United States
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Research Report
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Inventing and Reinventing Sodium Cyanide Ejectors

A Technical History of Coyote Getters and M-44s in Predator Damage Control

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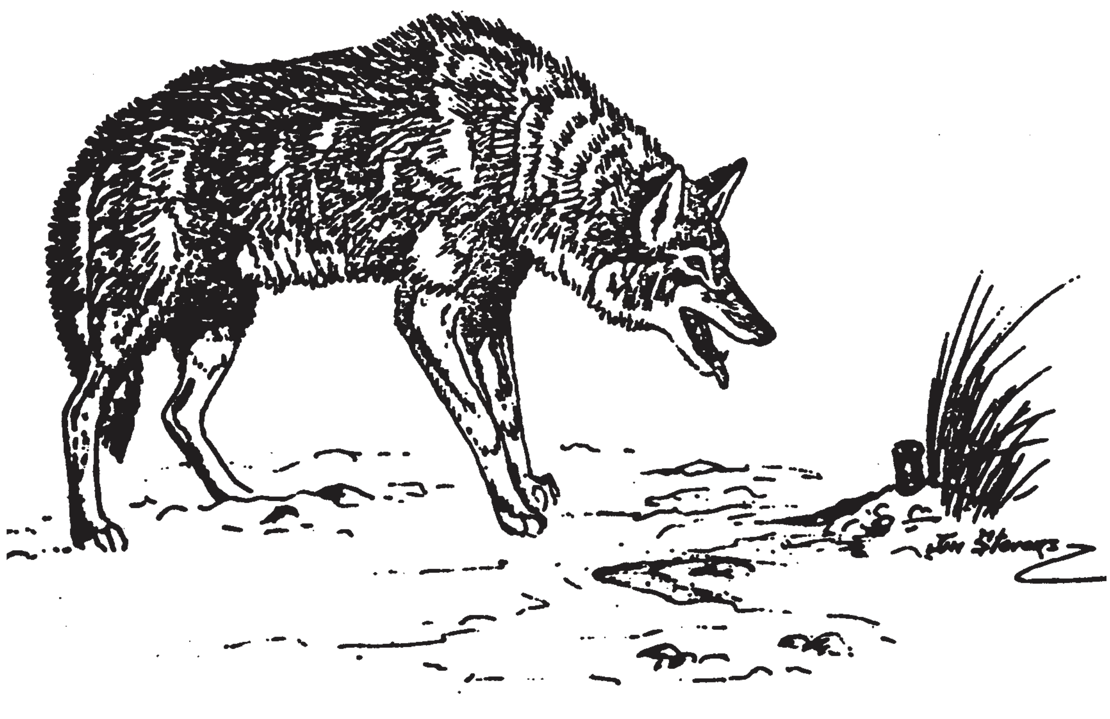

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2003
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Fort Collins, Colorado

ACKNOWLEDGMENTS

Over the years, many people inside and outside the Federal/Cooperative ADC/WS program contributed ideas and suggestions that led to the current M-44 device and NaCN capsule. It is not possible to give credit for every contribution since some were made so long ago that their origins are not known to us. Some innovations were developed repeatedly but independently by different people in different parts of the country. At the risk of omitting significant contributors, we offer a list of persons whose have contributed significantly to the development, improvement, and efficient manufacture of CG and M-44 devices.

Our list, in alphabetical order, includes Lee Bacus, Don Balser, Jerry Bean, Jim Beavers, Dennis Biggs, Dick Burns, Maynard Cummings, Gary Dasch, Paul Edstrom, Bill Fitzwater, John Foard, Ray Hall, Scott Huber, Pat Jaureguiberry, Norm Johnson, Vic Keenan, George Kerr, Fred Knowlton, A.J. Kriwox, J. Mike Laughlin, Gerald Lewis, John Leyerly, Fred and Ethel Marlman, J. Brad Miller, Joe Packham, John Peter, James Poteet, Weldon Robinson, Bob Sears, Gary Simmons, John Stanford, Don Thalheim, Steve Thompson, Jimmy Trampota, Mahlon Watten, Gary Whitehead, and Ade Zajanc.

Most of the information for this report came from published accounts or unpublished WS Program records and reports on file at PSD or the NWRC. Some data for Tables 3 and 4 were furnished by Martin Mendoza, Jessica Dewey, and Monte Chandler of the ADC (later WS) Operational Support Staff, Riverdale, Maryland and by Bob Phillips, NWRC, Fort Collins, Colorado. NWRC Pharmacologist Pete Savarie furnished information on NaCN toxicity and metabolism. In addition, Lyle Crosby, John Eisenbraun, Alan Foster, Nancy Freeman, Ray Hall, Fred Knowlton, Bill Marlman, and Don Zielesch contributed significant unpublished information. We thank Craig Maycock and Robert Maestas for technical assistance with photographs, and Jim Stevens for permission to use his artwork on our cover page. This report could not have been completed without the support and encouragement of WS Western Regional Director Mike Worthen.

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INTRODUCTION

Sodium cyanide (NaCN) ejectors have been used in Federal/Cooperative predator damage control programs since the late 1930s[1]. The first model was the Humane Coyote Getter (HCG), more commonly known as the coyote getter (CG). It was used in federally supervised control programs for almost 40 years, until November 1, 1970 when it officially was replaced by the spring-activated M-44. The M-44, with many modifications over the years, remains in use today. An enlarged M-44, the 'M-50', also was used during 1979-1983.

Both CGs and M-44s were designed to eject a toxic mixture of NaCN powder when pulled by a coyote. The 2 devices differ primarily in their mode of ejection – the coyote getter (CG) fired a .38 Special cartridge case that contained toxicant, whereas M-44 cyanide capsule contents are expelled by the release of a spring-driven plunger.

NaCN ejectors can be used to kill several species of canids but the coyote (*Canis latrans*) is and always has been the primary target species. Cyanide ejectors and their use have been described in many published and unpublished reports including Marlman (1936; 1939a,b), Robinson (1943), Young and Jackson (1951), Fitzwater (1964), Bacus (1969a,b,c; 1970), Clark (1976), Matheny (1976), Shult et al (1976), ASTM (1977), USDI (1978), Keenan (1979), Connolly and Simmons (1982; 1983a,b; 1984), Cadieux (1983), Henderson (1984), Boddicker (1988), Connolly (1988a,b,c; 1992; 1996; 2002), Anonymous (1989?), Uhden (1993), Sullivan (1995), and TDA (1997).

NaCN is registered by the U. S. Environmental Protection Agency (USEPA) for only 1 pesticidal use – to kill canid predators in M-44s. Technically, the EPA registration covers the M-44 Cyanide Capsule, not the ejector mechanism. The M-44 Cyanide Capsule is a restricted use pesticide for use only by specially trained and certified applicators. Most M-44 users are federal, state, or cooperatively-funded employees supervised by U. S. Department of Agriculture's Wildlife Services (WS) in western states, but livestock producers and other private citizens in certain states also can become certified M-44 applicators. Newly hired WS Specialists are instructed in the proper use of wildlife damage management tools, including M-44s in districts where they are expected to be used. Most new employees are aware of NaCN ejectors, but few are familiar with their history or with the problems, modifications, and solutions through which these devices evolved to become the present-day M-44. Even veterans today may take their equipment for granted and forget the problems associated with older equipment they formerly used.

NaCN ejectors have undergone numerous technical changes over the years. This report presents a technical history of NaCN ejectors, concentrating on problems encountered and efforts made to resolve them. The 60-year saga of NaCN ejector inventions and modifications has been chronicled in part by Connolly (2002). Additional technical information is presented here.

BACKGROUND & HISTORY

Cyanide ejectors for predator control did not exist until Fred Marlman invented the coyote getter (Fig. 1) in the 1930s[2]. The exact date of invention is not known to us, but the 1936 patent bears a 1934 application date and cites a prior application filed in 1931. Late in the 1930s, Fred and Ethel 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, and the company later moved to Pueblo, Colorado. In 1954 the Marlmans' son-in-law, Ray Hall, joined the business. He later assumed management of the company when Mr. and Mrs. Marlman retired

Fig. 1. Coyote getter as used by government hunters before 1970. From lower left: 5-inch stake, firing unit, cyanide shell, shell holder, 7-inch stake.

[1] "Federal/Cooperative predator damage control programs" refers to state programs conducted by the U. S. government and its cooperators under the 1931 Animal Damage Control Act. These programs collectively are administered by the U. S. government as one national program. This program was known as the Predator and Rodent Control (PARC) Branch of USDA, Bureau of Biological Survey, until 1939 when it was transferred to the U. S. Department of the Interior Fish & Wildlife Service (USFWS), Bureau of Sport Fisheries and Wildlife as Predator and Rodent Control. The program was renamed several times within USFWS. In 1986 the program was transferred back to USDA and placed in the Animal & Plant Health Inspection Service (APHIS) as Animal Damage Control (ADC). In August 1997 the name changed to Wildlife Services (WS). For a detailed history of the program, see Chapter 1 in USDA (1994).

[2] Contrary to common belief, Fred Marlman was not a 'government hunter' when he invented the CG. After his CG company was in operation, however, he did work briefly for Predator & Rodent Control in Wyoming in 1939-40 to train government hunters and generally help introduce CGs into the government's predator control work (personal communications, G. Connolly with Fred Marlman's son and son-in-law, Bill Marlman, Las Animas CO and Ray Hall, Pueblo CO, February 17, 2000, and with John Eisenbraun, WS State Office, Casper WY, February 24, 2000).

(personal communication, G. Connolly with Ray Hall at Pueblo, Colorado, July 21, 1982).

The Coyote Getter (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, and governmental predator hunters and researchers soon were documenting the utility of this new tool for killing livestock predators, particularly coyotes. Some of the earliest studies investigated how many CGs one hunter could use effectively (Sears 1941), winter performance of "tree-type" CGs in Wyoming (Robinson 1942), and CG performance in comparison with steel traps (Robinson 1943).

Government hunters were lukewarm about the new CG at first but, as soon as they learned how to use it, the CG quickly became one of the most popular coyote control tools. In time, some users 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. The 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).

Another early CG expert was Frank Martin, a government hunter stationed in the brush country of southwestern Texas. By working from dawn to dark, 6 and a half days each week during the busiest months, Frank took 2,714 coyotes in the year 1961. The count was verified by actual count of coyote scalps turned in to the PARC warehouse in San Antonio. Nearly all these coyotes were taken by CGs, and most of them were taken on 2 or 3 Texas ranches (Cadieux 1983).

CG Specialists also developed outside of the governmental predator control program. One of these was "Coyote Monte" Cook, a trapper who killed 454 coyotes with CGs in 110 days. He took a total of 1,539 coyotes with CGs in 6 years. Cook reported that few coyotes got farther than 40-70 yards from the set (Bennett 1945).

These early successes were made in spite of significant CG performance problems, which were being reported within the first year of CG use. Junior biologist Weldon Robinson (1941a,b) was detailed from the Denver Research Center (DRC) to investigate, as described in detail later (see "Coyote Getter Cartridges" and "M-44 Cyanide Capsules"). Permanent solutions to the problems documented by Robinson were never found, either for the CG or later for the M-44. Nevertheless, many government hunters over the years devised effective strategies to circumvent these problems, thereby achieving excellent performance with CGs and later with M-44s.

Beginning in the late 1930s, the Marlmans' successful CG business soon attracted competition. Several other models of NaCN ejectors were invented (Wainwright 1942, 1944; Koch and Lehn 1948; Graybill 1950, 1953) and some of them became available commercially (Fig. 2). Some of the competing models were tested by governmental experts, but were judged to be inferior to the CG in terms of effectiveness, cost, simplicity, and safety (Sears 1945, Cummings 1948). Based on these findings, no NaCN ejector model other than the Marlman CG was used significantly in Federal/Cooperative predator control operations until the late 1960s when CGs began to be replaced by the safer, spring-activated M-44 ejectors.

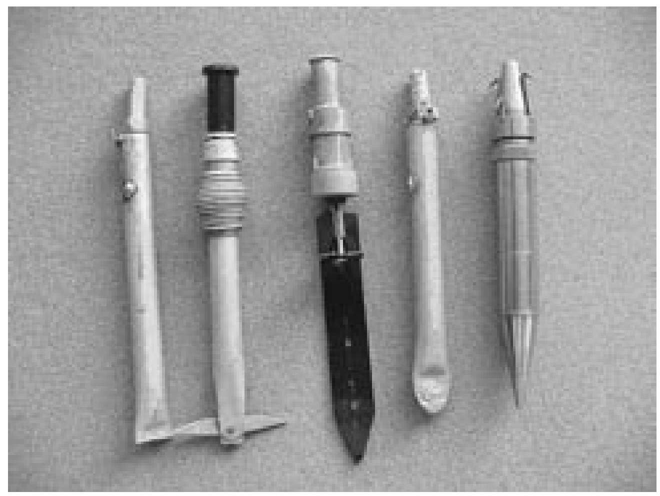

Fig. 2. Competing models of NaCN ejectors that appeared during the 1940s, 1950s and 1960s. From left, the Coyote Getter, Wainwright gun, Newhouse Safety Coyote Killer, Liquid Humane Coyote Getter, and an ejector of unknown origin.

Despite chronic malfunctions, the biggest problem with CGs was their hazard to humans due to the forceful ejection of the top wad and cyanide mixture. The CG was particularly hazardous to people who were unfamiliar with it. An early assessment of the CG (Robinson 1943) noted that it could be sprung 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 safety instructions provided to users.

Serious accidents occurred later, however. In 1959, a 15-year-old boy suffered the loss of an eye through an accidental CG discharge on a North Dakota farm. This CG was 1 of 8 that had been set by a USFWS mammal control agent, at the farmer's request, to protect turkeys from fox predation. All approaches to the CG placements were posted with warning signs, and a CG warning sign was attached to a post 35 feet from where the accident occurred (Memorandum, W. C. Hickling, Assistant District Agent, Bismarck, North Dakota, to District Agent, Mitchell, South Dakota, January 13, 1959).[3]

The injured youth, who testified that he had never heard of a CG, apparently caused it to fire by accidentally 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 under the Federal Tort Claims Act by the injured youth and his guardian. The case came to trial in U. S. District Court, Fargo, North Dakota, in April 1963 (Civil No. 3918), resulting in a judgment against the U. S. government. Damages totaling $65,000 were awarded.

In correspondence related to this case, Acting Denver Wildlife Research Center Director Jack F. Welch (Memorandum to Regional Director, Minneapolis, Minnesota, July 23, 1962) described a similar, accidental CG discharge experienced on October 1, 1961 by a Predator and Rodent Control (PARC) employee in Colorado. This individual accidentally kicked a CG while walking, and the top wad struck him under the chin causing rather severe lacerations. He was hospitalized for a few days for observation but no further damage was reported. Mr. Welch speculated that, had the top wad struck this person in the eye, extensive damage would have undoubtedly occurred with the probable loss of an eye.

In all the years that NaCN ejectors have been used, there has been only 1 accident that caused a human fatality. It happened about 30 miles southwest of Fort Stockton, Texas, in 1966, when 1 man in a party of 3 land surveyors touched a privately-set CG. The device exploded and hit him in the hand, where ejected material penetrated the skin. The injured man consulted a doctor in Fort Stockton approximately 1 hour after the accident, but was not treated for cyanide poisoning as neither the victim nor his surveyor companions realized that the exploding device was a cyanide gun. This unfortunate lack of awareness resulted in the victim not receiving proper treatment, and he 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 jury to the left hand by a cyanide loaded pellet" (Willey 1966).

At least 17 human injuries were caused by CGs from 1965 through 1971 (Anonymous 1973). By the late 1960s the Program was increasingly being criticized for continuing to use CGs, and several states had outlawed CGs as set guns. Colorado District Agent[4] L. C. Bacus (Memorandum to Manager, Pocatello Supply Depot (PSD), May 12, 1970) wrote that the Bureau of Biological Survey had used the CG for 30 years without making 1 basic change to the device. Actually, the Bureau had started to develop CG safety improvements as early as 1960. These were found to be inadequate, so FWS administrators decided to abandon the CG in favor of a safer, spring-activated cyanide ejector (Fitzwater 1964).

Several program employees, including James Poteet, a Predator Control Specialist in Midland, Texas, worked during the early 1960s to develop this spring-activated NaCN ejector mechanism. The early work, reported by Fitzwater (1964), became the basis for a patent application early in 1965; the patent was issued in 1967 (Poteet 1967). The patent was granted in Mr. Poteet's name, in exchange for which he granted royalty-free use of the invention to the U. S. government for governmental purposes. Mr. Poteet retained all other rights, including the right to manufacture and sell ejectors to users outside the Federal/Cooperative predator control program, and he later established the M-44 Safety Predator Control Company at Midland, Texas, for this purpose.

The Poteet patent did not contain the term, M-44, and it did not exactly describe the device that later became known as the M-44. Thanks to further development work, primarily by Vic Keenan (Bacus 1967, Bartnicki 1968), the spring-activated ejector device evolved significantly between 1965, when the Poteet patent application was filed, and September 1967 when the patent was granted. The new ejector was phased gradually into Federal/Cooperative wildlife damage management programs beginning in 1967, and was being called the M-44 by 1968 (Bartnicki 1968). The M-44 designation reflects the 0.44-inch diameter of the plastic cyanide capsule. We have been unable to determine the meaning of the "M" in the M-44 designation, but we think it is either an abbreviation for "model" or a reference to the mechanical mode of ejection. The earliest reference known to us in which the new ejector is termed M-44 stated "Giant strides were taken toward the development of another control device which will be SAFE to unsuspecting humans. This is the M-44, the mechanically activated cyanide ejector" (Bartnicki 1968). The change from CGs to M-44s was substantially complete by November 1, 1970, the date on which M-44s officially replaced CGs in federally supervised predator damage control programs.

As intended, the spring-loaded M-44 was much safer than the CG. When introduced to government hunters, however, it met resistance from the start. Colorado District Agent L. C. Bacus, who played a leading role in the Division of Wildlife Services campaign to

[3] Note: this memo probably was written on January 13, 1960.

[4] The 'District Agent' position was equivalent to 'State Director' in the current (2002) Wildlife Services program.

replace CGs with M-44s, reported that "The M-44 is performing to a great extent in direct degree to the interest and intelligence with which it is 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 to Manager, PSD, December 1, 1969). A year later, another progress report from Bacus (Memorandum to Manager, PSD, May 12, 1970) stated, "At the end of the first complete season's field use, the M-44 has proven to be a good control tool. There have been faults that have become apparent that could only be determined after extensive field exposure . . . One of the greatest problems we have to contend with in conversion to the M-44 is the fieldman's resistance to change."

Less than 2 years after M-44s officially replaced CGs in governmental predator control, most uses of predacides including NaCN were banned on federal lands and in federal programs by President Nixon's Executive Order 11643, issued on February 8, 1972. One month later the USEPA canceled most uses of predacides including NaCN as used in CGs (Ruckelshaus 1972). Technically, this cancellation affected only the CG as the M-44 had not yet been registered. Nevertheless, the cancellation was interpreted as applying not only to CGs but to M-44s as well. All M-44s were promptly withdrawn from the field and shelved. As noted previously, USFWS had stopped using CGs earlier.

The 1972 predacide ban, ostensibly based on a scientific review of predator control practices and policies by the Secretary of the Interior's advisory committee (Cain et al. 1972), generated a firestorm of opposition from livestock producers who had not been represented on the Cain committee and who felt that their views had not received fair consideration in the governmental decision to ban predacides. One result of the ensuing debate was a decision to reauthorize the use of NaCN in M-44s for predator control. Following large scale experimental use in 1974-75, NaCN was formally reregistered in September 1975 for use in M-44 cyanide capsules (Train 1975, Matheny 1976). The governmental decision to reinstate M-44s but not CGs was based on opinions and data that contended or showed the M-44 to pose lower risks to humans and the environment (Train 1975; USDI 1975, 1978).

As noted earlier, the technical problems that previously had plagued CG users - caked NaCN capsules and ejectors that malfunctioned or failed to eject - continued to be experienced with M-44s. Either for this or other reasons, the numbers of coyotes taken after 1975 with the newly registered M-44s were much lower than the kills recorded before 1972. Compared to the annual, west-wide take of 21,000 to 25,000 coyotes by NaCN ejectors in FY 1970 and 1971 (USDI 1975:88), the annual kill during FY 1976-1979 varied between 6,000 and 8,000 with an apparent declining trend of about 1,000 coyotes per year after FY 1977. This decline was believed by Connolly (1988c) to have resulted from reduced numbers of M-44s being used each year rather than from changes in M-44 performance.

Responding to field concerns about poor M-44 performance, the Program in 1977 appointed Colorado District Supervisor Vic Keenan to undertake an M-44 improvement project. Keenan developed a completely new cyanide ejector system (Keenan 1979). As detailed later, hand-made prototypes of the new M-50 ejector performed well for selected field men. When the M-50 came into mass production and large-scale field use, however, its performance was inferior to that of the problematic Poteet M-44.

By 1980 it was clear to ADC program leaders at all levels that the M-44 situation was worse than ever. PSD now was manufacturing 2 models of NaCN ejectors, including 2 kinds of capsules, but neither of them performed satisfactorily. Field personnel submitted increasing numbers of verbal and written complaints as well as suggestions for improvement.

In June 1981, USFWS established an M-44 Study Team to review the problems associated with NaCN ejectors and to develop a plan to achieve an acceptable level of performance from them. The Team included Paul Edstrom (Chairman)[5], Norm Johnson, Jerry Bean, and Guy Connolly (Memorandum from Acting Associate Director, USFWS, to Regional Directors and Research, June 26, 1981). The Team met in July 1981 to consider M-44 performance, performance goals, service and maintenance standards, and research & development needs. Plans were made for a rigorous field evaluation to document performance differences, if any, between the M-44 and M-50 (Memorandum from M-44 Study Team to Chief, Division of Wildlife Management, USFWS, August 28, 1981). In addition, "Guidelines for M-44 Users" were written in 1981 for dissemination to ADC Specialists. These guidelines, later known as "M-44 User Tips," have been revised several times over the years (Connolly 1988b, 1992; Connolly and Blom 1996). The latest version is included with this report as an appendix.

The M-44/M-50 field evaluation, conducted near Port O'Connor, Texas, early in 1982, is reported in detail elsewhere in this report. It showed beyond question that the M-44 was superior to the M-50 (Connolly and Simmons 1984). Based on these results, the Team recommended that the M-50 be phased out, which it was in 1983. Modifications also were made to the Poteet model M-44 ejector, as detailed later.

[5] Edstrom was Wildlife Biologist, USFWS Division of Wildlife Management, Washington, D.C.; Johnson was Regional ADC Supervisor, USFWS Albuquerque, NM; Bean was PSD Manager; Connolly was Wildlife Research Biologist, DWRC, Twin Falls, Idaho. Bean left the Team in August 1982 when he resigned as PSD Manager. Edstrom became PSD Manager in August 1983. Gary Simmons joined the Study Team early in 1984 when he assumed Edstrom's former post in Washington D.C.

Many more field and laboratory assessments of M-44 components followed through the 1980s, resulting in further recommendations for technical improvement. In addition, the M-44 ejector body and capsule holder were redesigned in 1984 when it became necessary to replace the dies that had been used since 1967 to cast these metal parts. The new, Edstrom model, M-44 went into production in January 1985 (Table 1). With modifications as detailed later, it remains in use today (2002). The Poteet model M-44 was discontinued when the Edstrom model was introduced. No NaCN ejector other than the Edstrom model M-44 has been made at PSD since 1984.

These improvements collectively resulted in improved M-44 performance, increased M-44 use by ADC field men, and increased coyote take by M-44s beginning in 1982 and continuing through 1995 (Connolly 1996). By the mid-1990s, coyote take with M-44s had increased to the level—approximately 24,000 per year—where it had been in the early 1970s, just before the 1972 predacide ban.

The M-44 Study Team formed in 1981 became inactive after 1986 when the ADC program transferred from USDI to USDA. The Team was not formally disbanded; it simply stopped meeting due to the press of other business incidental to the program transfer. The Team had planned a mail questionnaire survey of M-44 users' experience with the new (Edstrom model) ejector, but this survey was not completed. In 1987, however, the ADC National Technical Support Staff used the Study Team's questionnaire as the basis for a more general solicitation of M-44 users' suggestions for improve-

Table 1. M-44 Ejector Models Made at USDA/WS Pocatello Supply Depot, 1969-2002.

Designation	General Features	Variations and Dates of Manufacture
Poteet M-44	The original M-44 that officially replaced the Coyote Getter in 1970. Body cast from #3 zinc, length 2.98", diameter 0.50". Black plunger, trigger, and spring. Trigger wire diameter 0.08". Bottom plug crimped in place. Polyethylene NaCN capsule, 0.45" diameter.	Type 1 produced 1969-mid 1982. Solid bottom plug; plunger extends 1.20" out of ejector body. Type 2 made mid 1982-Dec 1984. Bottom plug has 0.19" diameter hole; plunger extends 1.08" out of body. Plunger is 1/8" shorter than in Type 1.
Keenan M-50	Cast aluminum body, length 4.04", diameter 0.59". Black plunger, trigger, and spring. Plunger extends .48" out of ejector body. Bottom plug threaded to permit disassembly. Has set screw to maintain proper plunger orientation. Trigger wire diameter 0.10". Polystyrene NaCN capsule, 0.50" diameter (not interchangeable with standard M-44 capsule)	One type, made Jan 1979-mid 1982. M-50 capsules were not made after 1983.
Edstrom M-44	Body cast from #3 zinc, length 3.36", diameter 0.56". Zinc-plated plunger, trigger, and spring. Trigger wire diameter 0.10". Bottom plug crimped in place; has 0.22" diameter hole. Capsule is the same one used in Poteet M-44. M-50 style stake was used with wire lock ring until 1996 when a stronger, flat lock ring was adopted. Capsule holders made since 1997 have a 1.1" diameter flange lip at bottom to deflect rain water.	Type 1 produced Jan-June 1985. No O-ring on plunger. Plunger extends 1.06" out of body. Trigger notch on body is about 0.12" deep. Throat diameter 0.249-0.250". Ejector body crimped at bottom. Type 2 produced June 1985 – late 1986. Like Type 1, except plunger has neoprene O-ring shock absorber (not visible unless ejector is disassembled), so that plunger extends only 1.01" out of body, and trigger notch is about 0.09" deep. Throat diameter 0.249-0.250". Type 3 produced late 1986-1992. Like Type 2, except throat diameter 0.004" larger. Type 4 produced 1992-2002. No bottom crimp; a retaining pin holds plunger and ejector spring in place. The pin permits field disassembly for cleaning, lubrication or replacement of inner parts.

ment. This was the most comprehensive effort ever made to gather field input about M-44 problems and their solutions. Over 200 ADC Specialists responded to the survey and provided valuable information about M-44 performance. As it turned out, most of the reported problems were already recognized and either had been resolved or were under study. Nevertheless, the input gathered from this survey confirmed that problems still existed and helped to prioritize the research efforts needed to solve them (Connolly 1988a).

Systematic efforts by the DWRC to improve M-44 ejectors and capsules ceased in 1989 when the project leader for Predator Depredations Control – Lethal Methods (Connolly) was reassigned to other duties and relocated to DWRC headquarters at Lakewood, Colorado. Nevertheless, PSD has continued to assess and often adopt suggestions for improvement from ADC field personnel. A formal quality control program for M-44 Cyanide Capsules was established at PSD in 1991 to ensure that capsules shipped to the field contained prescribed amounts of toxicant and that the contents were in a free-flowing state. Metal M-44 components made at PSD also are monitored for quality before they are shipped to the field.

The M-44 has evolved more or less continuously since its introduction in the late 1960s. Important models and model variations are summarized in Table 1. The descriptions and measurements provided there will enable M-44 users and collectors to identify just about any spring ejector used in Federal/Cooperative ADC and WS programs since 1969.

NaCN ejectors have 4 components: cyanide capsules or cartridges, ejectors, capsule holders, and stakes. Each of these components is discussed separately in following sections of this report.

CYANIDE CAPSULES (CARTRIDGES, SHELLS, OR CASES)

Over the years, cyanide cartridges or capsules have given more problems and received more research and management attention than other ejector components.

Coyote Getter Cartridges or Shells

A .38 Special pistol cartridge case, usually of nickel-plated brass, with primer was used to contain the NaCN mixture for CGs (Fig. 1). Problems with CG cartridges surfaced almost immediately after government hunters began to use CGs and, as noted previously, Denver Research Center (DRC) Junior Biologist Weldon Robinson was detailed to investigate them. He found that almost 30 % of coyotes that triggered CGs were not recovered. Possible reasons for this included (1) some coyotes died at long distances away from the units and therefore were not found; (2) some coyotes received sublethal doses of NaCN; (3) some firings were defective; and (4) some cartridges were ineffective due to caking of the NaCN mixture.

Robinson (1941a) compared cartridges taken fresh out of the box with those that had been exposed to field conditions during a fall and winter season. Tests on rats showed that fresh cartridges were 2 to 2-1/2 times as toxic as those from the field. Another test showed that all of the cartridges from the field had various flaws such as dud primers, case blow-outs, and caked NaCN. It was estimated that these aged cartridges would have provided 30 % less good kills in the field than the fresh ones.

Continuing his work, Robinson (1941b) fired 100 cartridges taken from the field after a government hunter reported low recovery rates from that batch. Seventy-three of the 100 cartridges exploded satisfactorily. Robinson noted that coyotes were already becoming “getter-wise” after they had adverse experiences with CGs in the field.

In the beginning, CG cartridges for use in governmental predator control were purchased from Marlman’s firm. However, government hunters soon became dissatisfied with the Marlman cartridges, so the Program began manufacturing its own CG shells at the PSD in the mid-1940s (Bacus 1969a). A royalty of 1 cent per cartridge was paid to the HCG firm. From July 1946 through January 1962, when payments stopped, total royalties of $24,612.50 were paid (personal communication, PSD Manager George Kerr to BSFW Regional Director Paul Quick, Portland, Oregon, April 4, 1962). At 1 cent each, these payments indicate that approximately 2.5 million CG cartridges were made at PSD during this 16-year period. Royalty payments stopped on January 30, 1962, the date on which the last Marlman CG patent (Marlman 1945) expired, but PSD continued to produce CG cartridges until July 1969.

Whether made by Marlman or by PSD, CG cartridges continued to exhibit quality problems through the 1940s and 1950s. In 1958, these continuing problems led USFWS to seek outside expertise. Idaho Chemical Industries of Boise, Idaho, was contracted to chemically investigate CG cartridges, determine the reasons for malfunctions, and recommend corrective measures. Both physical and chemical aspects of CG cartridges were studied. Idaho Chemical Industries’ report (Bush 1958) noted that the primers, ejectors, and cartridge seals were all subject to malfunction and would contribute to the problem of misfires.

After evaluating the NaCN mixture in CG cartridges, including inert ingredients and impurities, Bush (1958) concluded that many different chemical reactions could take place, depending upon the amount of moisture initially present within the cartridges at the time of manufacture. When NaCN and water combine, hydrogen cyanide gas is formed. Sulfide impurities within NaCN also react with water to form hydrogen sulfide gas. Both of these gases exert an upward force on the seal, causing it to break open and allowing more moisture to enter the cartridge. Yet another by-product of these reaction products is magnesium chloride which, once formed, readily turns to a liquid. These reactions continue until all the cartridge contents have become chemically reacted and cake to hardness.

From these findings, Bush (1958) recommended (1) using a desiccant within the NaCN mixture to collect moisture; (2) coating the metal cartridges with plastic; (3) using a nonacid dye; and (4) using a higher grade NaCN with less impurities, or an alternate toxicant. He also recommended that PSD standardize the (1) drying time of NaCN before loading the cartridges; (2) cartridge storage facilities; and (3) the length of time of storage. We believe that most of these recommendations were adopted, though explicit documentation is lacking. Whatever the reason, it seems that the volume of field complaints about CG cartridges declined after the Bush investigation. Some of the last CG cartridges made at PSD, in July 1969, were evaluated at Port O'Connor, Texas, in 1982 in comparison with M-44 and M-50 capsules. The 12-year-old CG cartridges performed very well (Connolly and Simmons 1984).

M-44 Cyanide Capsules

When the spring-activated M-44 ejector (Fig. 3) came into use, the same problems of faulty seals and caked cyanide that had been experienced with CG cartridges ever since the 1940s continued to occur within the plastic M-44 capsules. Lee Bacus investigated these problems and reported, "As with the Humane Coyote Getter, the major problem is, and will remain in the case or whatever we call the cyanide container" (Memorandum to Manager, PSD, December 1, 1969). Later he added that, "Caking of cyanide has been a problem with cyanide dispensers for over 30 years. The explosively activated models had sufficient force to rupture normal cake. Ejector force from the spring-activated M-44 is milder and the cyanide must be in a flowing condition to perform" (Memorandum to Regional Supervisor, Portland, Oregon, January 30, 1970).

Fig. 3. The "Poteet" model M-44 as made at Pocatello Supply Depot from approximately 1969 through 1984. From lower left, a 5-inch Leyerly top stake, ejector, polyethylene M-44 cyanide capsule, capsule holder, and 7-inch Leyerly top stake.

Caked cyanide and other technical problems became irrelevant in 1972 when the uses of NaCN and other predacides were banned, as detailed previously. For a couple of years it appeared that NaCN ejectors would never again be used in governmental predator control. With the M-44 reinstatement beginning in 1974, however, the unsolved technical problems also reappeared. One result of this was declining confidence among field personnel that M-44s would perform as intended. As noted previously, there was a corresponding decline in M-44 use through the 1970s resulting in declining numbers of coyotes taken by M-44s (Connolly 1988c).

Also as noted previously, Colorado District Supervisor Vic Keenan began an M-44 improvement project in 1977. The resulting new ejector, known as the M-50, featured a new cyanide capsule made of high density polystyrene and sealed with a solvent (xylol). The resulting seal was so strong that the M-50 ejector plunger sometimes failed to penetrate it, resulting in failure to eject cyanide when triggered by a coyote. Moreover, the M-50 capsules weren't field tested prior to mass production, so the excessively strong seal wasn't recognized as a problem until thousands of M-50 capsules were in the field. The upshot of all this, as reported earlier, was that the M-50 eventually was abandoned so that all improvement effort could be concentrated on the M-44. Attention quickly focused on M-44 cyanide capsule improvement as a high priority.

Various types of capsules including an experimental glass capsule were tested in Texas in 1982. The glass capsules, made from borosilicate laboratory ampules that were heat-sealed after being filled with NaCN, were monitored along with other capsules exposed outdoors. They failed, and it was recommended that some other type of glass be used in subsequent trials (Connolly and Simmons 1983a,b).

Glass capsules were investigated again in 1990 when Jerry Bean of the M-44 Company, Fredericksburg, Texas, asked Texas ADC personnel to test a new glass capsule that he had developed. Bean's capsules were evaluated in side-by-side field comparisons with PSD standard capsules during January-March 1990. The PSD capsules performed best. Approximately 96 % of coyotes that pulled M-44s containing PSD capsules were recovered, compared to only 78 % recovery of coyotes that triggered ejectors with glass capsules. Moreover, the average recovery distance (from ejector device to coyote carcass) was only 27 yards for PSD capsules, significantly lower than the 38 yards recorded for glass capsules. Several test participants reported problems with the glass capsules, such as NaCN not being pushed out of the capsules by the plunger. Instead, the NaCN caked and stuck to the capsule walls as the plunger passed through it (Memorandum, M. A. Dunaway, ADC San Antonio, Texas, to Director, ADC Western Region, Lakewood, Colorado, May 31, 1990). After these results were conveyed to Mr. Bean, nothing further was heard from him about glass capsules. We assume that he did not pursue this development any farther.

In 1987, PSD Manager Paul Edstrom obtained pilot lots of M-44 capsules made from several transparent plastic materials: acrylic, polycarbonate resin, K-resin, butyrate, ABS plastic, and clear polyvinylchloride. A study was planned to evaluate these capsules in comparison with the standard, translucent polyethylene (PE) capsule (Connolly 1987), but the study was not completed due to competing, higher priority demands for the investigator's time. This study also included evaluations of a "bottomless" capsule design and of improved packaging for M-44 capsules, both of which were adopted at PSD without advance field testing. They remain in use today (2002).

At this time (2002), the M-44 capsules supplied by PSD continue to be molded from the same translucent high-density PE that was adopted about 1969 or 1970. This material is described as "Polyethylene, High DIN, Marlex 6050, Phillips, or equivalent" in the design drawing of 6/24/69, by Omark-CCI, Inc., Lewiston, Idaho. Top wads are made of similar material.

Cartridge and Capsule Sealants

One of the first sealants used by Marlman in the CG cartridge was beeswax. Later, he used black roofing tar (Memorandum, L. C. Bacus, USFWS Division of Wildlife Services to Regional Supervisor, Division of Wildlife Services, Portland, Oregon, November 18, 1970). Black roofing tar also was the standard sealant for CG cartridges made at PSD in the 1960s and probably earlier. Though effective as a sealant, this tar constituted a hazard to humans. When fired, these CG cartridges expelled the tar-covered top wad with dangerous force. Human injuries caused by these projectiles were discussed earlier; see "Background and History." Despite its known hazards, however, the tar seal remained in use through 1969 when PSD stopped making CG cartridges.

New sealants were needed for M-44 capsules beginning in the late 1960s when M-44s began to replace CGs. The first mass-produced M-44 capsule, made of green, translucent cellulose acetate butyrate (CAB), was sealed both top and bottom with an unidentified clear, flexible sealant (Bacus 1969b,c). These capsules proved to be unsatisfactory as CAB is not water tight (M-44 Cases. L. C. Bacus, DWS, Denver Colorado, to Manager, PSD, August 24, 1970). Therefore, PSD soon switched to the PE capsule. By 1971, mass-produced PE capsules were being sealed with 3m #4693 adhesive, diluted with painters' naphtha in a ratio of 3 parts adhesive to 1 part naphtha (Quality Control Tests-M-44 Cases. Memorandum, L. C. Bacus, DWS, Denver, Colorado, to Manager, PSD, December 9, 1970). The 3:1 dilution ratio specified by Bacus later was changed by PSD to 2:1 (Connolly and Simmons 1983a). This mixture remained the standard sealant until it was replaced by beeswax as detailed later.

In 1982, several potential capsule improvements including sealants were evaluated in outdoor weathering tests at College Station, Texas. This location had been selected because the warm, humid climate in east Texas was perceived as being particularly stressful to M-44 cyanide capsules. In addition, a fenced and locked enclosure where exposed capsules could be protected from interference by humans or animals was available at Texas A&M University. The objective was to identify the sealant, or combination of capsule plus sealant, that would maintain NaCN mixture within M-44 capsules as a dry powder for the longest possible time. Various capsule treatments were placed outdoors, in trays designed to hold them upright, and inspected periodically to determine the condition of cyanide mixtures within the capsules. Based on visual inspection, each capsule was rated normal if its NaCN contents were normal in color, dry, and free-flowing. Deteriorated capsules had caked, liquefied, or discolored contents.

This study showed that only 26% of PSD production capsules contained normal NaCN after 6 weeks' exposure, and only 9 % were normal after 12 weeks. Addition of a beeswax seal to the standard PSD capsule yielded significant improvement—beeswaxed capsules were 100 % normal after 6 weeks' exposure and 82 % normal after 12 weeks (Connolly and Simmons 1983a,b).

The rationale for evaluating M-44 capsules in weathering tests is that outdoor exposure simulates the conditions under which M-44s are used. However, outdoor exposure takes time and can be expensive if it requires investigators to travel. A quicker, more efficient means for evaluating sealed capsules was developed in 1982. The so-called "torture test" was a laboratory procedure that treated M-44 capsules alternately by soaking in water, freezing, and exposure to outdoor heat at the DWRC field station at Twin Falls, Idaho (Memorandum, G. E. Connolly to M-44 Study Team, October 7, 1982).

One torture test compared standard, beeswax-sealed M-44 capsules to beeswax- and xylol-sealed M-50 capsules. This treatment destroyed most beeswax-sealed capsules but not the xylol-bonded polystyrene M-50s. However, the xylol seal had other drawbacks, as mentioned previously. In particular, it was so strong that the M-50 ejector plunger sometimes could not break it. This is an important reason why M-50s did not perform well in the field, and why this type of capsule and seal was not investigated further. These and other studies indicated that the beeswax seal was the best known alternative for sealing M-44 capsules. Therefore, it was recommended that PSD replace the 3M sealant with a hot beeswax seal on mass-produced M-44 capsules (Connolly and Simmons 1983a,b).

The beeswax seals tested in research had been applied by hand 1 capsule at a time, and it was obvious at PSD that this labor-intensive procedure was not practical for mass production. Before a beeswax seal could be used on mass-produced M-44 capsules, techniques had to be developed for efficient application. The first mass-produced, beeswax seal at used PSD beginning in December 1982 was an emulsified liquid that could be applied at room temperature. Capsules sealed with emulsified beeswax were not field tested prior to large scale manufacture, but in the field they 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). Therefore, the M-44 Study Team recommended in April 1983 that PSD should apply thick beeswax seals to both tops and bottoms of M-44 capsules (M-44 improvement. Memorandum, M-44 Study Team to Chief, USFWS Division of Wildlife Management, Washington, D. C., June 23, 1983). Nevertheless, the emulsified beeswax seal remained in use until August 1983 when Paul Edstrom became PSD Manager.

At Pocatello, Edstrom promptly developed an efficient procedure to apply a hot beeswax seal to M-44 capsules. Crude, yellow beeswax was applied in a molten state using an electrically heated pot from which the melted wax could be applied to the tops of M-44 capsules. Such pots are commonly used by firearms enthusiasts for melting lead to cast bullets for use in muzzle-loading rifles and pistols. With this technology, experienced PSD personnel can put top seals on 100 M-44 capsules in 75 to 90 seconds. The hot beeswax seal, using crude, yellow beeswax, was routinely applied to all PSD M-44 capsules beginning in August 1983.

Yet another capsule weathering test was conducted in Arizona, Montana, Oregon, and Texas during August 1984 – March 1985 with beeswax and other types of sealants and capsule types (Memorandum, G. E. Connolly to M-44 Study Team, April 16, 1985). Here the rationale for selection of tests sites was to expose capsules to 4 types of environments: hot & dry (southern Arizona); cool & dry (eastern Montana); cool & damp (Oregon coast); and hot & damp (east Texas). The beeswax seal continued to perform better than any alternative.

During this study, close examination of failed beeswax-sealed capsules revealed that most of them had cracks in the capsule bottom, or bottom membrane. Overall, 3 % of capsules examined in 1984-85 had cracked bottoms. Up to this time, PSD had been using beeswax only to seal the top wads but, beginning early in 1985, hot beeswax also was applied to the bottom. Field personnel soon learned that the bottom wax, if it was too thick, could retard or prevent penetration and ejection of NaCN by the ejector plunger. As an interim fix for this problem, field personnel were instructed to scrape out most of the bottom wax from M-44 capsules before setting them in ejectors.

In 1987, the bottom-membrane problem was solved by redesigning the capsule to eliminate the plastic bottom, as described previously (see "M-44 Cyanide Capsules"). PSD capsule manufacturing procedures were changed to accommodate the bottomless capsule by seating a cardboard wad inside each capsule at the bottom, then inverting the capsule and applying hot beeswax over the cardboard to create the bottom seal. This seal worked well to keep moisture out, yet was flexible enough for the ejector plunger to penetrate through the capsule. As of 2002, the bottomless capsule design remains standard for capsules manufactured at PSD.

Crude, yellow beeswax was used to seal all M-44 capsules at PSD from 1983 to 1989, except for a brief time in 1986-87 when a higher grade of white beeswax was used instead. Neither the date nor the reason for this change from yellow, crude beeswax to the more refined, white wax was documented, as far as we know. The white-waxed capsules were shipped to field offices with no notice of the sealant change. Within a few months, field personnel reported problems with them.

These complaints brought renewed research attention to the problem of M-44 capsule sealants. Connolly compared the sealant characteristics of white, refined beeswax to yellow, crude beeswax, and promptly found that the crude beeswax was much superior as an M-44 capsule seal. Therefore, PSD switched back to the crude, yellow beeswax seal in 1987.

Continuing research showed that both types of beeswax had 2 undesirable properties that limited their effectiveness as sealants – (1) they shrink as they cool, and (2) they have a low melting temperature (about 140 to 145 F). Therefore, a search was made for other wax-like sealants that did not have these disadvantages. After screening 9 candidates and intensively testing the best ones, Connolly found that Scheel SC-100 microcrystalline petroleum hydrocarbon wax (Scheel Corporation, Brooklyn, New York) was the best alternative. Unlike beeswax, the SC-100 wax had a melting temperature around 175 F. and did not shrink as it cooled. In other respects, including appearance, it was quite similar to crude beeswax. In fact, this material initially was identified as a potential M-44 sealant because it was being marketed as a beeswax substitute.

Connolly subjected M-44 capsules sealed with beeswax, Scheel SC-100, and other waxes to 5 rounds of environmental challenges consisting of controlled heat (in laboratory oven), freezing, submersion in water, and heat again, similar to the torture treatments described earlier. At the end of these treatments, all beeswax-sealed capsules were ruined whereas 64 % of Scheel-waxed capsules contained normal NaCN contents with no caking. Capsules sealed with Daige BB9 Speedcote, a pressure sensitive adhesive wax, also held up well. Based on these results, Connolly recommended that PSD switch immediately from beeswax to either Scheel SC-100 or Daige BB9 wax for sealing M-44 capsules. Either of the new materials would have been much superior to beeswax, but Scheel wax was recommended as the sealant of choice because (1) most observed test differences between Scheel and Daige waxes were in favor of the Scheel wax; (2) Scheel wax had less odor; (3) Daige wax remained tacky when cool, but Scheel wax did not; (4) Scheel wax produced less capsule flare (swelling of capsule mouth); and (5) Scheel wax was cheaper (Memorandum, G. Connolly to P. Edstrom, PSD, March 7, 1989). PSD acted on this recommendation at once, discontinuing the use of beeswax in favor of Scheel SC-100 wax in March 1989. This material has been the standard M-44 capsule sealant from 1989 to date (2002).

After the Scheel wax had been in use for several years, Connolly (1996) reported the research that led to its adoption together with an evaluation of the effect of this sealant change on M-44 performance in the ADC program. This analysis showed that, following the adoption of the SC-100 hot wax seal, the annual coyote take by M-44s doubled from 1989 through 1995 even as the numbers of M-44 capsules shipped annually from PSD declined 15%. The number of capsules used per coyote taken dropped from an average of 8.7 during 1983-1988 to only 3.8 capsules per coyote during 1990-1995. This improved efficiency was attributed to the new sealant. More recently, Connolly (2002) updated this analysis and reported that the improved M-44 efficacy continued to be apparent in program records up through FY 2000.

Stability and Shelf Life of M-44 Cyanide Cartridges and Capsules

The stability of NaCN mixtures in stored cartridges or capsules varies with the storage environment, quality of the capsule seal, age of capsules, the condition of capsule contents, and probably other factors. This was noted very early by Robinson (1941a) after the first season that CGs were used in the field (1940). Robinson (1941b) also reported that a batch of CG cartridges stored inside a building in California in their original boxes for 2 years had deteriorated to the point that they were duds.

Another report recommended that Specialists discard unused CG cartridges that had be been placed in the field during the previous winter. It stated, “The fact that Coyote-Getter shells will not last indefinitely should be kept in mind by the District Agents in planning purchases for the coming season” (Division of Predator & Rodent Control, Memorandum to Field Personnel and Regional Directors, June 18, 1944). Thereafter, almost all field reports related to CG cartridges or M-44 capsules mentioned reduced effectiveness after cartridges or capsules had been exposed to various weather conditions. Extreme high temperatures and humidity seemed to affect them the worst.

Responding to a field complaint about poor M-44 capsules in 1981, Connolly wrote, “It is a fact of life that NaCN is extremely hard to deal with under normal conditions of use in M-44s, and the chemical nature of this compound is beyond the control of persons who load or use these capsules. All we can do is use fresh capsules and test-pull them frequently to see that they are not caked. Any time you have reason to question the effectiveness of any capsules, replace them with new ones” (Memorandum, G. E. Connolly to H. Brusman, ADC District Office, Craig, Colorado, November 18, 1981).

Similarly, the “M-44 User Tips” issued to ADC/WS program field men (see Appendix for latest version) recommend methods for proper storage of M-44 capsules. M-44 users also were advised to use capsules within 6 months of the date of manufacture, if possible, and to carry no more capsules in the field each day than were likely to be needed for that day’s activities.

Storage stability of M-44 capsules has been evaluated several times over the years. When USFWS applied for reregistration of NaCN for use in M-44s in 1975, EPA required a storage stability test. Capsules stored for 1 year at PSD showed no apparent decrease in NaCN content, with year-old capsules containing only 0.2 to 1.4 % less than the amount specified on the label (Memorandum, PSD Manager J. R. Bean to J. Packham, ADC Region 1, Portland, Oregon, January 3, 1977).

Stored M-44 capsules containing both NaCN and methomyl were monitored for evidence of deterioration at Twin Falls, Idaho in 1981-82. Twenty-five capsules of each type were placed in 4 test environments: (1) metal storage cabinet in a partially-heated shop; (2) freezer at -20 C; (3) metal tool box in the back of a pickup truck parked outdoors; and (4) outdoors in capsule holders placed upright in a wood block. Four and a half months later, all of the capsules appeared to be as good as new. Nine and a half months into the experiment, all of the NaCN capsules appeared to be good, but a few methomyl capsules in the freezer and outdoor treatments were discolored and slightly caked. At the end of 1 year, some NaCN capsules in every treatment except the freezer had deteriorated. All 25 of the capsules placed outside had deteriorated. It appeared that storing capsules in a freezer might be beneficial but, before making a general recommendation for freezer storage, further testing was suggested to determine how capsules would perform in hot and humid climates after they had been stored in a freezer (Memorandum, G. E. Connolly to M-44 Study Team, October 7, 1982). No such study has been carried out. Many years earlier, however, Bacus (1970) had recommended that capsules be stored in a refrigerator or freezer to insure minimum moisture and temperature variation.

Current production M-44 capsules sealed with SC-100 wax appear to be more stable than capsules made earlier. Packham and Stanford (1991) determined that capsules stored at the PSD were not collecting significant moisture, and that they retained flowable characteristics after 2-1/2 years. However, they mentioned that capsules from the same lot numbers were reported to have caking problems when stored under field conditions.

The hygroscopic, or water absorbing, properties of NaCN are not fully appreciated by most M-44 users. Even the slightest crack in the capsule seal will admit air and moisture which is readily absorbed by the NaCN mixture. Even with a tight seal, extreme temperature and humidity conditions, as well as day-to-night temperature changes, may cause condensation within the capsule which in turn may contribute to the caking by the formation of moisture and gases.

In May 1991, PSD conducted a test that readily showed the propensity of NaCN to absorb moisture from ambient air (Packham and Stanford 1991). In a room with 35 % relative humidity, an M-44 capsule was opened and the contents were immediately weighed. The contents were then left in the open air and weighed repeatedly at 2-minute intervals. After 20 minutes, the weight of these capsule contents had increased by 0.02 grams. This could only have resulted from the NaCN absorbing moisture from the air. This absorption occurred even though the air in the room was quite dry.

Alternate Toxicants

Even though the early Marlman (1939b) patent, “Poison mixture for trap gun cartridges,” specified that either NaCN or potassium cyanide (KCN) could be used effectively in the CG, NaCN has been the toxicant of choice over the years, both for the CG and later for the M-44. However, KCN was used in the Newhouse Safety Coyote Killer (Gerstell 1946) and in a Liquid Humane Coyote Getter that was marketed during the 1960s (HCG n.d.). Both of these devices are depicted in Fig. 2. In addition, M-44s containing KCN rather than NaCN were used by some certified rancher applicators in Texas during 1974-75 as part of the experimental program that led to M-44 registration in 1975. Unfortunately, none of these uses produced coyote take statistics that might have been analyzed to compare the effectiveness of NaCN and KCN (Connolly et al 1986).

In the 1980s, KCN, calcium cyanide (CaCN), and methomyl were evaluated as possible alternatives to NaCN for use in M-44s. The rationale for this was that it might be possible to avoid the caking and deterioration problems associated with NaCN by switching to some other toxicant that would be less susceptible to such problems. The alternate compounds were evaluated for storage stability in M-44 capsules and toxicity to dogs or coyotes. Toxicity tests revealed that NaCN and KCN were fastest acting, CaCN was intermediate, and methomyl was slowest. Methomyl also was less toxic than any of the CN compounds. The slowest-acting toxicants, CaCN and methomyl, were least susceptible to caking. In addition, the odor of methomyl may have repelled coyotes. It definitely attracted opossums when methomyl capsules were field-tested in Texas. Based on these results, it was concluded that none of these alternate toxicants would be a suitable replacement for NaCN in the M-44 (Connolly et al. 1986).

In 1992, Blom reviewed the chemical properties of other cyanide salts such as silver cyanide, copper cyanide, and zinc cyanide as possible alternate toxicants for M-44s. None of these compounds were then or are now registered with USEPA for use as pesticides. Although they might have resolved some of the moisture and caking problems experienced with NaCN, they were extremely toxic and dangerous to handle. Therefore, they would have been impractical to use as M-44 toxicants and were not studied further.

Current M-44 Capsules

Current production M-44 capsules are loaded with a mixture of 99+ % active ingredient (AI) technical NaCN, a silica desiccant, and a Day-Glo fluorescent particle marker. Blaze-orange fluorescent particles are used in capsules loaded for use by WS program personnel, while saturn-yellow Day-Glo marker is used in capsules prepared for non-WS users. Each capsule contains 0.97 grams (plus or minus 3 %) of the NaCN mixture. The technical NaCN is ground to a powder with a maximum particle size of 0.036 inches before mixing with the other ingredients.

When work is to be done in the PSD cyanide room, a dehumidifier is turned on 24 hours ahead of time to reduce humidity as much as possible. Relative humidity levels of 20-30 % usually are achieved with the dehumidifier. Humidity levels in the cyanide room are monitored continuously while NaCN capsules are being made. After the NaCN has been mixed with other ingredients, the mixture is poured onto trays and placed in a drying oven for 24 hours at 115° C (239° F).

The dried mixture is then stored in sealed glass jars in a room of relatively consistent temperature and humidity until it is put into M-44 capsules. The plastic capsules are fitted with the bottom wad and wax seal before they are loaded. Capsules are loaded 100 at a time, and only 500 capsules are loaded with the NaCN mixture before they are quickly top-sealed and waxed to reduce exposure to air. A standard batch contains 12,000 M-44 cyanide capsules.

Before capsules are boxed, an adhesive-backed warning label is applied by hand to each capsule. Up to 1992, a paper label was used. These paper labels were unsatisfactory. Not only did their application require inordinate amounts of labor but, in the field, the paper would absorb moisture and swell, making it difficult to insert capsules into the capsule holders, or later to remove them. Vinyl labels have been used since 1992 to avoid this problem.

After the capsules are labeled, they are packed in Styrofoam containers within cardboard boxes. The date of manufacture is stamped on each box. The filled boxes of capsules are then stored a room under controlled temperature and humidity until they are shipped to the field.

During the manufacturing process, capsules are routinely sampled for quality control. Some capsules are sent to an analytical laboratory for NaCN analysis while others are checked for net weights of contents. Reference samples are maintained at the PSD from each batch of capsules manufactured. These quality control procedures are conducted to assure that each batch of capsules conforms to USEPA manufacturing requirements and to prevent bad capsules from being sent out for field use.

The condition of NaCN mixtures in M-44 capsules in the field always has been, and still is, the main factor limiting M-44 effectiveness. Even though some problems remain, current production capsules are better than ever before, thanks to all of the research and improvements that have been made over the years.

EJECTORS

Early reports on CGs (Robinson 1941a,b; 1942; 1943) did not identify ejector malfunctions as a major problem. Later, Bush (1958) noted that some older CG ejectors were corroded so badly that the firing pin did not reach the primer and therefore would not detonate the cartridges. This corrosion probably was caused by a chemical reaction between the metal shell case and the shell contents.

NaCN will react with water to produce highly caustic sodium hydroxide (NaOH). Nitrate impurities in the NaCN also can react with water to produce another corrosive agent, nitric acid. Bush (1958) also mentioned the possibility of corrosion due to an electrolysis reaction between the dissimilar metals used in the cartridge cases and the capsule holders.

When the M-44 came into production, ejector springs, plungers, and triggers were treated to resist rusting and corrosion. M-44 ejectors assembled at PSD (Fig. 3) were filled with a heavy grease lubricant just prior to closing the base disk with a 1-ton punch press. The lubricant that was sealed inside these ejectors sometimes was blamed for slow or delayed ejections, especially during colder weather. Some Specialists solved this problem by drilling holes through the base disks of the ejectors, draining out the lubricant, and relubricating with mineral oil, glycerin, graphite, or other materials. (Memorandum, D. H. Rasmussen, Bureau of Sport Fisheries & Wildlife Region 1, Portland, Oregon, to Regional Directors, Regions 2 and 3, February 5, 1971).

Another tactic considered at that time was making M-44 ejector bodies from plastic. Development of a plastic ejector, however, was given lower priority than more pressing issues such as M-44 capsule quality, and plastic ejectors were not pursued beyond handmade prototypes. Plastic ejectors were again considered in 1983 when handmade plastic M-44s and M-50s (Fig. 4) were submitted to the M-44 Study Team by Nebraska ADC Specialist Don Thalheim (M-44 Improvement. Memorandum, M-44 Study Team to Chief, Division of Wildlife Management, June 22, 1983). The Team planned a comparative field test of plastic and metal ejectors, but this test was not carried out. The reasons for this were not recorded.

As the M-44 was being developed in the 1960s, a spring with 40 pounds of thrust was selected to drive the plunger. This spring, much stronger than the CG firing-pin spring, was needed to provide increased force

Fig. 4. Prototype plastic M-44 ejectors (left and center), hand made by Nebraska ADC Specialist Don Thalheim about 1982. The ejector bodies were machined to accommodate stock M-44 metal plungers, triggers and ejector springs. A standard M-44 ejector and capsule holder (Edstrom model, ca. 1985) are shown at right for comparison.

sufficient for the plunger to penetrate the capsule seals and push the NaCN mixture out of the capsule and into the coyote's mouth (Fitzwater 1964).

During the first year of M-44 field use it was learned that, after repeated firings, the trigger sear contact became worn, causing the ejector to become hair-triggered or nonfunctional (Bacus 1970). Users were instructed to be aware of this problem and to discard hair-triggered or defective ejectors.

Other manufacturing defects in M-44 ejectors, and ways to fix or compensate for them, also were reported frequently by field men. In 1976, for example, it was noted that the plunger hole on the ejector was off-center in some units, hampering plunger travel and thereby causing delay in the ejector firing. Also, the plungers failed to puncture plastic capsule seals in about 20 % of firings. It was determined that this problem could be eliminated by grinding off the edge of the plunger tip with a 35 to 40-degree shoulder (Memorandum, L. W. Debates, FWS Region 1, Portland, Oregon, to N. Johnson, USFWS Washington D. C., October 13, 1976; Memorandum, G. S. Rost, USDI/FWS/ADC Region 2, Albuquerque, New Mexico, to State Supervisors, Region 2, September 22, 1976).

As noted earlier, Vic Keenan was asked to redesign the M-44 in 1977. His work resulted in the introduction of a completely new cyanide ejector system (Fig. 5). It was an enlarged version of the M-44, using a 0.50-inch diameter capsule, a larger ejector with a stronger spring, and a new stake design. The new unit soon was being called the M-50 to differentiate it from the Poteet M-44 which also remained in production. The M-50 ejector body and capsule holder were made of aluminum rather than the #3 zinc alloy used in the M-44. Keenan made the new ejector body about an inch

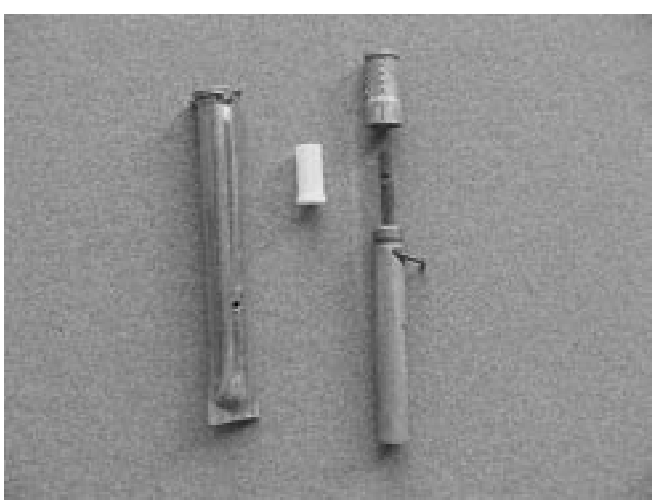

Fig. 5. The Keenan model M-50 cyanide ejector as made at Pocatello Supply Depot during 1979-1983. From left: 6-inch swaged-top stake, polystyrene cyanide capsule, ejector, and capsule holder.

longer than the Poteet M-44 body (Table 1). In addition, he replaced the crimped-in base disk with a threaded bottom plug that could be removed by field personnel to clean and lubricate the ejector. He thickened the ejector walls, used a larger diameter trigger for more sear surface, lightened the trigger pull, and increased the shoulder angle on the plunger tip from 32 to 49 degrees (Keenan 1979).

Six hundred and fifty hand-made M-50 units were sent out for field testing in 1978 (Memorandum, V. A. Keenan, ADC District Office, Monte Vista, Colorado, to Darrel Gretz, USFWS Region 6, Lakewood, Colorado, February 22, 1978). These hand-made prototypes performed very well, so the M-50 went to mass production and was issued to the field in quantity during 1979. Only later was it realized that the new M-50 capsules, made of a different plastic (polystyrene) and sealed differently from M-44 capsules, should have been field tested prior to mass production. Thousands of M-50 capsules had been shipped to the field before it was discovered that many capsule seals were too strong to be penetrated by the M-50 ejector. This of course meant that the units failed to eject cyanide when triggered by target animals. The ineffective capsules, coupled with failures of metal parts due to corrosion and to breakage resulting from poor quality control during manufacture, soon generated a large volume of field complaints about M-50 ejectors and capsules. Field reports were compiled at ADC headquarters for reporting to PSD (Memorandum, F. N. Swink, USFWS Washington, D. C. to Manager, PSD, July 3, 1980). By 1983, many Specialists had quit using the M-50s and returned to using M-44s, or they stopped using NaCN ejectors altogether.

As reported earlier, an M-44 Study Team established in 1981 was charged with correcting the problems associated with NaCN ejectors. Following a review of current problems with cyanide ejectors, the Team devised and carried out a mechanical performance comparison of standard M-44 ejectors, modified M-44 ejectors with shortened plungers, the M-50, and the CG in Texas early in 1982 (Connolly and Simmons 1984). The CG performed best, followed by modified M-44s and the standard M-44. Worst of all was the M-50.

Based on these results, the M-44 Study Team recommended that the M-50 be phased out entirely, and that the M-44 continue to be manufactured and improved. Also, the Team recommended that the M-44 ejector plunger be shortened 1/8 inches and a hole be provided in the base disk to allow drainage of water and access for lubrication. These changes were made promptly (Poteet ejector Type 2; Table 1). To reduce internal corrosion, the Team recommended that a less corrosive metal be used for triggers and springs or a suitable coating/plating be found to achieve this (M-44 Recommendations. Memorandum, M-44 Study Team to Chief, Division of Wildlife Management, Washington,

D. C., June 1982). Most of these recommendations were adopted. Perhaps the most significant result of the 1982 field evaluation was that manufacture of M-50 ejectors and capsules at PSD was halted in 1983, so that all subsequent effort could be directed toward improving the M-44 ejector and particularly the M-44 cyanide capsule.

The 1982 test results raised yet another issue: should FWS devote part of its effort to reregistering the CG, rather than focusing all attention on improving the M-44? It appeared for a time that an improved CG would be evaluated concurrently with M-44 improvements (Improvement of cyanide devices. Memorandum, Chief, Division of Wildlife Management to Regional Directors, DWRC, and PSD, May 1982). After due consideration, however, the Team realized that a CG reregistration effort would be costly and time-consuming, and might not be successful as it would necessitate a reversal of the official position taken by FWS on the CG in 1975 when the M-44 was registered. That registration had been granted, in part, on a contention that the M-44 was much safer than the CG. Since then, a newly designed, safer CG shell had been developed by HCG, Inc. This improved shell was never field tested by the USFWS, and neither the HCG firm nor USFWS ever attempted to reregister the CG following USEPA's 1972 cancellation of the original registration (Ruckelshaus 1972).

Following the cessation of M-50 manufacture in 1983, all available R&D effort was concentrated on fixing the M-44, as noted previously. The original M-44 Study Team chairman, Paul Edstrom, became manager of the PSD in August 1983. He promptly incorporated several recommended improvements into the M-44 ejector and cyanide capsules. In addition, he redesigned the M-44 ejector and capsule holder in 1984 because the original metal casting dies, that had been used to make the Poteet-model ejectors since 1968, were worn out. Since the replacement dies were so expensive that they could not often be replaced, this was the best time to incorporate any desired changes into these metal parts. Edstrom lengthened the Poteet ejector body by 0.375 inches to provide more room for a longer and stronger spring. The body walls were thickened 0.03 inches and changed to a straight wall from the bottle-neck design, the plunger diameter was reduced in its midsection to allow trigger engagement in any position, the trigger was enlarged to provide more sear surface area to increase trigger life, a stronger spring was selected to increase speed and longevity, threading was better defined in the die to improve the fit between ejector and capsule holder, and the plunger, trigger, and spring were all zinc-plated to reduce corrosion (Fig. 6).

This redesigned M-44, known as the Edstrom model, was distributed for field evaluation in 1985 (Memorandum, P. A. Edstrom, PSD to Regional ADC Supervisors, January 4, 1985). Within a few months, body cracks and broken plungers were being reported

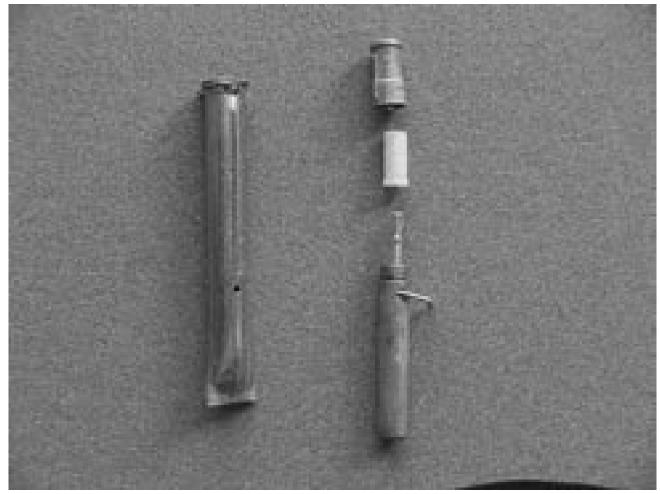

Fig. 6. The M-44 (Edstrom model) as manufactured at Pocatello Supply Depot from 1985 to 1992. From left: 6-inch stake, ejector, polyethylene M-44 cyanide capsule, and capsule holder.

(Memorandum, G. E. Connolly, DWRC Field Station, Twin Falls, Idaho, to G. Simmons, USFWS Division of Wildlife Management, Washington, D. C., May 30, 1985). Such breakage apparently was due to the stronger spring in the Edstrom-model ejector. To resolve this problem, A.J. Kriwox, a biological technician at the DWRC field station at Twin Falls, Idaho, suggested using a rubber O-ring on the plunger to cushion the impact at the top of its stroke (Memorandum, G. Connolly, Twin Falls ID to G. Simmons, USFWS Division of Wildlife Management, Washington DC, June 24, 1985). Repeated firings of ejectors so equipped showed that this simple modification increased ejector life at least 600 %, making the ejector for all practical purposes a lifetime tool. The O-ring shock absorber was adopted as a standard feature of M-44 ejectors beginning in July 1985 (Edstrom ejector, Type 2 in Table 1). The O-ring remains in use today (2002).

By 1986, it appeared to some that the M-44 ejector finally had been perfected. As time passed, however, new problems appeared due to lack of adequate quality control in the metal casting process. This process was beyond PSD's immediate control, as M-44 metal parts were (and still are) made by a private firm under contract to PSD. The metal in some lots of ejectors made in the late 1980s was grainy and brittle, leading to bottom-crimp blowouts and wall cracks following assembly of the ejectors (with plungers, triggers, and springs) at PSD. Ejector bodies with obvious flaws always had been routinely discarded on the assembly line, but some bodies now had internal cracks that could not be detected by visual inspection. The rejection rate became so high that the ejector casting company was asked to resolve the problem. Coincidentally, this company changed ownership during this time and the new owner also was notified of the problem. Our investigation revealed that extra metal (#3 zinc) left over as the ejector bodies and capsule holders were cast was being recycled into the casting pot. This apparently had an adverse effect on the granular structure in parts cast from this recycled metal, causing metal fatigue and, in turn, brittleness and cracking. Also, during this investigation, flaws were also discovered in the dies. It appeared that drastic action would be required to solve the problem of bottom-crimp blow-outs.

This problem was solved by PSD manufacturing Specialist John Stanford, who redesigned the ejector to eliminate the bottom crimp. The body walls were thickened for their entire length. In place of the bottom crimp used previously, a small hole was drilled through the body 1/8 inches from the bottom, and a small retaining pin was inserted through the hole after the spring, plunger, and trigger had been assembled (Fig. 7). This modification not only avoided the troublesome bottom crimp, but also provided a capability for field disassembly of ejectors when necessary to clean and lubricate the internal parts.

Prototype ejectors with this retaining-pin modification were tested by dry-firing up to 100 times each, or until the triggers failed to engage, in an effort to simulate or exceed the maximum amount of wear that would be expected in field use. Various types of retaining pins were lab-tested and 4 were field tested by several Specialists throughout the West under various weather and soil conditions during the summer of 1992. Only after the feasibility of this modification was confirmed in extended field use, during which the best pin type was identified, was the new ejector body using a zinc-plated pin put into production at PSD. This model is designated as the Edstrom M-44, Type 4 (Table 1). To date (2002), no complaints have been received

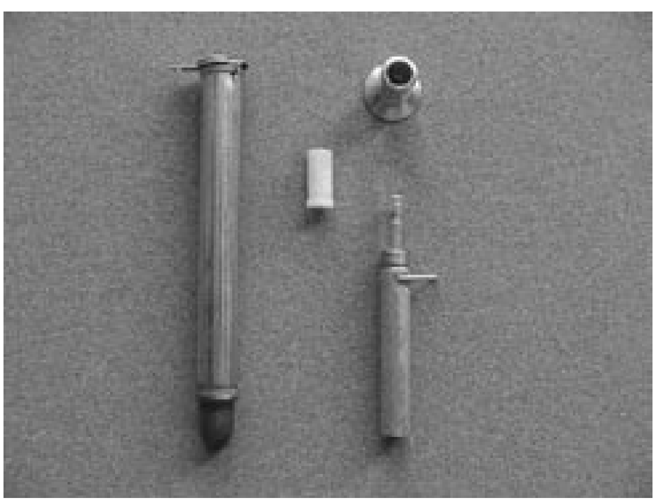

Fig 7. Current production (2002) M-44 equipment from Pocatello Supply Depot. From left: stake, polyethylene M-44 cyanide capsule, Edstrom-style ejector with retaining pin, and capsule holder with lip to deflect precipitation from running into the stake.

on bottom blow-outs or breakage with this redesigned ejector.

A specially-made setting pliers is needed to cock the M-44 ejector. A newly designed setting tool, conceived by Mahlon Watten, Gary Whitehead, and others in the Washington WS program has been evaluated and will replace the older tool beginning in late 2002. The new plier holds the ejector firmly in place while the plunger is being compressed, whereas the old tool was hard to keep in alignment during this compression stroke. Also, the handles on the new tool fit the palm of the hand better than those on the old tool. Advantages of the new tool are most apparent in colder weather that hampers users' manual dexterity (M-44 Setting Pliers. Memorandum, PSD Manager S. Blom to Field Testers, USDA Wildlife Services, March 7, 2002). Several kinds of setting pliers are illustrated in Fig. 8.

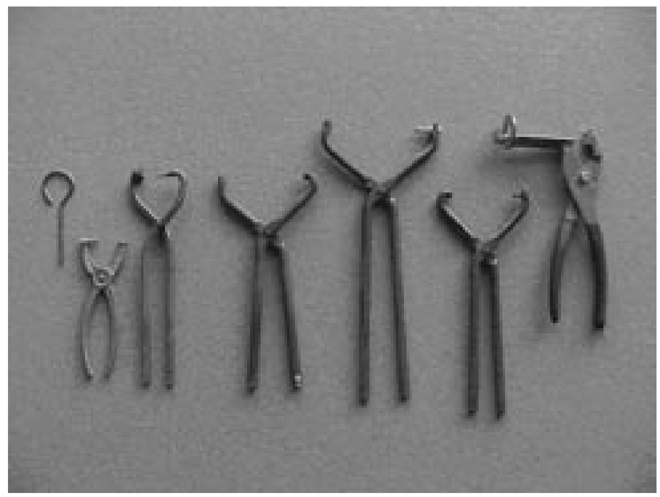

Fig. 8. Setting tools for sodium cyanide ejectors. From left: an early coyote getter setting tool, two plier-type coyote getter setting tools, early (Poteet era) M-44 setting pliers, M-50 setting tool, later (Edstrom era) M-44 setting pliers, and current production (2002) M-44 setting pliers.

CAPSULE HOLDERS

In contrast to cyanide capsules and ejectors, relatively few problems have been reported over the years with CG shell holders or M-44 capsule holders. Robinson (1941a.) reported that excessive caking of NaCN at the tops of cartridges would prevent the charges from penetrating the top seals, causing the sides of the cases to blow out through the sides of the shell holders. The .38 caliber cartridge cases used for CG cartridges had relatively thin walls that would allow this to happen. The earliest M-44s used capsule holders of similar thickness. Later, as the M-44 was being improved, the shoulders and rims of the capsule holders were thickened and a gap was provided above the threads to allow a jump space between plunger and capsule, giving the plunger a thrust advantage before it struck the capsule bottom (Bacus 1970).

Very early in the development of the spring-activated ejector that became the M-44, various protrusions on the ejector tops such as threads, grooves, knobs, etc. were suggested by Specialists to stabilize the wrappings and prevent them from turning on the tops or being pulled off by animals (Fitzwater 1964). After consideration of the various suggestions, it was decided that protrusions on each side of the capsule holder were sufficient to hold the wrappings.

Years later, when Keenan (1979) redesigned the M-44 to produce what became known as the M-50, he increased capsule holder diameter to accommodate the larger, 0.50-inch-diameter capsules. With this increased diameter, the thread size also increased from 9/16 to 5/8 inches for better alignment and stability on the ejector. Small points were added to the surface of the capsule holder to help hold top-wrapping materials in place.

When Paul Edstrom redesigned the M-44 ejector in 1984, as noted previously, he shortened the capsule holder and also sloped the top shoulder down from the top. These modifications were made to prevent water from being trapped on the capsule top, where it might eventually seep into the capsule. The walls also were thickened to provide greater strength and reduce deformation. The threads were returned to 9/16"-18 size and manufactured at closer tolerances. As with the Poteet model ejector, number 3 zinc was used to manufacture the redesigned capsule holder. This alloy still appears to be the best affordable alternative for strength and resistance to corrosion.

Before 1990, M-44 users had to manually peel off each capsule warning label in the field before the capsule would fit into the capsule holder. This was not only a possible violation of USEPA labeling rules, but was a great inconvenience to the user, especially during cold weather. Since July 1990, capsule holders have been manufactured with the bore (capsule cavity) 0.005 inches larger in diameter to accommodate capsules with the labels left on (Connolly 1992). Older capsule holders still in use can be reamed out with a 15/32-inch drill bit to accommodate capsules with labels.

As noted earlier in this report, the paper warning label was replaced by a vinyl label in 1992. The vinyl labels now in use do not absorb moisture and swell, like paper labels did. For this reason, capsules with the new labels are much easier to insert into and remove from capsule holders.

Also as noted previously, a large-scale survey of M-44 users was carried out in 1987 to identify performance problems and gather field suggestions for improvement (Connolly 1988a). One suggestion received in that survey was that a lip be molded onto the bottom of capsule holders to deter water from running down the sides of the ejector and into the stake. Since many Specialists were then using a “dirt skirt” (see ‘M-44 User Tips; Appendix) which served the same purpose if fit snugly around the ejector, modification of capsule holders in this manner did not receive immediate attention. The suggestion was not forgotten, however. Nine years later, in 1997, the capsule holder was redesigned to provide such a lip (Fig. 7), and all capsule holders shipped from PSD now are so equipped.

Another good way to keep moisture and sand from entering the stake is to place a rubber O-ring into the groove below the threads at the top of the ejector body, as was recommended by New Mexico ADC Specialist Pat Jaureguiberry in 1995. When the ejector is placed into the stake, the O-ring fits tightly against the inside wall of the stake thereby preventing moisture and soil from entering. PSD began stocking these O-rings for M-44 users in 1996. They continue to be available in 2002 (Ejector O-rings. Memorandum, Manager, PSD to All M-44 Applicators, December 16, 1996).

New capsule holders sometimes are difficult to thread onto the ejectors, due to the manufacturer of these parts not cleaning up the threads by running them over a die before shipping them to the PSD for assembly. By using a pair of pliers, field users can work new capsule holders up and down the ejector a few times to fit the components together more easily. Threads that become worn or cross-threaded can be restored or realigned by running them on a 9/16"-18 die or a 9/16-inch fine-threaded bolt. In addition to reworking threads in the capsule holder, the threads on the ejector body also can be cleaned or renewed by running a 9/16"-18 die or a 9/16-inch fine-threaded nut over them. If the threads become too worn, either the ejector or capsule holder should be replaced.

STAKES

The HCG firm supplied CG stakes in 2 lengths, either 5 or 7 inches, made from metal conduit with a groove cut out of the stake to accommodate the trigger. A spring wire clip soldered onto the stake held the trigger in place and served as the stationary object the trigger pushed against to activate the ejector (Fig. 1). These stakes were used by government hunters for many years.

In the early 1960s, an improved mechanism for securing CGs into the stakes was developed by John Leyerly, a PRC program employee in Colorado. The “Leyerly top,” as it came to be known, was a cast metal top that could be pressed onto the stake tube and secured in place by rivets (Fig. 3). This top featured a spring ring with an extended lip rotating in a groove to close the trigger slot after the firing unit was in place. The stake was 0.70 inches outside diameter and 0.625 inches inside diameter.

The Leyerly-top stake had several advantages over the standard Marlman stake: (1) the firing unit was locked into the stake and could not be pulled out by repeated tugging; (2) the spring lip, when in closed position, protected the trigger arm and reduced the likelihood of accidental firings; and (3) damaged stake tubes could be repaired in the field. Like the Marlman stakes, Leyerly-top stakes also were made in 5- and 7-inch lengths. Mr. Leyerly received a $30 award for this invention (Bacus 1962).

From our perspective today, the $30 award seems pitifully small considering the significance of Leyerly's contribution. The Leyerly-top stake eventually replaced the original Marlman CG stake in most Western PRC programs. Later, when the CG was replaced by the M-44, the Leyerly-top stake was retained as the standard M-44 stake (Bacus 1969c). It remained in use until the Poteet M-44 ejector was retired after 1984. By that time, the Leyerly-top stake had been a standard equipment item in governmental predator control programs throughout the western United States for about 25 years.

For the M-50, Keenan (1979) developed a slightly larger 0.75-inch outside diameter steel conduit stake to accommodate the larger ejector. Instead of the Leyerly top design, this new stake featured a rim that was swaged or pressed onto the stake tube to retain the lock ring (Fig. 5). Though inferior in field performance to the Leyerly top, this design was cheaper to make. After the M-50 ejector was abandoned, the M-50 stake became standard for use with the Edstrom model M-44 in 1985 (Fig. 6). Many field users preferred the Leyerly-top stake, however, and continued to use it even though the holes in some Leyerly tops had to be enlarged to accommodate the larger-diameter Edstrom model ejector.

The reason many field men preferred the Leyerly-top stake was that the M-50 stake had a serious flaw-the spring-steel locking ring was flexible enough to stretch and pop off, allowing the ejector to come out of the stake when an animal pulled it with great force. This most often occurred after an M-44 pulled by a coyote was visited by other coyotes before being reset. When coyotes attempted to pull the fired unit, it would not discharge. Occasionally a persistent coyote would continue to pull until the ejector came out of the stake. Then, because of the lure, the coyote often would carry the ejector away. Many units were buried or were carried so far that they could not be recovered. Such losses of capsule holders and ejectors were frequent enough to constitute a considerable financial loss of M-44 equipment. Connolly (Memorandum to Mike Worthen, ADC Western Regional Director, June 1, 1996) estimated that the magnitude of such losses to the ADC program was in the range of $3,750-7,500 annually.

To solve this problem, SD Extension Trapper Steve Thompson began in the late 1980s to use a 3/4-inch external flat retaining (snap) ring in place of the standard issue, round lock ring. With a wider surface area and greater rigidity, the retaining ring did help prevent 'pull-outs' but the short tabs on the retaining rings made them awkward to turn, posing a safety hazard to persons working above the ejectors. Another SD Extension Trapper, Scott Huber, also used these retaining rings and, in 1993, he developed a design for an improved, flat M-44 stake ring. His idea was submitted to PSD where Control Methods Specialist Sherm Blom solicited bids from potential manufacturers and selected a company to manufacture the new rings. PSD began distributing the improved lock rings in January 1996. A lack of field complaints since then indicates that the new ring has stopped most ejector pull-out problems.

PSD Manager Paul Edstrom had attempted to solve this same problem in about 1987 when he developed a modified M-44 stake (Fig. 9) that was similar in concept to the original, Marlman CG stake. The Edstrom stake had the retaining wire coiled around the stake, with one end of the wire inserted into the stake to hold it in place, whereas the Marlman stake had the retaining wire soldered to the stake. Even though a patent was issued for this design (Edstrom 1988), prototypes of the new stake did not perform as well as the standard stake. The new stake, in fact, turned out to be even more subject to pull-outs than the M-50 stake. Edstrom did not solve this problem with his new stake, so it was never put into production.

The M-50 style, rolled-top stake was manufactured at the PSD in a 6-inch length only. Users were advised that, if a shorter length was required, they could cut the 6-inch stake to the desired length with

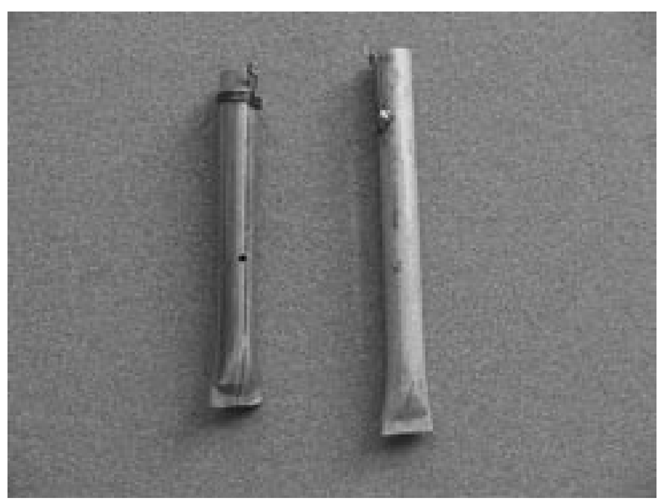

Fig. 9. Prototype of an M-44 stake designed by PSD Manager Paul Edstrom (1988). The Edstrom stake (left) featured an ejector retaining clip that was modeled after the wire clip on the much earlier coyote getter stake (right).

a hack saw and crimp the bottom in a vise or pound it with a hammer on a hard surface. Or if a longer stake was needed, the standard stake could be wired to a longer wooden stake which then was driven into the ground. Such longer stakes provide better anchoring in wet ground. PSD now manufactures custom stakes in any desired length for various soil conditions, upon request.

In 2000, the M-50 style stake was modified by inserting a 2-inch length of 5/8-inch diameter solid round bar one inch inside the conduit and welding the seam to make a solid-bottom stake (Fig. 7) that could be driven directly into the ground with a stake driver without first driving a pilot hole or filling the stake bottom with dirt/stones, as was recommended with older stakes. This idea was initiated by NV WS Specialist John Peter (Modified M-44 Stakes. Memorandum, Manager, PSD to WS State Directors and other M-44 Users, June 6, 2000).

Older models of M-44 stakes are no longer made at PSD but many remain in use. They should never be driven into the ground by hammering directly on the stake-top. Instead, use a driving rod or specialized driving tool (Fig. 10) as described by Foard and Dasch (1987) and in M-44 User Tips (Appendix).

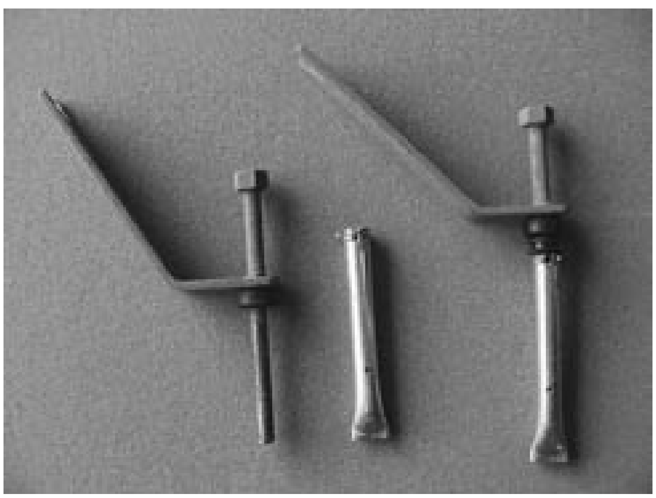

Fig. 10. M-44 stake driving tool developed by New Mexico ADC Specialist John Foard and DWRC Biological Technician Gary Dasch (1987). From left: the stake driving tool, a 6-inch M-44 stake, and the driving tool with stake in position to be driven into the ground.

Older (Poteet) model M-44 equipment is still being used by some WS Specialists. Some combinations of new and older components may not function properly, so Specialists should carefully check the combinations of ejectors, capsule holders, and stakes they plan to use before taking them to the field.

One cause for concern with all cyanide ejector models is the rattling noise that can occur from ejector movement inside the stake when a coyote grasps the top with its mouth and moves it. The noise may scare a coyote and cause it to release the top before making a pull (Keenan 1979). This noise is particularly noticeable when older model (Poteet) M-44 ejectors are used in the M-50 style, rolled-top stakes. The M-50 style stakes, having a larger inside diameter than the older Leyerly-top stakes, were not designed for use with Poteet model ejectors and should not be used with them if the more compatible Leyerly-top stakes are available.

In the past, Specialists have wrapped wool or other materials around their ejectors to reduce in-stake noise. During wet and freezing weather, the wool can collect moisture and when it freezes, the ejector is inoperable. This apparently has been a problem ever since the earliest days of the CG. An early CG patent (Marlman 1939a) recommended putting vaseline in the stake to prevent water from filling up the stake and freezing the ejector into it. This practice also would prevent rattling between the ejector and stake. One of the better methods we have seen for reducing ejector rattles is applying a length of thin rubber, heat-shrink tubing over the ejector body from below the trigger to the bottom. The late George Good, formerly of the Montana ADC program, used this method with good success and without interference to the ejector system. Depending on the desired fit, a second layer of the thin heat-shrink tubing could be added to fill wider spaces due to different size ejectors or stakes. Another good solution to this problem is a single rubber O-ring or sleeve placed towards the bottom of the ejector.

When M-44s are moved or removed from the field, the stakes must be pulled from the ground in order to be re-used. The stakes often are difficult to pull. Over the years, ADC Specialists have used pliers, shovels, or other digging tools to remove these stakes,

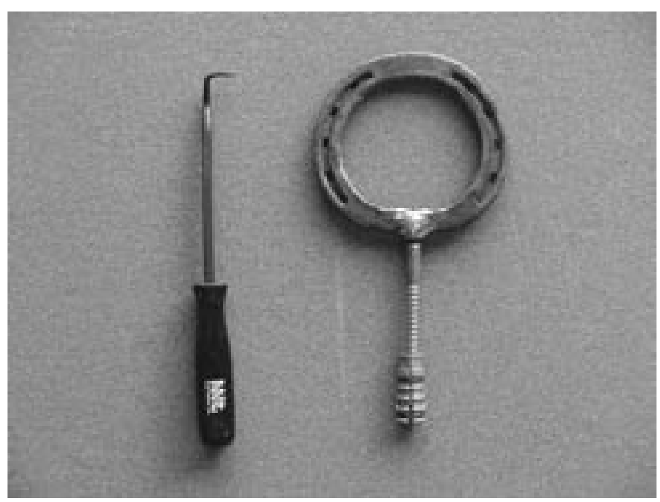

Fig. 11. M-44 stake pullers. From left, cotter-pin extractor tool modified by Montana ADC Specialist Denny Biggs and the 'horseshoe' tool developed by Arizona ADC Specialist J. Brad Miller. Both tools were introduced in 1996.

which sometimes were damaged in the process. Two improved techniques for stake pullers were suggested by field personnel in 1996 (M-44 Stake Pullers. Memorandum, PSD Manager S. Blom to M-44 users, December 31, 1996). One, developed by MT ADC Specialist Denny Biggs, is the use of a cotter-pin extractor, a tool that is readily available from hardware, auto-supply, or farm supply stores. The second device is a stake pulling tool designed by AZ ADC Specialist J. Brad Miller. The tool is made from a lag screw, wall anchor, 2 rubber o-rings, and a handle made from a #2 horseshoe. To use this tool, the wall anchor is inserted into the stake, the lag screw is tightened into the anchor causing it to expand inside the stake, and the stake is then extracted from the ground by an upward pull with the horseshoe handle. Both tools are illustrated in Fig. 11. Either one will pull M-44 stakes from hard, rocky, or frozen ground without damage to the stake.

RECOVERY RATES AND DISTANCES AS PERFORMANCE INDICATORS

When the M-44 was replacing the CG in ADC operations, L. C. Bacus (Memorandum, Division of Wildlife Services, Denver, Colorado, to Regional Supervisor, Albuquerque, New Mexico, August 29, 1969) wrote that, “The Coyote Getter owes some of its glamour to the fact it has been used for years and has been accepted by fieldmen. In spite of rumors to the contrary, its performance has never averaged over 65-75%. The M-44, if handled correctly and assembled carefully at Pocatello, will perform as well.” And later he wrote, “The M-44 cannot be used as a Coyote Getter. It will perform as efficiently or more so than the Coyote Getter but it must be handled correctly. Nine out of 10 kills will drop within 60 yards” (Memorandum, L. C. Bacus, Division of Wildlife Services, Denver, Colorado to Regional Supervisor, Portland, Oregon, January 30, 1970).

As implied in Bacus’s statement, performance in the field is the ultimate test of NaCN ejectors and capsules. We believe that the best indicators of field performance are recovery rates and recovery distances for target animals that pull the units. Recovery rate is the number of target animals recovered as a percentage of the number of units discharged by target animals. ‘Recovery distance’ refers to the straight-line distance from fired ejector to the dead target animal. A high recovery rate and short recovery distance indicates good performance, whereas poor performance either of ejectors or NaCN capsules would result in low recovery rates and long recovery distances.

One might expect the recovery rate from coyote pulls should be nearly 100 % if CGs and M-44s function as intended. However, field experience shows that such high recovery rates are achieved rarely if ever. The best-documented example known to us of a high recovery rate for the CG was recorded by David Crouch in Colorado during Fiscal Year 1960, during which Mr. Crouch recovered 560 coyotes from 661 CGs pulled by coyotes for a recovery rate of approximately 85 %. This rate was reported as being greater than for the Colorado District as a whole (Bacus 1960).

We do not know of any livestock damage field situation in which 100 % of coyotes killed by M-44s have been recovered. Bacus (1969a) similarly wrote, “In spite of rumors to the contrary, 100% recovery with field, weather, and handling variables is an impossibility.”

If 100 % recovery cannot be attained, what recovery rate should M-44 users expect? There is no established standard as to what constitutes acceptable recovery, but 70 % is the figure mentioned most frequently over the years. In 1981, when the M-44 Study Team proposed performance standards for the M-44, they suggested that 70 % would be an acceptable recovery rate (M-44 Improvement. Memorandum, M-44 Study Team to Chief, Division of Wildlife Management, FWS, August 28, 1981). No official action was taken on that proposal, but there seems to be a general, unwritten consensus among experienced M-44 users that recovery rates in the range of 70-75 % are reasonable goals.

Citing the lack of an established standard, Connolly (1988a) selected a 75% recovery rate and 35-yard recovery distance as arbitrary benchmarks in his analysis of M-44 performance reports from ADC program M-44 users. About 53 % of 191 respondents reported acceptable recovery rates (75 % or better), and 54 % of respondents reported acceptable, average recovery distances (no greater than 35 yards).

Coyote recovery rates recorded for CGs and M-44s have been quite similar over the years. However, recovery distances are a different story. Recovery distances for M-44s are much shorter, often about half of those recorded for CGs. This difference was recognized almost as soon as spring-activated ejector development began in the 1960s (Fitzwater 1964; Bacus 1969b). Of the many documented records of recovery rates and recovery distances known to us (Table 2), several are particularly noteworthy. An early, published evaluation of CGs showed an average recovery distance of 73 yards (Robinson 1943), whereas a 1982 research evaluation of M-44s in Texas yielded 20 coyotes at an average distance of 26 yards (Connolly et al 1986). The only compilation to date of M-44 users’ experience west wide estimated a composite, average recovery distance of 39 yards in 15 western states (Connolly 1988a). In our opinion, these records and the others cited in Table 2 leave no doubt that recovery distances historically were greater for the CG than they are today with the M-44.

For both devices, of course, recovery distances are highly variable from one pull to the next. As an example, the earliest study known to us in which recovery distances were recorded for coyotes killed with CGs

Table 2. Average recovery rates and distances reported for Coyote Getters and M-44s.

Year(s)	Location	Type unit	Average recovery rate/distance			Reference
1940	NP[1]	CG[2]	70% NP			Robinson (1941a)
1940-41	CO, WY, NM	CG		72% 73 yd		Robinson (1943)
1941	CO	CG		76% 46 yd		Sears (1941)
1942	NP	CG Full charge		86%	66 yd	WRL (1942)
		CG Half charge		85%	93 yd	"
		CG Qtr charge		82%	77 yd	"
1943	NP	CG Half charge		83%	NP	WRL (1943)
				23<100 yd		
				10@100-200 yd		
				1@200-300 yd		
		CG Qtr charge		78%	NP	"
				1<100 yd		
				9@100-200 yd		
				6@200-300 yd		
1946-47	CO	CG (4 Types)		74% NP		Cummings (1948)
1947-48	CO	CG (4 types)		49%	65 yd	"
1954	AK	Wolf Getter (coyote load)	Wolves	41%	68 yd	Robinson (1956)
			Coyote	NP	20 yd	
			Bears	75%	57 yd	
			Foxes	NP	34 yd	
			Lynx	NP	6 yd	
1954	AK	Wolf getter (more cyanide)	Wolves	44%	39 yd	Robinson (1956)
			Coyote	NP	18 yd	
			Bears	75%	40 yd	
			Foxes	83%	10 yd	
			Dog	100%	15 yd	
			Lynx	NP	9 yd	
		Wolf getter (more gun powder)	Wolves	36%	65 yd	"
			Coyote	NP	20 yd	
			Bears	71%	44 yd	
			Foxes	NP	21 yd	
			Dog	100%	17 yd	
NP	CO, NE	CG		84%	94 yd	Robinson (1956)
NP	TX	CG		NP	47 yd	"
		(less gun powder)		NP	31 yd	
FY 1960	CO	CG		85%	NP	Bacus (1960)
1963-64	Region 2 USFWS	Spring power ejector (M-44 precursor)		92%	24 yd	Fitzwater (1964)
1967	OK	CG (reduced load)		29%	NP	Meyers (1967)
1968-69	CO	M-44		71%	<50 yd	Bacus (1969d)
1969	TX	M-44		75%	15 yd	Bacus (1969d)
1970	OK	M-44		72%	32 yd	Bacus (1970c)
1969-70[3]	West-wide	M-44		>70%	NP	Bacus (1970b)
1970-71	CO, NM	M-44		75%	32 yd	Bacus (1970d, 1971a,b)
1965-71	TX	CG		55%	NP	Balser (1972)
	(census lines)	M-44		65%	NP	
1976	CA	M-44		29%	42 yd	Clark (1976)

Table 2. Continued

Year(s)	Location	Type unit	Average recovery rate/distance			Reference
1978	CA, NE, NM, OK, OR, TX	M-50[4]		87%	NP	Keenan (1979)
FY 1982	NV	M-44		61%	NP	M-44 Study Team (1983)
1982	TX	M-44 (Methomyl)		24%	105 yd	Connolly et al (1986)
		M-44 (sodium cyanide)		80%	26 yd	"
1983-84	NM	M-44		74%	27 yd	Fletcher (1984)
1988	15 Western States	M-44		73%	39 yd	Connolly (1988a)
1990	TX	M-44 (PSD Capsules)		96%	27 yd	Dunaway (1990)
1999	VA	M-44	Coyote	NP	31 yd	Lowney (1999)
			Red fox	NP	6 yd	
			Gray fox	NP	7 yd	
			Opossum	NP	3 yd	

Table 2. Additional references (See the main reference list for citations not given here)

Bacus, L.C. 1969d. Memorandum to Manager, Pocatello Supply Depot. December 1, 1969. BSFW, Division of Wildlife Services, Denver CO.

Bacus, L.C. 1970b. Memorandum to Manager, Pocatello Supply Depot. May 12, 1970. BSFW, Division of Wildlife Services, Denver CO.

Bacus, L.C. 1970c. Memorandum to Regional Supervisor, Division of Wildlife Services, Albuquerque NM, February 24, 1970. Bureau of Sport Fisheries and Wildlife. Division of Wildlife Services. Denver CO.

Bacus, L.C. 1970d. A-Report. Memorandum to Regional Supervisor, Division of Wildlife Services, Portland OR, December 8, 1970. Bureau of Sport Fisheries and Wildlife, Division of Wildlife Services, Denver CO.

Bacus, L.C. 1971a. B-Report. Memorandum to Regional Supervisor, Division of Wildlife Services, Portland OR, January 18, 1971. Bureau of Sport Fisheries and Wildlife, Division of Wildlife Services, Denver CO.

Bacus, L.C. 1971b. B-Report. Memorandum to Regional Supervisor, Division of Wildlife Services, Portland OR, Denver CO, February 4, 1971.

Balser, D.S. 1972. Memorandum to Research Staff Specialist, Washington DC and Regional Supervisors, BSFW, Division of Wildlife Services, Regions 1,2,3. Wildlife Research Center, Denver CO, May 26, 1972.

Dunaway, M. A. 1990. M-44 glass capsule field test. Memorandum, ADC, San Antonio TX to Director, ADC Western Region, Denver CO, May 31, 1990.

Lowney, M. 1999. Efficacy of M-44s in Virginia. Memorandum to G. Connolly, May 19, 1999.

M-44 Study Team. 1983. Memorandum to Chief, Division of Wildlife Management, June 22, 1983.

Meyers, J.C. 1967. Memorandum to Regional Director, BSFW, Albuquerque NM. ADC State Office, Oklahoma City OK, November 14, 1967.

Wildlife Research Laboratory (WRL). 1942. Quarterly Report, October-December, 1942. Denver CO. Quoted by Robinson (1956:4).

Wildlife Research Laboratory (WRL). 1943. Quarterly Report, April-June, 1943. Denver CO. Quoted by Robinson (1956:4).

[1] NP = not presented.
[2] CG = coyote getter.
[3] First year of large scale M-44 use.
[4] Hand made prototypes using M-44 capsules, rather than M-50 capsules.

showed a range of 3 to 300 yards with average recovery distance of 46 yards. Coyote pups averaged 39 yards, mature coyotes 56 yards, and old coyotes 78 yards (Sears 1941).

The traditional explanation for greater recovery distances with CGs is that coyotes pulling these explosive devices are frightened by the noise and by ejected material striking the insides of their mouths with force, causing them to run fast and far before the NaCN takes effect. With M-44s, conversely, the relatively quiet ejection and the less violent expulsion of NaCN is less frightening, making it less likely that the coyote will attempt to flee. This explanation seems plausible, but it must be regarded as unproven because research confirmation is lacking.

Because coyotes that travel far before they die are hard to find, fur trappers who wanted to recover pelts from coyotes killed by CGs recognized early on that short recovery distances were desirable. Marlman (1939b) claimed to minimize recovery distance by including 10 % capsicum powder (red pepper) in the NaCN formulation for CG cartridges. The capsicum was intended to cause a burning sensation so that the coyote would stop and claw at its mouth in an attempt to clear out the irritant, rather than run. The delay caused by this behavior would give the poison time to act, so that the coyote would die near the ejector. This imaginative concept apparently was accepted as fact at PSD, where capsicum was routinely included in CG cartridges right up to 1969 when the manufacture of CG shells was discontinued. Early M-44 capsules also contained a small percentage of capsicum, but its use was discontinued some time before 1975.

We know of no research showing that capsicum in NaCN mixtures actually produces the effect hypothesized by Marlman (1939b). Frankly, we doubt it. Our observations of coyotes pulling M-44s in research tests (Connolly et al 1986) have shown that NaCN without capsicum is very disagreeable to coyotes. Captive animals that pulled M-44s immediately coughed, spit, and rubbed their muzzles on the ground. It appeared that the animals were trying to clear the NaCN from their mouths. We find it hard to imagine that the addition of hot pepper would make the noxious toxic mixture any more repellent. What we do know for sure is that coyotes killed by M-44s don't travel as far as those killed by CGs, even though CG shells contained pepper and M-44 capsules don't.

M-44 users are quick to blame NaCN cartridges or capsules when coyote recovery rates drop or recovery distances are longer than usual. Defective cartridges often are to blame, but recovery failures also may result from many other causes such as mechanical ejector problems, poor ejector maintenance, difficult terrain, dense vegetative cover, or theft of coyote carcasses from trap lines.

A comprehensive summary of recovery rates and distances recorded during the 6 decades of NaCN ejector use by ADC personnel is presented in Table 2. As points of general interest, we also include one Alaska study with data for species other than coyotes and another study in which methomyl and NaCN were compared as M-44 toxicants. Some workers calculated capture and recovery statistics differently from others, but these reports provide a reasonable comparison of recovery values for CGs and M-44s. Except for the reduced-power CG cartridge loads (Robinson 1956), average recovery rates for CGs and M-44s tended to be about the same, as noted earlier.

The shorter recovery distances for M-44s, compared to CGs, constitute an important advantage for the M-44 because short recovery distances facilitate full recovery of target and nontarget animals killed by the devices. In this respect, M-44s also have another major advantage – they kill fewer small nontarget animals than do CGs (USDI 1978). This difference may result from the heavier pull force required to discharge M-44s – 4.3 pounds of average for Poteet model M-44s compared to 1.7 pounds for CGs under field conditions in Texas (Connolly and Simmons 1984). The lighter force required to discharge CGs probably explains why CGs are more likely to kill small nontarget animals.

Unusually long recovery distances are reported occasionally. A few examples for CGs are the 300 yards noted by Sears (1941); 600 yards by Robinson (1943); and a half mile by Cummings (1948). One of the longest recovery distances on record is 2-1/4 miles (Memorandum, T. J. Turner, North Platte, Nebraska to District Agent, Mitchell, South Dakota, March 14, 1960). Similarly long recovery distances have been reported for M-44s over the years, and they continue to be reported today. A variety of factors could account for these longer recovery distances and it is unlikely that there is any one specific reason for them. Capsules from different batches, or even capsules from different boxes within the same batches, sometimes are thought by field personnel to vary in killing power and therefore in recovery distances. This phenomenon may be genuine, but we think it more likely that these observations simply reflect normal variations in M-44 performance.

It is interesting to note the consistency with which the 70 % recovery rate has surfaced over the years from the first use of CGs in 1940-41, to the adoption of M-44s in 1970, and in many reports on M-44 modifications and improvements since then. As noted earlier, an early action of the M-44 Study Team in 1981 was a proposal for the establishment of M-44 performance standards. The Team suggested that a target animal recovery rate of 70 % would be a reasonable indicator of acceptable M-44 performance (Memorandum, M-44 Study Team to Associate Director of Wildlife Research, Washington, D. C., August 17, 1981). This goal was proposed for application to controlled tests. The Team suggested that it might be too high for routine field operations where less time and effort could be spent in searching for target animals. Seventy percent recovery actually would correspond to a higher target animal kill rate, since the unrecovered 30 % would include many animals killed but not recovered due to steep terrain, dense vegetative cover, theft, and animals dying beyond normal recovery range.

Recovery rates and recovery distances are useful because they can be recorded easily in the field. However, they are 'bottom line' measures. That is, they indicate only how well the ejector system in total is performing, not how well individual components perform or which components may be at fault when performance is substandard. Historically, the main cause of poor performance has been defective NaCN capsules. Some related aspects of NaCN and M-44 cyanide capsules are discussed below.

SODIUM CYANIDE TOXICITY

How much NaCN is needed to kill a coyote? W. H. Robison (Memorandum, Wildlife Research Laboratory, Denver, Colorado, to Regional Supervisor, Predatory Animal and Rodent Control Division, Albuquerque, New Mexico, August 8, 1955) stated that the lethal dose of commercial grade NaCN to most warm-blooded animals is from 3-5 milligrams (mg) per kilogram (kg) of body weight. Noble Buell (cited by Fitzwater 1964) gave a value of 6 mg/kg for dogs. More recently, DWRC Research Pharmacologist Peter Savarie reported to Blom (Telecommunication, February 10, 1992) that the LD_{100} dose for coyotes in tests he conducted was 7-8 mg/kg. Based on these figures, a 25 pound (11.4 kg) coyote would require a lethal dose of 80 to 91 mg of NaCN (7-8 mg/kg times 11.4 kg).

How does this compare to the amount of NaCN in one capsule? CG cartridges and early M-44 capsules contained 0.75-0.80g of total NaCN mixture with actual NaCN content of approximately 85-88 % of that, or 0.64-0.70g. Lee Bacus (Memorandum to Regional Supervisor, Portland, Oregon, January 30, 1970) wrote that early M-44 capsules each contained 12 grains (0.78 g) of NaCN and that 1/2 (0.39 g) or 2/3 (0.52 g) of this load would kill a coyote. Nevertheless, the full 12-grain load was deemed necessary, considering that some ejections would not deliver the entire load into the animal's mouth.

Bacus believed that 40 % of the load would kill efficiently, provided the NaCN was free-flowing and the ejector was performing properly (Memorandum, L. C. Bacus, Division of Wildlife Services, Denver, Colorado to Regional Supervisor, Division of Wildlife Services, Albuquerque, New Mexico, February 24, 1970). Reasons for only partially effective delivery could include caked contents and side-pulls. In addition, he thought it likely that larger-sized animals would require a heavier dosage of NaCN to be lethal. More recent experience with eastern coyotes, which tend to be larger than those in the western United States, confirms this.

Specified amounts of toxicant mixture in M-44 cyanide capsules have varied over the years. The first capsules contained 0.75-0.80 g, as noted above. In 1975 the amount of toxicant mixture per capsule was increased to 1.0 g (USDI 1975). Currently (2002), each M-44 capsule produced at PSD contains 0.97g of toxic mixture that includes 91.06 % NaCN as a nominal concentration with certified limits of plus or minus 3 %, as specified on the USEPA-Approved Confidential Statement of Formula (CSF). The other 8.94 % of the mixture consists of minute quantities (<1 %) of impurities in the NaCN, a desiccant, and the Day-glo particle marker. Thus, each capsule contains approximately 970 mg (0.97 g) of CN mixture, or about 883 mg of NaCN (970 mg capsule contents x 91.06 % NaCN).

Since the whole body lethal dose of NaCN for a 25-pound coyote is approximately 80-91 mg, as specified above, each M-44 cyanide capsule contains about 10 or 11 lethal doses (883 mg divided by 80 or 91 mg). Despite this theoretical, 10-fold overdose, however, M-44 cyanide capsules do not contain excessive amounts of toxicant. The delivery efficiency of cyanide ejectors is highly variable from pull to pull, and the actual amount of NaCN delivered to the target coyote has not been measured. For this reason, the ASTM standard guideline for 'Use and Development of Sodium Cyanide as a Predacide' (ASTM 1977) proposed that dosage should be based on an approximate LD_{100} of 20 to 30 mg/kg, and that any mixture containing lower amounts creates sublethal effects. Twenty to 30 mg/kg would equate to 228-342 mg for a 25-pound coyote. On this basis, the current M-44 cyanide capsule with 883mg of NaCN would contain 2.6 to 3.9 LD_{100} doses for a typical, 25-pound western coyote.

Eastern coyotes are significantly larger than western coyotes, as mentioned previously. Mean weights for adult coyotes collected in livestock depredation control efforts in Virginia during 1993-1996 averaged 16.2 and 13.4 kg, respectively, for males and females (Houben and Mason 1998). Many of these animals were killed by M-44s. In West Virginia, weights of 16 coyotes killed by M-44s during FY 1999 averaged 15.8 kg for males and 13.1 kg for females (personal communication, W. Bonwell, WS State Director, Elkins, West Virginia, to G. Connolly, April 19, 1999). These data show that adult coyotes are perhaps 15 to 40 % larger in these 2 eastern states than in the western U.S. We speculate that the whole body NaCN doses required to kill eastern coyotes also are larger.

Quality control records for M-44 capsules produced at PSD indicate that both the contents and weights of capsules vary somewhat, both within batches and among different batches. This is primarily due to the manufacturing process employed at the PSD which, though quite simple, produces adequate precision in the finished product. Based on the toxicity calculations presented above, individual capsules that fall into the lower limit range still have plenty of NaCN to be lethal to coyotes, even the larger eastern coyotes, provided the contents are not caked or otherwise deteriorated.

Many M-44 users have asked if cyanide is lost from M-44 capsules over time in the field, so that NaCN content eventually might decrease to a point that the capsules are no longer lethal to coyotes. The short answer to this question is, "no." This subject was investigated thoroughly in 1982 when several lots of capsules were placed outdoors at College Station, Texas, and monitored over time for evidence of deterioration. Actual cyanide content in standard PSD capsules changed little during the 86-day test, one laboratory reporting a 2 % increase while a second laboratory found a 6 % decrease. Based on visual inspection, however, only 21 % of capsules contained dry, normal-colored, cyanide powder at the end of the 86-day exposure period. Therefore, it was concluded that, for all practical purposes, M-44 capsule quality can be evaluated better by visual inspection, to assure that the cyanide mixture is dry, white powder, than by laboratory analysis of NaCN content (Connolly and Simmons 1983b).

To sum up, all the information we have about cyanide deterioration in M-44 shows that as long as the cyanide mixture retains its original color and dry, granular state, it also retains high NaCN content This means that visual inspection is more useful than expensive analyses of NaCN content (approximately $60 per capsule) for determining probable efficacy of M-44 cyanide capsules.

M-44 users should note that the normal color of NaCN in M-44 capsules was white, or off-white, up to 1989 when Day-glo particles replaced zinc-cadmium sulphide as the marker (Burns et al 1990). Because of the fluorescent marker, the normal color of cyanide in capsules made since 1989 is orange (yellow in non-WS program capsules).

Future researchers might profitably consider encapsulating or coating NaCN in some manner that would prolong its stability without compromising rapid reactivity when ejected into the mouth of a coyote.

THE NEED FOR DELIVERY

Regardless of the amount or toxicity of NaCN in ejector shells or capsules, effectiveness in killing coyotes depends on adequate delivery of capsule contents into the coyote's mouth. V. A. Keenan (Memoranda to Area Supervisor, ADC, Salt Lake City UT, March 23, 1977, and to D. Gretz, February 22, 1978) stated that just because a M-44 unit was fired clean was no sign you were going to kill the coyote. There must be delivery, which he defined as "the maximum effort of a mechanical unit in delivering a lethal dosage to the coyote quick enough, so that a minimum lethal dosage is still retained by the coyote." He continued, "In order to be quick enough to catch up with the coyote, the spring must eject the dosage without any hesitation, whatsoever, caused by thick wads, mechanical malfunction, or whatever. When developing his improved M-44 that became the M-50, Keenan found, even with this better and stronger unit, coyotes could not always be killed using the original shell without a "breaking rig" (a wire apparatus in the shell that preceded the plunger to break up the NaCN as the plunger passed through the capsule).[6]

"There was only a slight hesitation here, but enough to warn the coyote. He was able to turn loose of the unit quick enough to allow the cyanide to be fired into the air. The coyote has been grossly underestimated in his reaction time to warning signals. From timed pictures taken by DWRC of mechanical units being fired, the time period required for quick delivery was judged to be about 1 second."

Keenan went on, "It is easy at this point for those who do not understand the need of this, to cuss the cyanide or other fine points that come to mind, and completely overlook the real problem. The cyanide and various other elements have all been blamed for not killing coyotes when the teeth marks were plainly visible. Any trapper using the old shells who has seen teeth marks on the tops and not found the top wad close by, will know that he has been outsmarted by another coyote. The cyanide will kill the coyote if it is put into the animal's mouth." This last statement is somewhat vague. Keenan apparently assumes here that the entire NaCN charge will enter the coyote's mouth and that it will be a free-flowing and ideally reactive state.

The warning signals and reaction times mentioned by Keenan may be an important factor contributing to lower recovery rates. While making almost 400 observations of captive coyotes responding to attractant odors placed on scented M-44 capsule holders (Phillips et al 1990), Blom observed some coyotes nipping at the scented holders and then jumping back, alternately, for short periods of time. The coyote typically made its initial nip, then released it and jumped back in a very short time, perhaps only a fraction of a second. Therefore, it is possible, based on Keenan's figure of about 1 second for delivery time, that free-ranging coyotes in the field could pull an M-44 and quickly release it, if alarmed or for other reasons, without receiving a lethal dose of material ejected from the unit.

[6] However, neither M-50 capsules nor any other NaCN shells or capsules made at PSD have ever contained such a device.

We believe that an healthy adult coyote actually can release an M-44 top and avoid the ejection in a time much shorter than 1 second. Mechanical performance tests of M-44s conducted by Connolly showed that some M-44 ejectors will 'hang-fire' if not adequately cleaned and lubricated. Even the slightest hang-fire delay would give the coyote ample time to get its mouth off the capsule holder before toxicant is ejected. And when the M-44 was inspected later by a Specialist, there usually would be no direct evidence that a hang-fire had occurred.

Despite all the mechanical improvements made over the years to CG and M-44 devices and capsules, the problem of adequate delivery, or the lack of it, still remains. The chemical properties of NaCN probably contribute the most to poor or inadequate delivery, followed by inadequate maintenance and lubrication of M-44 ejectors..

SUBLETHAL CANID ENCOUNTERS WITH CYANIDE EJECTORS

Many examples of coyotes surviving encounters with CGs or M-44s have been recorded over the years. One of the earliest reports (Sears 1941) described 2 cases in which coyotes recovered after pulling CGs. Each coyote pulled the gun, ran a short way, struggled and kicked for some time, and then rested until it was able to recover and get away.

In Nebraska, a coyote that pulled a CG traveled about 25 feet, vomited, traveled another 50 feet, vomited, and gradually recovered and escaped after going 1-1/4 miles as indicated by tracks and sign in the snow (Memorandum, M. O. Vavak, Verdigre, Nebraska, to Tom Turner, North Platte, Nebraska, March 6, 1960).

In another wintertime incident, a Montana coyote pulled a CG and only received about half of the cartridge contents. The Specialist followed the coyote's tracks in fresh snow and saw where it had vomited after running about 50 yards, then continued on at a slow pace for several hundred yards, vomiting occasionally until it regained mobility and escaped. The Specialist gave up following the coyote after tracking it 1-1/2 miles (Memorandum, D. Gretz, District Office, Billings, Montana, to State Supervisor, Division of Wildlife Services, Billings, Montana, March 19, 1968).

Another Specialist reported an incident in which a ranch dog pulled a CG, then ran 1-1/2 miles to a ranch house where it lived for 1 hour before it died. The dog vomited frequently during that hour (Memorandum, W. C. Lemm, Spearfish, South Dakota to District Office, Mitchell, South Dakota, December 23, 1962).

Bacus (1969a) reported 6 cases of sublethal NaCN poisoning with the coyotes still alive, but immobilized, during the 1968 annual predator census in Webb and Zapata Counties in Texas. He noted, "This sublethal aspect has been noted for years in the Humane Coyote Getter operation. It was particularly apparent in this test because of frequency of line checks. Very possibly, there has been a greater sublethal effect with the Humane Coyote Getter than was noted because of longer periods of exposure." Over the years, similar reports with M-44s have been made, including 4 cases reported to the PSD during 1993.

Various speculations have been offered as to the causes of animals dying beyond normal recovery range or surviving the toxic effects of NaCN. For instance, PSD Manager P. A. Edstrom (Memorandum to G. Connolly, February 2, 1986) noticed the greater frequency of these reports from northern states during the winter months, which caused him to suggest that NaCN might be less lethal to coyotes in the winter. He thought there might be less saliva in coyotes' mouths during cold weather, so that less moisture was available to react quickly with NaCN. This could lengthen the reaction time, allowing coyotes to travel further or have more opportunity to spit out the NaCN. He suggested that pen tests be conducted to check this hypothesis, but such tests have not been carried out.

DWRC Research Pharmacologist Pete Savarie (Memorandum to S. Blom, PSD, January 21, 1993) stated that coyotes observed still alive and partially paralyzed after pulling M-44s have received a sublethal dosage of NaCN, which may cause such a deficiency of oxygen reaching the body tissues, that it results in severe or permanent damage to either the lower spinal cord or some structure in the brain.

KILLING TWO COYOTES WITH A SINGLE CYANIDE CHARGE

Though such episodes are rare, we are aware of 2 cases in which 2 coyotes were killed with a single CG or M-44 capsule. The first of these occurred in Colorado in August 1945, when a Mr. Terry of Eagle County reported 2 coyote pups killed by one CG. After observing this, Terry did not disturb the animals but called a government hunter, James Day, to confirm the event. Mr. Day visited the site and examined the animals, finding the yellow identifying stain on both of the dead coyote pups even though there was only 1 CG in this vicinity. "It was finally determined that both pups had their mouths very close to the getter when 1 of them pulled it, in such a manner that the charge sprayed and each animal received a lethal dose. So far as we know, this is the only record of 2 coyotes being killed by one coyote getter" (Fugate 1946).

The second case was reported in January 2002 by MT WS Specialist Rick Glover, who apparently killed 2 coyotes with a single M-44 capsule (Memorandum to S. Blom, January 22, 2002). Upon approaching a station where he had previously set two M-44 units, Mr. Glover recovered 2 dead coyotes, both healthy adults, 1 male and 1 female. The female lay 28 yards from the fired M-44 and the male was 142 yards away as measured with a laser rangefinder. Further inspection revealed that only one M-44 unit had been pulled. Glover surmised that the coyotes approached the station together. The female probably pulled the unit; the male then licked the same unit and picked up enough residual cyanide to kill him as well.

SIDE PULLS

Fitzwater (1964) reported that some Specialists had a tendency to wrap shell or capsule holders too thickly and carelessly, thereby facilitating side pulls by coyotes. The excessively thick top increased the amount of surface area available for the coyote to grasp, reducing the likelihood that its mouth would be centered over the top of the capsule holder at the moment of ejection. This would result in coyotes receiving sublethal doses, or sometimes no doses at all. Such coyotes, of course, would not be killed. Coyote side-pulls were observed by Blom during the attractant tests previously mentioned, even when smaller wraps were used. Some coyotes frequently laid down and licked-chewed-bit-pulled on the side of the capsule holder without placing their mouths directly over its top.

A first-hand observation of a side pull was made when a coyote pulled an M-44 containing a CaCN capsule during a test at the DWRC Logan, Utah, field station (Memorandum, G. Connolly to P. Edstrom and G. Lewis, PSD, Pocatello, Idaho, 1983). The coyote showed symptoms of CN poisoning after 2 minutes and 20 seconds, but it survived the sublethal dose.

Another interesting account of side-pulling was reported by G. Littauer (Telecommunication, ADC District Office, Uvalde, Texas to S. Blom, PSD, Pocatello, Idaho, February 23, 1993), who attempted to euthanize a captive coyote with an M-44. The attempt failed when the coyote side-pulled two M-44s placed on the ground and another M-44 presented directly to the coyote's mouth by hand. In all 3 attempts, NaCN was expelled on the side of the coyote's jaw and face, but not into its mouth.

Poteet (cited by Fitzwater 1964) suggested using collars made of carpet tacks or staples that fastened around the base of capsule holders to discourage side pulls by coyotes. This might be a partial solution to the problem but we have never seen or heard of anyone else using this method.

The problem of side pulls may be a worthy subject for systematic research to solve. Different-shaped capsule holders or different placement techniques might be developed to reduce or prevent side pulls, thus providing improved delivery of NaCN to coyotes that pull M-44s.

Several methods of better guiding a coyote's mouth over the M-44 capsule holder are currently used by knowledgeable Specialists. One widely used method is to set the M-44 into a shallow hole so that the capsule holder is slightly recessed below ground level. The hole forces the coyote to place its mouth directly over the capsule holder when pulling on it. To protect the hole from filling with water or blowing sand, a dry cow chip, piece of bark, etc. is placed over the set, with a slight air crack to allow the attractant odors to escape. The concealed bait also serves as a curiosity agent, often making a coyote more likely to uncover and pull the hidden M-44 than 1 totally exposed above the ground.

In areas of heavy rain and wind that could fill the holes with water or sand, the same coyote guiding principle can be applied above ground by placing rocks, pieces of wood, cacti, or other objects around the M-44 so that it is recessed below them. Still another method is to place the M-44 at a 45-degree angle facing the intended approach of the coyote. The M-44 should be set in front of a backing such as a rock, stump, clump of grass, or bush, to prevent a rear approach. The angle placement discourages side pulls and the 45 degree angle is more in line with the angle of a coyote's neck to its body as it approaches the M-44 while sniffing.

These 3 methods of M-44 placement may produce better pulls by coyotes, thus also producing better recovery rates and shorter recovery distances than M-44s set out in the open in a vertical position. Even so, there always will be coyotes that can't be found, or that are found at greater distances than usual due to caked capsules, warning signals, or other factors. We infer that Specialists who set their M-44s out in the open in a vertical position apparently are satisfied with their recovery rates, or they would change their method of placement.

TREE-TYPE COYOTE GETTERS

In the first patent issued for a "Device for Killing Fur-Bearing Animals," Marlman (1936) claimed that the CG device could be used in water, on land or snow, or in a tree by anchoring it to a wooden stake in the ground or to the side of a tree with the screw-eye provided with each unit. Later, tree-type CGs were tested during fall and winter of 1941-42 in the Big Horn Mountains of northern Wyoming (Robinson 1942). A hole to accommodate each ejector was bored into a tree or post, 12-24 inches above the snow level, and a staple was placed over the elongated trigger to hold the ejector inside the hole and act as a stop for the trigger. Four hundred ninety-four tree-type CGs were set out in November 1941, left unattended for almost 7 months, and then retrieved in late May or early June 1942. One hundred fifty-five (31%) of the units had been disturbed (chewed, fired, molested) and 76 (15 %) coyotes were accounted for during this unique test. Thirty-one

(6 %) more CGs were discharged due to undetermined causes, and were speculated to have been fired by coyotes.

CONCLUSIONS

Despite the problems encountered with cyanide ejector devices over the years, they have been consistently important for coyote damage control ever since their introduction into governmental control programs around 1940, and they remain important today. Minor improvements still can be and are being made, but most major M-44 problems have been addressed and resolved. During 1971-1976, M-44s accounted for an average of 8.9 % of all coyotes taken in 13 western states (Table 3). This percentage would have been higher except that M-44s weren't used for 2-3 years (1972-1974) during this time because of the 1972 predacide ban. From 1976 through 1986, the fraction of the ADC coyote kill attributed to M-44s increased to an average of 12.3 % in 15 western states (Connolly 1988c). After 1986 the M-44 percentage increased further, to 22.9 % by 1990. It remained above 20 % in every year through the 1990s, dropping to 18.8 % in 2000.

Table 3. M-44 coyote kills in relation to total ADC/WS program coyote kills, 1971-2000.

Fiscal year	––– Coyote kill ––– M-44	Total	M-44 kill as percent of total
1971[1]	18,332	67,150	27.3
1972	12,127	63,162	19.2
	–Predacide ban, February 8, 1972 –		
1973	0	68,629	0
1974	0	67,418	0
	–M-44 use reinstated, September 16, 1975 –		
1975	2,458	79,285	3.1
1976[2]	5,328	84,499	6.3
1976TQ[3]	793	14,731	5.4
1977	8,094	69,109	11.7
1978	7,206	61,823	11.7
1979	6,033	66,199	9.1
1980	6,282	58,861	10.7
1981	6,123	58,896	10.4
1982	6,874	56,914	12.1
1983	9,680	61,927	15.6
1984	11,577	73,306	15.8
1985	11,896	75,514	15.8
1986	12,957	73,364	17.7
1987[4]	12,249	74,764	16.4
1988	13,680	75,314	18.2
1989	15,618	86,383	18.1
1990	20,872	91,102	22.9
1991	24,762	95,996	25.8
1992	25,234	97,781	25.8
1993	23,183	96,158	24.1
1994	23,217	85,571	27.1
1995[5]	23,391	89,207	26.2
1996	21,919	82,230	26.7
1997	18,219	82,386	22.1
1998	19,405	77,985	24.9
1999	18,159	85,927	21.1
2000	16,354	86,944	18.8

[1] FY 1971-1975 data from Evans and Pearson (1980).
[2] FY 1976-1986 data from Connolly (1988c).
[3] Fiscal Year transition quarter (July-September 1976).
[4] FY 1987-2000 data from program records at WS Operational Support Staff, Riverdale MD.
[5] FY 1995-2000 data exclude coyotes killed in South Dakota.

Table 4. States in which ADC program personnel took more coyotes with M-44s than with traps in Fiscal Years 1986 and 1995. Numbers in parentheses are percentages of total take.

Fiscal year	State	––– Coyote Take ––– Total	Trap	M-44
1986[1]	CO	2,565	126 (5)	322 (13)
	NE	1,149	313 (27)	491 (43)
	NM	5,439	1,387 (26)	1,472 (27)
	OK	3,283	682 (21)	720 (22)
	SD	2,886	187 (6)	372 (13)
	TX	19,168	3,478 (18)	7,359 (38)
1995[2]	AZ	1,880	590 (31)	648 (35)
	CA	7,697	436 (6)	1,463 (19)
	CO	2,339	38 (2)	499 (21)
	MT	8,720	384 (4)	1,443 (17)
	ND	2,570	231 (9)	820 (32)
	NE	3,367	120 (4)	2,228 (66)
	NM	6,763	845 (13)	3,801 (56)
	OK	5,660	468 (8)	2,619 (46)
	SD	5,200	192 (4)	780 (15)
	TX	18,551	1,392 (8)	6,615 (36)
	UT	4,165	178 (4)	495 (12)
	WA	565	28 (5)	137 (24)
	WY	5,829	423 (7)	545 (9)

[1] Data from Connolly (1988c).
[2] Data from WS program records at Operational Support Staff, Riverdale MD.

In terms of numbers of animals killed, the M-44 is or has been the most important coyote removal method in several states. Considering 1971, for example, Texas and Nebraska took more coyotes with M-44s in that year than with any other method, and M-44s accounted for the second highest numbers of coyotes in three other states (Evans and Pearson 1980).

In 1986, 6 western states took more coyotes with M-44s than with traps (Table 4). Nebraska took the highest percentage of coyotes with M-44s (43 %) followed by Texas (38 %). By 1992, the number of states taking more coyotes with M-44s than traps increased to 10; Nebraska increased its M-44 fraction to 69 % followed by New Mexico with 56 %.

We note that Texas is, by a large margin, the number one M-44 state. In most of the past 25 years, the number of coyotes taken by M-44s in Texas has nearly equaled and sometimes has exceeded the total M-44 coyote kill in all other state WS programs combined. During the 11-year period 1976-1986, Texas accounted for 59.3 % of the total, national ADC program kill of target animals by M-44s (Connolly 1988c). Some of the reasons for this were (1) the Texas ADC program was much larger than other state programs, having many more ADC Specialists protecting much larger numbers of livestock from predators; (2) most Texas grazing lands are fenced and in private ownership, which is conducive to M-44 use; and (3) dense vegetative cover over much of Texas hampers aerial hunting, which is the most important coyote hunting technique in other western states.

The standardized quality control procedures used at PSD to monitor the manufacture of M-44 capsules and components are important to ensure that workable products go to the field. Once NaCN capsules leave PSD, the responsibility for proper storage and handling lies with the respective state or district warehouses and the Specialists. Following recommended procedures for storage, carrying in the field, and checking of cyanide capsules, as detailed in "M-44 User Tips" (see Appendix) will help users obtain the best possible performance. Also as detailed in "M-44 User Tips," proper maintenance of ejectors will contribute to trouble-free performance.

Because the tools and methods used in wildlife damage management are so specialized, there is little incentive or profit potential for commercial companies to invest in research and development on such methods. The M-44 offers a specific example showing poor economic return; the only private manufacturer of M-44s (The M-44 Company, Fredericksburg TX) went out of business in 1992. Since then, the PSD has been the sole world source for M-44 ejectors and cyanide capsules.

In this age of modern technology it is easy to assume that quick and easy fixes should be available for most problems. If this was true, however, we would have had a steel foot-hold trap replacement and an effective predator repellent long ago (Memorandum, M-44 Study Team to Chief, Division of Wildlife Management, Washington, D. C., June 22, 1983). The invention and improvement of cyanide ejectors has always been an underfunded or unfunded, shoe-string proposition. Except for the original invention of the CG and one later instance in which an outside firm was retained (Bush 1958), most development and improvement of CGs and M-44s has come from government hunters or researchers within the ADC or WS program. The greatest number of innovations have originated with wildlife damage management specialists who use these devices in the field. We think it will always be so, not only for NaCN ejectors and other predation control methods but for all the devices and techniques used to prevent or alleviate human/wildlife conflicts of all kinds.

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TECH NOTE
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M-44 User Tips

The M-44 Sodium Cyanide Ejector Mechanism

The spring-activated sodium cyanide ejector, known as the M-44 because of its 44-caliber (0.44-inch-diameter) cyanide capsule, has progressed through several model variations since it was introduced in the late 1960's. All M-44 equipment used by Wildlife Services (WS) personnel is manufactured by WS's Pocatello Supply Depot (PSD) in Pocatello, ID. The information in this technical note is intended to help WS employees who are trained and certified M-44 users achieve optimum results with their M-44 equipment.

The current M-44 ejector, designed by PSD manager Paul Edstrom in 1984, was introduced in January 1985. No other ejector model has been made at PSD since that date. The Edstrom ejector has a 3 1/3-inch-long body with no bottleneck. Capsule holders are stamped "U.S. GOVT." Edstrom-model ejectors are intended for use with the swaged-top stake, which is 6 inches long with an outside diameter (od) of 0.75 inch. This is the only M-44 stake available from PSD.

The standard M-44 ejector used by WS from the late 1960's through 1984 was called the Poteet model. It had a 3-inch-long body with bottleneck. Capsule holders were stamped "U.S." Poteet-model ejectors and capsule holders are no longer available from PSD, but much of this equipment is still in use. Poteet ejectors were designed for use with Leyerlytop stakes, which have a cast top riveted to the 0.70-inch-od stake tube. Most Leyerly stakes are 5 or 7 inches long. They are no longer manufactured.

In 1979, an improved M-44 device was introduced. It soon became known as the M-50 because of its larger, 50-caliber cyanide capsule. The M-50 ejector had a 4-inch-long body without a bottleneck. Capsule holders were stamped "U.S." Manufacture of M-50 ejectors, capsule holders, and capsules was discontinued in 1983. This equipment should not be used as its performance is poor compared to that of current M-44 equipment.

M-44 Cyanide Capsules

M-44 capsules contain a mixture of sodium cyanide and inert ingredients. The amount of sodium cyanide mixture in each capsule is approximately 0.97 gram (0.03 ounce). This includes 0.88 gram of sodium cyanide (active ingredient) and 0.09 gram of inert ingredients.

One of the inert ingredients is a marker that can be detected in or around the mouth of an animal killed by the M-44 device. Capsules made by PSD for use outside the WS program contain a marker of a different color than the color used by WS.

Both markers are usually easy to see in or around the mouth of animals killed by M-44's. If it is important to know whether or not a particular animal was killed by an M-44, a shortwave ultraviolet light (366 nm) should be used when marker particles are not visible to the unaided eye. With the animal specimen in a dark place, either marker will fluoresce under ultraviolet light even if it is not visible in daylight.

Capsule Storage

Waxed capsules are very susceptible to heat damage. Keep them at room temperature (70-75°F) in a dry place as much as possible. Avoid wide temperature fluctuations because capsules subject to repeated heating and cooling deteriorate faster than capsules kept at a constant temperature.

If capsules deteriorate under the storage conditions you normally use, try keeping them with a desiccant such as silica gel in a water-tight jar (1- or 2-quart, wide-mouth canning jar with good, tight lid) or a small metal, military-type ammo can with a snapdown lid. One good desiccant is indicating Drierite, which changes color as it absorbs moisture. By looking at the color, you can tell when the Drierite is waterlogged. You can then dry it out in an oven. When dry, it returns to the original color and is then ready for reuse.

Sealants

M-44 cyanide capsules were sealed with beeswax from August 1983 to April 1989, when a better sealant, Scheel SC-100 Petroleum Hydrocarbon Wax, was adopted. All capsules made since April 1989 have the new sealant.

Carrying Capsules for Use in the Field

Do not carry large numbers of M-44 cyanide capsules in your vehicle. Take only enough each day for the number of M-44's you plan to set or check that day. Keep capsules in your vehicle out of sunlight and away from heat. Do not carry capsules in the glove box or in toolboxes, where extreme temperatures may occur.

Checking Capsules

Whenever you get new capsules or use capsules that have been in storage, inspect them for the following:

Caking- Tip a few capsules back and forth, or listen while shaking them, to see if contents are free flowing. If there is any doubt, open a few carefully and pour contents out. Contents should drop out freely. Any sticking or clumping means the cyanide has started to cake. Capsules with caked ingredients should not be used.

Overfull- As filled at PSD, capsules have an air space of about 1/10 inch below the top wad. Cyanide expands when it absorbs water. When capsules appear to be too full, moisture has probably gotten in through the seal. This may have happened even if the seal looks as good as new. Overfull capsules often will be partly caked. Check for caking as explained above.

Age- Check the date of manufacture as marked on each box of capsules. A date stamp that reads "08 95" means that the capsules were made in August 1995. Be aware when you change from one lot of capsules to another, and inspect each new lot for caking as described above. Try to use capsules within 6 months from date of manufacture. The older the capsules, the more likely they are to be caked or otherwise defective.

Undersize Capsule Holders- Capsule holders made before 1990 may have undersized bores. If capsules do not easily fit in your capsule holders, enlarge the bores by running a drill bit 15/32 of an inch in diameter through each one. Capsule holders made since 1990 have a larger inside diameter and do not need to be drilled out.

Capsule Labels- Each cyanide capsule has a warning label. The capsule should fit in the capsule holder without removing the label. If your capsules do not fit well, drill out the capsule holders as described above. Do not remove capsule labels.

Flare- Flare, or swelling of capsule mouths, is caused by chemical reaction between wax ingredients and plastic. The reaction is accelerated by heat. Check for flare by inserting capsules in a capsule holder. If they do not slide in easily, they are flared. Do not force them in as that will damage the seal. Get new capsules as soon as possible.

Ejectors

Lubrication and Cleaning

M-44 ejectors need to be clean and properly lubricated to work well. Grease or oil the trigger and plunger whenever you set an M-44. There are many good lubricants. The following have been recommended by experienced M-44 users: silicone spray lubricant, mineral oil, Triflow®, petroleum jelly, and light greases such as Lubriplate® No. 105 or FML-O (food machinery lubricant). Glycerine is not recommended. Use whatever works for you, but lubricate those ejectors.

Cyanide is the chief cause of corrosion that produces ejector malfunctions. Once an ejector is fired and gets cyanide in it, the ejector should be cleaned carefully with a wire brush and lubricated before it is reset.

Ejectors made since 1992 use a retaining pin, rather than metal washer and crimp, to hold the ejector spring in place. The retaining pin can be removed to take these ejectors apart for cleaning. Compress the spring from the bottom end of the ejector with a small screwdriver; then remove the pin with a needle-nose plier.

Frequency of Servicing

Set M-44's should be lubricated and reset at least once each month if they haven't been pulled. When servicing undisturbed units, carefully test pull some of them to confirm proper functioning.

Bottom Blowouts

Failure of the bottom crimp has been a problem with certain M-44 ejectors, particularly those made early in 1985. (These are the only current model ejectors that lack the internal, 0-ring shock absorber on the plunger.) If you have had this problem, inspect similar ejectors for evidence of crystallization. Crystallized metal will have a grainy appearance, and the bottom crimp may show cracks. Crystallized ejectors should not be used. Return them to PSD for replacement.

In 1992, the M-44 ejector was modified to eliminate the bottom crimp. Ejectors now have a retaining pin rather than a bottom crimp to hold the ejector spring in place. This modification has eliminated bottom blowouts.

Trigger Pull Force

The current M-44 ejector requires a stronger pull to discharge than did the pre-1985, Poteet model ejector. The harder pull results from a new, stronger spring. Several things can be done to reduce the trigger pull:

1. When cocking the ejector, do not push the trigger as far up as it will go. Instead, set it at right angle to the body center line, or set it by feel to avoid excessive sear engagement.

2. Lubricate the trigger and plunger.

3. Before using brand new ejectors, cock and snap (fire) each one 6 times. This will reduce pull force by 1 to 2 pounds (new model ejectors). When snapping ejectors, hold them against a block of wood or other solid object to avoid internal damage.

4. When closing the lock ring (after ejector is in the stake), position the lock ring loop over the trigger. With new model ejectors and stakes, doing this reduces the pull force by about 1 pound. [Note: This recommendation does not apply to the flat metal lock ring introduced in 1996.]

Ejector Pullouts

When lock ring loops are positioned over the ejector trigger, as described above, ejectors may be pulled out and carried off. Pullouts occur when a coyote or other target animal initially pulls and discharges the M-44. If another coyote comes along and pulls on the M-44 before it has been reset, the discharged ejector may be pulled out of the stake and carried away. Pullouts can be reduced by reshaping the trigger or by replacing the wire lock ring with the flat metal lock ring that became available in 1996.

On the M-44 ejector as issued, the outermost trigger segment (3/8-inch long) is parallel to the ground when the ejector is set. To reshape a trigger, clamp the ejector in a vise and bend the trigger end up to a vertical position.

Stakes

Trigger Notch

The trigger notch is too shallow on some M-44 stakes. This creates a hazard because the ejector can fire when the operator attempts to close the lock ring, which will not close due to insufficient clearance over the trigger. To correct this hazard, inspect the notch on all swaged-top stakes and use a chain saw file to deepen any notches that are too shallow. Alternatively, defective stakes can be returned to PSD for repair or replacement.

Driving Stakes

Never hammer directly on M-44 stakes as that will break or deform the tops. Instead, use a driving rod inside the stake. In hard ground, make a pilot hole first. Before driving, put gravel or a wood block in the stake to protect the bottom from damage. For current model, swaged-top stakes, good wood blocks can be made from 5/8-inch hardwood dowel. Saw it into 7/8-inch lengths.

Another good way to avoid stake damage is to use a driving tool. Put a rubber bumper, such as an automotive shock absorber bushing, on a bolt of whatever length and diameter is right for your stakes.

Keeping Dirt and Sand Out

A "dirt skirt" can be used to keep sand or soil from getting in the stake and interfering with ejector movement. The dirt skirt is a round, 2- or 3-inch-diameter piece of inner tube, cloth, or plastic with a half-inch hole in the center. To use, place cocked ejector in stake. Set the lock ring; then place the skirt on the ejector before you screw on the capsule holder. Cover the skirt with soil.

Safety

Make Safety a Habit

When setting M-44's, never put yourself in a position where cyanide will hit your face or eyes if the unit discharges accidentally. Work on the upwind side and do not stand or kneel over the ejector.

A small pill vial, plastic bag, or thumb from a leather glove, when placed over the capsule holder, is a good safety precaution to confine ejected cyanide if the unit accidentally discharges while you are working on it.

Antidote Kits

Check expiration date to be sure your kit is current. Keep it on your person at all times while setting or servicing cyanide ejectors. Do not leave your antidote kit on the vehicle's dashboard or any other place where it will be exposed to excessive heat. Heating can cause amyl nitrite ampules to explode, thereby creating a health hazard to persons or animals exposed to the fumes.

Sources of Information

Additional information on this product can be found in the April 1994 ADC Final Environmental Impact Statement (Appendix P), in Material Safety Data Sheets supplied by the Pocatello Supply Depot, and in the 1995 Handbook on Prevention and Control of Wildlife Damage. Specific information on this product can be obtained through the National Wildlife Research Center (NWRC) (970-266-6000) or through the NWRC web site http://www.aphis.usda.gov/ws/nwrc. For further information about the availability of this product, contact your WS State Director, or the Pocatello Supply Depot.