. The dog, however, howled for 26 seconds and afterwards would not approach the investigators or the room which contained the machine.

The 1972 recommendation of the AVMA Euthanasia Panel to administer muscular paralyzing agents prior to electrocution does not meet with general animal welfare approval because of the apprehension and distress which can be caused to dogs so treated. The aim of this procedure was to avoid the unaesthetic appearance of the electroplectic shock for the sake of the operator. This is in contrast to the emphasis attached by British authorities that the operator must witness that each dog has such a shock before proceding to give the lethal shock. The giving of a tranquilizer prior to electrocution would, on the other hand, benefit the dog by reducing anxiety.

Summary

Electrocution can be an efficient method of killing dogs without pain. This possibility has led to its being widely used in Britain and elsewhere by animal welfare societies and by local government authorities.

Although the criteria for the humane use of electrocution for killing dogs have been known for some 20 years, it appears that only during the last twelve months have these principles been properly applied anywhere.

The experience in Britain, in which the recommending authorities believed that the only available apparatus conformed to the recognized standards although the manufacturers knew well that it did not, is a caution to authorities in other countries which might consider recommending similar apparatus. For continuing confidence, each new unit needs to be examined by a competent person with subsequent regular inspections of both apparatus and procedures followed.

Without these provisos, and also without a trustworthy operator, the method of electrocution should not be encouraged.

Addendum

One major negative aspect of electrical euthanasia is the aesthetic/psychological effect on the operator. For this reason, individual personal (and possibly cultural) differences have led to considerable controversy over this method. Hence, for some, the easier "pushbutton" decompression method, giving more "mechanical distance" between the operator and the animals, is more acceptable. Either way, both electrical and decompression systems need constant monitoring and maintenance.

This aesthetic/psychological effect on the operator is an important variable to consider in the over-all acceptance of one method of euthanasia over another. The curare-like drug, succinylcholine chloride, for example, has gained considerable popularity for euthanizing pets in the U.S.A. The immediate paralysis and lack of overt distress in the animal gives the impression that this is a humane method but (as with electrocurarization) it is a wholly inhumane method. One U.S. Department of Agriculture veterinarian stated that he preferred succinylcholine over shooting for the mass slaughter of infected farm livestock, a practice which is still continued today and which demonstrates clearly how personal aesthetic/psychological considerations can only too often take precedence over the actual humaneness of a particular method of euthanasia.

Recommendations for Research

There seems to be no indication for additional research into killing by shooting although wider dissemination of knowledge about the best procedures would be helpful.

Research proposals regarding decompression were made on page 9 and which could constitute Project I for further research.

Further research into electrocution does not appear to be worthwhile. Important factors identified more than 40 years ago have still not been generally adopted.

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INJECTION OF DRUGS
Barbiturates

Where a veterinarian is available and the numbers of dogs to be killed are not high, the intravenous injection of sodium pentobarbital is the technique which comes nearest to the ideal of euthanasia. Skilled persons working under the supervision of a veterinarian may also carry out this procedure successfully. A competent assistant is necessary to help with restraint of the animal.

Barbiturates depress the central nervous system and their first major effect is to produce unconsciousness. This is followed by arrest of breathing which leads to a rapid cessation of the heart action. The drug of choice is sodium pentobarbitone (pentobarbital sodium) and this is available in three forms vis:

—Sterile solution for anaesthesia at about 65 mg/ml.
—Non-sterile, triple-strength solution for euthanasia at about 200 mg/ml.
—Powder form, often in containers of 1 kg.

The anesthetic solution is too expensive for routine use and even the stabilized commercial euthanasia solution is considered too costly for mass euthanasia in many countries. Where it can be obtained, the powder is the most economic form to employ.

When using the powder, care must be observed that it is kept dry in an airtight container. The powder is readily dissolved at the rate of 200 mg per ml in distilled water, or water which has been boiled and allowed to cool. It is advisable to use the solution within one week during which time it should be kept in an airtight bottle in a cool dark place. A solution which has a deposit or has become cloudy should be discarded.

Although dosage rate of 50 mg per kg is sometimes used, it is generally recommended to employ 100 mg per kg as a routine minimum dose.

Apart from the intravenous injection other routes are employed. Intracardiac injection can give good results with a skilled operator and a reliable assistant. But the humaneness of intracardiac injection is to be questioned. When this method fails and intra-pulmonary injection occurs, the action is delayed and obvious or apparent distress is often caused. Intraperitoneal[4] injection is also used and although the full effects may not be seen for 15 minutes or longer, at least there is less discomfort than when the operator fails to inject into the heart.

One of the practical disadvantages of barbiturates is their price. In many countries the commercial solutions are too expensive for routine use while the powder form may not be marketed. In the industrial countries, especially, control over the use and distribution of barbiturates is likely to become progressively stricter and their availability to pounds may be greatly reduced: the social implications of handling dangerous and addictive drugs must always be stressed.

For regulations and sanctions governing the use of barbiturates for animal euthanasia in the U.S.A., see Appendix.

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[4]The intra-hepatic (liver) route is also claimed to be effective causing little discomfort and rapid uptake.

T61*

The use of this commercial product for killing dogs and cats was first reported by Eikmeir (1961) in West Germany and he concluded from experience in killing 350 dogs and cats that the material was very suitable for euthanasia in practice. Its use in private practice has spread in some countries and a major attraction has been that it is sometimes cheaper than commercial solutions of barbiturate (except when barbiturates are bought in bulk). In Italy, under the trade name "Tanax" this material is being widely used to kill unwanted animals in municipal animal pounds.

T61 consists principally of an agent (N [2- (m-methoxyphenyl) - 2 ethylbutyl - (1)] 2-hydroxybutyramide) which has a strong narcotic action as well as a paralytic effect on the respiratory center, combined with a curariform-like drug (4.4-methylene-bis cyclohexyl-trimethyl-ammonium iodide) which exerts a paralytic action on striated muscle and rapidly induces circulatory collapse.

With paralytic drugs of this nature, doubt naturally arises as to whether unconsciousness occurs before the paralyzing effects. There appears to be no reported work resulting from electroencephalograms (EEG) on test cases although an unpublished experiment in Canada (Roswell, 1974) determined that in a rat given T61, the EEG became isoelectric within 4 seconds.

The manufacturers recommend that in dogs the injection should preferably be given intravenously or into the heart, otherwise by the intrapulmonary route. With intrapulmonary injection, care should be taken not to displace the lung tissue and inject into the pleural cavity. This is avoided by using a sharp needle long enough to allow rapid, deep penetration. In cats the intrapulmonary route is considered by the manufacturers to be the most practicable method.

Dosage rates are as follows:

Dogs — intravenously: 0.3 mg/kg, given at medium pace with interruption. Similarly for intracardiac injection.

— intrapulmonary: up to 10 kg give 7-10 ml, above 10 kg give 10 ml, and after falling give additional 3-10 ml

Cats — kittens up to 6 months, give 1-3 ml by intrapulmonary injection

— cats up to 5 kg, give 5 ml

— cats over 5 kg, give 10 ml

When there is greater confidence that T61 is a painless way of causing death, it is likely to become more generally used. Its advantages include its relative cheapness, and the fact that it will not be controlled so strictly as barbiturates. In practice, its use intravenously seems far preferable to the slower and less certain intrapulmonary route.

In animals that are weak, emaciated or have some circulatory abnormality, absorption of the compound may be delayed, euthanasia protracted with distressing convulsions and possibly premature respiratory paralysis before narcotic unconsciousness.

In animals that are moribund, in extremely poor condition or have some circulatory abnormality, the uptake of the compound may be delayed,

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*Hoechst AG in Europe
 National Laboratories Corp., Kansas City, Missouri, U.S.A.

euthanasia protracted with distressing convulsions, and possibly premature respiratory paralysis before narcotic unconsciousness.

The curare-like drug is included to control seizures which may be triggered by the narcotic component. Cerebral excitation will occur if this drug is not administered intravenously according to the manufacturer's instructions (give the first two-thirds at a smooth rate of 1 ml per 5 seconds and then the rest rapidly). The curare-like drug also has a second purpose according to one company veterinary representative: it insures that "if the animal were to regain consciousness, it would die anyway from respiratory arrest" (i.e. suffocation).

Pain reactions, as when a little of the compound is injected subcutaneously by accident, may cause considerable distress even though a local anesthetic ingredient (tetracaine hydrochloride) has been added by the manufacturers.

The manufacturers are not stringent enough in their recommendations. This compound, because of the excitation effects, must be administered by an experienced person. T61 should never be given intraperitoneally or to a sick animal since its uptake will be slow and over-excitation would be unavoidable. There is also the possibility that the curariform effects may then begin to act before the animal is unconscious — a situation analogous to the use of siccinylcholine which is clearly contraindicted as a method of euthanasia. The recommended intrathoracic (lung) route should also be questioned since fluid in the lungs in some animals may cause significant distress prior to unconsciousness. For the same reason T61 should never be given via the intracardiac route unless the administrator is experienced and is 100% confident of entering the heart every time. This intracardiac route for the administration of any material for euthanasia should also be questioned since it may be extremely painful to the animal unless performed by an experienced person.

Other Agents

Chloral hydrate in a 100% aqueous solution and at a dosage of about 2 ml/kg has been used by the intravenous route to kill dogs.

Magnesium sulphate in a saturated aqueous solution approximately 1 g/ml) is also in use and effective when a dose of 2.5 to 4.0 mg/kg is given intravenously.

Chloral hydrate has a slower effect on the cerebrum than the barbiturates so that induction of unconsciousness is preceded by more tendency to struggle. Death may occur only after unpleasant manifestations such as gasping, muscle spasms and whining. There is also the reported problem of wide individual differences in response. Since chloral hydrate is a dissociative anesthetic, the corneal blink reflex may not be acceptable as an indicator of unconsciousness. Since it depresses the brain slowly, restraint is usually necessary.

In the case of magnesium sulphate the medullary and cerebral cortex depression occurs simultaneously so that there is loss of sensation before the respiratory paralysis, which causes death, occurs. It quite often happens that muscular spasms with gasping and whining are produced prior to death, especially when the lethal dose can be given only slowly as in the case with larger dogs (Aramez et al., 1958).

Lucke (1975) has drawn attention to experience with magnesium sulphate in humans in which muscle paralysis preceded loss of consciousness.

Small amounts have a neuromuscular blocking effect and in no way depress the nervous system.

Heavner and Rudolph (1973) in their study of magnesium sulphate in cats found that 50-75 mg/kg intravenously caused muscle paralysis and respiratory depression. There were no EEG signs of sedation or narcosis. Magnesium sulphate, to be effective, should be given at a higher dosage and rapidly, the immediate physiological consequence being cardiac arrest. This would probably not be painful and would be similar to fainting syncopy in man. Similarly, a high dose and rapid intravenous injection of potassium chloride may produce immediate cardiac arrest. The use of these relatively cheap chemicals warrants further evaluation, since they may be valid substitutes for more costly (and dangerous/addictive) drugs.

The attraction of these three drugs is that they are cheaper and more rapidly obtained than the barbiturates, but they have the limitation of being effective only through intravenous or intracardiac injection. While the use of either following a barbiturate injection sufficient to cause unconsciousness will effect a saving in cost, neither drug may have potential for the painless killing of dogs and cats in the future, except in those countries where costs are prohibitive for anything but the most inexpensive solutions.

Air Embolism

Air embolism is an extremely effective and rapid way of producing death in rats. H.C. Rowsell (personal communication) states, "Following 2 ml of air intravenously, the blinking reflex was present for 15 seconds and after 10 seconds, the electroencephalogram became abnormal and flat in 45 seconds. There was vocalization and gasping when 5 ml of air intravenously was given; it did not change the time for the blinking reflex to disappear. It disappeared in 15 seconds; however, the electrocephalogram became abnormal within 4 seconds and became flat within 29 seconds. I appreciate the fact that air is not included because of the variability of the amount required and the rapidity with which it can be injected in larger dogs. Again, however, if a standard method could be developed which would present the amount of air required for various sizes and weights of dogs, it may be less traumatic and faster than the exposure of animals to anoxic methods such as nitrogen, CO_2, decompression, etc. Of course there is a requirement for a considerable degree of technical competence in administering air emboli." However, it is comparable to the target effect of potassium chloride and magnesium sulphate in causing cardiac arrest and thus, in cutting off the blood supply to the brain, will render the animal unconscious quickly and efficiently. Dr. Rowsell concludes that air emboli works the best in any animal already anaesthetized.

Sanford (1976) has pointed out that ketamine and the mixture of steroids known as Saffan may find a use in euthanasia as they allow anaesthesia to be produced rapidly following intramuscular injection. Death could then be caused by injection of the previously mentioned drugs or by some other inexpensive means. Sanford (1976) states that, "The advantage of these compounds is that they act rapidly following intramuscular administration. This may be important where it is impossible to make an intravenous injection. The steroid mixture is not suitable for use in dogs, since, in this species, one of the ingredients of the solution causes histamine release with an anaphylactoid response. Ketamine induces a state described as "dissociative anaesthesia" with some muscular rigidity in which the animal may respond to external stimuli. It follows that neither of these anaesthetic agents can be regarded as a drug for first choice for euthanasia." (See also chemical capture/restraint).

There is a general agreement that strychnine, curariform drugs and hydrocyanic acid cannot be recommended for humane killing of any animal and so it is sufficient only to mention them. Their use can only be justified under extreme circumstances, such as with a savage or rabid animal. (see also poison baits, page 40)

Addendum

Professor H.C. Rowsell has made the following additional observations concerning the use of potassium chloride and magnesium sulphate for euthanasia.

"With respect to intravenous potassium chloride, this does cause rapid cardiac arrest. Our studies using the rats have demonstrated that as little as .125 ml. of a saturated solution of potassium chloride intravenously will produce a loss of the blinking reflex in 15 seconds. At the same time a flattening of the electroencephalogram occurs.

"Respirations ceased in three seconds following loss of the blinking reflex and the flattening of the EEG. In potassium chloride intravenously, the electroencephalogram and the blinking reflex both disappeared simultaneously in an average time of 14 seconds. There was however a variation in the degree of struggling after the electroencephalogram became flat. The muscular activity in the rats injected with potassium chloride was not visually as disturbing as that seen following the intravenous injection of a saturated solution of magnesium sulphate. With the magnesium sulphate the disappearance of the blinking reflex and the flattening of the EEG were comparable, however with magnesium sulphate the flattening of the EEG occurred on the average of three to five seconds after the blinking reflex disappeared.

"The Canadian Council on Animal Care has had some concern about the use of both potassium chloride and magnesium sulphate because of their neuromuscular activity. Both potassium chloride and magnesium sulphate, the EEG become flat and the blinking reflex disappears at a much earlier time period than in any of the anoxic methods for euthanasia. In the latter unconsciousness usually occurs around the 50-90 second period of time. Nevertheless we do not know whether or not the potassium or the magnesium in which affects muscle physiology, may also produce a period of pain albeit for a very short period of time. Therefore, I believe we must be cautious in our acceptance of both magnesium sulphate and potassium chloride."

Recommendations for Research

There does not appear to be need for further research into the use of barbiturates for killing small animals.

For the product T61, it seems essential to demonstrate that unconsciousness occurs before the effects of the paralyzing agent. It will be necessary to study EEG data obtained during trials following the procedures advised by the manufacturers. Only when evidence from such recordings can be examined and found to be acceptable could T61 be considered a satisfactory euthanasia agent. This could be termed Project 2.

Additional information on the efficacy and economics of using certain of the other agents mentioned, either alone or in conjunction with barbiturates, could prove useful. Further research on inexpensive chemicals such as magnesium sulphate and potassium chloride are warranted where economic restraints limit the choice of euthanasia methods.

Further research is needed on these euthanasia agents. Heavner and Rudolph (1973) reported that in cats, "Any anesthetic or analgesic action of magnesium is overshadowed by its neuromuscular blocking effect." Lucke (1975) similarly concludes that, "The use of magnesium salts for euthanasia does present a problem because, as far as I am aware, it is not known at what stage the animal becomes unconscious, if indeed unconsciousness does occur before respiratory paralysis and cardiac arrest."

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GASES, CHEMICALS AND POISONS
Gas Chambers

Many factors have to be considered in the design of a chamber to be used for killing dogs with gas. Details may vary from one gas to another and certainly the number of animals to be killed at a time will influence shape and design. Certain factors, however, can be considered to be common requirements for all gas chambers.

In the first instance, chambers need to be strong and durable. They should be airtight. One or more sides or ends should be arranged as doors which open fully so as to allow easy access and avoid leaving any fixed edges which will be difficult to clean. Corners within the chamber should be rounded for ease of cleaning and there should be a slope to allow drainage toward the door.

For safety, it is necessary to have in a chamber a means of exhausting gases harmful to attendants by use of a duct or chimney and an extractor fan.

For the welfare of the animals it is important that an unobstructed view should be ensured for the attendant by providing the chamber with large windows and an adequate electric light. Gas inlet valves should be muffled since cats especially may be alarmed by the hissing sound of gas entering the chamber.[5]

With most gases the concentration within the chamber is a critical factor in humaneness of the killing. It is then important to have a means of monitoring the concentration. Where this is not practicable, resort will have to be made to a timing device which under certain specified conditions of gas flow will permit an estimation of concentration in the chamber.

When several dogs are to be killed in one operation, it can help to have a mobile cage in which the animals can be wheeled towards and into the chamber.[6] Where this procedure can be avoided and the animals persuaded to enter the chamber voluntarily, considerably less anxiety will be caused to them.

The gases considered below will be:

1. Carbon monoxide
2. Carbon monoxide and chloroform
3. Carbon dioxide
4. Carbon dioxide and chloroform
5. Carbon dioxide with carbon monoxide
6. Nitrogen
7. Nitrous oxide
8. Cyanide
9. Chloroform

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[5]The possibility of using a low volatile and pleasant-natural or synthetic food odor or pheromone (in a container through which the incoming gas is passed) to make the animal less anxious and more relaxed during the induction phase of gaseous euthanasia is worth investigation.

[6]Over-crowding must be avoided.

Reported times to unconsciousness and death in dogs caused by gases are shown in Table I.

TABLE I.
REPORTED TIMES TO UNCONSIOUSNESS AND DEATH IN DOGS WITH VARIOUS GASES

Gas	Time to Unconsciousness Seconds	Time to Death Minutes	Authority
CO			
3%	330	14.5	Carding
4%	140	9.0	Moreland
4-6%	120	7.5	Moreland
4%	120	2.5	Blood et al.
5%	30	1.0	Blood et al.
CO & Chloroform			
	120-180	4-6	Richardson
CO$_2$			
70%	24	5	Carding
CO$_2$ & Chloroform			
0-80%	20	2	Despres et al.
40% CO$_2$ & 3.0% CO			
	30	4.5	Carding
Nitrogen with O$_2$ content reduced to 1.5% within 60 seconds			
	40	1.3	Fitch et al.

Carbon Monoxide

Carbon monoxide (CO) from a variety of sources has probably been the most used method of killing dogs and cats throughout the world during this century. It is still widely used in North America but its use in Europe has decreased in recent years. It has also been extensively used in Australia.

Carbon monoxide in concentrations as low as 2% will rapidly cause death through anaemic anoxia leading to paralysis of the respiratory and cardiac centers. Unconsciousness and death from this gas can occur without pain or appreciable discomfort.

The gas is non-flammable and non-explosive except under certain unusual conditions of temperatures and pressure and with concentrations about 10%. It has no odor below 80% concentration. The principal disadvantage is the danger to human health and life although no illness or deaths in attendants are known to have occurred through poisoning with this gas. Repeated, prolonged exposure to low concentration can have toxic effects similar to those experienced in cities with heavy traffic.

The following sources of carbon monoxide have been used:

1. Burning Charcoal
2. Coal gas
3. Exhaust fumes from petrol engines
4. Liquid gas from cylinders
5. Action of sodium formate on sulphuric acid
6. Reduction of carbon dioxide in a heated charcoal reactor

The average time of death in seven dogs inspiring 1% CO was recorded by Von Oettingen (1944) as 36 minutes. At 2% CO with an unstated number of dogs, Blood et al. (1968) recorded collapse at 4 minutes with death at 5.5 minutes while at 4% CO these times were reduced respectively to 2 minutes and 2.5 minutes. The times at 6% CO of .05 minutes for collapse and 1.0 minutes for death were not reduced by further increases in the concentration of gas. Thus higher concentrations of CO are not necessary.

The same investigators made the following observations on dogs killed in their tests: slight staggering for several seconds followed by complete collapse; a period of involuntary whimpering or crying for about 5 seconds succeeded by a period of supposed unconsciousness when there was no reaction to noise. Immediately before death there was a violent respiratory effort and a stiffening of all parts before relaxation and cessation of breathing.

The next report of trails on dogs recorded in the literature is Carding (1968), who used the action of sulphuric acid on sodium formate to generate pure CO to give chamber concentrations between 2% and 3%. Acid fumes were removed by passing the gas through sodium hydroxide. Fourteen adult dogs and eleven pups between three and six months were killed in a series of four tests. With the exception of several pups which moaned before collapse, all dogs collapsed without prior distress. Carbon monoxide is not recommended for puppies and kittens.

Moreland (1974) reported on trials involving more than 100 dogs killed either by exhuast fumes or cylinder gas. Some data from this work has been approximated where relevant and included in Table I. Finding no significant difference in killing efficacy between the two sources of carbon monoxide, the investigator made a useful comparison of their respective costs. He found that whereas costs of purchase were about twice as high as comparable costs for employing cylinder gas, the per animal cost of the engine exhaust method was less than one cent in terms of maintenance, fuel and labor charges. Per animal cost with pure gas varied from 8 cents at 4% to 12 at 6%.

Work on effects of carbon monoxide on other species includes:

Cats — Rohrie (1940), Gebauer and Pohlmey (1955), Gjesdal (1965) and Blood et al. (1968)

Guinea pigs — Ramsey and Eilmann (1932)

Various Species — Bancroft et al. (1966) reported that the dog is five times more sensitive to CO than the rabbit while humans are midway between the two.

Carbon monoxide is considered to be satisfactory as a means of killing cats with as little distress as in dogs (Blood et al., 1968).

The different sources of carbon monoxide present various advantages and disadvantages. The burning of charcoal either in blocks or small pieces

in a furnace is simple and practicable for less industrialized regions. In certain conditions there may be a significant rise in the temperature of the chamber so that the flue gases need to be cooled before entering the chamber. It may be that overheating was the cause of unpublished complaints which led to the abandonment of chambers using this source of CO in Italian cities in recent years. Coal gas is no longer widely available for killing animals and in any case the dangers of explosion do not recommend this source.

Exhaust fumes from petrol engines are the most usual source of carbon monoxide. Special precautions have to be taken to reduce the temperature of the fumes and to remove impurities. Passage of the gases through a large water chamber will cool them and remove some carbon particles, oxides of nitrogen, hydrocarbons and oxygenates of hydrocarbons. Subsequent passage through a filter box containing hot air furnace filters, or a metal gauge filter with cloth screen, will remove carbon particles. Any motor vehicle engine in good operating condition is suitable if it is run at idling speed and on choke but adjusted to give minimum smoke. Killing by using exhaust fumes from a traveling vehicle produces a low concentration of carbon monoxide with a consequent long exposure to some irritating impurities before unconsciousness can occur and therefore should not be used. Pure carbon monoxide in cylinders is available in industrial areas but it is the most expensive source. It is also the most convenient.

Generation of the gas from sodium formate and sulphuric acid requires some simplification to make it more practical. The ideal would be an apparatus similar to a fire extinguisher in which the two chemicals are brought into contact by pressing a plunger or inverting the container. The carbon monoxide would then have to be passed through 10% sodium hydroxide to remove the acid fumes.

Reduction of carbon dioxide passed over a bed of charcoal heated electrically to about 800° C was used by Blood et al (1968). Ninety per cent pure carbon monoxide could be produced at very low cost. The charcoal bed had to be heated for an hour beforehand in order to reach the required temperature. To obtain a 6% CO concentration in their 50m^3 chamber took about 15 minutes and the cost was less than a tenth of cylinder gas. The generator was not recommended because of danger from poisoning by 90% CO and the danger of explosion at this concentration with high temperatures (Blood, 1968).

If pure carbon monoxide were always to be employed, it is less likely that there would be criticisms of this method on humane grounds. After very many years of experience with carbon monoxide killing of dogs and cats (mostly under motor exhaust fumes) many agencies running pounds and shelters have been eager to abandon their use. Systems using such exhaust fumes require some maintenance and care and this may often have been overlooked. The most likely causes of poor results are probably low concentration of CO, high concentration of impurities, and overheating. These would be contributed to in the case of exhaust fumes by lack of proper tuning of the engine and poor function of the water tank and filters.

Sensitivity to carbon monoxide pollution is discouraging wider use of this gas for killing animals in industrial countries. In less industrial countries, where sophisticated apparatus and materials are less readily available for alternative methods of killing, the development of a reliable procedure for producing carbon monoxide by burning charcoal in a furnace would have considerable potential. A practical apparatus for generating

pure gas from chemicals might also help to make the systems more attractive and efficient.

Unless excellent ventilation is available in a room, a chamber used with carbon monoxide should always be outdoors. There may be a roof for protection of the apparatus and the attendant but the structure should remain open at the sides.

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Carbon Monoxide with Chloroform/Carbon Disulphide

In order to end the killing of dogs by forced oral dosing with prussic acid, Dr. Sir Benjamin Ward Richardson (1884) designed and constructed a new apparatus capable of killing without distress 100 dogs at a time. This was to deal with the maximum daily kill of dogs at the then Temporary Home for Lost and Starving Dogs, Battersea, London, where the apparatus was installed.

Following the death of the designer, his son in 1910 enlarged the unit to accommodate 150 dogs in two chambers in line with the increased surplus of dogs. Richardson's system was used for fifty years at this one site and it was only in 1934 that it was replaced. Sweeny (1975) reports that the Committee of the Home learned from the operators that with the large numbers of animals killed at a time there was often some howling and the dogs struggled with one another. The unit was replaced with an electrocution apparatus in which dogs were killed one at a time.

The chamber was constructed of double wooden walls separated by a filling of sawdust. Extensions protruded on either side to facilitate diffusion of the vapors when the body of the chamber was occupied by a two-tier cage. This has six wheels of 20 cm diameter and ran on rails from the kennels. When the sliding door at the front end of the chamber was raised, the

cage was pushed up against a hinged safety door and traveled on rails to the interior. The door was then closed. Opening of a 3 meter chimney was controlled by a damper at its base.

The chamber was charged with gases before the dogs entered. Carbon monoxide was generated from two gas-fired condensing stoves, each capable of burning 1 kg charcoal/hour, arranged on one side of the chamber. The condensers removed water vapor together with the water-soluble impurities and the temperature of the fumes was reduced by this means.

To hasten the effect of the CO the gas was passed through a mixture of chloroform and carbon disulphide in a box filled with a highly porous material. There were two such boxes and into each was poured 300 ml of a solution containing equal proportions of the two fluids. At this point the dogs were placed in the chamber and a further 300 ml of the solution was added to the boxes.

Richardson reported that in the last 6,000 animals killed there were none which took a long time to die. They were gradually all unconscious in 2-3 minutes and dead after a further 2-3 minutes. If, after 4 minutes, animals could still be heard breathing by means of a stethoscope permanently fixed in the chamber wall, an additional 140-300 ml of the chloroform/carbon disulphide solution was added to the box. The chamber door was not opened until one hour after starting the operation.

It was noted that cats took longer to die than dogs but collapsed as quickly.

The 1903 annual report of the Home stated that Richardson had altered the procedure to good effect. The chamber now closed automatically as the cage was removed and so remained permanently charged with lethal gases. This greatly shortened the preparatory stages.

There are no other records known of this method in the scientific records and no indication that it has been used elsewhere. The same chamber is referred to in a popular journal of the times (Newnes, 1891). This method is probably of historical interest only.

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Carbon Dioxide

Carbon dioxide (CO_2) has not been used for killing dogs routinely except in one small government shelter in Brazil (Dunin, 1969). Following work in Britain (Glen and Scott, 1973) the gas has been introduced by animal welfare agencies in that country and abroad for use on cats and kittens. In Canada, CO_2 cabinets are also used for killing dogs and newborn pups if they have first been made unconscious with chloroform.

Low concentrations of CO_2 up to about 10% are used in anesthesia to stimulate respiration. Higher concentrations depress the central nervous system which leads to unconsciousness, followed by respiratory arrest and death.

Carbon dioxide is a non-flammable, non-explosive gas, heavier than air of which it is a normal constituent to a very small extent. The gas is readily obtained from "dry ice" or, in compressed form, in cylinders available as a byproduct from breweries and other fermentation industries. Cylinder gas is generally used by preference but its cost is a significant item of expenditure.

Experimental use of 30% to 40% CO_2 was found to produce anaesthesia in dogs in 1 to 2 minutes, but with occasional struggling (Leake and Waters, 1929). Brown and Miller (1952) found in dogs that blood pressure fell precipitously as CO_2 concentrations exceeded 70% but that at 90% cardiac arrest was delayed until 4-9 minutes.

Trials in a chamber which involved 11 dogs in six tests reported by Carding (1968) indicated that 70% CO_2 was an approximate optimum. At this concentration collapse occurred after 20 seconds and presumed death at 5 minutes with practically no hyperpnoea before collapse and little paddling afterwards. At concentrations between 50% to 60% and at 80% hyperpnoea and paddling were pronounced. Average times of collapse at these concentrations were 30 seconds with presumed death occuring after an average of 10-18 minutes. At a concentration of 45% to 50% CO_2 collapse also occurred after 30 seconds but the dogs were still breathing after one hour.

The process of collapse in these trials varied. In the best result at 70% CO_2, the animal fell suddenly with no sign of previous anxiety and with transient paddling afterwards for 10 seconds. In other cases there was a similar rapid collapse but sudden collapse was replaced by a gradual sinking with mounting hyperpnoea followed by rapid paddling and unsuccessful attempts to regain the standing position. There was one disagreeable test in which the gas was introduced into the relatively large chamber after the dogs were placed inside. Collapse did not occur until 4 minutes after removal from the chamber. There was no marked excitement but some vocalization and scratching to get out. Salivation was marked.

Glen and Scott (1973) describe a simple cabinet and procedure by which they killed 10 cats and 20 kittens. Results were variable but, with one exception at 90 seconds, all animals had collapsed within a range of 25-60 seconds, at which moment they were presumed unconscious. In half the tests with initial CO_2 at more than 60% death occurred within the range of 1.5 to 6 minutes while in the remainder, with the initial CO_2 at 60% or less, the cats were still alive after 10 minutes when additional CO_2 was added to cause cardiac arrest. In each of these cases the cabinet was already charged with gas before the cats were introduced. When the gas was introduced after the cats were put in the cabinet, the time before collapse increased to a range between 80 and 140 seconds but there was no greater degree of excitement.

Some excitement was noted in most of the tests and was described as slight or moderate. Slight excitement consisted of obvious resentment against the gas as by licking and sneezing, and movements about the cabinet to seek the highest point. These signs never lasted more than 30 seconds. Moderate excitement involved more erratic movements and "yowling" but these signs also were of short duration.

The authors of the above work concluded that CO_2 represents a marked advance on the use of chloroform for killing cats and kittens from the humane viewpoint.

The use of 32% oxygen when anaesthetizing sheep with CO_2 was observed by Mullenax and Dougherty (1963) to cause less struggling. Klemm (1964) noted that the danger of respiratory and cardiac arrest in CO_2 anaesthesia in cats was reduced with supplementary oxygen. Mac

Arthur (1975) has subsequently described a double chamber in which a cat may first be made unconscious in a mixture of 70% CO_2 and 30% O_2 and then placed in the second chamber to die in pure CO_2. Unconsciousness is produced within 20 seconds mostly without struggling and death occurs within three minutes. The chambers are open-topped and glass fronted and they are charged with gas before the cats are placed inside. Trials have shown that cats can be killed at the rate of one every four or five minutes. Equally satisfactory results have been achieved with puppies and laboratory animals.

Extensive work has been reported on the effects of CO_2 on small animals extending from basic research to routine killing by this method. The list includes:

Cats — Klemm (1964), Glen et al. (1973) and MacArthur (1976)

Dogs — Leake and Waters (1929), Brown and Miller (1952) and Carding (1968)

Laboratory Animals — Woodbury, et al. (1958), Stone et al. (1961), Hyde (1962), Rudolph (1963), Kline et al. (1963), Lampman (1964), Breazile and Kitchell (1969), MacArthur (1976).

Low concentrations of CO_2 up to about 10% are used in anaesthesia to stimulate respiration. Higher concentrations depress the central nervous system which leads to unconsciousness, followed by respiratory arrest and death.

Work on domestic animals with CO_2 has centered on attempts to produce anaesthesia prior to slaughter. The list includes:

Pig — Blomquist (1957), Mullenax (1963)

Sheep — Mullenax (1961)

Chicken — Kotula et al (1957 & 1961)

Turkey — Drewniak et al (1955)

Comparatively little work has been reported on attempts to develop CO_2 as a practical and humane method of killing dogs. The expense of the cylinder gas is insignificant but not excessive in industrial countries, especially if the gas can be conserved for several cycles of operation. Conservation of the gas which is heavier than air suggests the necessity for loading through the top of the chamber. This in turn suggests that the chamber should be below floor level in which case a hoist is required for a large cage. When further work has been undertaken to determine optimum concentrations using a significant number of dogs a satisfactory range of chambers could be designed. A dip-lift apparatus would be necessary for animals larger than cats.

In the case of cats, CO_2 with oxygen appears to be reliable, rapid, safe, and simple as well as humane. Details of cost are awaited. At present CO_2 has not been adapted for satisfactory use on dogs, and until further developments show it to be humane, it should not be used on dogs. It is a valid alternative to intravenous barbiturate, which may be difficult to give to cats, and may be more humane than forcibly restraining wild or fearful cats for injection.

Addendum

Professor C. Health, Department of Pharmacology, University of Alberta, Edmonton, Alberta, comments:

"I worked with Brown, to whom you refer, from 1951 to 1955, giving 30% and 40% CO_2 mixed with oxygen, and have found it very distressing indeed. When, together with Brown, we used CO_2 alone to anesthetize dogs (administered via a mask) the dog fought and showed every sign of distress, and had to be very strongly restrained. It required at least 40% CO_2 on these occasions to produce unconsciousness.

"Because of these experiences, and on theoretical ground (CO_2 is a very strong respiratory stimulant known to cause dyspnoea) I fail to see any advantages of CO_2 over either decompression or nitrogen, and feel that the potential and real disadvantages of this gas should lead to its rejection as a practical method of euthanasia."

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Carbon Dioxide with Chloroform

The combination of these agents for killing dogs was first reported by Desprès and Arlattaz (1967) who introduced the system at the municipal pound in Geneva where owners often stayed with their animals to witness its death. In 1969 a similar apparatus was installed in a private dog shelter just across the border in France. In Spain, de Bruyn (1969) modified the design of the apparatus for local manufacture and demonstrations were given at Gerona before public health and veterinary officials. Subsequently, a unit was installed at the new municipal dog center at Canto Blanco, Madrid, where it has given satisfactory service when properly used.

The reason for combining these agents was to utilize the rapid unconsciousness produced by relatively high concentrations of CO_2 with the more rapid lethal effect of chloroform.[7] The procedure of Desprès and Arlettaz (1967) was to place usually one dog in the chamber and then introduce CO_2 rapidly up to approximately 80%. The animal collapsed in about 20 seconds after which further CO_2 was passed through a vaporizer containing chloroform. Within 2 minutes the dogs were dead. Observations in France and Spain suggest that such rapid times are not invariably achieved with the modified apparatus under local conditions. The method was said by the originators to be equally satisfactory for cats.

Addendum

Professor H.C. Rowsell adds the following observations:

In our laboratory we have used both uncharged chambers mixing carbon dioxide and chloroform as well as charged chambers with chloroform-carbon dioxide mixtures. The chloroform was vaporized. Death of rats had occurred in as short a period of time as 5 seconds with little evidence of muscular activity. Additionally, we have observed it with cats and dogs. We have demonstrated no signs of hyperventillation and collapse occurring within 3 to 10 seconds of exposure to the combined gases in cats and within 20 to 30 seconds in dogs. Carbon dioxide does have an interesting action. It not only produces a narcosis but it also stimulates the respiratory center, therefore, hyperventilation may be commonly observed. An additional action which probably relates to the success of the chloroform-carbon dioxide mixture is that carbon dioxide produces a dilation of the blood vessels in the brain, therefore, the chloroform is more rapidly taken up, producing the state of anaesthesia rapidly. It is in this area that I believe additional work should be done. Unfortunately at the present time, chloroform has been listed as a carcinogen. Additionally, we have known for years that it has an effect upon the liver and renal function as well as spermatogenesis. It is important, therefore, that before carbon dioxide and chloroform mixtures can be recommended, adequate methods must be developed to exhaust fumes to the outside. Again, if the chloroform is a carcinogen, then we must ensure that air dilution is sufficient so that it does not pose a human hazard.

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[7]See *Addendum,* following.

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Carbon Dioxide with Carbon Monoxide

Von Oettingen (1944) reported that the toxicity of CO is increased by an increase in CO_2. In order to utilize this effect and to check if an economy in the quantity of CO_2 could be achieved by employing a small concentration of CO, Carding (1968) made a single trial with two dogs. The dogs were introduced to a chamber with about 40% CO_2 and collapsed after an average of 30 seconds. At this point CO generated from chemicals was introduced up to about 3% and death occurred at 4-5 minutes. The time of collapse was 10 seconds slower and death occurred 30 seconds sooner than with CO_2 alone at 70%.

Addendum

Professor Heath adds, "I see no value in considering adding CO_2 to other lethal gases such as chloroform or CO, both of which are individually excellent means of producing first unconsciousness, then death without recovery of consciousness. While technically it may be correct to say that CO_2 increases the toxicity of CO, i.e. lowers the LD_{50}, CO is very potent without the CO_2, and, in fact, the side effects of the added CO_2 are undesirable.

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Nitrogen

The first record of using nitrogen to kill animals was from Vinter (1957) who worked on ways for the humane killing of mink. She reported that although mink became restless while the gas was being introduced, they became unconscious after about 90 seconds. Death invariably occurred before 5 minutes. Vinter (1965) tested the use of nitrogen on chinchillas and found it satisfactory from a humane viewpoint. The AVMA Panels on Euthanasia (1963 and 1972) recommend that trials with nitrogen should be undertaken on other animals to check its feasibility for euthanasia. This work was carried out by Fitch, et al. (1974).

Nitrogen is an inert gas which is a major constituent of air. In high concentrations it can, by displaying oxygen, produce unconsciousness through hypoxia. Death occurs as a result of paralysis of the respiratory center. The gas, obtainable in liquid or gaseous form in pressurized cylinders, is readily available in industrial countries although it tends to be relatively expensive in some areas.

In their investigations, Fitch et al. (1974) who used the term "nitrogen flushing," killed 313 dogs, 36 cats, 1 pig, 2 rabbits and 8 ducks. Electroencephalograms (EEG) were recorded from 34 dogs as well as electrocardiograms (EKG) and arterial blood pressure. The animals were placed in a chamber for 5 minutes. EEG patterns showed the characteristic for sleep and unconsciousness in an average of about 40 seconds and became isoelectric at 80 seconds. When there had been an isoelectric EEG, zero arterial blood pressure and no spontaneous respiration for 30 seconds, attempts at revival were unsuccessful.

Behavior of the animals was summarized as follows:

All became unconscious and collapsed within one minute; there were no signs of pain in any animal before unconsciousness including cases in dogs of upper respiratory disease. After unconsciousness, there were instances of muscle twitching, gasping, convulsions and yelping. The authors suggested that these were a result of acute hypoxia occurring in the unconscious animal (Fitch et al., 1974).

The same authors noted that the technique was successful in all species tested except for neonate puppies and kittens, while reptiles and amphibians were not effectively killed. They add that unborn young were killed in a pregnant female euthanized.

They recommend that the nitrogen should be exhausted to the exterior of the building where no environmental harm could be caused. In their view, nitrogen would be economically competitive with other approved euthanasia methods in use.

Since the end of 1974 three companies[8] in the U.S.A. have marketed a cabinet lined inside and out with formica and having plexiglas doors complete with all the ancillary apparatus for nitrogen killing of dogs and cats.

Addendum

As yet, nitrogen for euthanasia has not been approved by UFAW. Hypoxia and paralysis of the respiratory center may be distressing and unavoidable prior to unconsciousness. Professor H.C. Rowsell adds the following pertinent observations:

"In our hands, the nitrogen flushing method for euthanasia has been frustrating. As an agent to kill rats, there is much more muscular activity with nitrogen flushing as compared to CO_2. The experience which we have had with dogs and cats using the nitrogen flushing method has left some serious doubt in our minds as to its suitability as a method to produce a humane death. We used a chamber produced by Clark & Cote in Calgary, Alberta. The chamber is designed on that distributed by Snyder Manufacturing of Denver, Colorado, the group that I believe made the prototype for Dr. Fitch and his associates for their studies. We compared in these studies simultaneously the use of nitrogen and CO_2 as a method for producing a humane death in cats. We found in cats that very quickly these animals responded to the CO_2 level and would do some sniffing and in many cases, attempting to escape from the container (which was of the UFAW design). When the oxygen level in the container was down to 8%, they would collapse. On the other hand, with nitrogen, when the oxygen level fell to 3% or less, the animals

would drop with rigidity in their limbs, throwing their heads back, and emit vocalizations (that one normally associates with extreme pain or distress) for 5-15 seconds. For the operators this was far more distasteful than the appearance of the animals with the carbon dioxide.

"With the study of nitrogen flushing method in dogs, we found again that the dogs showed very little evidence of distress when the oxygen was around the 8% level, but once it fell to 3% and then onto the 1.5% when the machine was turned off, the dogs would fall, stiffen their legs and throw their heads backwards and vocalize very loudly. It was at the terminal end of this vocalization that the chambers were opened; on almost every occasion we found that the blinking reflex was present. This is an indication to us that the animal does not have a depressed central nervous system and is not unconscious when this stage is reached. It may be disorientated; however, animals at this stage can feel pain. We cannot categorically state that they are feeling pain during the induction of death at the 1.5% oxygen level. In many of the dogs that were tested, the chamber would only be opened 5 to 10 seconds; the oxygen level would rise to 8%. Before the nitrogen gas would come on again, approximately 20 seconds would have elapsed and the dog would be on his feet without staggering or falling about. One would expect that an animal in a state of depression of the central nervous system would not show such rapid recovery at this low oxygen level.

"The fact that dogs in the nitrogen flushing method show a blinking reflex when the chamber is opened during the vocalization and the rapid return to a standing position without signs of central nervous depression suggests that the nitrogen flushing method may not be acceptable as a humane killing technique.

"Using the carbon dioxide method and the nitrogen flushing method, the administration of a tranquilizer prior to putting the animals in the euthanasia chambers, changes the behavioral attitudes of the animal significantly: in both the nitrogen and the CO_2 chambers, struggling, escape reaction and vocalization will not then occur. It is, therefore, suggested that the only one way the nitrogen chamber might be acceptable is when it is used in animals that have been previously tranquilized."

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Nitrous Oxide

There has been little application of this gas in animal euthanasia. Ms. Gretchen Wiler (personal communication) has used this on a small scale for euthanizing kittens, puppies and adult cats. Monitoring two pound pressure release from a gas cylinder into a small, glass fronted chamber (with air vents on the lid), the animal falls within 25-30 seconds. The gas is turned off after 3 minutes and the animal removed after a further 5-7 minutes. Nitrous

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[8]Snyder Manufacturing Co., 5500 East Pacific Place, Denver, Colorado 80222, Schroer Manufacturing Co., 2217 Campbell Street, Kansas City, Missouri 64108, Kirschner Scientific Products, Seattle, Washington.

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oxide appears to be less irritating than CO_2, is safer to personnel than CO, and on humane grounds, it is attractive since it is both an analgesic and an anesthetic. Adequate ventilation to prevent personnel from becoming intoxicated, is essential. The use of this gas, especially for euthanizing small numbers of animals, deserves further evaluation.

Cyanide Gas

Hydrocyanic acid (HCN) gas has a long history as a lethal agent for animals and humans. Polson and Tattersall (1959) mention its use to control scale on California citrus trees in 1886, to destroy vermin in carriages by the Cape Government Railway in 1898, to kill rats in ships in New Orleans in 1929 and by the Nazis in concentration camps from 1939. One Robert B. White had been executed in 1930 in a cyanide chamber in the U.S.A. The use of HCN to kill laboratory animals was referred to by Smith in 1965, and HCN has also been widely used in the last twenty years to kill wild animals such as rabbits. Unwanted dogs have been killed by HCN in outdoor pits, notably in Spain in former years.

A cyanide-cytochrome link is formed and this is reversible only if respiration can be continued (Polson and Tattersall, 1959). Cyanide gas is very irritating to the respiratory mucosa and the hypoxia acting on the brain leads to violent clonic convulsions and opisthotonous prior to death.

The inhalation by humans of HCN in doses of 2 ml/liter or more will cause immediate giddiness, unconsciousness and collapse while death may follow quickly or following some delay (Polson and Tattersall, 1959). With smaller doses, collapse may be preceded by watering of the eyes, headache, irritation of the throat, palpitation of the heart, difficulty in breathing and weakness of the limbs.

The usual way of generating HCN for a gas chamber is to allow pellets of sodium cyanide (NaCN) or potassium cyanide (KCN) to react with sulphuric acid. Smith (1965) describes a common procedure for killing laboratory animals whereby pellets of KCN in a cheese cloth bag are suspended over a vessel in the chamber containing sulphuric acid. The bag of pellets can be dropped into the acid by means of a pulley or by cutting the attached cord and immediately the two chemicals come into contact the HCN arises as fumes.

Calcium cyanide (CaCN) is used in the fumigation of greenhouses at a rate of about 100 gm/1,000m^3. The CaCN is simply exposed to damp air at a temperature of 18°C or more. This procedure was used by the Nazis for mass murder at Strathof in Alsace (Polson and Tattersall, 1959).

Magnesium cyanide (MgCN) similarly reacts with moist air or water to generate HCN and in granule form is used to kill rabbits in their burrows, as well as occasionally for poaching river salmon.

There do not appear to be any cases recorded of death from accidental inhalation of HCN while poisoning rabbits, although Hume (1961) reported a case of accidental inhalation in which the victim became unconscious without distress and recovered spontaneously in the fresh air sufficiently to return home and eat lunch.

It is clear that HCN is too toxic to be recommended for routine use indoors because of danger to operators but the wide safety margin which exists when it is employed outdoors under stringent conditions is evidenced elsewhere. In World War I, the British used HCN in shells for a time, but they were found to be not very effective (Polson and Tattersall, 1959).

The present situation with regard to HCN and the killing of dogs and cats is that it is not now known to be in regular use anywhere. The reasons seem to be the violent convulsions which result and which are most disagreeable to witness either by operators or casual observers, and also the hazard to operators. While HCN cannot be considered an ideal method of killing, it may have a useful application in outdoor situations in less developed areas where better alternatives are not available. It could replace more painful methods and has the advantage of being cheap, irreversible (in the absence of treatment) and very quick-acting and, by virtue of its speed of action, it may be considered quite humane.

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Chloroform

This volatile substance was once commonly used as an anesthetic. Exposure to the fumes (either inhaled via a mask or when the animal is placed in properly constructed box containing chloroform) leads to unconsciousness with ten to twelve minutes: prolonged exposure leads to brainstem inhibition, respiratory then cardiac arrest and death. There are many effective designs of chloroform boxes for euthanizing small animals — cage birds, kittens, puppies, and cage pets such as mice and hamsters. The animals should not come into direct contact with the chloroform nor with a strong concentration of the vapor since it is extremely irritating to the eyes. To induce gradual anesthesia and death, the animal should not, therefore, be placed directly into a box already saturated with chloroform. In order to insure a smooth induction, it should be put in the box before the chloroform is poured onto a gauze/cotton-wool dispenser. A concentration of only 1.5 to 2% chloroform vapor in the air is sufficient to produce anesthesia and death. A stethoscope should be used when possible to make sure the animals are dead since short exposure (under ten minutes) may result in deep anesthesia and not death, especially if the chloroform vapor concentration is low. A ventilation fan and extractor hood should be used to evacuate the chamber after use since chronic exposure to chloroform fumes is an occupational hazard, being linked with sterility, liver and kidney damage and cancer in man.

Chemical Capture/Restraint

One critical area of animal control that also requires further research is in chemical capture and restraint of free roaming/feral animals. The following observations on the situation in America are relevant:

The use of nicotine sulphate and nicotine alkaloids is gaining widespread use as a means of capture and restraint, especially of free roaming

dogs. It is administered by injection: a syringe loaded dart gun is one of the more popular methods used today by municipal animal control officers and police in various parts of the country. Correlated with the increasing use of this drug is an increase in owner complaints of their free roaming or accidentally escaped pets having been killed by such injections.

Nicotine sulphate or nicotine alkaloids are very potent, causing voluntary muscular paralysis, convulsions and ultimately respiratory arrest. Death is due to respiratory failure. Such problems could be avoided if,

(1) Accurate doseage could be assured. This is difficult without first weighing the dog. A dog with a thick coat, at a distance, may seem heavier than it actually is. It is, therefore, easy to miscalculate.

(2) A wide safety margin could be assured. Nicotine has a very narrow safety margin. A mere five pound body weight overdose could kill a dog.

(3) High species susceptibility could be avoided. The dog is one species that is particularly susceptible to the central nervous system effects of nicotine sulphate and nicotine alkaloids.

Nicotine preparations for capture/restraint of animals does not fulfill any of the above three criteria — it is easy to kill a dog with an overdose, there is virtually no safety margin and the dog is particularly prone to nicotine poisoning.

There are safer drugs which are already in use in several municipalities and which satisfy the above criteria and also satisfy two other criteria namely: (1) effects are easily reversible with in injectible antidote or the effects are transient and the animal recovers rapidly, and (2) from a humane viewpoint the drugs induce muscular relaxation, tranquilization and/or light anesthesia in contrast to the extremely distressing physiological and psychological effects of nicotine sulphate.

The following statement from a veterinary colleague, Dr. William J. Boever, Senior Veterinarian, St. Louis Zoological Park, St. Louis, Missouri, who has had considerable field experience on immobilization and capture techniques in wild and domestic animals, gives further warnings and guidelines:

"The feat of capturing free roaming dogs is an extremely difficult one. First of all one is dealing with an animal in which (1) its exact weight and physical condition are not known, (2) the animal is already excited, making immobilization and anesthesia a poor risk, and (3) you are not sure when he last ate or his nutritional state. On top of all this, you have to load a dart and hit the animal in the muscle, making sure not to dart him in the head, thorax, abdomen, or lower leg. Then hopefully, if you are an expert marksman, the dart will fire and not misfire as sometimes happens and that the complete dose and not a partial dose is administered into the muscle and not into the fat or skin. This is a monumental task for someone educated and trained in anesthesiology, etc. much less the caliber of most individuals working for most of the municipalities. No wonter the success rate with nicotine and capture gun is usually less than 30%. (I have heard that in some municipalities of no dogs ever recovering from nicotine)."

It is, therefore, strongly recommended that alternatives[9] to nicotine sulphate be utilized where this drug is currently in use by police or animal control officers.

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[9]eg. Rompun (xylazine) a sedative analgesic from Haver Lockhart.

Other chemicals with a wider safety margin have been used in the field, notably Ketamine (a phencyclodine derivative) and Rompun (a tranquilizer), the two being mixed in the dart syringe to give a single dose estimated at 10 mg/kg Ketamine plus 1 mg/kg Rompun. For small and delicate animals, a blow gun may be safer and more effective than a dart gun. Other effective tranquilizer/analgesic mixtures include Hypnorm (containing fentanyl, an analgesic and haloanisone, a butyrophenone tranquilizer) and Immobilon (which contains etorphine, analgesic, and a phenothiazine tranquilizer).

Animal Control and Poison Baits

This report would be incomplete without considering the use of poisons in animal control. Under certain circumstances, the use of poisons to destroy dangerous (eg. rabid) or otherwise harmful free-roaming and feral cats and dogs, becomes a necessity.[10]

The search for a quick acting poison that causes either no or minimal suffering and is palatable (or easily masked by the bait), continues. Scott (1976) has reviewed the various poisons available that have been used in animal control. (See Table II)

More research in this area is needed to develop a quick acting poison with minimal distressing side effects. It is unlikely that a dog/cat species-specific poison could be developed, but this would be advantageous considering the risk to human beings and other "non-target" species. Also secondary effects, as with sodium fluoracetate, should be considered; other animals eating the carcass of the poisoned animal may also be poisoned.

References

Scott, W.N. (1976) The use of poisons in animal destruction. In *Humane Destruction of unwanted Animals*. UFAW, Potters Bar, Herts, England, pp. 33-42.

Recommendations for Research

In the preceding pages consideration has been given to several different agents or combinations of agents which are often considered capable of causing unconsciousness and death in dogs or cats with limited or no distress. In only one of these cases, nitrogen, is there good scientific evidence and this has yet to be substantiated by further corroborative studies. In the case of carbon monoxide and carbon dioxide it remains important to establish more scientifically if they are equally able to produce unconsciousness without prior distress. This will require the collection of data from EEG[11] and arterial blood pressure recordings. Pure gas should be used.

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[10]Where trapping is possible, a padded offset "steel jaw" trap is one of the more humane traps; cats and dogs may be live trapped in a humane trap-door type box trap.

[11]The electroencephalogram can provide useful information, particularly with respect to the length of time it is normal, abnormal and the period it takes in order to become flat. We should not delude ourselves into believing that it will tell us precisely what the animal is experiencing. Again, it must be re-emphasized that we can never put ourselves within the brain of that animal to really understand precisely the feeling of the animal. — H.C. Rowsell

TABLE II
A SELECTION OF FREQUENTLY USED POISONS (from Scott 1975)

Substance	Advantages	Disadvantages	Major Symptoms	Time to Death
Alphachloralose	Narcotic	Temperature-dependent	Excitement, convulsions, coma	seconds
Cyanide	Immediate death	Operator hazard	Convulsions, coma	1-24 hours
Norbormide	Toxic only to *Rattus norvegicus*	Bitter taste in baits		
Fluoracetates	Relatively quick death	Operator hazard	Excitement, convulsions, coma	hours
Anti-coagulants (e.g. Warfarin)	Operator safety	Ingestion over a period required. Days to death.	Diarrhea, vomiting, coma	days
Zinc Phosphide	The most humane of metallic compounds	Abdominal pain	Abdominal pain, coma	2-3 days
Antu*	Non-toxic to adult chickens	Bitter taste Death from "drowning"	Pulmonary oedema	hours/2 days

*use discontinued in the U.K. because it contains carcinogens.

The most valuable way of achieving this information would be for each gas to be tested on dogs, and where applicable on cats, in a similar chamber or cabinet. This would permit a study of the most effective concentration for each gas and a comparison of the costs involved at optimum concentrations of each gas (Project 3).

Investigations along these lines should quickly reveal the respective merits of the three principal gases. In order to obtain nearly simultaneous comparisons with the hope of mutual corroboration and international acceptance it would be extremely helpful to have such tests carried out in both North America and Europe.

It might already be surmised that in the industrial countries the preferred gas will be either nitrogen or carbon dioxide, perhaps both. In such areas these gases are readily obtained in cylinders although their costs may vary from country to country. In less industralized countries, these gases will not be so readily available. Provided carbon monoxide is satisfactorily vindicated, attention should be given to methods of production of CO suitable for less developed areas.

In a project for a chemical engineering laboratory, it will be important to determine the optimum specifications of a furnace for the burning of charcoal to produce CO and the practical procedure for ensuring that satisfactorily cool and pure fumes are delivered to the chamber (Project 4).

Another important project for a similar laboratory would be to design a suitable low-cost apparatus for the safe evolution of pure CO from chemicals such as sodium formate and sulphuric acid (Project 5).

There are cases in which HCN could prove practicable when other alternatives are not available.

Definitive directions for the design of chambers or pits, specifications for the type, quality and quantities of reagents, procedure for handling the reagents and the operational procedures for the whole process need to be drawn up. Safety precautions and emergency treatment measures should be included (Project 6).

Behavioral Tests

An additional project to cover "unknowns" in the area of overt behavioral reactions as indices of pain, distress and consciousness, is indicated. This would not only complement physiological data, but would also help overcome the serious limitations of relying upon basic physiological parameters as indices of emotional distress and pain. The following suggested studies are most applicable to evaluating decompression and gas chamber euthanasia methods.

(1) Control (sham) studies: observe behavioral reactions in confines of chamber with the system not operating. Blood samples may be taken before and after to measure plasma cortisol[12] levels as a biochemical index of stress.

[12]An additional measure of stress might be applied to the objective evaluation of euthanasia methods. Carney and Walker (1973) for example, measured plasma *corticosterone levels* in the rat and showed, on the basis of such biochemical evidence, that chloroform euthanasia is more stressful than either pentobarbital injection or decapitation. Carney, J.A. and Walker, B.L. (1973) Mode of Killing and Plasma-cortiscosterone Concentrations in the Rat. *Laboratory Animal Science 23, No. 5*

(2) As above, but with system in operation.

(3) If the method is non-traumatic to the animal, the animal should presumably show no increase in fear/anxiety, or escape reactions, or higher plasma cortisol levels when the procedure is repeated. In this test, (1) above would be repeated to evaluate habituation, and (2) above, with the animal being resuscitated with minimal trauma. With this design, we may be able to "ask" the animal to tell how it felt during (2) above. Great care would have to be taken with recompression — in fact, this test may only be applicable to evaluating gas chamber euthanasia. The possibility that the animal is rendered amnesic should also be considered.

(4) Conditioned Reflex Test. A sophisticated procedure which will tell if the animal is still conscious, may have application in future studies. A cat or dog may be quickly conditioned via an auditory signal (a bell or tone) to anticipate receiving a mild electric shock. It may be trained to escape or raise one leg in order to avoid the shock (EKG-associated tachycardia may also be monitored). Since an unconscious animal would have no overt reaction to the bell or tone, a clear behavioral index of consciousness is available. This technique will not, however, be reliable when an animal is (a) attempting to escape from the chamber (prior "shaping"/habituation may be needed), (b) semiconscious, (c) conscious but in a state of muscular rigidity. EKG or auditory evoked potential changes (necessitating the implantation of electrodes in the auditory cortex) following the conditional signal (bell or tone) may help overcome such variables.

SUMMARY

Of the physical methods, the captive bolt pistol comes nearest to being a proven method of killing dogs and cats in a manner approaching the ideal of euthanasia. It has been rejected, often with little consideration, because the sight of blood disturbs some people more than other features associated with killing. From the animals' viewpoint, its use should be considered.

Decompression does not yet appear to have been adequately investigated with respect to its effects on dogs and cats for it to be considered as an acceptable form of euthanasia. It is an efficient means of killing large numbers of animals.

Electrocution is an effective method of killing. In view of the difficulty experienced in having long-known precautions utilized in the design and operation of equipment, the method is deservedly treated with the greatest circumspection.

Among drugs which can be administered by injection only one group is considered effective and humane. This is the barbiturates of which sodium pentobarbitone (pentobarbital sodium) is the example most widely used. Properly administered, it causes death in a way generally considered to be the ideal for euthanasia. Providing the proper administration, overcoming the relatively high cost and the difficulty of obtaining supplies are the chief obstacles preventing the wider employment of barbiturate euthanasia.

Of the gases and their various combinations, only carbon monoxide from exhaust fumes is in wide use for killing dogs. Carbon dioxide is being used on a small scale to kill cats and laboratory animals while carbon dioxide with chloroform is being used in a few places on dogs and cats in the U.S.A. Seven critical areas where knowledge needs to be deepened before a more definitive assessment of available and potential methods can be made have been isolated and recommended for research deserving priority attention. The projects are:

(1) Decompression studies (page 9)
(2) T61 (page 21)
(3) Comparison of certain gases (page 39)
(4) Carbon monoxide production from charcoal furnaces (page 41)
(5) Carbon monoxide generation from chemicals (page 41)
(6) Hydrocyanic acid gas (page 41)
(7) More refined behavioral tests to complement basic physiological measurements as well as to overcome some of the intrinsic limitations of such indices of pain, distress and consciousness (page 41)

CONCLUSION

Various methods of euthanasia have been described and the need for further research and refinements where appropriate have been emphasized. This report would be incomplete, however, without stressing what the Humane Society of the United States considers to be one of the most important variables in humane euthanasia: namely, the human factor. No matter how humane a particular method of euthanasia is, in the wrong hands, it may be quite inhumane. For example, rough handling and restraint, over-crowding too many animals together in a gas or decompression chamber, inadequate routine checking and maintenance of equipment can, singly or in combination, make any given method of euthanasia distressing and inhumane. For an overly distressed or excited animal, the whole euthanasia process will take longer and often result in even more distressing side effects. No matter what agent, drug or method is used to cause death, the way in which it is used may be even more important than the relative merits of one method over others. Once a particular agent, drug or method is selected for use, two controls to reduce the probability of improper use must be instigated; namely: educational instruction of personnel and frequent supervisory scrutiny and re-evaluation; routine maintenance and "spot" tests for the working efficiency and accuracy of all equipment and monitoring devices (pressure gauges, flow meters, etc.). In some states in the United States, laws have had to be enacted to insure proper use and maintenance of such equipment, but without adequate enforcement and frequent supervisory scrutiny and "spot checks" of personnel and equipment alike, there is no way to guarantee that any given method of euthanasia is always humane. These considerations should always be kept foremost in mind in the application of current methods of euthanasia and in the development of future refinements and new methods.

Postscript

In developing more humane methods of euthanasia, and especially in developing more accurate techniques to assess the degree of consciousness, we should be mindful of the following phenomenon: that under apparently deep anesthesia, some human patients may have periods of total awareness as to what is going on in the operating room. We still have much to learn about various states of consciousness in humans and other animals and this is of particular concern in those methods of euthanasia where there is a relatively long latency between "unconsciousness" (as determined clinically or by EEG) and death, as there is more general concern over a long latency between consciousness and unconsciousness.

It is apparent from the foregoing review that there is not one ideal method of euthanasia. But on the basis of the criteria listed on page 17, sodium pentobarbital rates highest. Whenever possible, therefore, this agent should be used, since, on the basis of all available evidence to date, other techniques, especially decompression, fall short on many counts as being reliable and humane.

Reference

Mostert, J.W. (1975) States of awareness during anesthesia *Perspect Biology and Medicine*. Autumn, 68-75.

APPENDIX
Regulations and Sanctions Governing the Use of Barbiturates for Animal Euthanasia in the U.S.A.

Sodium Pentobarbital is a Schedule II substance and can be obtained only by a licensed medical practitioner, such as a physician or veterinarian.

The physician or veterinarian must apply for and be issued a Controlled Substance Registration Certificate by the Drug Enforcement Agency. The application forms are available from any of the DEA Regional Offices. Normally it requires about six (6) weeks for a veterinarian to obtain a DEA Registration Certificate.

Also in Texas, a Texas Controlled Substances Registration Certificate, issued by the Texas Department of Public Safety, is required.

Each of these Registration Certificates is issued to the veterinarian as an individual and drugs must be delivered, stored, and used only at the address shown on these Certificates.

The veterinarian or physician who obtains the controlled drugs is personally responsible and accountable for all drugs received and dispensed. Records must be maintained for at least two years and are subject to audit by DEA at any time.

Even though the veterinarian is properly registered with DEA and DPS, each drug order must be accompanied by a DEA Order Form. Each of these forms is numbered and must be accounted for. Each form is made in triplicate which is precarboned. The first two copies are sent to the supplier. Even the carbon paper must be sent with the order. The supplier is **not** allowed to fill any order unless it is properly made out and the carbon paper is intact.

Drug Security

When a shipment of controlled drugs is received, each carton should be checked for leakage, breakage, or any shortages. After the individual cases are checked, they should be resealed and a notation made on the case of the date the check was made. At this time the last copy of the DEA numbered form is completed showing the number of units received and the date of receipt.

Also, a record should be maintained on a local form. This will give you a running summary of all drugs received as well as all other information needed for an inventory or audit.

DEA requires that stocks of controlled substances be kept in a securely locked cabinet or safe. I strongly recommend that you use a combination safe for the best security of your stock of drugs. Access to the safe should be limited to as few employees as possible.

Facility and Equipment

A room which is adequate in size and basic standard equipment is essential when large numbers of dogs and cats are destroyed by the injection of pentobarbital sodium. Many times the room which was formerly used for euthanasia was converted after the old equipment was removed.

Guidelines for State Sanction

The previous page consists of the Federal Government Regulations. In your state, you may first have to introduce and enact state legislation to permit the use of sodium pentobarbital for euthanasia. In other words, the Federal Drug Enforcement Agency recognizes the present need of humane societies, but first, existing state regulations limiting the use of barbiturates may have to be changed. It should be emphasized that according to the DEA, a veterinarian need not be on the premises when the drug is received and/or administered. For further information, you may contact your regional DEA office (see list on following page).

The following bill from the state of Indiana is a useful guideline for implementing state sanction for the use of barbiturates in animal euthanasia.

House Enrolled Act No. 1136

AN ACT to amend IC 1971, 35-24.1-3 as it concerns the regulation of manufacture, distribution, and dispensing of controlled substances.

Be it enacted by the General Assembly of the State of Indiana:

SECTION 1. IC 1971, 35-24.1-3, as added by Acts 1973, P.L. 335, SECTION 1, is amended by adding a new and additional section to be numbered 1.5 and to read as follows: Sec. 1.5 Humane Societies — Limited Permits. (a) Any humane society is entitled to receive a limited permit only for the purpose of buying, possessing, and using sodium pentobarbital to euthanize injured, sick, homeless, or unwanted domestic pets and animals if it:

(1) makes appropriate application to the board according to rules established by the board; and

(2) pays to the board annually a fee for the limited permit.

(b) All fees collected by the board under this section shall be credited to the state board of pharmacy account.

(c) Storage, handling and use of sodium pentobarbital obtained according to this section is subject to rules and regulations of the board.

SECTION 2. Because an emergency exists, this act takes effect on passage.

DEA DOMESTIC REGIONAL OFFICES

Region I — Boston
JFK Federal Bldg., Rm G-64
Boston, Mass. 02203
(617) 223-2170
(Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)

Region II — New York
555 West 57th Street
Suite 1900
New York, New York 10019
(212) 971-5151
(New York, Northern N.J.)

Region III — Philadelphia
600 Arch Street
Room 10224
Philadelphia, Pa. 19106
(215) 597-9530
(Delaware, Southern N.J., Pennsylvania)

Region IV — Baltimore
31 Hopkins Place, Rm. 955
Baltimore, Maryland 21201
(301) 962-4800
(District of Columbia, Maryland, North Carolina, Virginia, West Virginia)

Region V — Miami
8400 N.W. 53rd Street
Miami, Florida 33166
(305) 591-4870
(Florida, Georgia, South Carolina, Puerto Rico)

Region VI — Detroit
357 Federal Bldg. &
U.S. Courthouse
231 W. Lafayette
Detroit, Michigan 48226
(313) 226-7920
(Kentucky, Ohio)

Region VII — Chicago
Suite 1810
219 South Dearborn
Chicago, Illinois 60640
(312) 353-7875
(Illinois, Indiana, Wisconsin)

Region VIII — New Orleans
1001 Howard Avenue
Suite 1800 Plaza Tower
New Orleans, Louisiana 70113
(504) 527-6841
(Alabama, Arkansas, Louisiana, Mississippi, Tennessee)

Region X — Kansas City
U.S. Courthouse, Suite 231
811 Grand Avenue
Kansas City, Mo. 64106
(816) 374-2631
(Minnesota, North Dakota, South Dakota, Iowa, Kansas, Missouri, Nebraska)

Region XI — Dallas
1100 Commerce Street
Room 4A5
Dallas, Texas 75202
(214) 749-3631
(Oklahoma, Texas)

Region XII — Denver
U.S. Customs House
Room 336, P.O. Box 1860
Denver, Colorado 80201
(303) 837-3951
(Arizona, Colorado, New Mexico, Utah, Wyoming)

Region XIII — Seattle
U.S. Courthouse
Room 200
Seattle, Washington 98119
(206) 442-5443
(Alaska, Idaho, Montana, Oregon, Washington)

Region XIV — Los Angeles
1340 W. 6th Street
Los Angeles, Calif 90017
(213) 688-2650
(California, Hawaii, Nevada)

There is no Region IX