Chapter II

DETAILED FINDINGS

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Chapter II
DETAILED FINDINGS

This chapter presents the findings of the study in some detail, along with a sketch of the data and analytical methods used to arrive at them. **The full analyses on which these findings are based are found in the subsequent chapters and the appendixes.**

The analysis proceeded **in two stages, which were conducted simultaneously. The first stage assessed the technical efficacy of the taggants, and their compatibility with explosive materials. Definitive judgments on these points must await the results of further technical development and testing. The second stage estimated the cost and law enforcement utility of taggants, *assuming* that taggants can be made which work and are safe. It should be clearly understood that a taggant program is only appropriate if all the conditions are met: it must be technically sound, it must be safe, it must have value for law enforcement, and the costs must be reasonable in the light of this law enforcement value.**

The analysis and discussion of technical efficacy and safety were conducted as if it had been established that taggants are useful in relation to their cost. The analysis and discussion of cost and utility were conducted *as if* it had been established that taggants work and are safe.

Because a variety of implementation plans are possible, costs and utility are evaluated parametrically in order to show how the choices made in writing regulations would lead to variations in cost and law enforcement value.

OVERVIEW OF THE PROBLEM

In order to appreciate the potential benefits and shortfalls of a tagging program it is necessary to understand the magnitude of the current and projected future bombing threat, as well as the processes involved in the manufacture, distribution, and sale of the various explosive materials.

The Bombing Threat

Both the Federal Bureau of Investigation (FBI) and the Bureau of Alcohol, Tobacco, and Firearms (BATF) maintain national bombing data information centers which collect statistics on bombings and other explosive incidents. The data are not consistent between the two centers, however, and many bombings are not reported to either center. The formatting of the data, and the lack of updating procedures, make accurate analysis difficult. Appendix F explains in some detail which data sources were used, and why. While BATF and FBI data differ in the absolute values (e. g., number of bombings in a year), both sets of data support the OTA findings. Most tables in this report make use of BATF data because its format appeared more amenable to analysis.

The BATF 1978 Explosives Incidents Report includes over 3,000 incidents for both 1977 and 1978. The incidents include accidents, threats, seized and recovered explosives, and hoaxes, as well as actual explosive and incendiary bombings. Of these incidents, 1,377 represented actual explosive detonations, accidental detonations by criminals, or recovered bombs that failed to detonate in 1977, with

1,250 the corresponding number for 1978. At least 953 of these in 1977 and 787 in 1978 represent actual detonation of explosive bombs against substantial targets (mailbox and open-area bombings are not included).

During 1977, BATF estimates that 38 people were killed and 180 wounded by explosive and incendiary bombs, while the numbers in 1978 were 23 and 185, respectively. Due to the way initial estimates of property damage are made, and the lack of updating, only the crudest property damage estimates can be made. There was at least $10 million in direct property damage due to explosive and incendiary bombs in 1977, and at least$17 million in 1978. In 1977, 35 of the 38 reported deaths and 20 of 23 reported in 1978 were from bombings against vehicles, residences, and commercial establishments. Similarly, about 80 percent of the injuries from bombing of known targets in 1977 and about 70 percent in 1978 were caused by bombings of those three types of targets. The 1977 and 1978 statistics are summarized in table 6, and discussed in more detail in appendix F.

The available data do not sustain any conclusions about trends in the bombing threat; both the number of incidents and the extent of deaths, injuries, and property damage vary from year to year, and from data base to data base. Management Sciences Associates (MSA) conducted a detailed study of the data in the 5 years from 1972 through 1976 without discovering any significant trends. Many experts on terrorism believe that the United States may experience an increase in bombings, particularly catastrophic bombings, in the years ahead. However, this belief is based on an assessment of U.S. vulnerability to bombings and the observation that the United States has recently had less of a terrorist problem than other developed countries; there is no evidence that this increased threat has materialized. In looking at bombing statistics, one should bear in mind that a single incident involving an aircraft exploding in flight could produce more deaths than have occurred in any year to date.

Data on the types of fillers used in bombs are also not consistent between the FBI and the BATF data banks. It is instructive to look at two BATF data sources, however, as shown in table 7. The second column represents 1978 data for the fillers identified in the field for all explosive bombs that were detonated, bombs recovered undetonated, and criminal accidents. The first column represents 1978 data for only those fillers that were identified in the laboratory from postdetonation analysis. The third column averages the first two. In both cases, black and smokeless powders and cap-sensitive high explosives all occur with high frequency. Table 8 shows a breakout of the minimum number of significant bombing incidents, deaths, and injuries occurring during 1978 by explosive material fillers. The average column in table 7 was multiplied by data on

Table 6.–Minimum Bombing Incidents Statistics Summary [a]

	BATF		FBI	
Hem	1977	1978	1977	1978
Explosive bombings, number.	1,037b	896[b]	867	768
Undetonated explosive bombs, number.	319	287	118	105
Incendiary bombings, number . .	339	446	248	349
Unignited incendiary bombs, number	81	71	85	79
Criminal accidents, number[c]	21	67	–	–
Property damage from bombings, millions of dollars[c d]	$ 10	$ 17	$ 9	$ 9
Injuries [c]., ...	180	185	162	135
People killed by bombings[c]	38	23	22	18

aBATF reported 3,177 total incidents in 1977 and 3,256 in 1978 Total incidents include accidents threats, seized and recovered explosives and hoaxes as well as actual explosive and incendiary bombings The OTA study was concerned only with explosive bombings
b of these 953 in 1977 and 787 m 1978 were against substantial targets
includes both explosive and incendiary bombings OTA was unable obtain separate figures for number of criminal accidents, injuries deaths, and property damage caused by explosive and incendiary bombings Incendiary bombs and bombings would not be affected by a taggant program value **probaly** Considerably higher due to lack Of data file updates

SOURCE : *BATF 1978* Explosive Incidents *Report,* FBI Uniform Crime Report: *Bomb Report 1978 See* app F for a discussion of the derivation of these figures

Table 7.–Identified Explosive Fillers Used in Bombs

	Lab identified fillers 1978	All Identified fillers 1978	Average
Black powder ., .	13%	21%	17!40
Smokeless powder .	16	19	17.5
Military ., ., ., ...	2	7	4.5
Cap sensitive ., .,	32	30	31
Blasting agents,	–	1	.5
Chemicals . .	–	1	.5
Others, ...,	36	21	285

See app F for derivation of these numbers

SOURCE BATF data

Table 8.–Bombing Casualties and Damage in 1978 by Typo of Bomb

Filler material	Number of bombings against substantial targets	Deaths	Injuries	Property damage $ millions'
All fillers. .,	1,298	23	185	$17.2
Incendiary . . . .,	428	3	13	3.7
Black powder	148	4	19	.2
Smokeless powder : : : : : : :	152	3	23	.2
Military explosives.	39	0	7	—
Cap sensitive.	270	7	26	3.3
Other		3	40	2.4
Unknown ., .,		3	57	7.4
Total for those fillers which would be directly tagged[b].	570	14	68	3,7

[a]Value probably higher due to lack 01 data update
b cap-sensitive explosives black powder and smokeless Powder would be tagged

SOURCE BATF data See app F for a derivation of these figures

total bombing to generate the table 8 estimates. See appendix F for details.

Manufacturer to User Chain

Explosives

Approximately 4 billion lb of explosives are manufacturered and used annually in the United States. Of this amount, approximately 600 million lb are standard explosives and 3.4 billion lb are blasting agents, primarily ammonium nitrate-fuel oil mixtures. Of the 600 million lb of standard explosives, about half are cap-sensitive (will reliably be detonated by a #8 detonator) dynamites, emulsions, gels, and slurries, and about half are non-cap-sensitive gels, slurries, and emulsions. Most of the standard explosives are manufactured in a plant, packaged in cartridges, and shipped, either directly to a large user such as a coal mine or to a distributor, although some are processed essentially onsite. Some of the blasting agent products are prepared by a manufacturer and sold in packages, some are prepared by a manufacturer and sold in bulk [tanker truck), while some are mixed onsite and used the same day they are prepared.

Standard explosives are made by mixing together the fuel and oxidizer ingredient and feeding the mixed product into the final cartridges by a batch, semicontinuous, or continuous process. I n a batch process, the ingredients for a particular batch are first mixed and then packaged before another batch is started on that production line. In a semicontinuous process, the mixed batch is fed into an intermediate hopper from which packaging takes place, while another batch is mixed in parallel to the packaging of the first batch. In a continuous process, the material is continuously added to the mixer, processed, and packed in a continuous flow.

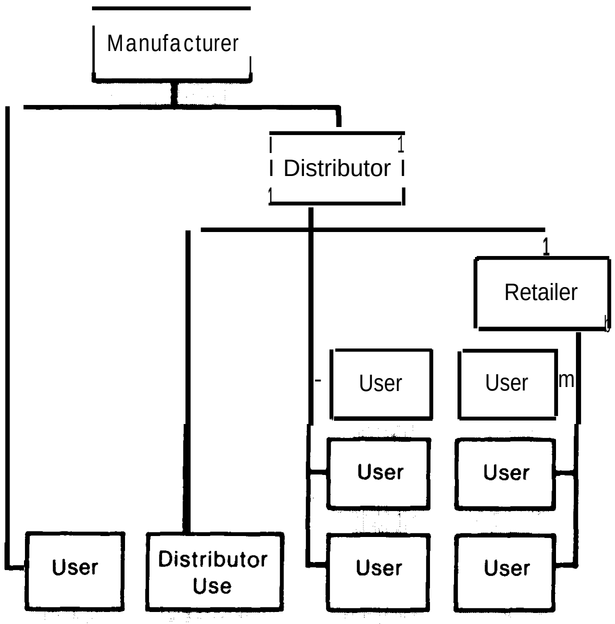
If taggants were added to standard explosives, they would be added at the mixing stage. Taggants could also be added to packaged or bulk form manufactured blasting agents at the mixing stage. If the ammonium nitrate used to make onsite-fabricated blasting agents were to be tagged, identification taggants could be added during the “prilling” process, while detection taggants, which are not batch specific, could be added with the fuel oil.

Boosters are generally fabricated by pouring a molten, high-energy, cap-sensitive explosive, such as TNT, into containers. Taggants could be added during the cooling process of the explosive.

Detonators and detonating cord are manufactured products in which the product is built up around an explosive core in an assembly-line process. In both cases, the taggants would be added during the assembly process, rather than directly to the explosives.

All of the products have a similar flow from manufacturer to ultimate user, as shown in figure 1. Some of the products are sold directly by the manufacturers to large users, such as a

Figure 1.— Explosive Distribution Chain



SOURCE: Off Ice of Technology Assessment

mine or large construction company. Such sales may represent an entire day's production. The rest is sold to distributors, who may buy portions of several production batches, entire batches, or even several batches. The distributors in turn sell to retail stores, supply explosives directly to some users (such as a quarry or construction site), and may also do explosive contracting themselves. A particular uniquely tagged batch of explosives may, therefore, go directly to one user, may go to one distributor, or may be sold to a number of users and distributors. From the distributor it may again go to one of several users, sometimes with a further distribution level (retailer) involved. A list of the ultimate purchasers of one specific batch of explosives could, therefore, contain one name, or up to a hundred names for a worst case example, although generally the number would be at the low end of that range.

Gun powders

The manufacture and distribution processes for gun powders are significantly different from those of explosives. Approximately 2 1/2 million lb of black powder and 20 million lb of smokeless powder are produced for commercial use each year. Most of the smokeless powder is used in fixed ammunition for rifles, pistols, and shotguns, would not be sold to users as an end product, and would not be tagged under S. 333. Approximately 5 million lb per year would be sold to the end user, primarily for handloading of ammunition. Of the black powder production, approximately 2 million lb are used as an intermediate product in the manufacture of fuzes and other finished products and would not be tagged; approximately **400,000** lb per year are sold for use in muzzle-loading guns and would be tagged if a taggant program were legislated.

The basic process for the manufacture of gunpowders involves the following steps:

- mixture of ingredients, which may include the raw ingredients as well as surplus and reworked powders;
- granulation, where the "dough" is extruded, chopped, or otherwise granulated to form the various grains;
- screening of grains into designated sizes; and
- blending of various batches to get the desired ballistic characteristics.

In the smokeless powder manufacturing process, nitroglycerine, nitrocellulose, and other additives are combined to make various grades before the blending process. Smokeless powder grades therefore differ due to size differences and composition differences (various amounts of nitroglycerine), while black powder and black powder substitutes such as Pyrodex®* vary only by grain size. In a given grade of powder, variations in density and other fluctuations during the manufacturing process can cause considerable variations in the ballistic properties of the final powder. As the handloader generally has no means of controlling his ballistics other than the weight or volume of powder added, the ballistic properties of a particular grade of powder must be carefully controlled by blending. A given brand name

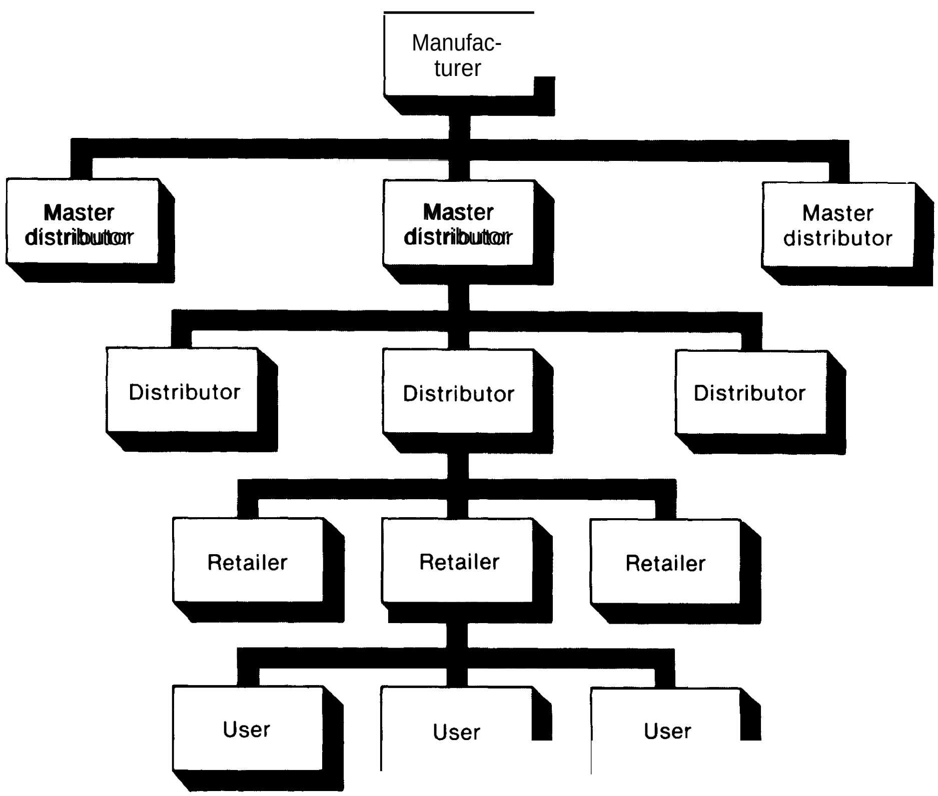
*A registered trademark of Pyrodex Co

product may therefore contain parts of several batches, blended like brandy to give the desired ballistic properties. Several sequential blending operations may be necessary before the product meets the required specifications. If the ballistic properties of a particular batch or blended lot are too far off, the material must be reprocessed or used for something other than hand loading.

If taggants are added to gunpowders, they may have to be added at different stages in the manufacturing process for different manufacturers, due to the differences in blending and reworking processes. As an example, at one smokeless powder factory that makes powder for both handloading and fixed ammunition, taggants could be added during the blending stage; blended batches that were still not satisfactory could be used for fixed ammunition. At another factory, due to their large rework factor, an additional taggant-mixing stage might be necessary. For some products, it may be possible to add taggants to the dough, although this may affect the granulation process and present blending problems.

The distribution network from gunpowder manufacturers to users differs markedly from that of explosives, since there is a very large number of ultimate users, each of whom consumes a small amount of powder. The network is shown schematically in figure 2. The manufacturer has several master distributors, each of whom supplies a number of distributors. Each distributor supplies a number of retailers, who sell the product, often in lots as small as 1 lb. A 2,000-lb uniquely tagged batch of product “A” may therefore ultimately be sold to over a thousand customers. Not only does this produce a much larger list of last legal purchasers, but considerably more record keeping would be involved at the retail level.

Figure 2.—Gunpowder Distribution Chain



SOURCE Off Ice of Technology Assessment

TECHNICAL EFFICACY

The issues to be addressed here include the survivability of the identification taggants and the status of the detection taggant materials and sensors. A detailed discussion of the research program related to technical efficacy is in chapter I I 1; chapter IV discusses in detail the research related to safety.

The identification taggants developed by 3M appear to survive the detonation of commercial explosives under ideal conditions. Confinement and fire may adversely affect survival, although the test data are very limited. Recovery of the taggants appears to be a function of the specific conditions in which the explosion and taggant recovery take place, as well as the training of the field and laboratory investigators.

A large number of laboratory survival tests have been conducted to establish the postdetonation survivability of the 3M identification taggants. In many of these tests, the chamber used to recover the taggants was not ideal, resulting in low recovery rates. For example, when relatively small steel-walled chambers were used, the impacting taggants either broke up upon impact, or flowed plastically due to the impact pressure pulse. When the explosive charges were detonated in large chambers, or on a large open pad, however, several hundred tags were recovered from a single, one-half-lb stick of the cap-sensitive explosives, including Atlas Power Primer, the most energetic of the standard commercial explosives. Similarly, the taggants should survive the detonation of black and smokeless powders, which have much lower energy than the more energetic explosives, under idea l conditions. The individual taggants are not expected to survive the detonation of high-energy explosives, such as the TNT used in boosters or military explosives; Aerospace Corp. calculations have shown that the taggant material would be raised above the taggant decomposition temperature in these explosives. Survival in these energetic explosives has been demonstrated when the taggants are pressed into large pellets (one-fourth inch), but no definitive recovery testing has been conducted.

When conditions are less than ideal, survival decreases. The number of surviving taggants decreases sharply as the size of the charge increases, although sufficient taggants have been recovered even from a 25-lb Power Primer charge to establish a definite identification. The number of taggants also decreases if the explosive is confined, for example, in a pipe bomb. Hundreds of taggants survive a black powder pipe bomb; tens of taggants have been recovered, under nonideal recovery conditions, from smokeless powder pipe bombs. Only one test seems to have been conducted with cap-sensitive high explosive in a pipe bomb; scores of taggants were recovered from a pipe bomb filled with 60-percent Extra, a low-energy explosive.

The recoverability of the taggants under real-world conditions is less well-established. The vast majority of the tests of recovery have been demonstrations and training exercises, with little attempt at scientific controls, procedures, or documentation. Table 9 shows the results of 10 demonstrations using explosives tagged during the manufacturing process with encapsulated taggants at a 0.05 percent by weight tagging level. The number of taggants recovered is shown in each case; in some cases heroic recovery efforts were required. Statistical analysis by the Aerospace Corp. indicates that it is highly desirable to recover 20 taggants; that many were not recovered in each case. In some tests, particularly the last one, recovery was halted after the reported number was found. Table 10 shows the results of 14 similar tests, conducted without the assistance of the Aerospace Corp. and the BATF laboratory team. These tests were significantly less successful.

Due to the apparent inconsistency of the test results and the lack of documentation, OTA had a limited series of five recovery tests conducted. The purpose was twofold: to get a feel for the recovery process and its difficulties, and to generate a limited number of data points for which the testing, recovery, and analysis were well controlled and docu-

Table 9.–BATF Recovery Demonstrations

Place	Time	Target	Explosive	Test conditions	Taggant recovery
Birmingaham, Ala.	February 1977	Car	1 1/2 -lb Power Primer	Against engine, fire, firefighting	35 from soil sample in laboratory
		House	11/2 -lb Coalite-8S	Table, near front hall	Hundreds, at scene
		House	j/4-lb, 60% Extra in pipe	Outside house, near wall	Scores, at scene
Donaldson, Pa	March 1977	Borehole in coal mine	101/2 -lb Coalite-8S	7 each, 1 l/2-lb packages in separate boreholes	20 from coal in laboratory
Seneca, Md.	June 1977	House	2-lb Coalite-8S	Exterior room	Dozens at scene
		Car	2-lb Coalite-8S	Passenger compartment	Few at scene
Fort McArthur, Calif,	November 1977	House	1/2 -lb Powerdyne	–	Many at scene
Los Angeles, Calif.	August 1978	Open	1-lb Powerdyne	In suitcase	20 at scene
Otis AFB, Mass.	October 1978	Open	1-lb. Tovex 220a	Three shots, 1 lb each	Less than 10
Fort Belvoir, Va	March 1979	Car	2-lb. Coalite Z	Trunk	3 in field

a Undetonted stick had only 10 percent of expected taggants Data Indicates that this explosive was from end of a batch

SOURCE Office of Technology Assessment

Table 10.–Recovery Tests Participated in by Summit County (Ohio) Sheriff's Office

Date	Explosives	Target	Conditions	Recovery results
May 2, 1978	Total of 41/z-lb permissibles	Two cars, ground	—	2-hour field search (night), 10 men, 4 taggants in one car, no tags from other targets.
May 11, 1978	2-lb permissibles	Car	—	2-hour field search (night) by 2 men. No taggants
May 17, 1978	3-lb permissibles, 1 black powder pipe bomb (untagged)	3 cars, pipe bomb in open	1 car fire	1-hour field search (daylight with blankets). No taggants.
Oct 12, 1978	2-lb permissibles	Car	—	2-hour field search (night). by 2 men. No taggants.
May 16, 1979	1/2 permission	Car	—	1 l/2 -hour field search (daylight with blankets), 20 men. No taggants
May 17, 1979	2-lb permissibles	Car	—	2-hour field search (night) by 2 men. No taggants
Aug 14, 1979	2-lb water gel	Car	Under driver seat	3-hour field search (dark), 6 men Found 3 taggants from water gel. Laboratory analysis of 60-lb debris from each car Found 5 more taggants from water gel.
	1 3/4-lb gelatine dynamite	Car	Under driver seat	
	2-lb permissible	Car	Under driver seat	

SOURCE Office of Technology Assessment

mented. The results of the tests are summarized in table 11 and described in detail in appendix C. Sample photomicrographs of recovered taggants are shown in figure 3. Although these tests were extremely limited in scope, and covered only one type of target (automobile), they provided a great deal of insight into the recovery process and suggest a reconciliation of the prior test results. However, a full-scale test program must be completed before a definitive assessment of taggant recovery is possible. With that caveat, the following tentative observations may be made:

1. The recovery process does **not** appear to be a **field-readable** process under the tested conditions. No taggants were spotted, and identified as such, in any of the five tests, under daylight or night conditions, without the use of a laboratory separation procedure. However, the recovery conditions were not ideal. Field recovery and identification of the taggants may be more likely on paved surfaces.
2. Under ideal conditions (no fire, subsequent firefighting activities, or adverse weather), sufficient debris can be gathered in a short time (less than 1 hour) by an untrained team to produce a positive taggant identification (more than 20 taggants) in the laboratory. Only a moderate (1 to 2 hour) laboratory effort is necessary by a highly trained laboratory team to isolate and identify the taggants. This probably holds for all classes of unconfined commercial explosives (excluding very high-energy explosives such as boosters or military explosives). The laboratory need not be elaborate and could well be transportable to the bombing site.
3. Under conditions of confinement (bomb placed between the engine block and the

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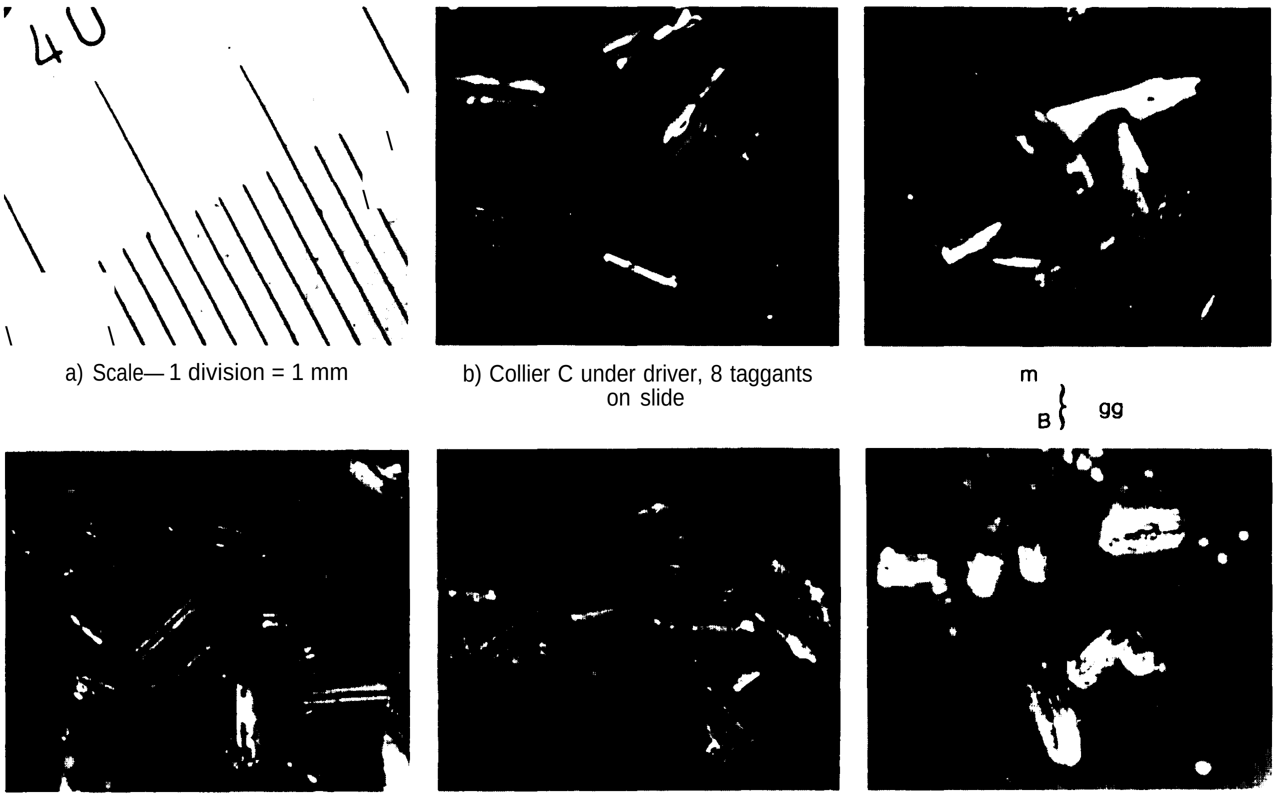
Table 11 .–OTA Recovery Test Resutts

Target	Placement	Dynamite	Test condition	Taggant recovery
Auto	Under driver seat	2-lb Collier C	5-gal gas in tank; no fire	28 taggants in 1 M-hour lab time
Auto	Under driver seat	2-lb Unigel	5-gal gas in tank; no fire	23 taggants, 1 contaminant in %-hour lab time
Auto	Under driver seat	2-lb Power Primer	5-gal gas in tank; no fire	21 taggants in 1 1/2-hour lab time: 12 of type A oftype - dual tagged
Auto	Under driver seat	2-lb Collier C	1-gal gas adjacent to bomb, fire, firefighting	23 taggants in3-hour lab time
Pickup	Between engine and firewall	2-lb Power Primer	Dry tank, no fire	26 taggants, plus one contaminant in 4 hours lab time, 5-hour induction time preceded the search time due to confusion caused by equipment contamination,

SOURCE Off Ice of Technology Assessment

Figure 3.—Photomicrographs of Recovered Taggants



a) Scale— 1 division = 1 mm

b) Collier C under driver, 8 taggants on slide

m B gg

g gg

e) Collier C under driver, 17 taggants on slide

m gg

Photo credits' U.S Department of the Treasury

firewall), sufficient taggants can still be recovered for a confirmed identification, although somewhat more effort is probably necessary, both in the field and in the laboratory. This tentative conclusion would hold for all cap-sensitive commercial explosives (excluding boosters and military explosives).

4. Taggants can be recovered from an automobile bombing with a low-power explosive, even after a gasoline fire and subsequent firefighting efforts. Tests would be necessary to determine if taggants would survive a postdetonation fire in conjunction with a more energetic explosive. It should be noted that no fire occurred in

the three tests in which gasoline was placed in the gas tank. Fire had to be specifically induced (a gallon of gasoline was placed adjacent to the bomb) for the burn test.

5. The results of the automobile tests may well be generalizable to other test conditions (buildings, open areas), but testing would be required before that claim could be made.
6. No substantive recovery data are avail able for large charges, explosives in pipe bombs, tagged boosters, detonators or detonating cord, or charges consisting of an untagged blasting agent with a tagged booster and detonator. Taggants were reported recovered from a large bomb consisting of an untagged blasting agent and a tagged booster, conducted in December 1979, but the test specifics have not yet been examined by OTA.

The technology for detection sensors has been demonstrated in the laboratory, but at least several years of development would be necessary before field models would be available. Three types of sensors are being considered for use with the microencapsulated vapor detection taggants. Each type is capable of sensing, under properly controlled conditions, in the parts-per-trillion regime envisioned for the system. The mass spectrometer sensor is a simplified version of a standard laboratory instrument. The spectrometer, however, must be calibrated regularly, requires ski lied scientists to operate and maintain it, is large, and is quite expensive. The ion mobility spectrometer has been commercially available for approximately 5 years, with approximately **50** machines being used in laboratory analyses. It shares the laboratory instrument characteristics of the mass spectrometer. The continuous electron capture detector has been produced as a laboratory instrument, but in limited numbers. Laboratory and controlled-environment testing with the three types of instruments has shown promising results. For example, a less sensitive mass spectrometer is currently operating in an online process mode at Libby-Owens-Ford, maintained by regular maintenance personnel. Testing of the ion mobility spectrometer in an airport environment has indicated that the spectrometer can differentiate molecules of mass similar to the vapor taggants from the ambient environment. Similarly, laboratory testing of the continuous electron capture detector has indicated its ability to discriminate taggant-like molecules.

These limited tests, however, are a long way from demonstrating that the sensors can distinguish the specified vapor taggant species from other molecules, particularly those in the same mass range. The ion mobility spectrometer and mass spectrometer have an active separation mechanism to preclude interference with molecules that differ significantly in mass; the continuous electron capture spectrometer must rely on a far less reliable passive breakup mechanism.

No estimates have been made of the time required to produce fielded units, once a feasibility demonstration has been made (none of the three candidates has yet progressed that far). The only time estimate so far made is an estimate by the Aerospace Corp. that it would take 14 months from demonstration of feasibility to the completion of the prototype stage for the ion mobility spectrometer. This estimate is quite optimistic for an instrument that would be produced in large numbers by a small company. OTA feels it would be at least 3 years, and probably more like 5, before a taggant sensor could be fielded. The estimate is based on generalizing from other commercial and military instrument development experience.

The candidate detection taggant vapors appear promising, but more research is necessary. Several hundred candidate chemicals have been screened in a search for a vapor that exhibits the desired properties of scarcity in nature, long-term stability, chemical inertness, vapor pressure, penetration, and nonadhesion to surfaces likely to be present in containers used to conceal bombs. The five candidate perfluorinated cycloalphones appear promising on the basis of early tests. (No long-term stability data are available, however, nor are there data on the long-term stability of the diffusion rate through the encapsulating material). Additional problems, such as ease of manufacture, specificity with respect to the detector, and compatibility, have not yet been addressed. Ease of manufacture is a double-edged problem — if manufacture is too difficult, then costs will be high; if it is too easy, then illegally manufactured material can be used as a countermeasure to the detection sensors. The most promising candidates are difficult to manufacture, require highly specialized equipment, and would be hard for bombers to make or acquire for use as countermeasures. Once the equipment is operational, unit costs should not be unreasonable. A problem which probably applies to all varieties of vapor taggants is that seals can be made that are taggant proof — although apparently common seals are insufficient.

COMPATIBILITY OF TAGGANTS WITH EXPLOSIVE MATERIALS

The compatibility of explosive materials with the specific identification and detection taggant materials is addressed here. Compatibility has two connotations: the first concerns the safety during manufacture, transportation, storage, and use of explosive material due to the addition of taggants; the second concerns changes in the performance of the explosive materials to which taggants have been added. Such compatibility must be demonstrated by specific tests. Generalization of the results to other hypothetical taggants is hazardous at best.

Safety tests conducted to date with the encapsulated 3M identification taggants have shown no incompatibilities with dynamites, gels, slurries, emulsions, or black powder, allowing a presumption that comprehensive testing would show that these taggants are compatible with these explosives. High concentrations of taggants do react with one kind of smokeless powder and one type of cast booster material at elevated temperatures, and consequently incompatibility must be presumed pending further research. A large number of paired safety tests have been conducted comparing the sensitivity and stability of commercial explosives and gunpowders with and without identification taggants added. Safety tests included mechanical impact, thermal stability, thermal impact, friction, electrical properties, and chemical reactivity, although no single explosive has been subjected to al l of the above tests. I n no case did the addition of encapsulated taggants significantly increase the sensitivity of the explosive materials to the test conditions. No evidence of any decreased stability, or other significant changes, was found in any of the tests with dynamites, gels, slurries, or black powder.

The tests with tagged cast booster materials showed some indications of instability at elevated temperatures. A mixture of RDX and TNT (Composition B) showed evidence of reaction and probable decomposition at temperatures of 120° C when **taggants** were added to the booster mix; significantly less reaction occurred without taggants. Tests with Octol showed little reaction whether taggants were present or not. Pentolite showed little evidence of reaction with taggants in one test at 120° C; the gas evolution from untagged pentolite was too high for comparative testing on a second series.

Similarly, the stability of one type of Hercules smokeless powder has been shown to be significantly decreased by the addition of the 3M identification taggants at elevated temperatures and taggant concentrations. (Although Hercules tested only Herco * powder, Hercules believes that their other brands of powder designed for the reloading market are so similar to Herco® that similar test results could be expected.) Tests were conducted at temperatures ranging from 80° to 120° C and at taggant concentrations of 50 percent. Tests at the Lawrence Livermore Laboratories appear to indicate that the incompatibility is between some element of the powder and the basic melamine/alkyd material of the taggants, rather than with the encapsulant or a pigment.

*A registered trademark of Hercules Inc.

Both the smokeless powder and booster material tests took place at high temperatures, and, in most of the tests, at high taggant concentrations. The temperature used for the smokeless powder test was higher than would be expected in actual manufacture, storage, or use; the temperature used for the cast booster is sometimes reached in manufacturing processes. In each test, a taggant concentration of 50 percent was used rather than the 0.05-percent tagging concentration suggested for routine use. The tests, nonetheless, indicate that the stability of the materials has decreased, due to the addition of taggants, and that a reaction is taking place between elements of the taggant and elements of the explosive material. Standard qualification test procedures require that such evidence be considered a sign of an existing incompatibility between the materials. Carefully controlled testing and extensive analysis must be completed before it can be determined if the observed evidence of incompatibility does, in fact, indicate a potential safety problem during the manufacture, storage, transportation, and use of the tested materials. Unless demonstrated otherwise, it must be assumed that it is unsafe to add the taggants to that smokeless powder or to the booster material. Until the elements of the incompatibility have been identified, a question remains as to the safety of adding the taggants to similar smokeless powders and booster materials, although tests with other smokeless powders and boosters have shown no evidence of incompatibility.

The tests so far conducted are only a small fraction of the total number of tests that must be performed before it can conclusively be determined whether taggants are compatible with commercial explosives and gun powders.

Even if the current question of the stability of smokeless powder and boosters is resolved, **it is not possible to generalize from the results of the limited test program so far completed and conclude that the testing has demonstrated that taggants can be safely added to explosives. Thousands of people come into** contact with explosives every day during the manufacture, storage, transportation, and use of explosives. Accidents involving explosives can have extremely severe consequences to these thousands of people; therefore, safety must be demonstrated. A carefully administered qualification program of analysis, safety testing, manufacturing procedures control, and experience is necessary before a new explosive, or an explosive with a significant change in composition, can be considered safe. In addition, each type of explosive product requires individual evaluation and testing, The type of qualification program considered necessary before safety can be demonstrated is shown in table 12 and discussed in detail in chapter IV. A particularly important aspect of that qualification testing is the effect of long-term storage.

While the qualification program outlined in table 12 must be performed before taggants can be safely added to explosive materials, **the apparent incompatibility with the Herco”smokeless powder must be resolved before it makes sense for the taggant compatibility qualification program to proceed. Resolution** of this problem is pertinent for the entire identification taggant program, not simply for smokeless powders or for Herco®. As discussed in detail in chapter VI, smokeless powders are used in a significant number of criminal bombing incidents and account for a significant fraction of bombing casualties. If smokeless powders are not controlled, then more bombers may well switch to their use, resulting in an even greater smokeless powder born bing problem. The resolution could take any of several forms, including:

Table 12.–Elemertts of a Suggested Compatibility (qualification Program

- unique with each manufacturer
- analysis to define the new explosive or Ingredient
- laboratory testimg
  - —impact, friction, thermal, chemical composition
  - –electrical, aging, chemical interactions, performance
- pilot production
  committee and management review
- early production and review
  special tests
- experience

SOURCE Off Ice of Technology Assessment

- *Reformulation of the 3M taggant* — this could require starting essentially from scratch in the taggant testing program, as the reformulated taggant would undoubtedly exhibit different compatibility, as well as survivability, properties.
- *Reformulation of the particular reactant smokeless powder*— this may or may not be easily accomplished, once the element or elements that react with the taggant are isolated. This option would be viable only if no other smokeless powders were found to show incompatibilities.
- *Exe/us ion of the reacting smokeless powwaler from the taggant program*– the economic effects on competition could need to be carefully considered, as would alternate control mechanisms.
- *Exclusion of smokeless powders from the identification taggant program* — such an exclusion would rely on the fact that smokeless powders would be less effective than cap-sensitive high explosives and that the detonators would be tagged. OTA believes that this last approach may not be viable–too many people are currently killed or injured by bombs using smokeless powders and the numbers would almost certainly increase if this approach were adopted. Alternate control mechanisms for smokeless powders could also be adopted.
- Development of a different type of taggant for use with Herco®, or with all smokeless powders, while retaining the existing taggant for high explosives. This would somewhat complicate field investigation of bombings.
- Demonstration that the observed stability problem does not constitute a safety hazard. The observed decreased stability occurs at elevated temperatures and taggant concentrations 1,000 times greater than "normal. " As the decomposition rate is both temperature and concentration sensitive, it may be that no safety hazard exists under realistic conditions. If it could be positively demonstrated that the decomposition rate was within the normally accepted range for temperature regimes and concentrations which reflect worst case actual use conditions, then it *may* be possible to add taggants to the smokeless powder, particularly if no further incompatibilities surface. Demonstration of safety would have to be quite convincing, however, to overcome the currently perceived incompatibility.

Similarly, the apparent incompatibility with one cast booster material should be resolved before the taggant compatibility qualification program should proceed. Booster material is rarely used as a bomb filler, but it is used to initiate blasting agents. The current BATF plan would be to not directly tag blasting agents, but to tag the booster and detonators used to initiate the blasting agent. Exclusion of boosters from the taggant program may well require an alternate control mechanism for blasting agents. Given the extremely large quantity of blasting agents produced (3.4 billion lb annually), any other control mechanism may have serious cost consequences.

The limited number of tests conducted, the conditions under which some of the tests were conducted, and the preliminary manner in which the tests have been reported, make it difficult to definitely assess the extent of the potential compatibility problem. If definitive test results do show an increased decomposition rate, at least for RDX/TNT explosive materials, the incompatibility will have to be resolved before those booster materials can be tagged. Most of the mechanisms for resolution of the smokeless powder incompatibility are applicable to booster materials, with the same consequences and caveats.

While the testing program conducted to date gives an indication that the identification taggants may well be compatible with most commercial explosives and gunpowders, **little data are available as to the potential compatibility of detection taggants with explosive materials.** Compatibility testing with gunpowders and cap-sensitive high explosives has recently been initiated under contract to the Aerospace Corp.; however, no compatibility testing has as yet been reported. As indicated above, each change to an explosive composition must be evaluated separately. Successful completion of the preliminary detection compatibility program would indicate the need for a full qualification program. As some compounding of sensitivity may occur with both types of taggants present, the full qualification testing program should address that issue.

Compatibility testing includes performance testing, as well as the safety testing discussed above. In **most cases, the performance of explosive materials is unlikely to be significantly affected by the addition of small amounts of taggant materials. Performance proof-testing must be completed, however, before a definitive statement could be made. The** energy density and rate of energy release are the two most important performance attributes of commercial explosives. Energy density is a fundamental chemical property of the explosive formulation. The rate of energy release is a function of the materials involved and the physical proximity of the fuel and oxidizer components. The presence of taggants, in the few hundreths-of-a-percent by weight basis being considered, is unlikely to directly affect either of those performance characteristics. Similarly, the presence of taggants in the suggested concentration is unlikely to affect the ballistic properties of gunpowders. The few tests conducted *so* far, including tests of the basic properties of explosive materials, such as detonation velocity, cap sensitivity, chamber pressure, and projectile velocity, support that conclusion.

Physical segregation of the taggants is one mechanism which could affect performance. If the gunpowder grains segregate from the taggant, then it is statistically possible that a clump of taggants could cause uneven burning, prevent ignition, or result in a hazardous hangfire condition. Similarly, in some specialty explosive products, such as shaped charges used for oil well perforators, migration of the taggants to the explosive-metal interface could cause poor jet formation. Testing with gunpowder has shown that migration apparently does occur, at least u,nder vibration conditions consistent with truck transportation. I n tests with gunpowders that differ in both size and density from the taggants, the taggants and powder fines tend to separate from the larger powder grains. Tests with smokeless powder matched in size with the taggants, but different in density, were inconclusive. Testing is required to determine both the extent of segregation which could be expected if tagged gunpowders went through extreme but plausible conditions of transportation and storage, and also the statistical probability that segregation to this degree would adversely affect ballistic performance or in-gun safety.

The Winchester Western Division of the Olin Corp. recently conducted a series of tests to evaluate the effects of segregation and high taggant concentration on the ignition properties of smokeless powder. Significantly reduced ballistic performance was noted on one round, fired at – 30° C with four times the suggested taggant concentration. The other rounds fired in this test series showed acceptable performance (velocity, chamber pressure, and ignition time).

Olin-Winchester conducted additional tests using 100-percent segregation of taggants from powder grains, a condition so extreme that no conclusions can be drawn (see ch. IV).

OTA believes that although testing is indeed required to establish the ballistic effects, if any, of adding taggants to smokeless powder, it is necessary first to establish (by testing and by statistical analysis) the extent to which variation in taggant concentrations and segregation of taggants in normal conditions of transportation and use could be expected.

Taggant clumping (10 to 15 taggants) sometimes occurs when the taggants are added to explosive materials. It is unlikely that the clumping would affect performance or safety, but that type of anomalous behavior should be investigated, particularly as the physical chemistry of some of the explosive products, particularly the gels and slurries, is so poorly understood.

As for the possible performance degradations in shaped charges due to taggants, OTA estimates, based on tests conducted by the U.S. Army Ballistics Research Laboratory, indicate that a clump as large as 0.02 inch would not affect performance, even for precision-shaped charges, unless the clump contained a large hollow center. Clumps as large as 0.1 inch could cause some degradation to occur, but it is difficult to envision a mechanism which would allow that large a clump to accumulate, as that would represent all of the taggants in approximately one-half lb of explosives.

COST OF A TAGGANT PROGRAM

Estimates can be made of the total cost of a taggant program, the cost impact on manufacturers and users of explosives, the effects of a legislated monopoly, and the possibility of added liability of manufacturers due to the inclusion of taggants in explosives. In the above safety and efficacy discussion, the status of the current identification and detection taggant systems was evaluated. In the following cost section, an assumption is made that the taggants work and are safe, and cost estimates are generated parametrically as a function of the implementation plan. It is specifically assumed that the resolution of the smokeless powder and booster material incompatibility questions, and any subsequent questions which may arise, do not have significant cost impacts. I n the case of the smokeless powder and booster materials, this assumption is probably justified, as the cost of the taggant materials represents only a small fraction of the total cost added by a taggant program.

The primary finding of the cost analysis is that **the cost of a taggant program can vary by almost an order of magnitude, depending on the implementation plan. A baseline program is identified that would increase the cost of explosives and gunpowders to the ultimate user by approximately 10 percent.** The primary variables affecting the total program costs are the class of explosive materials to be tagged, the uniquely tagged batch size, and the number of locations at which the detection sensors would be deployed. Cost estimates for total program cost, added cost per pound of explosive or gunpowder, and public overhead costs are shown in table 13 for three implementation levels. The cost estimates include the costs for both identification and detection taggant programs. The total program cost for separate implementation of identification and detection taggant programs is included in the discussion of each case. The low, baseline, and high cost estimates do not correspond to different estimates of the same program; rather they refer to different tagging levels, different explosives tagged, and different numbers of sensors. Chapter V contains a detailed discussion of the cost estimates and a discussion of the sensitivity of the costs to the accuracy of the cost element estimates. To compare the program costs for a constant number of detection taggant sensor locations, it is only necessary to adjust the high- and low-program cost figure by $4,370 for each sensor deployed.

Table 13.–Cost of a Taggant Program as a Function of Implemmtation Plan

Cost parameter	Program level Low	 Baseline	 High
Added cost per pound to cap-sensitive explosives	3.5$	6.0$	9.6c
Added cost per pound to gunpowders . .	3,5c	65.8c	$1.04
Public overhead cost, millions of dollars per year	$5,3	$8.5	$24.5
Total program costs, millions of dollars per year	$30.5	$45	$268

SOURCE Office of Technology Assessment

1. The low-level program would use a unique identification taggant for each manufacturer, type of product, and year of manufacture. A total of 800 detection sensors would be deployed, one for passengers and one for baggage at each airport location currently deploying magnetometers and hand baggage X-ray units. Cap-sensitive high explosives, detonators, boosters, detonating cord, and smokeless and black powders would be tagged with both identification and detection taggants. Blasting agents would not be directly tagged. The

cost of separate low-level identification and detection taggant programs would be approximately $15 million and $22 million, respectively.

2. The baseline program would tag the same materials as the low-level program, but would use a unique identification taggant for each shift of each product –analogous to the current date-shift code marking on the exterior of explosives. Traceability to the list of last legal purchasers would be maintained, as the taggants would contain all the information needed for a BATF trace (date, shift, product, and size). Approximately 2,500 detection taggant sensors would be deployed at airports and major controlled-access facilities such as powerplants, refineries, and Government buildings. Major police bomb squads would operate portable units,

   This baseline program differs from the program proposed by the BATF/Aerospace Corp. team in only two respects. The most important is that a full shift of the same product (a different cartridge size would be treated as a different product) would be tagged with the same taggant, rather than an arbitrary 10,000 to 20,000 lb. The practical utility result is that a potentially longer list of last purchasers would be produced by a trace, at least for those lines that make more than 10,000 to 20,000 lb of a product in a single shift. The second difference concerns rework. It has been assumed that a special taggant will be added to material with more than 10-percent cross-containination; such a taggant would indicate that the material used was a composite and that taggant codes other than the specific composite code should be ignored.

   The cost of separate baseline identification and detection taggant programs would be approximately $25 million for each.

3. The high-level program would uniquely tag each 10,000-lb batch of explosive and each 2,000- l b batch of gunpowder. All explosive materials, including blasting agents, would be directly tagged. Ammonium nitrate fabricated for use in blasting agents would be tagged, but not fertilizer-grade ammonium nitrate. Approximately 5,000 detection taggant sensors would be deployed at every major transportation facility, controlled-access utility, Government facility, and other potential high-value targets such as campus computer locations. Portable units would be routinely available to police bomb squads. The taggant level and types of explosives to be tagged in the high-level program correspond to a strict interpretation of S. 333, as propounded by the Institute of Makers of Explosives (IME). The cost of separate high-level identification and detection taggant programs would be approximately $214 million and $65 million, respectively.

The identification taggant cost figures used in all three levels of the analysis are based on price estimates furnished by 3M, for specific implementation guidelines. 3M furnished management-approved cost estimates for unencapsulated taggants for three different quantities of explosives to be tagged, assureing a firm order for 2 years (costs would remain the same for a 5-year contract). These cost estimates represent the firmest figures possible short of an actual contract. Assuming linear interpolation between data points furnished, the unencapsulated taggants would cost between $93 and $114/lb for the amount of taggants necessary for the baseline level case (41 9 million lb of explosive equivalent). The first figure represents a cost goal and the second a worst case estimate. 3M technical people also furnished an estimate of encapsulating cost, but were unable to estimate the cost of the opaque encapsulation assumed by OTA as the baseline product. Based on the above data, OTA estimated that it would cost approximately $55/lb for opaque encapsulated taggants; as the baseline tagging level is 0.05 percent by weight of encapsulated taggants, and the *encapsulating* material weighs the same as the unencapsulated taggants, this corresponds to 2.75 cents/-lb of cap-sensitive explosives for the identification tagging material ($93 for 1 lb of unencapsulated taggants plus $17 for 1 lb of encapsulating material plus the process equals $110 for 2 lb of encapsulated taggants, or $55/l b.) OTA estimated the same cost for taggants at the other two implementation levels. Chapter V includes an analysis of how changes in the cost and/or concentration of the taggants themselves would affect the cost of the program.

All other cost figures are estimates based on specific inputs submitted to OTA by manufacturers, distributors, and end users. Detailed treatment of the cost elements is contained in chapter V.

The cost impact to end users of explosives can be considerable. Implementation plans that do not take into account the impact on manufacturers and users of explosives could drive a number of manufacturers and users out of the market; could make some classes of finished products, like copper, uncompetitive in the world market; and could force entire segments of industries to radically change operating procedures, such as shifting underground coal mining from explosive mining to mining machines. Detailed discussions and analysis, however, indicate that **it is quite unlikely that a taggant program similar to the "baseline" would eliminate any current uses of explosive materials, although marginal companies and product lines might be eliminated. As indicated above, the baseline program differs from the BATF-proposed implementation only in that batch size takes into account** the normal production processes and quantities of the explosives and gunpowder manufacturers. This finding is based on detailed discussions with a limited number of users and manufacturers about current costs and the possible impact of cost increases.

Some examples are illustrative. Increasing the cost of cap-sensitive high explosives the 12 percent projected would increase the cost of extracting coal in a particular modern underground mine by only 0.1 percent. Such a small increase would not be significant to this intensive user of cap-sensitive explosives, and would be quite unlikely to cause a shift to mechanical mining machines or render a particular mining operation uneconomic. Similarly, that type of increase in the cost of cap-sensitive explosives, boosters, detonators, and detonating cord in a large, open pit copper mine would increase the cost of producing copper only 0.03 percent. As blasting agents are currently used whenever possible in that mine (cap-sensitive explosives are used only for secondary breakup), no shift in explosive products used would take place. The cost of a recent explosive-intensive dam construction project would increase 1 percent under the baseline program, a larger percentage, but not enough to be significant or force alternate uses. A price differential of approximately five-to-one currently exists in favor of blasting agents over cap-sensitive high explosives, which has caused most users of explosive materials to consider blasting agents, and shift where feasible; an increase in that differential to six-to-one is unlikely to significantly change the current status.

As a final example, consider the cost impact on handloaders. Handloaders load their own ammunition for two reasons—economy and the hobby aspect. A less-than-l O-percent cost increase in expendable material is unlikely to affect a hobby for which hundreds of dollars in costs have already been incurred (hand loading equipment and guns). As powder is only one of several materials on which a handloader saves costs (cartridge cases, projectiles, wadding), and additional cost-savings are realized from labor and by eliminating the excise tax on purchased ammunition, an 8-percent increase in powder cost would translate into an even smaller increase in total reloading costs. It is possible, however, that manufacturers would shrink the range of available product lines in order to minimize the startup costs of tagging. A smaller choice of products would bean additional "cost" to the handloader.

The identification taggants currently proposed to be used are manufactured only by 3M and are a proprietary product manufactured by a proprietary process. In addition, a significant public overhead cost would have been incurred before the compatibility of explosive materials with the taggants could have been demonstrated. Mandating the addition of identification taggants to explosive materials would, therefore, ensure a monopoly of the Government-mandated market for 3M, at least for a period of several years. Under such circumstances, **development of a mechanism to regulate the virtual monopoly of the identification taggant market which 3M would enjoy is highly desirable.**

A number of mechanisms are available to regulate the price of taggants, including:

1. a price level set by Congress in the enabling legislation,
2. regulation as a public utility,
3. licensing by 3M of competitors,
4. a multiyear, fixed-price contract, and
5. a free-market price, regulated only by the possibility of competition or sanctions if prices get too high.

The free-market mechanism may be unacceptable to manufacturers of explosives and gunpowders, given the long time needed to either develop and qualify an alternative taggant or enact sanction legislation. Legislation of a price or use of a regulation mechanism similar to that used for public utilities would be an awkward, time-consuming process for a product whose total annual value would be on the order of $10 million.

Licensing is not only disagreeable to 3M, but it is probably not cost-effective. The cost of the taggant material includes a component for amortization of the taggant production facility, as a new facility must be built and the primary market for identification taggants would likely be the mandated explosives market. The process which 3M plans to implement is capital intensive. Licensing of other manufacturers would therefore require the construction of facilities for the licensee, in addition to a new 3M facility, resulting in a substantially higher total cost.

A long-term contract is a potentially attractive mechanism, In fact, the 3M cost estimates are conditional on firm orders for a 2-year period, although 3M is willing to consider contracting periods of up to 5 years. The details of the regulating mechanism have not been addressed by this study; if a multiyear contract is an acceptable mechanism, there may be some advantage to a single contracting agency (presumably within the Government), rather than separate contracts with each manufacturer of explosives and gunpowders. I n addition to saving the cost of multiple contracting, the single contract concept would limit the amount of information on numbers of product lines and production quantities of explosives available to 3M, a matter of some sensitivity to the explosive manufacturers.

A final cost-related issue merits attention. **The legislation of a taggant program might change the extent to which manufacturers are held liable for accidental explosions.** In the event that an accidental explosion takes place, those injured may attempt to hold the manufacturer of the explosives, the seller of the explosives, or the manufacturer of the taggants liable. The addition of taggants to explosives could change the existing situation in several possible ways:

- The use of taggants would make it easier to identify undetonated explosives from the same batch as those involved in the accident, thus facilitating proof or disproof of allegations that the explosive, the taggant, or both were incorrectly manufactured.
- Evidence that incorrectly manufactured taggants had been involved in an accident would probably subject the taggant manufacturer to liability, regardless of any disclaimers made at the time of sale.
- Evidence that taggants had been incorrectly added to explosives (e. g., an excessive concentration) might expose the explosives manufacturer to liability, if evidence could be presented that such a high concentration posed a danger.
- There should be no cases in which the evidence shows that taggants were unsafe if made and used correctly, due to the extensive qualification program required to demonstrate taggant safety. In any event, the fact that Federal law required the use of taggants would be a defense.

- If, however, taggants actually create a hazard but there is no evidence that they do so, the manufacturers of explosives might be exposed to liability based on an (incorrect) assumption that the manufacturing process was somehow at fault.

Furthermore, Congress could include in the legislation mandating a taggant program provisions directing who should bear the costs of accidents. For example, Congress could shift the cost to the Government by allowing suits against the Government for accident losses allegedly due to taggants. Alternatively, by legislating a presumption that taggants are safe or simply by granting immunity to manufacturers, Congress could shift the cost of any taggant-caused accidents to explosives users. A third possibility would be to legislate in a way that would make taggant and/or explosives manufacturers liable for accidents caused by taggants despite legislative coercion to use them. A final option would be to divide the costs of accidents by legislative limits on the dollar amount of claims arising from accidents allegedly caused by taggants. The issue of liability is treated in detail in appendix D.

UTILITY OF TAGGANTS

Before the utility of identification and detection taggants to law enforcement, security, and other regulatory agencies can be assessed, it is first necessary to examine the bomber threat in some detail. The utility against each segment of the bomber population can then be assessed, together with the possible responses of the criminal bombers, and be compared to the utility of other control methods. identification taggants may also have utility for purposes other than tracing of criminal bombers.

The bomber population of the United States is extremely heterogeneous, with varying motives, resources, skills, and ability to adapt to a changing control environment. For ease of discussion, bombers are divided into four categories which differ from each other in most characteristics. These categories include terrorists, common criminals, the mentally disturbed, and vandals and experimenters. The characteristics of the various types of bombers are summarized in table 14 and briefly described below.

Terrorists

The terrorist groups active in the United States vary widely in ability, resources, training, and adaptability. They share the common characteristics, however, of high motivation, action as a part of a group, and a continuing involvement in catastrophic, illegal activities against society. These characteristics make the terrorist particularly dangerous to society and a particularly appropriate target for anti bombing controls. Terrorists can be roughly divided into political, reactionary, and separatist groups. Political groups are primarily interested in attracting attention to, and sympathy with, their cause. For that reason they engage in spectacular events, such as bombings, but generally attempt to avoid or limit injury and death resulting from their bombings. Political terrorists often have considerable resources available to them, due to the significant number of people who support their aim, if not necessarily their means. The leadership of most of these groups are of above-average inteliigence, and have either had specialized training or have studied extensively in terrorist activities. They are thus able to adapt to a changing environment, although the range of responses available to them may be limited by their political aims. Such political groups have been relatively inactive in the United States in recent years.

Separatist groups, such as FALN (a Puerto Rican terrorist group), generally hope to gain their aims by generating a reaction to their activities, rather than a sympathy to their aims. They are therefore generally less concerned with public revulsion to bombings that cause

Table 14.–Attributes of Criminal Bomber Groups

Perpetrator	Experience and training	Resources	Motivation	Individual or group	Reaction capability	Frequency
Criminal						
Unsophisticated	L	L	M	I	M	Mu lt!
Sophisticated .	H	M	H	I	H	Multi
Terrorist						
Political .,	M-H	M-H	M-H	G	M-H	Multl
Separatist	M-H	M	H	G	H	Multi
Reactionary	L	L	H	G	L-M	Multi
Mentally disturbed						
Disenchanted	L	L	L-M	I	L	Single
Vengeful	L	L	M-H	I	L-M	Single
Pathological . ,	L-M	L	H	I	L-M	Varies
Other						
Vandals	L	L	L-M	I	L	Single
Experimettor	M	L	L-M	I	L-M	Single

L Low M-Moderate H-High I Individual G. Group
SOURCE Oftice of Technology Assessment

substantial injury and deaths. Separatist groups have been credited with more than 25 percent of catastrophic bombings—those resulting in major property damage, injuries, and deaths. The resources of domestic separatists vary from group to group, but are generally less than for comparable groups of political terrorists.

Reactionary groups, such as the Ku Klux Klan and the American Nazi Party, share some of the characteristics of the political terrorists, but generally do not possess the same levels of training, motivation, and resources, and are not as capable of reacting effectively to a changing control environment. They also differ in that their bombings are usually directly targeted at the individual or group they intend to influence, rather than simply at a spectacular target.

Terrorists have been responsible for approximately 12 percent of those bombing incidents in the past 5 years to which law enforcement agencies assigned a motive.

Common Criminals

Criminals range from the petty operator who utilizes a bomb for extortion to the professional bombers of organized crime. The petty operator is generally poorly trained, is not very motivated, has limited resources, and cannot readily adapt to a changing enforcement environment. The only major characteristic he shares with the professional bomber is that his targets are generally individuals or small commercial establishments, unlikely to be protected by a detection taggant sensor. The professional bomber is highly trained and motivated and generally has considerable resources available to him, either directly or through his "employer." Criminals share with terrorists the characteristics of engaging in repeated bombings, but differ in that the professional criminal bomber usually works alone, rather than as part of a group. Criminals as a group are responsible for approximately 6 percent of bombing incidents. Most incidents are limited to specific targets and do not generally cause substantial injury or death to innocent bystanders.

Mentally Disturbed

The mentally disturbed bomber differs from terrorists and criminals in that he generally does not engage in multiple bombings, although exceptions such as the Los Angeles "Alphabet Bomber" certainly exist. He generally is poorly trained, has limited resources, and acts alone. He is often highly motivated, but perhaps only for short periods of time, in direct response to some stimulus. He is extremely limited in his ability to respond to changing control situations, either through lack of care of consequences or belief in his invincibility. As his motives are hard to identify, it is difficult to predict his targets.

Vandals and Experimenters

vandals and experimenters share the characteristics of poor training, limited motivation, and limited resources. They generally work alone or in small groups, and do not generally intend to harm people or cause extensive damage. Their targets are often of little value, like mailboxes or outhouses, but some acts of vandalism can cause extensive damage to buildings such as schools. While accounting for over 40 percent of the reported bombing incidents, they are responsible for little damage and few casualties.

Given the diversity of the criminal bomber population, the range of targets involved in bombings, and the choice of explosives available to the bombers, it is difficult to assess the utility of taggants to law enforcement agencies. The assessment is made particularly difficult by the lack of experience with taggants, although the McFillan case (recently tried in Baltimore) provides one example where identification taggants were an extremely important piece of evidence linking a suspected perpetrator to the crime. Inferences can also be made from experience with the date-shift code and with the X-ray machines and magnetometers used at airports to prevent hijackings. A useful construct for viewing the findings is shown in table 15, the discussion of which follows.

Both identification and detection taggants would have limited utility in combating bombings of low-value targets. Due to limitations on law enforcement time and resources, minor bombings, such as a vandalism bombing of a mailbox, do not warrant as thorough an investigation as bombings involving casualties or significant property damage. In New York, for example, such cases are generally handled at the individual precinct level, without the use of the trained bomb squad, bombing investigators, and forensic laboratories. As evidenced by the results of the recovery demonstrations, a visual search of the area by untrained law enforcement personnel is unlikely to turn up identification taggants. Similarly, detection taggant sensors are unlikely to be present before the detonation. The lack of utility in these cases, however, does not greatly diminish the overall utility of a taggant program, as the intent of the program is not to prevent this type of bombing, but to help prevent significant bombings and to help in the arrest and conviction of the perpetrators of such bombings.

Table 15.–Taggant Utility Summary

Specific bombing conditions	Identification taggants	Detection taggants
Low-value targets	Limited utility	Limited utility
High-value targets, no bomber countermeasures	High utility	Extremely high utility
High-value targets, bomber countermeasures	Countermeasures costly due to increased risk	Countermeasures require technical knowledge, planning

SOURCE Office of Technology Assessment

Identification and detection taggants would provide a quantum increase in utility in combating bombings of high-value targets, assuming the absence of effective bomber responses.

The current procedure for the apprehension and control of criminal bombers consists of three phases:

1. the postdetonation search of the area for physical evidence;
2. the investigation, based on the results of the analysis of the physical evidence; and
3. intelligence gathering on, and surveillance of, suspected perpetrators or expected targets.

The search for evidence phase includes a detailed analysis to try and determine the type of explosive used (successful approximately **50 percent of the time) and examination of whatever parts of the bomb,** such as elements of the timing device, may have survived the detonation. This evidence, together with any evidence of the presence of the perpetrator (such as hair or footprints) serves as the starting point for the investigative phase.

The investigative phase consists primarily of trying to generate some type of lead to the perpetrators from the physical evidence gathered, as well as tracking leads provided by informants or witnesses and attempts to correlate the characteristics of the bombing with similar instances. A great deal of effort may be expended, for instance, in investigating the sources of a common c ock used as the timing mechanism.

The addition of ident fication taggants to explosives would aid the investigatory efforts of law enforcement personnel in a number of ways, provided that tagged explosives are used, the taggants survive the detonation, and the taggants are recovered from the explosive debris. The taggants provide a good starting point for an investigation as they directly indicate the type of explosive used, manufacturer, time of manufacture, and provide a list of the last legal purchasers. This information may lead directly to a bomber who purchased the explosives legally. In some cases, the bomber would not otherwise be identified with the bombing; in others, as was the case with the McFillan incident in Baltimore, the taggants add a strong link in a chain of evidence, which may help to obtain a conviction. Taggants may provide intelligence information, such as linking a series of bombings, or linking a suspect to a theft of explosives by establishing that one of the legal purchasers reported a theft at the time the suspect was in the city in which the theft occurred. Finally, bombers may be deterred from committing bombings by the knowledge that the chances of their being apprehended are increased by a taggant program.

In order for the taggant information to be useful, however, the bombing must be of sufficient importance (in terms of property damage, notoriety generated, or casualties produced) to warrant a thorough investigation. In such cases, identification taggants will provide much more information, and more reliable information, than present methods, and this information will require much less effort by the investigating team.

The value of the list of last legal purchasers will depend somewhat on the length of the list. A trace which indicates that the full taggant batch of explosives was sold directly to a mine by the explosives manufacturer obviously provides a more useful lead than a trace which shows a large number of purchasers of a lot of smokeless powder. Even for the smokeless powder case, the list of names would probably not be excessively long. The types of bombings likely to warrant a detailed investigation are unlikely to be caused by 1 or 2 lb of gunpowder, eliminating most purchasers from the list or providing multiple traces of the multiple 1-lb lots used to make up the filler.

The utility of detection taggants in protecting high-value targets is obvious. The current procedures for protection of potential high-value targets vary with the type of the facility and the time since the last perceived threat. Airports are protected by requiring all carry-on luggage to go through inspection (usually X-ray) and all passengers to walk through a magnetometer. Search of checked baggage is not routinely required, although spot checks, sometimes with trained dogs, do occur, particularly when the perceived threat is high. Many Government buildings and other controlled-access facilities require a package or briefcase check as well as personnel identification to gain entry. The airport instruments are operated and inspection checks conducted primarily by personnel who are poorly trained, poorly paid, and subject to the problems of maintaining alertness over long periods while performing a dull job. The magnetometers are useful solely to detect metal, and information from the X-ray machines must be interpreted by the attendant. The use of a self-calibrating sensor, which would reliably give an alarm at the presence of explosives in hand baggage, checked baggage, or on a person would offer an enormous increase in utility over current methods.

Many of the criminal bombers who would be likely to attack a high-value target would be deterred by the knowledge that the target was protected by a sensor that would detect the explosives in their bombs (assuming no effective countermeasures by the bomber). The deterrence might work to redirect the bomb against another target, to cause a less vulnerable part of a target to be attacked, or (perhaps infrequently) to deter the attack altogether. Those who were not deterred would have their bombs intercepted, protecting that target and providing security personnel with additional clues to the perpetrator.

Detection taggants would only provide utility to those targets that were protected by a detection taggant sensor. Portable detection taggants sensors would also be quite valuable in locating a bomb whose approximate location was known and in determining if a suspected package contained explosives.

In summary, identification taggants would provide a quantum increase in utility for those bombings significant enough to warrant a thorough investigation, while detection taggants would provide that increased utility in protecting those potential targets sufficiently important to warrant a detection taggant sensor.

The above discussion assumes that the criminal bombers do not respond to the introduction of a taggant program. However, **countermeasures exist which would enable bombers to evade the effects of a tagging program. The available countermeasures require varying degrees of specialized knowledge, and some of them involve significant risks. Because most bombers would probably not avail themselves of the possible countermeasures, a taggant program would probably retain substantial law enforcement utility.**

Bombers seeking to respond to a taggant program by using countermeasures can use any ot several approaches:

- removal of the taggants,
- fabrication of homemade explosives,
- use of incendiary bombs,
- theft of explosives,
- black-market purchase of explosives,
- use of explosives manufactured before the taggant program commenced,
- use of blasting agents,
- sealing of detection taggants,
- "spookng" of taggant sensors, or
- resorting to another unlawful activity, such as assassination or kidnapping.

The baseline 3M identification taggants contain both a magnetic layer and a fluorescent layer to aid in recovery after a detonation. The taggants could therefore be removed from powdery explosives by using a magnet; the process would be both easy and safe, and would require less than an hour for a typical bomb. In order to hinder this countermeasure, taggants have been manufactured without a magnetic layer. If a powdery explosive were tagged with a mixture of magnetic and nonmagnetic taggants, then the use of a magnet would enable a criminal to remove only a portion of the taggants; the remainder would be present after an explosion, although they would be somewhat more difficult to recover than the baseline taggant. If the criminal were deterred from attempting magnetic removal by the knowledge that about half the taggants were nonmagnetic, then postdetonation recovery would be only marginally more difficult than the baseline case.

Another possible technique for removing taggants from an explosive is to use a black light to identify the taggants by their fluorescence, and then remove them with a tweezer. This process is safe, but more difficult than magnetic separation, and would probably require many hours of painstaking effort for a typical bomb. Unlike magnetic separation, it could be used to remove taggants from explosives that are tacky rather than powdery. It has been proposed that the encapsulation of the taggants be made opaque, and matched to the color of the explosive, in order to render such removal impossible. Since the encapsulant would be melted by the heat of a detonation, postdetonation recovery would not be affected. Although it should not be difficult to develop an opaque encapsulant, this has not yet been done. Opaque encapsulation would make quality control, both of manufacturing taggants and mixing them with explosives, more difficult, and its cost impact has not been evaluated.

In order to remove a nonmagnetic taggant with an opaque encapsulant from an explosive, the explosives could be acetone dissolved, the taggants and other Solid material removed by filtering, and the explosives reconstituted. This complex operation would require specialized knowledge, be roughly equivalent in danger and difficulty to fabrication of explosives from raw materials, and would result in less reliable (less likely to detonate) explosives.

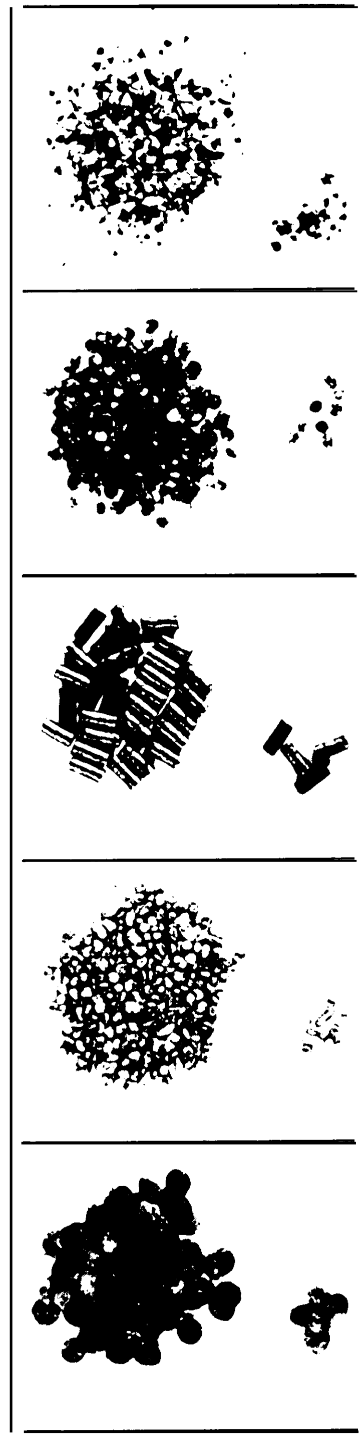
Taggant removal from some gunpowders could be significantly easier than from explosives, as some gunpowder grains are considerably larger than the identification taggants, as shown in figure 4. Separation from these powders may therefore be accomplished simply by screening, even if the taggants are nonmagnetic. Tests with several Du Pont IMR powders have shown that it would be difficult to separate the taggants from the chips and fines contained in the gunpowder package, but all small particles could easily be separated from the intact grains by screening. It has been proposed to alleviate this problem by agglomerating the taggants into clumps whose size roughly matches the specific powder grain size. The cost impact of such a solution was not addressed during this study.

Removal of the detection taggants would not be feasible.

Fabrication of explosives may be accomplished by a variety of means, but a considerable degree of expertise is required to avoid the risk of premature detonations, and to ensure high reliability. It should be noted that fabrication of detonators is significantly more difficult than fabrication of the explosive charge.

A substantial number of bombing incidents involve the use of incendiary bombs; it is quite impractical to tag the wide range of materials from which incendiary bombs could be fabricated. It may be more difficult, however, to fabricate a reliable delay fuze for an incendiary bomb. In addition, while incendiary bombs may be effective in destroying structures and jeopardizing groups of people, explosive bomb

Figure 4.—Size Comparison of the 3M Identification Taggant and Some Smokeless Powders



fillers offer a better chance of killing, injuring, or intimidating a particular individual.

A significant fraction of the explosive currently used for fabricating bombs is stolen. A taggant program may well increase the theft of explosives; however, additional explosive security could reduce the incidence of theft. Taggants from stolen explosives would not provide a direct clue to the purchaser, but would help law enforcement officials to establish patterns and links between crimes, improving the chances of apprehending the criminals. The bomber who steals explosives further increases the risk of apprehension by committing an additional crime. Finally, taggants could pinpoint locations from which explosives were stolen, providing a guide to tightening security in those places most vulnerable to theft.

Explosives could be purchased on the black market or illegally imported from abroad. Both courses of action subject the bomber to increased risk of capture, from informants or undercover agents in the former case and as a result of smuggling, in the latter. Both courses of action would require substantial resources and the ability to plan in advance.

Explosives manufactured before the implementation of a taggant program could be used to fabricate bombs. There is some evidence that a considerable stockpile of explosives currently exists in the hands of criminal bombers, and this stockpile could be expanded in the time between legislation and implementation of a taggant program. Acquisition and storage of the explosives for a period of time require considerable advance planning and resources, however, and increase the risk to the bomber of discovery of the explosives. While the use of explosives manufactured prior to a taggant program may be an effective countermeasure initially, most explosive materials have a limited shelf-life. Gels, slurries, and emulsions are generally reliable for less than 1 year; the sensitivity of dynamites tends to increase with age; gunpowders and booster materials have a long shelf-life.

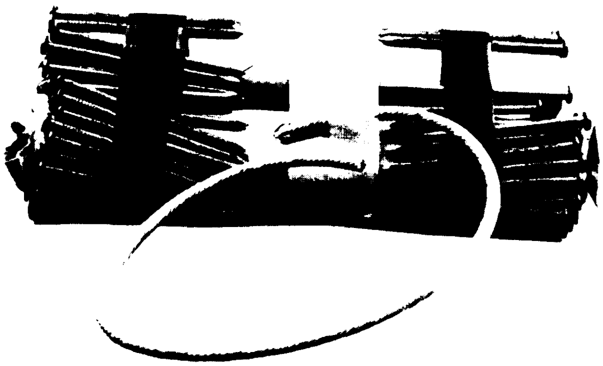
Blasting agents, such as ANFO, are not among the explosive materials BATF plans to directly tag. (OTA finds that tagging blasting agents, if it were judged desirable, would greatly increase the cost of a taggant program.) Effective bombs can be fabricated from ANFO; to do so requires a certain level of skill to ensure reliable detonation and the assembly of a number of components, some of which may not be readily available. The risk of premature detonation is small for a bomber with adequate knowledge and patience, but may be significant for bombers without those characteristics. Blasting agents are infrequently used at present in criminal bombings.

The effectiveness of detection taggants can be severely limited by creating a seal between the explosives and the detection taggant sensor as the vapor could not escape the package to trigger the sensor. Such a seal can be constructed with the appropriate industrial materials and equipment, but a reliable seal would be very difficult to fabricate with the resources normally available to individuals. Hence specialized knowledge, advance planning, and the resources to buy the required material, would be needed to defeat the detection taggants.

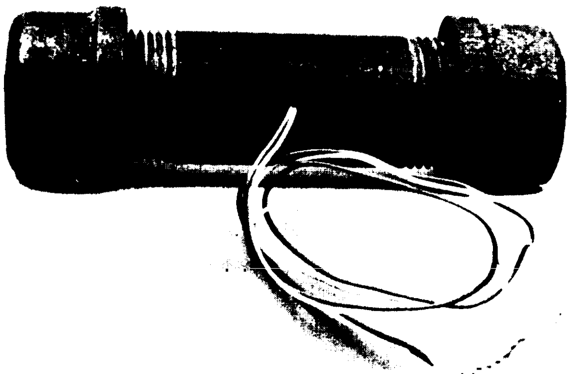
Detection taggant sensors could be purposely triggered or "spooked" by placing detection taggants, or other materials so similar chemically to the detection taggant that the sensor could not make the distinction, in nonexplosive materials. If several suitcases or packages within a short period of time triggered the detection taggant sensor for no apparent reason, those operating the sensor might well conclude that it was malfunctioning, and disconnect it. It would then be possible to introduce tagged explosives into the protected area. This countermeasure would require that the bomber obtain a supply of the detection taggant material; access to detection taggants could and should be made difficult.

Finally, bombers can turn to other crimes, such as murder, assassination, or kidnapping. These crimes, however, are often not as spectacular as bombings and all involve greatly higher risk to the perpetrators than do bombings. In addition, a direct action against a visible target requires more motivation and a different temperament than does an indirect crime such as a bombing.

Dynamite bomb with nails



Pipe bomb



Molotov cocktail, dynamite, and grenade

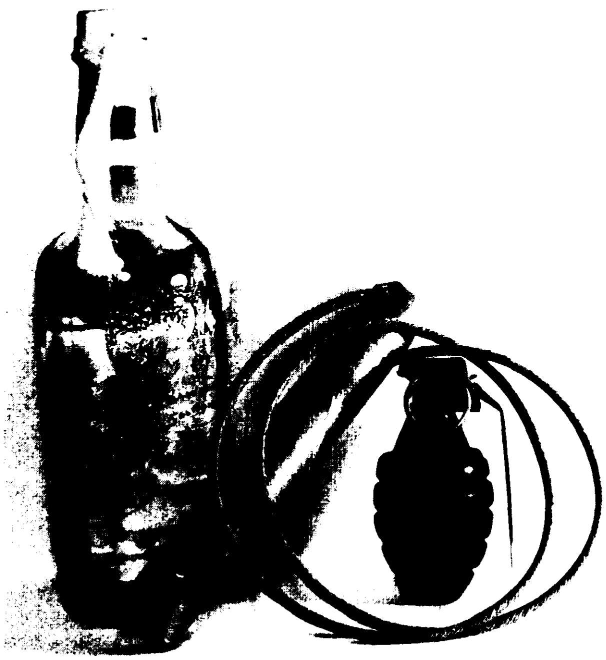


Photo credits US. *Department of the Treasury*

Various types of explosives used by terrorists

OTA consulted numerous explosives experts, all of whom agreed that countermeasures such as these are possible. However, the experts on law enforcement and terrorism which OTA consulted agreed that **criminal bombers would fail to make use of countermeasures, even when the necessary knowledge and equipment could be obtained without enormous efforts. However, some terrorists and professional criminals would make use of countermeasures.** This judgment appears to be based on an assessment of the type of personality that is generally involved in this kind of criminal activity. Bombings are currently a low-risk, relatively simple type of criminal activity. Each added element of risk, or additional stage necessary to fabricate a bomb, will decrease the likelihood of the prospective bomber actually committing the bombing. An instructive analogy is aircraft hijacking. It is possible to smuggle a weapon on to an airplane by a number of means, but, in fact, since the antihijacking program started there have been thousands of weapons found annually by the screening process, hundreds of weapons found abandoned near the controlled boarding gates, and few or no cases of aircraft hijacked with the use of smuggled weapons.

Consequently, OTA believes that countermeasures are not likely to greatly diminish the law enforcement utility of a taggant program, despite their potential to do so.

The above discussion has been essentially qualitative, as little quantitative data is available. However, an attempt was made to draw inferences from similar programs. **The data available from the date-shift program suggests that identification taggants may prove effective in increasing the arrests and convictions of criminal bombers. However, the data base is too small to be more than suggestive. Similarly, data on the reduction of hijackings after the introduction of an antihijacking program suggests that detection taggants would prove an effective deterrent.** The program most directly analogous to the proposed identification taggant program is the requirement that the date and shift of cap-sensitive high explosives be clearly printed on each stick. For undetonated bombs the date-shift code provides the same information as identification taggants would provide for the post-detonation case. No total review of the cases involving explosives recovered from malfunctioning bombs has been conducted. A limited set of 55 cases was examined, however, by BATF. In that sample, six cases were forwarded for prosecution (10.9 percent). That is twice the percent forwarded in cases that did not include date-shift code data. Similar results were obtained by MSA during a review of the BATF data. Of the 10 bombing attempts MSA reviewed, the date-shift code proved useful in 40 percent of the cases, was not useful in 50 percent of the cases, and was of questionable utility in 10 percent. While the results were positive in both cases, the extremely small sample size makes it impossible to draw significant conclusions. I ME reported to OTA that manufacturers are seldom requested to appear in court to testify regarding a date-shift trace; in recent years less than 1 percent of the traces requested led to a court appearance.

The most direct analog of the detection taggant program is the antihijacking program initiated in 1971. There was an average of 27 hijackings from domestic origins in the 4 years preceding full implementation of the program. In the next year (1973), hijackings decreased to a single incident, and have averaged only four per year since. It should be noted that a number of countermeasures are possible that would evade the currently used magnetometers and X-ray machines. However, essentially no incidence of the use of these countermeasures have occurred since the inception of the anti hijacking program.

Numerical estimates of the numbers of bombers who would be arrested and the number who would be deterred by a taggant program were made by MSA in order to generate input to their cost-effectiveness analysis of the taggant program. The numbers they used in the analysis were a 50-percent increase in the arrest rate (from 8 to 12 percent) and a 5-percent detergency rate. These numbers are simply guesses and OTA has no data that would allow it to make guesses or assess the accuracy of the MSA guesses.

The above discussion dealt with the utility of taggants for the control of criminal bombers. **There exist other approaches to the problem of control of criminal bombers which could be used in conjunction with, or instead of, a tagging program. Some of the methods, however, may be unpalatable or not cost-effective. Other** approaches, **some of which have been implemented** in areas facing a more severe bomber threat, particularly from separatist terrorist groups, include:

- alternate detection approaches,
- control of explosive materials,
- better security,
- more coordinated police response, and
- harsher judicial response.

The Aerospace Corp., the Federal Aviation Administration, and the military are currently investigating, or have investigated, a large number of techniques for detection of untagged explosives. Methods investigated have included X-ray fluorescence, gamma ray excitation, nuclear magnetic resonance, both fast and thermal neutron activation, dual energy tomography, detection of the characteristic vapors of explosives, and deactivation of blasting caps. Some of the approaches are promising, although all but the last two would be limited to checked baggage. However, none of the approaches, with the exception of non-tagged vapor detection, has progressed as far as the detection taggant research and most appear to be significantly more expensive, both for the instrument and for personnel to man the instrument. Commercial vapor detectors are currently marketed for explosive detection, but their sensitivities and flexibility fall far short of the goals of the taggant vapor detection devices. Research on the promising approaches should continue; it may be most effective to deploy a detection taggant system in conjunction with one of the other systems.

Control of explosive materials could range from uniform procedures for the purchase of explosives to the total control by the military or police of all explosives, from manufacture to the legal detonation. In some States, explosives are tightly controlled. For instance, in Louisiana all users or transporters of explosives must be licensed by the State police. In some other States, however, explosives may be purchased over-the-counter simply by providing identification and presenting a Federal permit or filling out a form. Uniform tight control would make it more difficult to purchase explosives for illegal use and would be particularly effective in combating the less sophisticated bombers. Complete control of explosives, to the point of requiring police or military personnel to physically be at the site of a legal use of explosives and be responsible for each detonator, as is the case in Ireland, would essentially eliminate the use of domestically produced commercial explosives in bombings. Sophisticated bombers would be forced to fabricate their own explosives (or purchase "homemade" explosives on a black market), while the unsophisticated bomber would be eliminated. Such a program would entail extremely high costs however, both in monetary terms and in terms of the disruption to industries that currently use explosives.

Better security is possible, both to protect potential targets and to protect explosive materials from theft. It would be possible, as an example, to hand-search all checked luggage being loaded on an airplane; in fact, EL AL (national airline of Israel) does conduct such searches. Similarly, it would be possible, although extremely time-consuming, to search every person entering the Rose Bowl for the Rose Bowl game. However, detection taggants appear a more reasonable alternative.

Protection of explosives from theft could be improved, however, and may well have to be to prevent a wholesale shift to theft as a source of explosive material if a taggant program is instituted. All of these controls have cost impacts which have not been calculated in this study; a match must be made between their cost and their marginal utility in the face of the current bomber threat. As an example, if the use of military explosives in criminal bombings increases markedly it may become necessary to counter that threat. Tagging of military explosives would be extremely costly, due both to the large amount produced and to the requalification cost of all current munition systems which would be necessary. A reasonable alternative may be to increase the security of military explosives.

A more coordinated law enforcement response to the bomber threat would be effective, whether a taggant program were instituted or not. At present, "major" bombings must be reported to either the FBI or BATF. However, no uniform definition of "major" exists. Other agencies, including some State agencies, also collect bombing statistics. Examination of the statistics shows a significant lack of uniformity in what is reported to each, the information available on each incident reported, the retrievability of information from the data bank, and the methods for updating the files. One responsible center, to which all bombing information would be required to be reported in a uniform, easily updated, easily accessed format, would be an obvious aid to law enforcement efforts against criminal bombers.

Better coordination and communications between the forensic laboratories and the field investigators would also be helpful. Agents in the field are sometimes not sensitive to what information or what physical evidence would be useful to the laboratory. This coordination will be particularly important if an identification taggant program is introduced, as the recovery of the taggants appears to be a laboratory-intensive procedure.

Finally, control of the physical site of the bombing by a single responsible individual would be extremely useful. A major incident may involve several levels of law enforcement agencies, several levels of elected representatives, and other activities such as first aid and fire control. Uncoordinated activity by all these people could well destroy valuable physical evidence. Excessive use of water by firefighters is a potentially serious problem if identification taggants are used, as they might be washed totally away from the bombsite.

The utility of a harsher judicial response to criminal bombers is a particularly sensitive issue, with little technological insight available, and is mentioned only for completeness.

Program Implementation

Given the current development state of the identification and detection taggants, a number of options are available regarding the method of implementation of a taggant program. Among the issues are what, if any, taggant program should be legislated; if a taggant program is legislated, what materials should be tagged, what level of tagging should apply, and what is the procedure for making decisions not specifically resolved by the legislation.

One of the first issues needing resolution is what explosives should be tagged. The analysis conducted showed that **criminal bombers tend to use the most readily available source of explosives. Therefore the tagging program with the highest utility would include provisions for tagging of commercial explosives and gunpowders.**

Table 7 showed the frequency-of-use distribution of explosives for bombings, including explosives identified both in the field and in the BATF laboratory. While the completeness of these statistics may be open to interpretation, it is clear that a wide variety of materials are used as bomb fillers. Discussion with both domestic and foreign law enforcement officials has stressed the fact that all types of bombers will use the most readily available source of explosives, although sophisticated bombers would be more likely to limit their use to materials that are efficient for the intended purpose. As an example, a relatively small amount of a powerful explosive was appropriate for the La Guardia Airport bombing, as it would cause extensive damage and be concealable in a relatively small package. The amount of gunpowder needed to do as much damage would occupy a much larger volume, and might be noticed; it would therefore not be an appropriate choice for a sophisticated bomber.

If one type of explosive material is not as highly controlled, then bombers will tend to shift toward that material. For that reason, it may be desirable to tag or otherwise control military explosives. Although current statistics show a relatively infrequent use of military explosives in criminal bombings, tagging of commercial explosives may shift the expected future frequency. Similarly, tagging of black and smokeless powders is of critical importance to an overall taggant program.

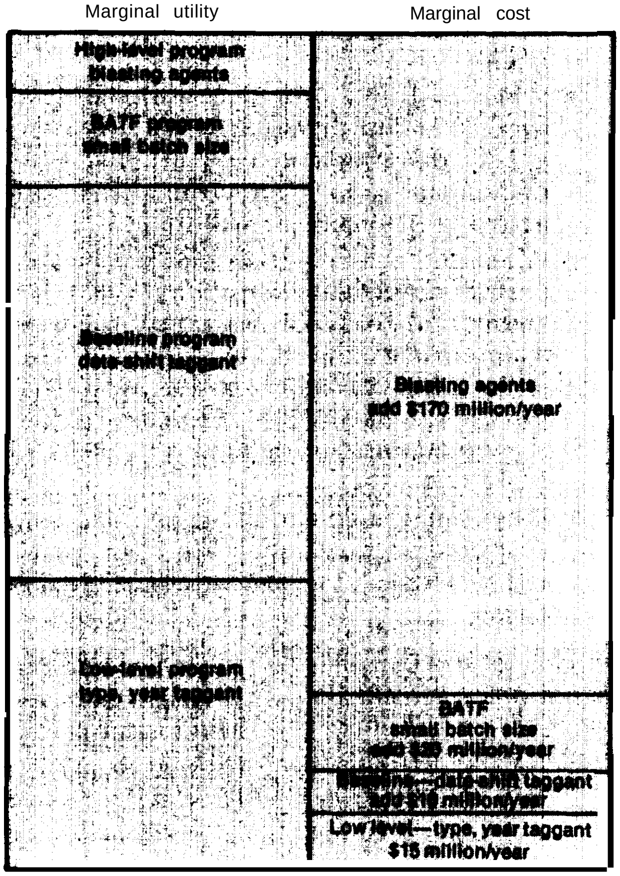
Some mechanisms to tag blasting agents may also be desirable. However, the cost of directly tagging the agents would be extremely high. The BATF plan to tag the detonators, boosters, and detonating cord normally used with blasting agents may be a reasonable compromise, particularly as blasting agents are now rarely used in criminal bombings and approximately half of the blasting agents are mixed and used onsite in the same day.

As indicated above, various levels of implementation of a taggant program are possible, each with an associated cost of implementation. **The most reasonable way to determine the optimum program to implement may be to consider the marginal additional cost of each additional element of utility.** This approach is illustrated in figure 5, where the identification taggant utility function is varied. Qualitative estimates of marginal utility are shown to approximate scale, along with quantitative estimates of the cost of implementing a program that would yield that level of utility.

The lowest implementation option would tag cap-sensitive explosives, boosters, detonators, detonating cord, and gunpowders, but not blasting agents. A unique identification taggant would be used for each manufacturer, type of product, and year of manufacture. This program corresponds to the low-level program previously discussed. That level of implementation would directly provide most of the physical evidence information that current methods attempt to provide. However, it would not directly provide a list of last legal purchasers. The relatively modest cost for that program would be approximately $15 million per year, * probably less than is currently expended in an attempt to provide the same information by current means, although the cost would be shifted to manufacturers and users of explosives.

*The cost estimate In this sectton IS for an Identification taggant program only

Figure 5.— Marginal Cost-Utility Function



SOURCE Office of Technology Assessment

The next option would be to provide a unique taggant code for each shift of each product manufactured and to keep a record of the movement of explosives from the manufacturer to the last purchasers, in a manner analogous to the date-shift code currently marked on the casings of explosives. This option corresponds to the OTA-identified baseline program, and would provide a list of last legal purchasers and additional intelligence information, at a program cost increase of approximately $10 million per year.

A further implementation option would be to uniquely tag each 10,000-lb batch of explosives and each 2,000-lb batch of gunpowder. This would lead to a somewhat smaller list of last legal purchasers, which would mean fewer places that must be investigated, as well as a somewhat finer grain of intelligence information. However, the cost increase of $20 million per year would be fairly substantial.

Additional marginal utility could be gained by tagging blasting agents. This would be of value in two cases —the case in which the identification taggants from the detonator and booster used to ignite the blasting agent did not survive (or were not recoverable) from the debris of an explosion, or the case in which a bomb was fabricated that used some other (untagged) means of detonating the blasting agent. There is no body of test data to indicate the likely frequency of the first condition; while the second condition is certainly possible, almost all bombers capable of detonating a blasting agent without commercial detonators and boosters would also be capable of obtaining or fabricating untagged explosives in the first place. At present blasting agents are infrequently used for bombings — averaging two BATF sources suggests that blasting agents are used in about 0.5 percent of bombings, and account for a small percentage of the property damage and casualties. Since the cost of tagging blasting agents would be approximately $170 million per year, several times that of all the other elements of a tagging program combined, the marginal utility of doing so appears relatively low.

In short, the implementation of a taggant program would require unambiguous decisions about which materials required taggants, and what the applicable regulations would be. It would be desirable if any legislation on the subject either made these determinations or unambiguously delegated authority to do so.

Given the present state of development of taggants, OTA'S data and analyses appear to be consistent with any of three possible courses of congressional action:

1 Pass legislation requiring taggants, and set up a procedure to determine if and when the technical development and testing have progressed to the point where implementation can begin.

2. Defer legislative action on taggants, but encourage (inter alia by appropriating

adequate funds) BATF to continue taggant development, with a view to consideration of legislation when development and testing are complete.

3. Take no legislative action on taggants, and encourage the executive branch to search for other ways of improving the effectiveness of law enforcement against terrorists and other criminal bombers.

If Congress chooses the first of these options, it should recognize that even though the legislation can define precisely what materials would require taggants and provide guidance on the stringency of regulations, there will remain some determinations which it is not yet possible to make:

- When and if an adequate number of successful compatibility tests have been conducted. Particularly pertinent in this regard would be a determination of what constitutes a resolution of the current incompatibility between the 3M identification taggants and one type of smokeless powder or the RDX-based booster material. The 3M identification taggants cannot safely be added to these materials until such a resolution is accomplished, and neither smokeless powders **nor** boosters should be excluded from a tagging program.
- When and if a sufficient probability of survival and postdetonation recovery of a given identification taggant has been demonstrated to justify adding that taggant to a given type of explosive.
- When and if a detection sensor has demonstrated adequate sensitivity, low false-alarm rate, ease of operation, ease of maintenance, and acceptable unit cost under field conditions to be considered sufficiently "available" to justify requiring the addition of detection taggants to explosives.
- When and if a detection taggant has demonstrated adequate shelf-life, nontoxicity, and penetrativity to be considered "available."

In view of the fact that BATF has become the major proponent of the use of taggants in explosives, there is much to be said for entrusting such determinations to an official or procedure outside the Treasury Department.