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A History of Toxicant Ejectors in Coyote Control

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Abstract: Toxicant ejectors have been important in coyote control since the late 1930s when the coyote getter (CG) was introduced into Governmental wildlife damage management programs in the western United States. The CG was replaced during 1968-1970 by the similar but safer, spring-activated M-44 device that remains in use today. Significant aspects of this history include the private development and manufacture of the CG, first called the Humane Fur Getter, in the 1930s; adoption of the CG by governmental and private predator hunters; technical performance problems with CGs (and later M-44s) and their cyanide cartridges and capsules; governmental efforts to resolve these problems; development of competing toxicant ejector models, and evaluations of them compared to the CG; human injuries from CG accidents, leading to development and adoption of the safer M-44 ejector; the 1972 ban on sodium cyanide (NaCN) and other predacides; resumption of NaCN use in M-44s experimentally in 1974, followed by EPA registration in 1975; evaluation of alternate toxicants compared to NaCN; and the many minor but collectively important changes that have resulted in today's improved M-44. The invention and technical evolution of CG and M-44 devices is described chronologically, with emphasis on the development, manufacture, and use of these devices in Federal/cooperative animal damage control programs.

Key Words: canids, coyote, coyote-getter, cyanide ejector, M-44, Pocatello Supply Depot, predacide, predator control, sodium cyanide, vertebrate pest control

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INTRODUCTION

Toxicant ejectors have been important in coyote control in the United States for about 60 years. Several ejector models have been developed but only 2 have been used widely by governmental predator control workers—the CG from about 1939 to 1970, and the M-44 from 1968 to date.

CGs and M-44s are lethal devices that are set in hollow stakes driven into the ground. The tops, protruding above ground (Figure 1), are treated with attractants or lures that stimulate coyotes or other target animals to bite and pull upward, thereby triggering an ejection of toxicant. The 2 devices are similar except for their modes of ejection: the CG fires a specially loaded 38 Special cartridge containing the toxicant mixture, whereas the M-44 releases a spring-driven plunger to eject its toxic contents. The toxicant used almost exclusively in both devices has been NaCN. Potassium cyanide (KCN) also has been used occasionally.

Toxicant ejectors can be used to kill many kinds of predatory mammals but the coyote (*Canis latrans*) is and always has been the main target species in the United States. These ejectors were and are used by some private ranchers and predator hunters, but the major use always has been by governmental predator control specialists. Many papers on toxicant ejectors have been presented at previous Vertebrate Pest Conferences (VPCs), beginning with the first conference when Robinson (1962) described current coyote control methods including the CG and Crabtree (1962) discussed vertebrate pesticides including NaCN as used in the CG. Hey (1964, 1967) reported the use of CGs to control black-backed jackals and vagrant



Figure 1. A set M-44 ready for baiting. The top (capsule holder) is wrapped or covered with an absorbent material, such as cheesecloth as shown here, to which an attractant lure or scent will be applied.

dogs in South Africa, and CG use by livestock producers in Alberta, Canada was described by Dorrance (1980).

Most uses of predacides including NaCN were banned in the United States in 1972. Two years later, NaCN was re-authorized for experimental use in M-44s and, in 1975, NaCN was registered for use in M-44s but not CGs. Details of these regulatory actions, together with a discussion of related social and political considerations, were discussed at the 9th VPC by Wade (1980). The experimental programs that led to NaCN registration in 1975 were described by Clark (1976) and

Table 1. A selection of U.S. patents related to toxicant ejectors for coyote control.

<u>Date</u>	<u>Patent No.</u>	<u>Inventor</u>	<u>Title or Name of Invention</u>
July 17, 1928	1,677,394	Albin Maki	Trap Gun
Oct 25, 1932	1,884,721	George Karr	Trap Gun
Oct 27, 1936	2,059,127	Ethel P. Marlman	Device for killing fur bearing animals
Jan 31, 1939	2,145,488	Ethel P. Marlman ^a	Trap Gun
July 18, 1939	2,166,168	Ethel P. Marlman ^a	Poison mixture for trap gun cartridges
Nov 10, 1942	2,301,764	Charles L. Wainwright	Chemical-Gun Trap
July 18, 1944	2,353,798	Charles L. Wainwright	Ammunition (for Chemical Gun Trap)
Jan 30, 1945	2,368,368	Ethel P. Marlman ^b	Poison mixture for trap gun cartridges
June 5, 1945	2,377,658	Vaude L. Wintersteen	Trap Gun
Aug 31, 1948	2,448,418	Cootes and Graybill ^c	Chemical Gun Trap
Dec 21, 1948	2,456,957	Koch and Lehn ^c	Gun Trap
Aug 30, 1949	2,480,593	Moen and Graybill ^c	Cartridge for Trap Guns
June 20, 1950	2,512,252	John U. Lehn ^c	Chemical Trap Gun
July 18, 1950	2,515,447	Hershey R. Graybill ^c	Chemical Gun Trap
Nov 20, 1951	2,575,515	Hershey R. Graybill ^c	Gun Trap for Predatory Animals
Jan 6, 1953	2,624,148	Hershey R. Graybill ^c	Gun Trap and Safety Setting Device
Oct 6, 1953	2,654,178	Hershey R. Graybill ^c	Chemical Gun Trap
Sep 12, 1967	3,340,645	James L. Poteet	Trap Gun
July 9, 1968	3,391,483	Fred W. Marlman	Fluid Gun
Mar 29, 1988	4,733,493	Paul A. Edstrom ^d	Trap Gun

^a Assignor to the Humane Fur Getter, Inc., Las Animas, Colorado

^b Assignor to the Humane Coyote Getter, Inc., Las Animas, Colorado

^c Assignors to Animal Trap Company of America, Lititz, Pennsylvania

^d Assignor to United States of America as represented by the Secretary of Agriculture, Washington D.C.

Matheny (1976). A more general regulatory history of vertebrate pesticides including NaCN was presented by Ramey et al. (1992). The hazard to nontarget wildlife posed by NaCN in M-44s was compared to other vertebrate pesticide hazards by Littrell (1990).

Animal Damage Control (ADC) program¹ researchers and managers have made many efforts over the years to identify and correct technical problems responsible for poor M-44 performance. Much of this research has been described at previous VPCs by Connolly and Simmons (1984), Connolly et al. (1986), Fall (1990), and Connolly (1996). A program-wide summary of animals killed with M-44s from 1976 through 1986 was presented as well (Connolly 1988a). Development of a new marker to identify animals that trigger M-44s was reported by Burns et al. (1990). ADC program scientists also have studied chemical attractants for use as M-44 lures and in other wildlife management applications (Phillips et al. 1994, Kimball et al. 2000).

¹ The Federal/cooperative ADC program has been reorganized or renamed often. Some of its names over the years include Predator and Rodent Control (PARC); Division of Wildlife Services (DWS); Animal Damage Control and Wildlife Services (WS) since August 1997. The program was administered by USDA Bureau of Biological Survey before 1941, USDI Fish & Wildlife Service, Bureau of Sport Fisheries & Wildlife, from 1941 to 1985, and USDA Animal & Plant Health Inspection Service (APHIS) since 1986. All mention of government hunters and governmental programs in this paper refers to the same program.

The sole manufacturer of M-44 ejectors and cyanide capsules is USDA APHIS's Pocatello Supply Depot (PSD) in Idaho. A description of the PSD, including specifics of M-44 production and sales, was presented at the 15th VPC by Packham (1992).

This paper reviews the development and evolution of toxicant ejectors for coyote control, concentrating on ejector devices used in Federal/Cooperative predator damage control programs in the United States. My chronological presentation starts with the CG in the 1930s, followed by the development and evaluation of competing ejector models in the 1940s, and on through the 1960s transition to the safer M-44 ejector. M-44 improvements since 1970, when the M-44 officially replaced the CG in governmental control programs, are summarized together with the evolution of toxicant cartridges and formulations from 1939 to date.

The story of toxicant ejectors in predator control cannot be fully told in this brief paper. Readers who wish to dig deeper into this history may find useful leads in the compilation of patents related to toxicant ejectors (Table 1) and in *Literature Cited*.

THE COYOTE GETTER

Toxicant ejectors did not exist before Fred Marlman invented the CG, but set guns were well established earlier. Set guns, also known as trap guns, functioned much like the CG or M-44 except, when discharged, they fired a bullet rather than a toxic chemical. Some set guns

were placed in the ground, like the later cyanide ejectors. Two set guns (Maki 1928, Karr 1932) are included in my list of patents (Table 1) because of their similarity to the later CG and M-44. The Maki patent, for example, described a trap gun primarily for destroying predatory and other animals. Set in the ground, it had an exposed top with a bait attractively displayed to animals. According to Maki, should an animal seize the bait in his mouth and tug at it, he will cause the firing mechanism to explode the shell and the ‘cartridge’ therefrom to pierce the head of the animal thus wounding or killing him. Similarly, the 1932 Karr patent described a trap gun which is anchored, baited, and cocked, and fires a bullet upwardly into the brain of any animal which takes the bait in his mouth and pulls upon it.

From these descriptions, it is clear that the concept of a baited ejection device that attracts animals to pull and, in so doing, to destroy themselves, predates the CG. But because it ejected toxic powder rather than a bullet, the CG was safer and better suited to widespread application.

The Humane Coyote Getter (HCG; Figure 2) was not only the first toxicant ejector for predator control, but the first one to be produced commercially. Its exact date of invention is undocumented. The earliest patent (Marlman 1936; Table 1) resulted from an application submitted in 1934; this application cited an earlier one filed in 1931. The 1936 Marlman patent was supplemented by three others, two in 1939 and another in 1945 (Table 1). All of these were filed in the name of Ethel P. Marlman, the wife of inventor Fred Marlman.

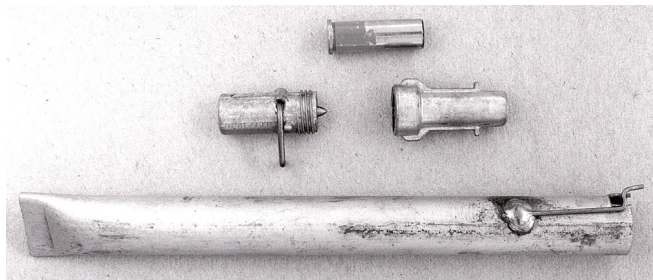


Figure 2. Coyote getter components (clockwise from top): cyanide shell, shell holder, stake, and firing unit. The shell is 29mm long.

Late in the 1930s, Mr. and Mrs. Marlman established a company, “The Humane Fur Getter, Inc.,” at Las Animas, Colorado to manufacture CG devices and cartridges. The company name changed to “The Humane Coyote Getter, Inc.” before 1945. The Las Animas factory employed up to 15 people in its heyday (Marlman 1987). The firm later moved to Pueblo, Colorado, where it continued in operation into the 1990s. In later years, it was managed by Ray Hall, the Marlman’s son-in-law.

The CG was one of those rare developments in wildlife damage management— a true innovation that had an immediate and lasting impact on damage control practice. CGs came into widespread use for coyote

control by 1940, with government hunters and researchers soon documenting its practicality and effectiveness. Examples of early studies include an attempt to determine how many CGs one hunter could use effectively (Sears 1941), winter performance of “tree-type” CGs (Robinson 1942), and CG performance compared to steel traps (Robinson 1943).

Few objective field assessments of CGs have been published. However, Robinson (1943) presented an excellent comparison of CGs and leghold traps for coyote control. Robinson worked with government hunters using CGs and foothold traps for 1 year in Wyoming, Colorado, and New Mexico. He found when trapping conditions were favorable (June to October) the coyote catch with traps exceeded that with CGs, but during the remaining 7 months the reverse was true. The CG was most superior when frozen ground impeded the action of traps but not CGs. CGs were much more selective than traps for target canids, being less destructive to small mammals, birds of prey, ground-nesting birds, deer, antelope, and domestic sheep but more destructive to dogs, bears, and cattle. Disadvantages of CGs included potential hazard to users and other humans, loss of pelts because not all coyotes were recovered and much of the fur spoiled in warm weather, and equipment defects, particularly with the cyanide cartridges. Overall, Robinson concluded that the CG should be considered as an adjunct to but not a replacement for the steel trap.

Initial reactions of government hunters to CGs tended to be lukewarm. For example, the Colorado District, Bureau of Biological Survey, delegated 4 hunters to use CGs exclusively in lieu of steel traps in Fiscal Year 1940. The annual report for that year stated, “To date the results obtained from the humane fur getters have not been particularly encouraging; however, we are hopeful that as the hunters become more proficient... better results will be obtained” (Quick and Kelly 1940).

This is just what happened. Two men using CGs in Moffat County, Colorado during August–November 1941 recovered 326 coyotes. Recovery distances (from fired ejector to dead coyote) averaged 46 yards (range 3 to 300 yards). Coyote pups averaged 39 yards, mature 56 yards, and old coyotes 78 yards. Six of the old coyotes were “peglegs” (meaning that they previously had been caught in steel traps and had lost one or more feet while escaping). In addition, 106 coyotes believed to have been killed were not recovered for various reasons, including limited search time and theft. A few coyotes survived the effects of the poison and 7 were missed because of defective shells (Sears 1941).

By 1944, Colorado’s government hunters were taking more coyotes with CGs than by any other method. These results were due to increased efficiency of CG shells, increased numbers of CGs in use, improved methods of use, and better attractant scents. One hunter watched a coyote approach a CG. “The coyote went direct to the station and made almost a complete circle around one of the coyote getters, about 5 feet from it.

Then the coyote went straight to the gun and, from the motion of his head, it looked as though he was licking the gun. The coyote jumped into the air and ran straight 62 yards, then fell. It was not dead, but its hind quarters were paralyzed. It tried to get up but could not and it died in about 3 minutes. This coyote was a male and of normal size" (Hill 1944). Similar observations were reported from other states.

In time, some government hunters became CG specialists, finding that they could take more coyotes with CGs than with other methods. One example of this is the record catch of 522 coyotes in a single month (October 1946) in part of Maverick County, Texas by A. B. Bynum, Assistant District Agent at Uvalde, Texas. These animals were captured by the exclusive use of CGs, of which Bynum had as many as 325 in operation at one time. He made 3,000 or more CG sets and resets during the month. One day he made 160 sets on a 39-mile line; next day, he recovered 46 coyotes off that line. During his best 3 days he took 119 coyotes (Green 1946). Bynum reworked part of this same area in January 1947, taking an additional 340 coyotes (Young and Jackson 1951).

By the late 1940s, the CG was a well established coyote control tool. It proved to be more useful than steel traps in some situations, was more humane, and was effective against some trap-wise coyotes (Young and Jackson 1951). These authors provided detailed instructions for safe and effective use of the CG, which continued to be among the most important coyote control tools until the late 1960s when it was replaced by the M-44.

COMPETITION FOR THE COYOTE GETTER

Marlman's successful CG business, which began in the late 1930s, soon attracted competition. Several other ejector models were patented between 1942 and 1953 (Table 1) and some of them became available commercially. The first serious contender was the Wainwright getter, which was evaluated in comparison with the Marlman CG by a U.S. government researcher near Ft. Collins, Colorado (Sears 1945). Sears concluded that the Wainwright gun was less useful than the CG for governmental control work, being more complicated, more expensive, more prone to malfunction, and more dangerous to humans than the CG.

Research assessments of the Wainwright gun continued in 1946 and 1947 (Cummings 1948). In addition to the Marlman and Wainwright getters, Cummings evaluated two other new models— a Wintersteen gun and the Horne "Allways Chemical Gun." The Wintersteen unit enclosed a Marlman firing unit within a cup-like holder that was intended to prevent cattle and other nontarget animals from firing the gun.

The Allways Chemical Gun was much smaller than other getters. Rather than being set in the ground, the Allways gun was designed for attachment to a tree, fence post, log, or stake by means of a stiff wire that could be

hammered into wood. None of these new ejector models performed as well as the Marlman CG, so Cummings' findings are not discussed further here.

Yet another competing ejector model was the "Newhouse Safety Coyote Killer" made by the Animal Trap Company of America, Lititz, Pennsylvania. I have found no research report on the Newhouse coyote killer, but it may have been tested by the Denver Wildlife Research Center (DWRC); a cache of these ejectors was discovered in storage at the DWRC in the 1980s. Bacus (1969a) reported that the relatively heavy Newhouse device was never accepted to any extent in the West. It was more expensive than the Marlman CG, unwieldy and difficult to set and maintain.

A well-known maker of predator lures, Jim Mast, recorded his impressions of the state of the art of cyanide guns in 1947. He wrote that, in addition to Marlman's Humane Coyote Getter, two other kinds of cyanide guns were available: the Newhouse coyote getter and the more expensive Wainwright gun. According to Mast (1947), Fred Marlman was selling more guns than his competitors; the Fish and Wildlife Service (FWS) setup in Idaho (PSD) had bought 50,000 cyanide guns since 1941. "The Lord only knows how many guns Fred has disposed of since he placed his device on the market" (Mast 1947). Years later, Fred Marlman's son wrote that CGs were sold by the hundreds of thousands to both the Fish and Wildlife Service and private trappers and ranchers (Marlman 1987).

From the information I have seen, it appears that the Marlman CG did not receive serious competition from other ejector models, at least in governmental control programs. The Marlman CG was phased out only after FWS managers decided in the 1960s to stop using cartridge-type ejectors because they were too dangerous to humans.

COYOTE GETTER ACCIDENTS

From the earliest days of the CG, users were aware of the hazards posed by this device. The primary hazard resulted from forceful ejection of the top wad and cyanide mixture by the primer and powder charge in CG cartridges. Such ejection was particularly hazardous to people who were unfamiliar with CGs— most of the general public, in other words. The first published assessment of CGs in coyote control (Robinson 1943) noted that the units could be discharged accidentally by the trapper or by others with possibility of a severe injury or even a fatality. No serious accidents had occurred, Robinson wrote, due to careful placement of CGs, posting of warning signs, and provision of safety instructions to users.

Serious accidents did occur later. The earliest, documented human injury known to me occurred in 1945. It was not caused by a Marlman CG but by a Wainwright gun in the research trial of Sears (1945). A woman who was on a picnic in Sears' study area accidentally discharged an ejector. The explosion broke

the skin of her palm and imbedded the paraffin and wadding in her hand. The wound bled profusely and no effect was felt from the cyanide. A doctor removed the wadding and paraffin 5 days after the accident, and the patient recovered completely in a few months. Sears (1945) noted that the Wainwright cartridges contained about 6 times as much gunpowder as Marlman's CG shells, making the Wainwright unit considerably more dangerous.

In 1946, the U.S. government stopped using Marlman's cartridges and began making its own CG ammunition at PSD. PSD cartridges were sealed with a substantial plug of roofing tar that was ejected very forcefully when the cartridge fired. One of these cartridges caused a 15-year-old boy to lose an eye when he discharged a CG on a North Dakota farm in 1959. The CG was one of 8 that had been set by a FWS mammal control agent, at the farmer's request, to protect turkeys from fox predation. Appropriate warning signs had been posted, but the boy apparently caused the CG to fire by stepping on the trigger mechanism. Ejected material struck him in the right eye, necessitating hospitalization and subsequent removal of the eye. A claim for damages was filed. The case came to trial in U.S. District Court, Fargo ND, in April 1963 (Civil No. 3918), resulting in a finding against the government. Damages totaling \$65,000 were awarded.

In correspondence related to the North Dakota case, Acting DWRC Director Jack Welch reported a somewhat similar accident that occurred in Colorado in 1961 (Memorandum to FWS Regional Director, Minneapolis MN, July 23, 1962). A Predator and Rodent Control (PARC) program employee unintentionally kicked a CG while walking. It fired, and the top wad struck him under the chin causing severe lacerations. The employee was hospitalized for observation for a few days, but no further damage was reported.

In all, at least 14 human injuries due to CGs were documented after 1959 (Train 1975). I have seen detailed reports for only 5 cases including the 2 described above. The other 3 accidents involved CGs set by private persons rather than government employees. Two similar accidents occurred in Kansas when persons touched or attempted to pick up CGs. Both CGs discharged and drove ejected materials into the victims' hands. Each of the injured parties immediately realized that he had fired a cyanide gun and promptly sought medical attention, which included treatment for cyanide poisoning. One injured person was hospitalized for 6 days and the other for 1 day (Poskin 1973).

The worst CG accident on record—the only accident ever to cause a human fatality—occurred about 30 miles southwest of Fort Stockton, Texas in 1966. One man in a party of 3 land surveyors touched a privately-set CG, which exploded and hit him in the hand. The injured man saw a doctor approximately 1 hour after the accident, but was not treated for cyanide poisoning as neither the victim nor witnesses realized that the exploding device

was a cyanide gun. The victim died in a Fort Stockton motel room about 3 hours after the accident. The acting coroner concluded that "...the cause of death was by cyanide poisoning following a penetrating injury to the left hand by a cyanide loaded pellet" (Willey 1966).

Many potential human injuries from CGs have resulted from accidental discharges when the units were being set or serviced. This is true for M-44s as well. All experienced users have experienced such discharges, which rarely cause harm if recommended safety procedures are being followed. Unlike the CG, the main hazard from accidental M-44 discharge is from cyanide which, if ejected into the eyes, may cause caustic burning and temporary blindness. Second to eye injury, the next greatest hazard is from overuse of the cyanide antidote, amyl nitrite, which is carried by all government employees who use M-44s ('M-44 Accidents.' Memorandum, Acting Western Regional Director to ADC State Directors, Western Region, November 27, 1989). As far as I know, no person has been seriously injured by an M-44.

Incidentally, the amyl nitrite antidote kit for cyanide poisoning has been used by government hunters for at least 40 years (Composition of coyote getter chemical shells. Circular Letter, C. C. Presnall, Chief, Predator and Rodent Control [PARC] to Regional Directors, et al., October 4, 1962; 2 pp.).

THE QUEST FOR A SAFER COYOTE GETTER

For CGs used in governmental predator control, the initial approach to mitigating hazards was training of CG users to use CGs safely, to select placement locations carefully to avoid or minimize exposure of untrained persons, and to post warning signs where CGs were set (Robinson 1943).

Safety enhancement through technical modifications of ejectors and cartridges also was attempted as early as 1942. The first experiments along this line tested cartridges containing reduced amounts of cyanide, with the object of making CGs less dangerous to cattle. Cartridges containing only ½ as much cyanide as the standard load were almost as effective against coyotes. Cartridges containing only ¼ of the standard charge were less effective (Robinson 1956). The ½ charge cartridges were used for a while in control operations. As expected, they appeared to be safer than standard CG shells but, according to Bacus (1969a), they also were less effective in the field and therefore weren't accepted to replace the standard load. A similar attempt to minimize hazards of the Newhouse Safety Coyote Killer by limiting toxicant content and explosive force to the minimum necessary for coyote-killing efficacy was reported by Gerstell (1946).

Around 1960, researchers developed a crossed-wire coyote-getter guard to disperse the cyanide charge and retain the wads that otherwise would be ejected when the CG was discharged. This modification clearly reduced the hazard (Wildlife Research Laboratory 1960, 1962), but it was not popular with field personnel, who believed

that it reduced efficacy against coyotes and made the CG harder to set and maintain. Not surprisingly, they objected to its use (Fitzwater 1962, 1964). Bacus (1969a) too noted that this guard reduced the accident potential but was unacceptable because it reduced CG effectiveness. The CG guard received very little use.

Yet another research development in the early 1960s was a polyethylene capsule to enclose the cyanide mixture within the 38 Special CG cartridge. The capsule top was designed to open without ejecting any plastic material when the cartridge was fired, thereby eliminating the top wad ejection which, "...in the present CG, constitutes a serious hazard to those who may accidentally set off the device" (Wildlife Research Laboratory 1960). Field tests reportedly were scheduled but I have found no record of them, nor any indication that this modification was incorporated into CG cartridges made at PSD. In 1982, however, I visited the HCG firm in Pueblo and learned that they were manufacturing CG cartridges of this or a similar design (for export only). HCG, Inc. had been producing these safer cartridges for some years.

Aside from these potential fixes for the CG, U.S. Government personnel began work toward a spring-activated cyanide ejector early in the 1960s. According to Fitzwater (1964), the spring-ejection principle was first suggested by James Poteet, a PRC Mammal Control Agent stationed at Midland, Texas. Demonstrations in 1961, followed by further development, led to successful field tests in 1963-64. Based on these results, Fitzwater (1964) recommended that the CG be replaced operationally with this new device as soon as was practical. Much more research and development work would be needed before this could happen. Meanwhile, the government proceeded early in 1965 to file a patent application in Poteet's name. The patent was issued in 1967 (Table 1).

By 1966 at least 3 governmental predator control agents were experimenting with spring-activated ejectors— J. L. Poteet, V. Keenan, and R. McDonald. Each of them demonstrated their equipment at a Coyote Getter Symposium in San Antonio, Texas in November 1966. At this meeting it was reported that the Southwest Research Institute (SRI) had been developing a liquid-ejecting coyote getter under contract with the U.S. government (SRI 1966). This research did not lead to a satisfactory product (Conversion to spring-activated coyote getter. Memorandum, H. S. Ford, Regional Supervisor, DWS to Regional Director, BSWF, Portland, Oregon, May 15, 1969; 2 pp.). At about this same time, however, the HCG firm developed and marketed a Liquid Humane Coyote Getter (Bacus 1969a; HCG n.d.). This undoubtedly was the "Fluid Gun" described in Fred Marlman's 1968 patent (Table 1). It was filled with KCN solution in the field by means of a hypodermic syringe (Personal Discussion, Ray Hall, HCG, Inc., Pueblo,

Colorado with G. Connolly, July 21, 1982). The Liquid Getter was effective but was believed to be more hazardous than the standard CG and therefore was not approved for use by government personnel (Bacus 1969a).

Governmental predator control agents continued to use CGs while research proceeded on spring-action ejectors. CG accidents also continued to occur, prompting FWS leaders to direct that, pending deployment of the non-explosive ejector, field personnel would use a safer, interim cartridge. This interim cartridge used only the pistol primer as propellant, omitting the powder charge that was used in standard loads, and contained only $\frac{3}{4}$ as much toxicant as the standard cartridge. Immediate, mandatory use of this reduced-power cartridge was required, and the change-over was to be completed by August 1, 1967 (Interim Coyote Getter Cartridge. Memo, FWS Acting Assistant Director to Regional Directors, Portland OR, Albuquerque NM, and Minneapolis MN, May 29, 1967).

This interim cartridge was essentially the same as the reduced-power CG loads tested in 1942-43, as described previously. The results this time around also were about the same as they had been 25 years earlier. The change-over was completed as ordered, but field men soon reported that the new cartridges malfunctioned or were less effective than the standard load. The new policy was reversed, and the use of standard CG cartridges was reauthorized before year end.

By 1966, Fitzwater had moved on to other duties but Vic Keenan and others carried on the work to perfect a spring-action cyanide ejector. These efforts were successful. By September 1967, when the Poteet patent was issued, a 'Keenan model' ejector (not to be confused with the later Keenan M-50) had been produced in large quantities for field testing (Bacus 1969a). This so-called 'Keenan model' differed from the ejector described in the Poteet patent; in particular, the Keenan device used a cartridge-like cyanide capsule inside a capsule holder like the CG, whereas Poteet's patent featured a reloadable top rather than the capsule and capsule holder. Because of this difference, government officials reviewed the patent status of the Keenan device prior to large-scale deployment. Following an examination, the Branch of Patents, Office of the Solicitor, U.S. Department of the Interior (USDI), concluded that the new model was covered by the Poteet patent (Memo, Field Solicitor, Albuquerque NM to BSWF Regional Director, Albuquerque NM, October 12, 1967). As Mr. Poteet had granted royalty-free use of his invention to the U.S. government, this opinion cleared the government to proceed with deployment of the new ejector. The new equipment soon was being produced and distributed from the PSD. Mr. Poteet, meanwhile, established the M-44 Safety Predator Control Company in Midland, Texas to

make and sell M-44 equipment to persons who were not affiliated with the Federal/Cooperative ADC program.²

Large-scale field tests of the 'Keenan model' ejector during 1967-68 yielded results comparable to that of the CG (Bacus 1969a). Continued favorable results in 1968-69 led to a decision in May 1969 that the spring-activated device, now called the M-44, would replace the CG in BSW-supervised control programs. The target date for full conversion was January 1, 1970 (FTS Teletype, Acting Director BSW to Regional Directors, Portland OR, Albuquerque NM, and Minneapolis MN, May 21, 1969; 3 pp.).

This target date was not met, but another directive in September 1970 was more successful: "Upon receipt of this memorandum, the M-44 replaces the Coyote Getter as a control device" (BSFW 1970). The conversion was essentially complete by year end. Except for limited research in later years, the use of CGs in Federally-supervised coyote control programs officially ended in 1970.

Subsequent experience confirmed that M-44 efficacy in killing target predators was equal to that of the CG, and M-44s killed fewer nontarget animals. Data collected during 1965-71 from coyote census lines in Texas showed recovery rates of 11.3 and 11.5 coyotes per unit year, for CGs and M-44s, respectively (1 unit year = 1 device set for 365 nights). But CGs killed 1.4 nontarget animals per unit year, much higher than the 0.3 nontargets per unit year for M-44s. About 97.5% of animals recovered from discharged M-44s were target canids (coyote, dog, fox); the comparable value for CGs was 90.6% (USDI 1978:55).

In addition, the M-44 was safer. A graphic demonstration of this was provided by a FWS witness, Joe Packham, during EPA's M-44 registration hearings in August 1975. Mr. Packham discharged a CG and then an M-44 while holding 3 sheets of paper above each device. The CG penetrated all 3 sheets of paper and punctured a hole in the hearing room ceiling, whereas the M-44 failed to penetrate the paper (Pesticide Chemical News 1975).

Based on evidence presented at these hearings, EPA concluded that NaCN should be registered for use in M-44s (Train 1975). Reregistration of the CG, which had been cancelled in 1972, was not considered in 1975 because no one applied for CG registration at that time. To the best of my knowledge, no serious attempt to reregister the CG has been made since 1972. However, a 1982 study showing the mechanical performance of CGs to be better than that of M-44s (Connolly and Simmons 1984) generated renewed interest in CG reregistration as an option for solving or circumventing M-44 performance problems (Further work on the M-38, coyote-getter. Memo, FWS Associate Director, Wildlife Resources to Associate Director, Research, July 16, 1982). The CG

option was considered again in 1988 (Options for registration of the coyote getter. Memo and Briefing Paper, Chief, Predator Control Research to Director, Denver Wildlife Research Center, December 16, 1988). But, on both occasions, decision-makers elected not to pursue CG registration. It was deemed more expedient and cost effective to fix or improve the M-44 that already was registered.

THE M-44

The persons who coined the term 'M-44' in the 1960s didn't document its meaning, as far as I know. Bacus (1969a) indicated that the new mechanical ejector was named 'M-44' to differentiate it from previous designations and to insure that it was not confused with the explosive CG. The '44', I believe, refers to the size and shape of the M-44 cyanide capsule which evolved from the very similar 44 Magnum cartridge case.

The M-44 consists of 4 components—ejector mechanism, cyanide capsule, capsule holder, and stake (Figures 3, 4, 5). Each component has changed in various ways through the years. Most changes have been made with the object of improving M-44 performance or ease of manufacture. Some components have changed many times since the 1960s.

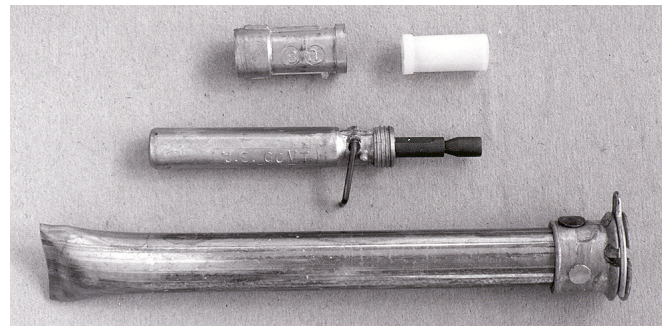


Figure 3. M-44 cyanide ejector components as used about 1970-1980 (from top): capsule holder, polyethylene cyanide capsule, ejector, Leyerly-top stake. The capsule is 27mm long.

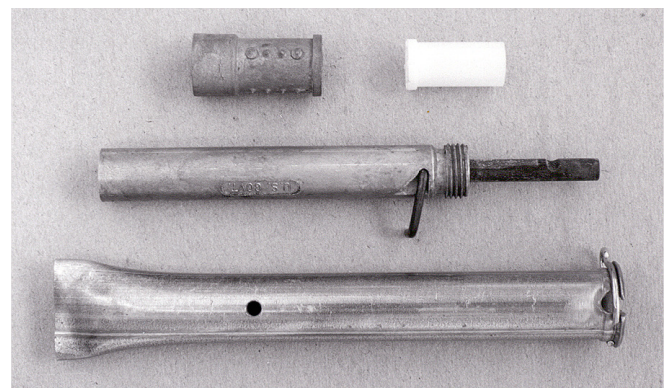


Figure 4. M-50 cyanide ejector components as used 1979-1983 (from top): capsule holder, polystyrene cyanide capsule, ejector, stake. The capsule is 27.5mm long.

² In 1984, Mr. Poteet sold his company to former PSD manager J. Bean who operated the business as the 'M-44 Company' at Fredericksburg, Texas into the 1990s.

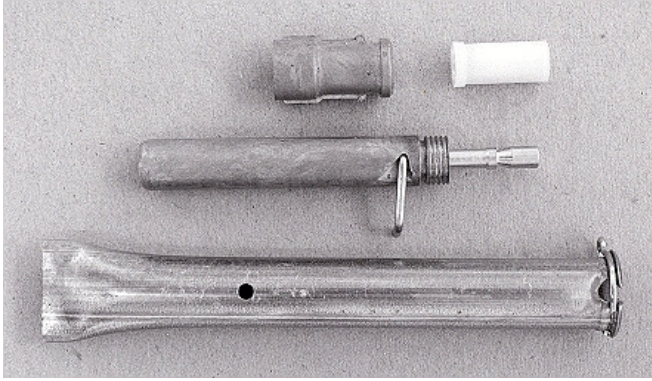


Figure 5. M-44 cyanide ejector components as used after 1985 (from top): capsule holder, polyethylene cyanide capsule, ejector, stake. The capsule is 27mm long.

Whatever its technical details at any given time, each M-44 from the 1960s to date has included the same fundamentals— a toxicant mixture within a plastic capsule that is expected to preserve the toxicant in dry, powder form until ejected, a capsule holder that positions the capsule atop the ejector, a spring ejector mechanism that expels the toxicant when triggered, and a stake to hold the other components in position at the desired field location until a target predator pulls at the device and triggers an ejection. The M-44 has been in a continuous state of evolution since the 1960s. Therefore, the M-44 designation does not refer to one specific device with precise specifications but to all spring-activated cyanide ejectors used in coyote control over the past 35 years. Older equipment rarely has been recalled from the field when improved components were introduced, so the M-44 devices in use at any particular time and place have been an assortment of newer and older components. The M-44 system probably will continue to evolve as long as it remains in use.

Though the M-44 has evolved over time, its outward appearance has changed little. Many improvements or changes have been so inconspicuous that they are apparent only to expert M-44 users if at all. No one working in coyote control today is personally acquainted with all the M-44 variations that have occurred over the years. In this paper I describe only the most significant variations known to me. The evolution of metal parts (ejector, capsule holder, and stake) is discussed here; variations in M-44 cyanide capsules are detailed later— see *Toxicant Cartridges and Formulations*.

As noted earlier, M-44s were phased gradually into Federally-supervised coyote control programs in the late 1960s. CGs were withdrawn as M-44s became available, so that the M-44 had essentially replaced the CG by the end of 1970. According to Bacus (1970), approximately 50,000 M-44 units were issued "...during the last season" (probably 1969-70). Lee Bacus, District Agent for the Division of Wildlife Services (DWS) in Colorado, was the principal manager and chief spokesman for the transition to M-44s. He wrote and distributed several

"Field Training Aids" to introduce the new ejector unit to field personnel (Bacus 1969b, 1969c, 1970). These publications provided good descriptions of contemporary M-44 equipment, together with detailed instructions for use. They also explained the differences between CGs and M-44s and detailed the advantages of the new unit.

Despite Bacus's vigorous advocacy, the M-44 met resistance from the start. "The M-44 is performing to a great extent in direct degree to the interest and intelligence with which it is being used in the field. Some fieldmen are openly prejudiced against the M-44, partly because it is new, but mainly because it requires effort to place and maintain" (Memorandum, L. C. Bacus to Manager, PSD, December 1, 1969; 4 pp.). A few months later, he commented that "...one of the greatest problems we have to contend with in conversion to the M-44 is the field man's resistance to change" (Memorandum, L. C. Bacus to Manager, PSD, May 12, 1970; 4 pp.).

Little more than a year after the changeover to M-44s was completed, the use of NaCN and most other predacides on Federal lands and in Federal programs was stopped by Presidential Order 11643, issued February 8, 1972. EPA quickly acted to cancel existing predacidal use registrations for NaCN, Compound 1080, and strychnine (Ruckelshaus 1972). One result was an abrupt withdrawal from the field of all M-44 ejectors and cyanide capsules. At the same time, efforts to correct problems with the new ejectors also came to a halt, leaving the problems unresolved.

The 1972 predacide ban generated a firestorm of opposition from livestock producers who felt that their views had not received fair consideration in that decision. One result of the ensuing controversy was a decision to resume the use of M-44s. Experimental M-44 use was authorized in 9 experimental use permits (EUPs) granted by EPA in 1974-75 (Matheny 1976). The USDI FWS experimental program used M-44 equipment made at its PSD while the state programs, with minor exceptions, used M-44 devices and capsules from Poteet's M-44 firm in Midland, Texas. The FWS-supervised program, conducted in 11 states, used more M-44s and took more target canids than all 8 state programs combined. FWS was permitted to use 56% of the 35,850 M-44 devices authorized in all 9 EUPs, and FWS-supervised personnel took 69% of the 5,986 target canids killed in all 9 programs (Matheny 1976).

Following these experimental programs, FWS also provided most of the technical data to support M-44 registration. FWS formally applied for registration in July 1975 (USDI 1975). Following formal hearings, EPA decided in September that NaCN should be registered for this purpose (Train 1975). The FWS registration, number 6704-75, was approved by EPA on November 3, 1975. Six registrations for state certified-applicator programs in Wyoming, Montana, Oregon, California, South Dakota, and Colorado also were approved in November and December 1975 (Matheny 1976). In addition, state certified, rancher applicators in Texas were authorized to

use M-44s under a registration granted in March 1976 to the M-44 Safety Predator Control Company, Midland, Texas. The FWS registration has remained in effect continuously since 1975; in 1987 it was transferred to USDA APHIS with the ADC program. Other registrations have come and gone over the years. In December 1979 there were 13 (Matheny 1980). At present (February 2002) there are 8 registrations for M-44 Cyanide Capsules (Active M-44 registrations. E-mail memorandum, J. D. Eisemann, NWRC to G. Connolly, February 19, 2002; 2 pp.).

Despite the wave of enthusiasm that accompanied the resumption of M-44 use in the mid-1970s, the coyote take with the newly-registered M-44s was much lower than that recorded before 1972. Compared to the annual, west-wide take of 21,000-25,000 coyotes by government hunters using CGs and M-44s in 1970-71 (USDI 1975:88), the annual kill during 1976-1979 varied between 6,000-8,000 with an apparent decline of about 1,000 coyotes each year after 1977 (Connolly 1988a). The decline, I believe, resulted from reduced M-44 use as increasing numbers of field men experienced significant malfunctions, causing them to scale back their use of M-44 devices.

In response to this crisis of confidence, ADC program leaders turned again to Vic Keenan, who had played a key role in M-44 development during the 1960s. In 1977, Keenan was detailed to a new M-44 improvement project. The result was a completely new ejector system (Keenan 1979). It was, in effect, a bigger M-44 using a 0.50-inch-diameter capsule; a longer, heavier ejector with stronger spring; and a new stake design (Figure 4). This overgrown M-44 soon was being called the M-50 to differentiate it from the older M-44. The M-50 ejector body was made of cast aluminum, rather than #3 zinc alloy as used in the M-44. Neither cyanide capsules nor any metal parts were interchangeable between the M-44 and M-50.

Keenan's handmade prototypes performed well in field tests, so the M-50 went into mass production at PSD early in 1979 alongside the M-44 which also remained in production. M-50s were distributed promptly, and ADC field men soon experienced problems with them. Many M-50s failed to eject when coyotes pulled them. Compared to the zinc alloy M-44, the aluminum M-50 ejector turned out to be more susceptible to corrosion and more prone to malfunction. My impression from conversations with ADC field men around 1980-1982 is that the use of M-50s almost stopped; users returned to the older M-44 or quit using NaCN ejectors altogether.

By 1980 it was clear to ADC program leaders that the M-44 situation had gone from bad to worse. PSD now was making two different ejection systems, neither of which performed satisfactorily. The increased volume and urgency of field complaints eventually resulted in creation of an M-44 Study Team to review the situation and develop a plan to achieve acceptable M-44 performance (M-44 Study Team. Memorandum, Acting

Associate Director, FWS to Regional Directors, June 26, 1981; 2 pp.).³

The team met promptly to plan a course of action. Our perception was that ADC field personnel already had overwhelmingly rejected the M-50. A telephone survey of field men confirmed this; 91% of 254 respondents were using M-44s; only 9% were using M-50s (Personal communication, P. Edstrom, FWS, Washington DC to G. Connolly, DWRC, Twin Falls, Idaho, September 9, 1981). Nevertheless, the Study Team felt that more definitive data were needed to document alleged performance differences between the M-44 and M-50.

The Team decided upon a comparison of the mechanical reliability of the 2 models side by side in a rigorous research evaluation. The results of this evaluation would support a decision to abandon the inferior unit so that subsequent improvement efforts could concentrate on the better one. The CG also was included in this study because many field men had suggested that it would outperform both the M-44 and M-50.

The study was carried out near Port O'Connor, Texas early in 1982. This gulf coastal site had been selected because it was known to be a difficult environment for M-44s. Cyanide ejectors, 120 of each model, were set inside a fenced plot. They subsequently were test-pulled and reset on 7- or 21-day cycles until large numbers of some ejector models failed to eject satisfactorily. The results confirmed that the M-44 was superior to the M-50. In addition, M-44 performance was found to improve significantly when the ejector plungers were shortened, as had been suggested by field personnel. Also as expected, the mechanical reliability of the CG was superior to that of any spring-activated ejector (Connolly and Simmons 1984).

Based on these results, the M-50 was phased out and the plungers were shortened on all M-44s made at PSD after mid-1982. The excellent performance of CGs led to consideration of CG reregistration, as discussed later.

In addition to hands-on testing of the equipment, as described above, the M-44 Study Team also wrote detailed technical instructions that, if followed in the field, would help ADC Specialists obtain the best possible M-44 performance. These instructions, initially titled "Guidelines for M-44 Users," were modeled after the earlier Field Training Aids of Lee Bacus (1969b,c; 1970). They incorporated many practices suggested by successful M-44 users in western ADC programs. The "Guidelines for M-44 Users" were revised many times following their original appearance (Memorandum, M-44 Study Team to Chief, Division of Wildlife Management, FWS, August 28, 1981). The latest version, "M-44 User

³ Original team members included P. Edstrom, Staff Specialist, FWS Division of Wildlife Management, Washington D.C. (Chairman); N. Johnson, ADC Supervisor, FWS Region 2, Albuquerque, NM; J. Bean, Manager, PSD, Pocatello, ID; and G. Connolly, Research Biologist, DWRC, Twin Falls, ID.

Tips” (Connolly and Blom 1996), is used in M-44 training nationwide.

After the M-44 improvements made in 1982, as detailed above, the next major change occurred in January 1985 when the original M-44 ejector, now called the “Poteet” model, was replaced by a new one. This change was made because the original dies, that had been used since 1967 to cast ejector bodies and capsule holders, were worn out. When new dies were ordered, the ejector body and capsule holder were redesigned to eliminate flaws in the original design. The new ejector body was 0.375 inches longer to provide room for a longer, stronger spring and the body walls were thickened. Inside the ejector, a straight-wall design replaced the ‘bottleneck’ where breakage had been common in the original model. The plunger diameter was reduced in its midsection to allow better trigger engagement, and the trigger was enlarged to provide more sear surface. The body, plunger, trigger, and spring were zinc plated to reduce corrosion (M-44 Improved Model. Memorandum, P. Edstrom, PSD to Regional ADC Supervisors, January 4, 1985; 3 pp.).

This improved ejector (Figure 5) became known as the ‘Edstrom’ model after its designer, PSD Manager Paul Edstrom. All M-44 ejectors assembled at PSD since January 1985 have been this model. Production of the “Poteet” M-44 at PSD ceased at that time. The hundreds of thousands of “Poteet” ejectors then in the field were not recalled, but were intended to be replaced gradually over time by the new model.

The new ejector was released for field use early in 1985, and field personnel soon reported problems with it. In particular, the plungers and ejector bodies were breaking, apparently because of the stronger ejector spring. Laboratory evaluation confirmed this: new ejectors failed due to breakage after an average of 15 ejections, whereas old (Poteet style) ejectors on average gave 30 ejections before they failed. Thanks to a suggestion from A. J. Kriwox, DWRC technician who had participated in laboratory evaluation of the 2 ejectors, the breakage problem was solved simply by placing a neoprene O-ring on the plunger, prior to assembly of the ejector, so as to cushion its stop after ejection had occurred. This simple modification made the new ejector into a lifetime tool. Ejectors equipped with the O-rings were still functioning normally after having been fired 100 times (O-ring Shock Absorber Increases M-44 Life. Memorandum, G. Connolly, DWRC to G. Simmons, Leader, M-44 Study Team, June 24, 1985; 4 pp.). As a result of this finding, all M-44 ejectors made at PSD since July 1985 have included the O-ring shock absorber.

By 1986 it appeared that the M-44 ejector had been perfected. Within a few years, however, M-44 users were reporting increasing numbers of bottom ‘blow-outs’ due to failure of the crimped metal closure used to secure the ejector spring and other internal parts inside the ejector body. Investigations at PSD revealed that these crimp failures resulted from graininess or brittleness of the

ejector body walls, due to flaws introduced during the casting process.

The solution to this problem was devised by PSD Manufacturing Specialist John Stanford, who redesigned the ejector to eliminate the bottom crimp. The ejector body walls were thickened at the bottom so that holes could be drilled for a removable pin that would hold the inner parts in place. Besides eliminating the ‘blow-out’ problem, this modification also allowed disassembly and reassembly of ejectors in the field for cleaning, lubrication, or repair. This field servicing capability had previously been feasible with the M-50 ejector but not with M-44s that, up to this time, had always been assembled with the bottom crimp. All M-44 ejectors made at PSD since 1992 have featured the user-removable spring retaining pin.

When the ‘Edstrom’ ejector was introduced in 1985, it was intended for use with the Leyerly-top stake that had been standard with the original M-44 (Figure 3). However, the new ejector body was too ‘fat’ to fit in some Leyerly-top stakes, so they were replaced by the swaged-top, M-50 style stake (Figures 4, 5). This stake, in turn, has been improved by replacing the original, flimsy lock ring with a more substantial one that prevents ‘pullouts’; that is, coyotes pulling fired ejectors out of the stakes and carrying them away. Distribution of the improved lock ring began in 1996 (Introduction of a New-style Flat M-44 Stake Ring. Memorandum, Manager, PSD to All M-44 Users, January 29, 1996; 4 pp.).

Yet another important improvement was made in 1998: the location of the trigger hole in the ejector body was moved 0.10 inches from its original position, thereby solving a chronic problem with trigger malfunctions (Letter, S. Blom, PSD Manager to E. Huntington, Springfield Die Casting, Springfield, Oregon, October 16, 1998; 2 pp.).

Other improvements also have been made in recent years. They include stake-pulling tools, a redesigned capsule holder with a flange-lip to deflect rain water from running down into the stake, and addition of steel ‘rebar’ to stakes to strengthen them and improve their holding power in loose soil. The net result of these and other innovations, I believe, is that today’s M-44 is better than its ancestors.

CYANIDE CARTRIDGES AND CAPSULES

Coyote Getter Cartridges

Before 1946, CG cartridges used in governmental coyote control were purchased from Humane Fur Getter, Inc. (later HCG, Inc.). Exact specifications for those cartridges are lacking in my records, but their contents presumably were as described in the 1939 Marlman patent, “Poison Mixture for Trap Gun Cartridges” (Table 1). This patent depicted an ordinary shell provided at its closed end with a primer. A moderate amount of gunpowder was placed above the primer and covered with a wad. Above this a poison mixture, preferably in

the form of powder or small crystals, was loaded followed by a top wad sealed with beeswax or paraffin to prevent the entrance of moisture. The poison mixture consisted of 85 parts NaCN or KCN, 5 parts magnesium oxide to prevent the poison from caking or solidifying, and 10 parts capsicum to irritate the coyote's mouth. The capsicum was intended to cause a burning sensation so that the coyote would stop and claw at its mouth in an effort to clear it and this delay would give the poison time to act before the animal gets very far away, causing it to die near the trap. The net weight of toxicant per cartridge was not specified in the patent, nor was a preference stated for NaCN or KCN.

Robinson (1943) indicated that NaCN was used in the CGs set by government hunters. Governmental use of CGs began about 1939, and the hunters soon were reporting performance problems with the cyanide cartridges. Weldon Robinson, Junior Biologist at the Denver Research Center (later DWRC) was detailed to investigate. He found that almost 30% of coyotes that pulled CGs were not recovered. Some coyotes died at long distances away from the units, so were not found. Others apparently received sublethal doses of toxicant due to defective firings. Some cartridges were ineffective due to caking of their toxic contents.

Robinson (1941a,b) found that fresh cartridges were more toxic than 'aged' ones that had been set in the field through a fall and winter season. Many 'aged' cartridges had defective primers or caked cyanide. Robinson expressed concern about 'getter-wise' coyotes that, in his view, would not pull another CG after they'd survived an unpleasant encounter with one. Both Robinson and another early-day researcher, Sears (1941), reported progress in devising a moisture-proof seal for fur getter cartridges.

A later Marlman patent, "Poison Mixture for Trap Gun Cartridges" (1945; Table 1), described an improved toxicant formulation that was claimed to be less susceptible to caking. The cyanide was to be mixed with mineral oil or vaseline, forming a paste that would not harden but would become plastered over the mucous surfaces of the coyote's mouth so that it could not be dislodged by coughing as sometimes occurred with dry powder. This mixture was claimed not only to be more effective in killing coyotes, but capable of being stored for an unlimited time without deterioration due to its noncaking properties. Despite these promising claims, I have found no record of such a mixture ever being tested or used in governmental coyote control.

Due to continuing dissatisfaction with Marlman's cartridges, the U.S. government in 1946 negotiated a license agreement with Mr. Marlman to make its own CG ammunition at PSD. A royalty of one cent per cartridge was paid to HCG, Inc. Total royalties of \$24,612.50 were paid from July 1946 through January 1962 when payments stopped due to expiration of Marlman's patents (Royalty Payments – Humane Coyote Getter, Inc. Memorandum, Manager, PSD to Regional Director, BSFW, Portland, Oregon, April 4, 1962). Based on these royalty

payments, approximately 2.46 million CG cartridges—about 159,000 per year, on average—were made at PSD during this 15½-year period (Memorandum, S. Blom, PSD to G. Connolly, DWRC, November 1, 1995). That rate of cartridge production was more than double the average annual production of 77,000 M-44 capsules in the latest decade (1992-2001).

The decision to make CG cartridges at PSD was based on an assumption that the PSD product would be better (Memorandum No. 72, Supplement No. 7. D. Green, Chief, PARC to Division Field Personnel and Regional Directors, February 21, 1946; 3 pp.). However, I have found no documented research comparison of PSD vs. commercial CG cartridges. A contemporary observer, Lee Bacus, later wrote that PSD took over the manufacture of CG shells thinking that they could improve on Marlman's product, but this did not occur (M-44. L. C. Bacus, Denver, Colorado to Regional Supervisor, WS, Albuquerque, New Mexico, August 29, 1969; 2 pp.).

It seems obvious that cartridge defects continued after the transition to PSD manufacture, since a private consulting firm, Idaho Chemical Industries (ICI), Boise, Idaho, was hired to investigate CG cartridges and PSD manufacturing procedures, determine the reasons for malfunctions, and recommend corrective measures. Both physical and chemical aspects of CG cartridges were studied. The ICI report (Bush 1958) noted that both ejectors and cartridges were subject to malfunctions and misfires. Mr. Bush recommended several lines of research including use of a less deliquescent toxicant or a higher grade of NaCN with less impurities, adding a desiccant within the NaCN mixture to collect moisture, replacing the Auramine O marker with a nonacid dye, and using selected plastics to coat the outside of the cartridge with a perfect, airtight seal. He also suggested investigating and revising drying and storage procedures for NaCN mixtures.

Some of these recommendations may have been implemented, but some obviously were not. For example, Auramine O was not dropped; it continued to be used up to 1969 when PSD stopped making CG shells. In fact, the composition of the cyanide mixture in CG cartridges appears to have changed little, if at all, during the years when CG shells were made at PSD (1946-1969). The earliest official record I have that details the contents of CG shells made at PSD (Composition of Coyote Getter Chemical Shell. Memorandum, D. G. Crabtree, WRC, Denver, Colorado to Regional Director, BSFW, Minneapolis, Minnesota, May 9, 1962; 2 pp.) describes a mixture identical to that reported by Bush (1958): 80 parts NaCN (95% a.i.), 2 parts capsicum (cayenne pepper), 2 parts magnesium oxide, 4 parts potassium chloride, and 4 parts yellow dye (Auramine O). The net contents per shell averaged 0.81g. Each shell contained about 0.5 grains (0.03g) of Bullseye pistol powder as a propellant. The top wad was covered with asphalt sealing material.

These specifications also were provided to USDA

for the “Chemical Shells Containing Sodium Cyanide” that were registered in 1967, except that the net weight per cartridge was given as 0.94g (USDA Registration No. 6704-3, accepted May 1, 1967 by USDA, ARS, Pesticide Registration Division). The cartridges we tested at Port O’Connor, Texas in 1982, as described previously, were made under this registration in 1969 (Connolly and Simmons 1984). From the information available to me, it appears that the technical specifications and manufacturing procedures for CG cartridges made at PSD did not change from 1958 through 1969.

An interesting sidelight of the CG story is the mid-1950s effort to develop a ‘wolf-getter’ cartridge for use in Alaska. Ordinary CG cartridges had been tried there for several years but were rated unsatisfactory because too few wolves were recovered after they pulled CGs. Larger experimental cartridges that contained more cyanide or more gunpowder in 357 Magnum and 44 Special cases were tested. The results suggested that increased cyanide charges were more effective than standard CG loads, but increased powder charges were not. Only small numbers of wolves were killed with CGs (Robinson 1956).

M-44 Cyanide Capsules

When the spring-activated M-44 ejector was under development in the 1960s, it became apparent that cyanide caking would be a greater problem than it had been with the CG. The explosive CG had enough eruptive force to break up partially caked cyanide during ejection, whereas the milder ejection thrust of the M-44 would break up caked cyanide less effectively. Therefore, it seemed essential to prevent the toxicant in M-44 capsules from caking so that, when ejected, the mixture would be a dry, free-flowing powder (Bacus 1969a).

To achieve this, a variety of anti-caking additives (also called flow agents or glidants) such as graphite, magnesium stearate, cabosil, and perlite were evaluated in cyanide mixtures. These additives added much bulk to the mixtures, and the 38-caliber CG cartridge was found to be too small to contain the required amount of such mixtures. The larger 44 Magnum cartridge case was the obvious choice for greater capacity, so the first cyanide capsules tested in M-44s in 1967-68 were made from 44 Magnum cases (Bacus 1969a).

Later, the plastic capsule was designed to be essentially the same size. This is why today’s M-44 capsule resembles the 44 cartridge case in size and shape. The current (2002) M-44 capsule has an overall length of about 1.05 inches. The rim diameter is 0.50 inches and the case body, forward of the rim, is 0.45-0.46 inches in diameter. These dimensions have not changed since 1969 when they were established in a design drawing by the firm that molds M-44 capsules under contract with PSD (Special 44 Cal. Case – Cyanide. Drawing No. 1265-B, Omark-CCI, Inc., Lewiston, Idaho, 6/24/69).

The first mass-produced M-44 capsule was made of cellulose acetate butyrate (CAB), green in color and translucent. It contained 12 grains (0.78g) of NaCN plus

an additive to retard caking and a fluorescent tracer. Both top and bottom were sealed with a clear, flexible sealant (Bacus 1969b,c). These capsules proved unsatisfactory as CAB is not water tight (M-44 Cases. L. C. Bacus, DWS, Denver, Colorado to Manager, PSD, August 24, 1970; 2 pp.). Following a flurry of consultation with plastics experts, capsules made of polyethylene (PE) and polypropylene were tested during fall and winter 1970-71.

Capsules sealed at PSD, either with ‘sealastic’ or a newly-identified 3M ScotchGrip adhesive diluted with naphtha (3 parts sealant: 1 part naphtha) were tested by immersion in water for 10 days, after which all capsules with 3M seals were intact with tight seals, cyanide flowing, and no evidence of moisture seepage. About a third of the seals had leaked on comparable capsules with ‘sealastic.’ The 3M product was described as the best sealant tested so far (Quality control tests – M-44 cases. Memorandum, L. C. Bacus, DWS, Denver, Colorado to Manager, PSD, December 9, 1970; 4 pp.).

Further testing in a Weatherometer at the DRC showed that capsules sealed with the 3M adhesive, when exposed to extreme temperature and moisture in repeated 2-hour cycles, remained in perfect condition through 48 hours, with 30% to 40% failing after 72 hours (Testing – M-44 caseload #3. Memorandum, L. C. Bacus to Regional Supervisor, DWS, Portland, Oregon, February 18, 1971; 2 pp.).

Based on these results, the PE M-44 capsule sealed with 3M #4693 adhesive diluted with naphtha was adopted for mass production at PSD in 1971. The 3:1 dilution ratio specified by Bacus later was changed to 2:1 at PSD (Connolly and Simmons 1983b).

Capsule development, like other aspects of M-44 improvement, came to an abrupt halt early in 1972 when the predacidal use of NaCN was stopped by Presidential Order, as noted earlier. When M-44 use resumed experimentally in 1974, the technology that had been shelved in 1972 was resurrected. This presumably included the PE capsule with 3M #4693 adhesive, which continued to be used as the standard M-44 capsule sealant until December 1982. The high-density PE capsule adopted in 1971 remains in use today (2002) with only minor modification.

The M-44 cyanide capsules used by FWS experimentally in 1974-75 probably contained the same toxicant formulation that was later submitted for registration in July 1975. The registration application (USDI 1975) specified net weight of 1.0g per capsule of the following mixture: 88.78% NaCN (95% a.i.); 5.98% Celatom MP-78 (diatomaceous silica, desiccant); 4.99% potassium chloride (KCl, flowing agent); and 0.25% FP tracerite-yellow (zinc/cadmium sulfide, fluorescent particle marker). As noted previously, the FWS registration was approved by EPA on November 3, 1975. Later, the original registration number (6704-75) was changed by EPA to 56228-15 effective January 13, 1987, in conjunction with the ADC program transfer from USDI to USDA.

In the 1980s, PSD switched from the technical NaCN (95% a.i.), that had been routinely used in cyanide cartridges and capsules since 1958 or earlier, to a reagent grade of NaCN (99% a.i.). Except for this minor change, the cyanide formulation described in 1975 remained in use until January 1990 when tracerite was replaced by a Day-Glo fluorescent particle marker. This change was made because tracerite contains cadmium which had been listed by EPA in 1987 as an 'inert ingredient of toxicological concern,' meaning that expensive studies would have been required to retain EPA approval for continued use of this material.

In addition to the marker change, KCl was deleted from the NaCN formulation in January 1990. KCl had been included for about 20 years based on a belief that it retarded caking of NaCN. M-44 capsule weathering tests in 1984-85, however, showed no difference in cyanide caking with or without KCl. The same tests showed that neither Day-Glo nor tracerite adversely affected NaCN mixtures. The formulation changes approved by EPA in 1990 were based on these and other studies (Burns et al. 1990). The formulation with Day-Glo remains in use today.

The plastic M-44 capsule and its seals also received much research attention over the years. As described previously, M-44 use in the FWS-supervised ADC program declined for several years following the 1975 registration. The malfunctions that caused increasing numbers of field workers to lose confidence in M-44s stemmed from several causes including defective capsules. Also as reported earlier, Vic Keenan was assigned in 1977 to correct the M-44 problems. He completely redesigned the M-44 including the capsule.

Keenan's larger, 50-caliber capsule caused the new ejector to be termed the M-50 to differentiate it from the older M-44. The M-50 capsule was made of high density polystyrene that could be sealed with a solvent; toluene was specified by Keenan (1979) but PSD used xylol. Seal strength varied with the length of time each capsule top was immersed in the solvent. Some seals were so strong that M-50 plungers failed to penetrate them, resulting in ejection failures. This problem was discovered only after thousands of M-50s were in the field. A less effective seal then was adopted to assure ejection. Subsequent field experience and research showed this seal to be inadequate, though superior to the M-44 seal (Connolly and Simmons 1984). The poor performance of M-50 ejectors and capsules in the 1982 study led FWS to abandon the M-50, so no further effort was expended to improve the M-50 capsule.

The 1982 study (Connolly and Simmons 1984) identified M-44 capsule improvement as a high priority need; NaCN was caked in half of the capsules after only 6 weeks of outdoor exposure. This finding led to evaluation of a beeswax seal that was already in use in the Uvalde, Texas ADC district. These capsules, shipped from PSD with the standard 3M adhesive seal, were hand-dipped in melted beeswax after they arrived in Texas.

Beeswax already had a long history as a sealant for cyanide cartridges, having been identified as such in the 1939 Marlman patent, 'Poison Mixture for Trap Gun Cartridges' (Table 1). In addition, it had been used on early spring-ejection devices that were precursors of the M-44 (Fitzwater 1964). Later, Lee Bacus had suggested trying beeswax when the then-new 3M ScotchGrip adhesive proved inadequate (Memorandum, L. C. Bacus, DWS, Denver, Colorado to Regional Supervisor, DWS, Portland, Oregon, November 18, 1970; 4 pp.). Jim Beavers, the ADC specialist credited with developing the supplementary beeswax seal in Texas, as described above, had participated many years earlier in the tests of beeswax-sealed, spring ejection devices reported by Fitzwater (1964).

In October 1982, Mr. Beavers volunteered to prepare beeswaxed capsules for a side-by-side comparison to standard PSD capsules. M-44 capsules selected at random from regular production at PSD were sent to Texas where Mr. Beavers applied beeswax to half of them. The waxed and unwaxed capsules then were exposed outdoors at College Station, Texas. After 6 weeks' exposure, the beeswaxed capsules were as good as new but only 26% of unwaxed capsules were unimpaired. After 12 weeks, 82% of the waxed capsules contained normal, dry cyanide, compared to only 9% of unwaxed capsules (Connolly and Simmons 1983a). These results led to a recommendation that the supplementary beeswax seal should be applied routinely by field personnel until the seals on mass-produced PSD capsules could be improved through further research.

In December 1982, PSD began using beeswax on standard production M-44 capsules. The wax was applied on top of the 3M adhesive after it had dried. Rather than hand-dipping each capsule in melted beeswax, as field men were doing, PSD expedited the process by emulsifying the beeswax with additives so that it could be more conveniently applied as a liquid at room temperature. The emulsified beeswax seal was not tested prior to adoption. In the field it proved to be ineffective (Results from ejector capsules weathered at College Station, Texas. Memorandum, G. Connolly and G. Simmons to M-44 Study Team, March 30, 1983; 5 pp.).

Based on these and other findings, the M-44 team recommended in April 1983 that PSD should use thick beeswax seals to both the top and bottom of M-44 capsules (M-44 improvement. Memorandum, M-44 Study Team to Chief, Division of Wildlife Management, June 23, 1983; 20p + 4 Attachments).

When Paul Edstrom became PSD Manager in August 1983, he promptly replaced the 3M/emulsified beeswax combination with crude yellow beeswax. Edstrom devised procedures, still in use today, for efficient application of melted wax to M-44 capsules for enthusiasts use to cast bullets from lead. With this technology, experienced technicians routinely apply top seals in 75 to 90 seconds to each batch of 100 capsules.

The hot beeswax seal was very successful at first. A large weathering experiment was carried out in 4 states in 1984-85 with beeswax-sealed PSD capsules and a variety of experimental capsules. The beeswax-sealed capsules performed very well, with most lots containing 90% or more of capsules rated 'normal' (contents were dry, white powder). However, about 3% of the capsules had bottom cracks. Most of these cracked capsules failed, meaning that their cyanide contents had deteriorated (Capsule weathering test – August 1984 to March 1985. Memorandum, G. Connolly, DWRC to M-44 Study Team, April 16, 1985; 7 pp).

This new problem— cracked capsule bottoms— had been recognized since 1981. It originated from an earlier fix for a different problem. In the mid-1970s, some M-44s failed to eject when pulled by coyotes because their plungers were unable to penetrate the capsules. To correct this, the capsule bottom was made thinner. The first lot of modified capsules, received at PSD in November 1977, was normal but later lots (received May 1980 and March 1982) contained many bottom cracks (Quality of M-44 capsules. Memorandum, G. Connolly to M-44 Study Team, December 2, 1982; 4 pp.).

To solve this problem, PSD began inspecting all capsules on the assembly line and culling out the cracked ones. Cracks continued to be reported from the field. Subsequent study revealed that some capsules that were intact when shipped from PSD developed cracks later. About 2% of 600 loaded capsules that were kept in storage and examined periodically developed bottom cracks within a year (Trouble with M-44 capsules... Memorandum, G. Connolly to M-44 Study Team, November 26, 1984; 4 pp.).

Late in 1984, PSD adopted an effective solution to this problem: capsule bottoms were sealed with the same beeswax that already was used for top seals. Capsules with beeswax seals on top and bottom performed better than standard capsules, sealed only on top, in the 1984-85 weathering experiment described previously. Beeswax seals were discontinued in 1989 when a better wax was found, but hot wax seals remain in use today (2002) on both tops and bottoms of M-44 capsules.

By the end of 1984, yet another M-44 capsule problem had surfaced: application of the hot beeswax seal caused expansion of the capsule mouth. This problem was discovered when field personnel complained that many capsules were too big to fit in capsule holders. This condition, 'capsule flare,' was found to develop within 24 hours after capsules were sealed. It resulted in loss of the waterproof seal (M-44 capsule flare. Memorandum, G. Connolly to G. D. Simmons, Leader, M-44 Study Team, October 17, 1985; 3 pp.).

Nothing was done about capsule flare for several years, other than instructing field personnel how to deal with it (M-44 capsule flare. Memorandum, P. Edstrom, PSD to B. Acord, ADC Western Regional Director, Denver, Colorado, October 13, 1987; 5 pp.). In 1989, a new capsule sealant replaced beeswax. The new material, Scheel SC-100 petroleum hydrocarbon wax, proved

superior to beeswax in several respects. It caused less capsule flare and had a much higher melting temperature. Unlike beeswax, the Scheel wax did not shrink as it cooled. When capsules sealed with Scheel wax, beeswax, and other materials were subjected to environmental stress, all beeswaxed capsules were ruined while 64% of Scheel-waxed capsules still contained normal NaCN contents. PSD acted promptly to implement these findings (Recommendations for improved M-44 capsule sealants. Memorandum, G. Connolly, DWRC to P. Edstrom, Manager, PSD, March 7, 1989; 17 pp). All M-44 capsules produced at PSD since March 1989 have been sealed with the Scheel wax.

Several years later, Connolly (1996) analyzed the effects of this sealant change on M-44 use in the ADC program. He found that the annual coyote kill with M-44s had doubled from 1989 through 1995, while the numbers of M-44 capsules shipped from PSD to ADC program field offices declined 15%. Average numbers of capsules used per coyote taken dropped from 8.7 during 1983-88 to 3.8 during 1990-95. This improved efficacy was attributed to the new sealant.

A review of recent WS program records suggests that the apparent gain in M-44 efficiency due to the Scheel wax sealant has continued through 2000. The average annual coyote kill by ADC program M-44s declined from about 23,000 during 1990-95 to approximately 19,000 in 1996-2000, based on WS program records (E-mail memorandum, J. Dewey, WS Operational Support Staff, Riverdale, Maryland to G. Connolly, January 23, 2002; 2 pp.). Average annual numbers of M-44 capsules shipped from PSD also declined, from about 89,000 to 63,800 respectively, in the 2 time periods. The average number of capsules used per coyote killed by M-44 during 1996-2000 was 3.4, even lower than the 3.8 recorded during 1990-95.

ALTERNATIVE CAPSULE MATERIALS

Only 2 cartridges or capsules have been used in large quantities in toxicant ejectors for coyote control—the brass (often nickel plated) 38 Special CG cartridge and the PE M-44 capsule. In addition, a cellulose acetate butyrate (CAB) M-44 capsule was used in 1968-69, before the PE capsule was developed. Through the entire history of toxicant ejectors, however, cartridge and capsule problems have stimulated efforts to develop better cyanide containers. As early as 1949, an explosive cartridge formed of frangible material such as glass, plastic, pottery, metal or any other material that would shatter upon explosion of the cartridge was patented (Moen and Graybill, Table 1). As far as I know, this invention was not developed commercially.

An experimental glass capsule was tested in Texas in 1982, along with other capsules as described elsewhere in this paper (Connolly and Simmons 1983b). The intent was to determine if a glass container would protect NaCN from caking or deterioration during outdoor exposure. Capsules adapted from 1-ml borosilicate glass ampules were filled with NaCN powder and heat-sealed using an

oxy-acetylene torch. They proved to be unsatisfactory. Several of them broke due to undetermined causes during 12 weeks outdoors at College Station, Texas. At the end of this trial only 20% of the ampules contained normal, dry cyanide. We recommended that another kind of glass be used in future trials.

A few years later, a glass M-44 capsule was developed by the M-44 Company, Fredericksburg, Texas. A representative of this firm met with Texas ADC personnel in 1987 to request a field trial of the new capsule. The Texas program bought several hundred of them for field testing in comparison with standard M-44 capsules. Thirteen trappers ran lines of paired ejectors with glass or standard capsules for approximately 15,600 unit nights. The glass capsules did not work as well as PSD capsules. About 96% of coyotes that pulled PSD capsules were recovered, compared to only 78% recovery from glass capsules. Average recovery distances were 27 yards and 38 yards, respectively, for PSD and glass capsules. Texas personnel concluded that they could not identify any advantages of the glass capsules in their present form (M-44 glass capsule field test. Memorandum, M. A. Dunaway, ADC, San Antonio, Texas to Director, ADC Western Region, May 31, 1990; 3 pp.). As far as I know, the M-44 Company did not perfect its glass M-44 capsule.

In 1987, PSD obtained pilot lots of M-44 capsules made from several transparent plastics— acrylic, polycarbonate resin, K-resin, butyrate, ABS plastic, and clear polyvinylchloride. A study was planned to evaluate them as possible replacements for the PE capsule (Connolly 1987), but I was reassigned to other duties before this study could be carried out. As of February 2002, the study has not proceeded. M-44 capsule improvement appears not to be a high priority research need at this time, perhaps because current production capsules are performing well.

ALTERNATE TOXICANTS

Throughout the 60+ years that toxicant ejectors have been used in coyote control, NaCN has been the preferred toxicant even though the earliest patented “Poison mixture for trap gun cartridges” (Marlman 1939; Table 1) stated that either NaCN or KCN could be used. KCN was used in the Newhouse Safety Coyote Killer (Gerstell 1946) and in the liquid humane CG (HCG n.d.), as noted earlier. In addition, KCN was used in M-44s in some counties concurrently with NaCN in other counties during the Texas Department of Agriculture experimental M-44 program of 1974-75. Unfortunately, data that might have been analyzed to compare the efficacy of KCN and NaCN were not collected (Connolly et al. 1986).

In the 1980s, ADC program researchers considered alternatives to NaCN as a possible solution to the capsule caking problems that were impeding M-44 effectiveness at that time. The underlying rationale was that toxicant deterioration in M-44 capsules might be reduced by switching to another chemical that was less prone to caking. Tests revealed that that calcium cyanide and

methomyl, a carbamate insecticide, caked less readily than NaCN but they also were slower to kill coyotes. KCN was more similar to NaCN, both in speed of action and propensity to caking in M-44 capsules. Both NaCN and methomyl were 100% lethal in pen tests, but field tests yielded recovery rates of only 24% of coyotes that pulled M-44s containing methomyl versus 80% for NaCN. We concluded that none of these alternatives offered enough advantage over NaCN to warrant the costs of obtaining a new registration (Connolly et al. 1986).

Compound 1080 is another toxicant that obviously could be delivered to canids by means of M-44 or other ejector devices. The use of 1080 in CGs or M-44s has been considered many times over the years. In explaining why NaCN rather than another toxicant was used in the CG, Crabtree (1967) pointed out that a fast-acting lethal agent is necessary so that poisoned animals may be recovered as proof of efficacy. If the CG toxicant required hours instead of minutes to produce death, as 1080 would, evaluation of its efficiency for coyote control would be difficult if not unfeasible. Also, if 1080 was used, the CG hazard to cattle would be increased compared to NaCN.

Nevertheless, other experts such as Boddicker (1988) have suggested that 1080 would be an excellent CG or M-44 toxicant since it can be selectively dosed as well as delivered. Boddicker pointed out that a properly formulated 1080 shell would offer little hazard to humans or most other animals, yet would be deadly to canines.

The concept suggested by Boddicker has been adopted by Australian researchers who have used M-44s to deliver small, lethal 1080 doses to red foxes. This technique was noted as being superior to 1080 meat baits as a fox control technique. Advantages of delivery by M-44s include improved specificity in delivering toxicant to the target species and elimination of bait caching. In addition, M-44s may be able to deliver smaller lethal doses of toxicant, thereby increasing the margin of safety for nontarget species (Marks et al. 1999).

For coyotes in the U.S., like red foxes in Australia, I believe that CGs or M-44s would be superior to tallow or meat baits for delivering 1080 or almost any toxicant. However, this does not mean that 1080 would be an ideal M-44 toxicant. I agree with Crabtree (1967) that NaCN is better than any slower-acting toxicant for CGs or M-44s. With any lethal method nowadays, particularly in governmental control work, it is essential to document both target and nontarget animals killed. For M-44s this is most feasible with a fast-acting toxicant such as NaCN.

DISCUSSION

The story of toxicant ejectors in coyote control appears to me as an endless paradox over the years, with users continually striving for and often getting good results with imperfect equipment while, at the same time, researchers (including users, manufacturers, and other inventors) have worked almost continuously for 60 years to fix and improve that equipment. This paper recounts a

seemingly endless succession of problems and fixes followed by other problems that ultimately were never quite resolved. This portrayal is true, but it is only part of the truth. The other side of the coin is that, in spite of the problems, many government hunters and others have used CGs and M-44s with great success.

That part of the story has not been documented so well. The written record, upon which this paper is necessarily based, is biased toward CG and M-44 problems because people over the years tended not to write when the equipment was working well. Despite the recurring technical problems, CGs and M-44s have ranked near the top of the list of valuable coyote control tools over the past 60 years. Compared to other set capture devices such as traps and snares, today's M-44 is more selective for target species and more humane. These attributes are more valuable today than ever before, and are important reasons why the M-44 should continue to be used in damage management situations that require wild canids to be killed.

I have been impressed over the years by the fact that, whatever CG or M-44 equipment was being used at any time and place, some users achieved good results with it and others did not. The statement by L. C. Bacus that "the M-44 is performing to a great extent in direct degree to the interest and intelligence with which it is being used..." (Memorandum, L. C. Bacus to Manager, PSD, December 1, 1969; 4 pp.) was equally true for CGs from the first day they were set, and it will remain true for as long as CGs or M-44s continue to be used. As a general principle, of course, Bacus's comment applies to all control methods, not just M-44s.

One of the best-documented examples of user variations in M-44 performance came from a survey of ADC program M-44 users in 1988. The questionnaire asked users for quantitative data on their recent experiences— number of M-44s pulled by coyotes, number of coyotes recovered, and average recovery distance. As a general standard, M-44 performance is considered to be acceptable if at least 75% of the coyotes that pull M-44s are recovered at an average recovery distance (from ejector) that does not exceed 35 yards.

In the 1988 survey, 53% of respondents reported coyote recovery rates of 75% or better and 54% reported average recovery distances of 35 yards or less. These results suggest that 53-54% of the M-44 users were achieving acceptable performance but 46-47% were not. Such results indicate a potential to improve performance through better training or better supervision of the users who reported unsatisfactory results (Connolly 1988b). It would be desirable to repeat these surveys at 10-year or other standard intervals to track M-44 performance trends over time.

As noted earlier, the WS program coyote kill with M-44s declined during the 1990s. I speculate that the number of WS employees who used M-44s also declined, particularly after 1998 when the use of NaCN in predator control was banned in California. Currently, the WS program has approximately 215 certified M-44 applica-

tors in 15 states⁴ (Email Memorandum, J. Dewey, WS Operational Support Staff to G. Connolly, January 23, 2002; 2 pp.). In addition, the state-supervised ADC program in South Dakota has 18 M-44 applicators (E-mail memorandum, P. Mastrangelo, WS State Director, Bismarck, North Dakota to G. Connolly, February 21, 2002; 1 p.), making a current (February 2002) total of about 230 M-44 applicators in governmental coyote control programs in the U.S.

Although the M-44 is one of the most widely used predacides, it is an insignificant source of environmental pollution. The total number of M-44 cyanide capsules shipped from PSD, the sole manufacturer, over the past 10 years (1992-2001) has averaged about 77,000 annually. Yearly totals during this period varied between approximately 54,000 and 100,000. The corresponding amounts of NaCN used in M-44 capsules varied between approximately 105 and 194 pounds annually, based on 0.88g per capsule as specified in the current (May 1995) confidential statement of formula. These amounts are a miniscule fraction of the 250 million pounds of NaCN produced in the U.S. each year for use in gold extraction, electroplating, and other industrial applications (HSDB 1991). The small amounts of NaCN used in M-44s are subject to EPA pesticide regulations, whereas the millions of pounds used industrially are not.

In addition to the traditional use pattern for killing wild canids with toxicants, CGs and M-44s have potential nonlethal applications. They could deliver markers, tranquilizers, fertility control agents, or vaccines such as the oral rabies vaccine that currently is administered to coyotes in baits dropped from aircraft (Fearneyhough 1996). Few such nonlethal applications of M-44 ejector technology have occurred to date, but they can be expected to increase in the future.

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⁴ The states are AZ, CO, ID, MT, NE, NV, NM, ND, OK, OR, TX, UT, VA, WV, WY.

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