SAFETY RECOMMENDATIONS FOR SENSITIZED AMMONIUM NITRATE BLASTING AGENTS

By the Staff, Bureau of Mines
SAFETY RECOMMENDATIONS
FOR SENSITIZED AMMONIUM
NITRATE BLASTING AGENTS

By the Staff, Bureau of Mines

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SAFETY RECOMMENDATIONS FOR SENSITIZED AMMONIUM NITRATE BLASTING AGENTS

by

The Staff, Bureau of Mines

INTRODUCTION

A revolutionary development in blasting materials has occurred in recent years. Ammonium nitrate, sensitized by the addition of a small percentage of No. (class) 2 diesel fuel or other suitable petroleum product, has been adopted as a low-cost, efficient blasting agent in a wide variety of mining, quarrying, and heavy construction operations. Moreover, the ready availability of the component supplies throughout the Nation, together with the ease of formulating them into effective blasting agents, has made it possible for the blaster himself to prepare the mixes at the site of use. Recently, most established explosives manufacturers have begun supplying premixed AN-FO (ammonium nitrate-fuel oil) or a comparable product to various mining operations. However, many individuals and small business establishments are marketing premixed products prepared in facilities that are often poorly constructed and poorly located. Although these blasting agents have partly or wholly displaced explosives such as dynamites in many applications, there are some blasting operations in which the fuel-sensitized ammonium nitrate agents do not appear to be well adapted.

As long as the hazards they present are clearly understood and respected, ammonium nitrate-based blasting agents have important safety characteristics when prepared under competent factory control or field-mixed under equivalent close control. This publication attempts to summarize the knowledge of those hazards and to incorporate practical ways to cope with them.

The development of Akremite (5) brought to the attention of the mining industry and others the basic principles and advantages of using fuel-sensitized ammonium nitrate mixtures, prepared at the site of use, as low-cost blasting agents. Industry responded with enthusiasm, promptly adopting the concept and adapting it to a wide variety of uses. As a result, after only

1Division of Bituminous Coal, Washington, D.C.
2The term "blasting agent" is defined in the Definitions section.
3Underlined numbers in parentheses refer to references at the end of the publication.

Work on manuscript completed January 1963.
7 years, about 60 percent of all blasting done in the United States is performed with fuel-sensitized ammonium nitrate blasting agents.

The Bureau of Mines has followed this phenomenal development as it progressed and has conducted research on certain phases. The Bureau's interest is twofold: (1) Safety in preparation, storage, transportation and use of these blasting agents and (2) the potential for important reductions in cost of blasting operations in many types of mining.

This publication presents a series of recommendations designed to provide the best possible safety without making operations so burdensome as to lose the basic advantage of lower costs. These recommendations cover the preparation, storage, transportation, and use of blasting agents based on ammonium nitrate. The promulgation of any additional or modified recommendations will depend upon the results obtained from a continuing study of the hazards, particularly those created by newer technical developments in the product and its use.

The use of ammonium nitrate as an ingredient in blasting compositions is not new. In 1867 two Swedish chemists, Ohlsson and Norrbin, patented Ammoniakkrut, consisting of ammonium nitrate, either alone or in mixture with charcoal, sawdust, naphthalene, picric acid, nitroglycerin, or nitrobenzene (2). Almost continuously since that time, ammonium nitrate has been used as an ingredient in most dynamite and blasting agent formulations, often comprising from 75 to 90 percent of the compositions. Although it is an important ingredient of such commercial products, ammonium nitrate by itself is not considered an explosive.

In recent years, the Bureau of Mines, the chemical industry, and others have conducted extensive research to define conditions under which ammonium nitrate can undergo explosive decomposition. Based on findings from such investigations, the Manufacturing Chemists' Association published Manual Sheet A-10, "Fertilizer-Grade Ammonium Nitrate-Properties and Recommended Methods for Packaging, Handling, Transportation, Storage, and Uses" (6). Under these recommendations and under regulations of the Interstate Commerce Commission several billion pounds of ammonium nitrate are transported each year with relatively few difficulties (9).

Rapidly increasing consumption of fuel-sensitized ammonium nitrate blasting agents has prompted many inquiries to the Bureau of Mines from mine or quarry operators, local law enforcement agencies, and others for guidance on safe handling and storage. To supply information, the Bureau prepared some "Tentative Recommended Practices" in October 1958. These recommendations were made available informally to many specialists in the field of industrial blasting with requests for review, comments, and criticisms. On the basis of replies and additional information derived from the Bureau's own research, the recommendations were revised substantially in mid-1959 and again in 1960, each revision being reviewed by specialists. These recommendations served as a guide for a chapter in the National Fire Protection Association's recently revised Code for Explosives and Blasting Agents (7). After considering all commentaries received, in 1960 the Bureau of Mines published Information
Circular 7988 titled "Tentative Safety Recommendations for Field-Mixed Ammonium Nitrate Blasting Agents" (2). Since then, many new problems have been created by changes in methods of compounding, handling, storing, and using blasting agents. Prior to 1960 a large part of the compounding of AN-FO was done by mining personnel in the field and the mixed product was generally confined to mine property. Now an increasing amount of the mixed material is being prepared by established explosive manufacturers, chemical companies, and small manufacturing concerns. This trend results in increased transportation of the mixed product over public highways. Furthermore, the growing use of blasting agents underground and the bulk handling of premixed material has created many new problems. Because of these additional problems and the fact that a better assessment of the hazards has been achieved through additional research and field studies, the Bureau believes that a revision of the 1960 recommendations is urgently needed.

This publication contains practical safety recommendations and general information that should help those concerned with blasting to take maximum advantage of blasting agents and minimize the danger in handling them. However, laboratory and field investigations still underway should yield information for additional or further modified recommendations. Accordingly, further revision of this publication at a later date may be advisable.

DISCUSSION

Definitions

Ammonium nitrate.--A chemical compound represented by the formula $\text{NH}_4\text{NO}_3$.

Blasting agent.--Any material or mixture consisting of a fuel and oxidizer intended for blasting, not otherwise classified as an explosive and in which none of the ingredients is classified as an explosive (provided that the material or mixture cannot be detonated by a No. 8 test blasting cap under the conditions specified for the cap sensitivity test).

Nitro-Carbo-Nitrate.--A blasting agent that has been classified as a nitro-carbo-nitrate under the Interstate Commerce Commission regulations and that is packaged and shipped in compliance with the regulations of the Interstate Commerce Commission.

Grades of Ammonium Nitrate

The many grades of ammonium nitrate being sold for field mixing into blasting agent compositions have led to much uncertainty and confusion. There are prilled, flaked, and grained ammonium nitrates, which may be uncoated or coated with clay, diatomaceous earth, or proprietary inorganic or organic antisetting agents. A clay coating may comprise from 0.1 to 4 percent of the total weight. The bulk density may range from less than 0.8 gram per cubic centimeter ($\text{g/cm}^3$) to over 1 g/cm$^3$. Particle sizes may range from 4- to 7-mesh to 90 percent through 100-mesh (grained or crushed prills). Additionally, it should be noted that ammonium nitrate prills, both raw and sensitized, tend to disintegrate physically, producing fines, when their temperature
passes 90° F, a solid-phase transition point (8). Temperature fluctuations past 90° F could readily occur twice daily under some conditions of storage. When mixed with oil, in proportions that may range from 2 to 10 percent (though more commonly from 4 to 6 percent), these different kinds of ammonium nitrate form compositions of widely varying sensitivity. Investigations have shown it possible to produce cap-sensitive compositions (1) while other compositions have failed to propagate in large diameters even though large gelatin-dynamite boosters were used.

**Cap-Sensitivity Test**

It is advisable, in the interest of simplicity and uniformity, to establish a simple yardstick of AN-FO sensitivity—one that can be employed by operators, blasting foremen, and safety engineers alike. The best test, meeting requirements of simplicity and general availability, is that of cap sensitivity. This test determines the ability of a blasting cap to initiate detonation. The Bureau suggests that all field-mixed compositions be regularly and routinely tested for sensitivity to initiation by a commercial No. 8 blasting cap. Here, a commercial, rather than a test, blasting cap is recommended because of the general unavailability of test blasting caps in the field. The test is simple: Put charge material into a 1-quart, cylindrical paper carton at its approximate packaged density and insert a No. 8 detonator. Place the prepared charge on soft ground in an isolated area provided with an amply safeguarded spot for the shotfirer and others, and fire the detonator. If a crater is formed, the composition tested is cap-sensitive and must be treated as a high explosive and handled with the care normally given to dynamite and comparable explosives.

**Fire Hazards**

It is important to make a definite distinction between ammonium nitrate and mixtures of ammonium nitrate with sensitizing agents such as fuel oil. The fire and explosion hazards of these two classes of material are different, the mixtures presenting a greater hazard. If ammonium nitrate is stored near or with explosives or blasting agents, reasonable safety considerations (4) suggest that isolation distances be established for the aggregate lot.

The most important consideration in the safe storage of ammonium nitrate, blasting agents based on ammonium nitrate, or explosives is the prevention of fire. Under some conditions ammonium nitrate fires can develop into a detonation.

**Fighting Fires in Ammonium Nitrate**

In the absence of nearby stores of sensitizing agents such as fuel oils, unconfined, limited-area fires in even large quantities of ammonium nitrate can be fought with copious amounts of water. However, massive fires may present a substantial hazard, and firefighting efforts on these should be abandoned unless water can be applied by remote control. Water acts solely as a cooling agent. Ammonium nitrate, an oxidizing material, does not need atmospheric oxygen for combustion. Consequently, ammonium nitrate fires cannot be smothered, and chemical extinguishing agents are essentially ineffective.
Fighting Fires in Fuel Oil-Ammonium Nitrate Mixtures

When not confined, incipient fires in fuel oil-sensitized ammonium nitrate can be fought with copious amounts of water. Here again, the water acts only to cool the burning mass to temperatures below the autodecomposition range. When fires develop beyond the incipient stage, the method for handling the situation becomes more difficult to determine. One decision may be to deluge such a fire with water in an attempt to extinguish it. On the other hand, it may be decided to abandon firefighting efforts and evacuate the area in anticipation of a possible explosion. For example, a recent fire at Norton, Va., in a mixhouse containing about 30 tons of AN-FO and 20 tons of ammonium nitrate resulted in a violent explosion after burning for approximately 30 minutes. The fact that there were no fatalities or serious injuries can no doubt be attributed to the prompt action taken by the Norton fire marshal who realized the seriousness of the situation and evacuated the area rather than attempting to fight the fire. The Bureau believes that such established fires should be fought with water only by means of a remotely controlled system. When stocks of ammonium nitrate and AN-FO are stored close to each other, the explosion potential of a fire occurring in either should be based on the sum of the two stocks.

Fighting Fires Involving Explosives

If high explosives are present in a fire involving either or both ammonium nitrate and fuel-sensitized ammonium nitrate, they should be removed from the danger area if this can be done promptly and safely. However, if this is impossible or the explosives are already aflame, the entire area should be evacuated in anticipation of detonation, and the fire should be allowed to burn.

Underground Applications

The economic advantage of using blasting agents, as demonstrated in almost every aboveground blasting application, has led to their adoption in many underground noncoal mines. This trend was advanced by the development of compositions sensitive enough to assure complete propagation in small-hole blasting and pneumatic loading equipment that provided a simple means for charging the boreholes. Blasting agents are not approved by the Bureau for use in underground coal mines. However, the Bureau recognizes that many underground, noncoal mining operations can be performed more economically with these blasting agents without sacrificing safety, provided additional precautions are observed. These additional safety precautions are listed as recommendations 70 through 84.

RECOMMENDATIONS COVERING BLASTING AGENTS

The following recommendations for preparing, storing, and transporting ammonium nitrate blasting agents and for using them in blasting operations are based on the most reliable information available to date. In many cases, rather restrictive recommendations have been chosen to suggest best practice. The term "should" is deliberately chosen to emphasize that these are recommendations, rather than regulations or inflexible requirements.
Storage of Ammonium Nitrate

1. Ammonium nitrate should be stored in accordance with recommendations of the Manufacturing Chemists' Association (6).

2. If ammonium nitrate is stored in the same building with a blasting agent, the combined quantities of both materials should be considered as blasting agent, and the building should be isolated from inhabited buildings, passenger railroads, and public highways in accordance with the American Table of Distances. 5

3. If ammonium nitrate is stored with explosives, only a properly constructed explosives magazine should be used. The aggregate weight of all stored materials should be the determining factor in establishing the location of the magazine in accordance with the American Table of Distances.

4. Storage buildings should preferably be constructed of noncombustible or fire-resistant materials. It is desirable for such a building to be equipped for fire protection with an adequate-capacity, automatic water-deluge system. Only a limited degree of fire protection is provided by a conventional sprinkler system.

5. The storage building should be dry and well ventilated.

6. The storage-building floor should be of noncombustible material and its design should be such as to eliminate open, piped drains into which molten ammonium nitrate could flow and be confined in case of a fire.

7. The following factors should be considered in judging the adequacy of a site for a storage building: Maximum amount of intended storage, congestion of the area, firefighting facilities, local regulations, toxic-fume hazards in event of fire, etc.

8. Smoking and open flames should not be permitted in the storage building.

9. Under no circumstances should caked ammonium nitrate in bags or bulk be loosened by blasting with explosives.

10. Ammonium nitrate from broken bags should be cleaned up promptly and removed from the premises.

4 It is reemphasized that the term "ammonium nitrate" is meant to refer only to the compound before its admixture with oil or other fuel or sensitizing materials. Any grade of ammonium nitrate may be used, although the sensitivity of the resulting blasting agent will be greater if the ammonium nitrate contains little or no inert coating. Blasting agents prepared from ammonium nitrates of small particle size, such as crushed prills or fines, are generally more sensitive than ordinary prills and may even be cap sensitive.

5 See appendix.
Mixing Plants

11. Plants used for mixing ammonium nitrate with fuel oil or other carbonaceous materials should be isolated from inhabited buildings, passenger railroads, and highways according to American Table of Distances for explosives.

12. Fuel oil or other carbonaceous fuels should be stored in a separate, isolated building or an outside tank to minimize possible contact between molten ammonium nitrate and fuel in the event of fire. A shutoff valve should be provided at the tank.

13. Magazine separation distances based on the American Table of Distances, should be used to locate the mixing plant with respect to the permanent storage area for blasting agents.

14. A mixing plant should be laid out so that daily operation stocks of unprocessed ammonium nitrate and finished products are physically separated from the area or areas in which mixing or packaging operations are conducted.

15. Floors in the mixing plant should be of the nonabsorbing type, preferably concrete.

16. The building should preferably be of noncombustible construction.

17. One or more natural-draft vents, equipped with spark-arresting screens, should be provided.

18. A washdown hose and drain should be provided. However, any pipe-connected drains should be provided with a closure, and this closure should be in place at all times except during washdown.

19. Heat should be provided exclusively from a source outside the building. However, space heaters that do not depend on combustion processes within the heating unit may be satisfactory if they are suitably located overhead to provide minimum clearances of 30 inches from raw materials and finished products. The space heaters must also meet the requirements of the most recent edition of the National Electrical Code for the specific type of hazard encountered.

20. All electric switches, controls, motors, and lights—if located in the mixing or blasting agent storage area—should conform to the requirements of the most recent edition of the National Electrical Code; otherwise they should be outside the mixing room. The frame of the mixer and all other equipment that may be used should be electrically bonded together and be provided with a continuous electrical path to ground.

21. The design of the mixer should minimize the possibility of frictional heating, compaction, and especially confinement. Bearings and gears should be protected against the accumulation of product dust and should preferably be of the outboard type.
22. Mixing and packaging equipment should be constructed of materials compatible with the ammonium nitrate composition. Zinc should be avoided because of its tendency to promote or accelerate decomposition of ammonium nitrate. Copper is also unsatisfactory because of corrosion problems.

23. An automatic water-deluge system with adequate capacity is recommended to protect the mixing and packaging areas as well as any stocks of ammonium nitrate and blasting agent that may be in the plant.

Operational Control

24. Personnel limits should be established, posted and enforced while operations involving blasting agents are underway in the mixing house.

25. Smoking should not be permitted in or near the mixing house.

26. No cutting or welding should be done in the mixing or storage building while any AN-FO or ammonium nitrate is present in the building. The equipment and area involved should be washed free of ammonium nitrate and AN-FO before any welding or cutting operations are conducted. Where feasible, the equipment should be removed from the building for repairs.

27. The floors and equipment of the mixing and packaging room should be cleaned frequently to prevent accumulation of ammonium nitrate or fuel oil and other carbonaceous materials. The entire mixing and packaging plant should be cleaned regularly to prevent excessive accumulation of dust.

28. Discarded empty ammonium nitrate bags should be disposed of daily in a safe manner, such as by burning in an isolated area or by burying.

29. The area surrounding a mixhouse should be kept free of rubbish, dry grass, or other combustible materials for not less than 25 feet in all directions.

Composition

30. No liquid fuels with a flashpoint lower than that of No. 2 diesel fuel oil (125° F minimum or legal) should be used. More volatile fuels, such as gasoline, kerosine, or No. 1 diesel fuel, are not recommended because they offer no advantage in blasting and would increase the hazard of a vapor explosion (fire).

31. The addition of an oil-soluble dye to the fuel oil produces a colored product that would be advantageous in promoting safety. The color would aid primarily in distinguishing between a mixed product and unprocessed ammonium nitrate and would also provide an indication of the distribution of the oil throughout the mix.
32. The fuel oil content of AN-FO should be approximately 5.7 percent by weight, which yields an oxygen-balanced composition. If other carbonaceous material is substituted for fuel oil, oxygen-balanced compositions should be maintained.

33. If solid fuels are used they should be chosen to minimize dust-explosion hazards.

34. Crude oil and crankcase oil should not be used because they may contain volatile constituents that increase the hazard of vapor explosions (fire) or may include gritty particles that might increase the sensitivity of the resulting blasting agent.

35. Metal dust (such as aluminum powder), sulfur, perchlorates, or explosive substances (such as nitroglycerin or other high explosives) should not be used to sensitize ammonium nitrate unless the strict standards of normal explosive-plant operations are met and unless approval is obtained from authorities who have jurisdiction. Nitrites and chlorates should never be used in blasting agent formulations.

36. Other unusual compositions should not be attempted except under the supervision of competent personnel able to evaluate the possibility of new hazards in the operation and equipped to determine the sensitivity of the resulting compositions.

37. The cap sensitivity of a composition should be determined at regular intervals and after every change in proportion, character of ingredients, mixing, or packaging.

Storage of Blasting Agents

38. No more than 1 day's production of blasting agent should be permitted in the mixing and packaging plant.

39. Blasting agents should be stored in clean, dry buildings that are located in accordance with the American Table of Distances.

40. Standard explosives-magazine construction is preferred for buildings where blasting agents are stored. However, if buildings of other construction are used for such storage, they should be one-story, without basement, and of noncombustible or fire-resistant construction.

41. The interior of buildings used for storing blasting agents should be kept clean and free of debris and empty containers.

42. Combustible materials (including flammable liquids), corrosive acids, chlorates, nitrites, or similar materials should not be kept in any structure used for storing blasting agents.

The optimum content of diesel fuel depends upon the amount of inert coating on the ammonium nitrate.
43. Semitrailer or full trailer vans used for highway or on-site transportation of the AN-FO compositions are satisfactory for storing these materials temporarily, provided the vans are located in accordance with the American Table of Distances.

44. The storage building or van should be well ventilated, kept locked when unattended, and posted with proper warning signs.

45. Smoking and open flames should not be permitted in or near storage buildings or vans containing blasting agents.

46. The area surrounding a storage facility should be kept free of rubbish, dry grass, or other materials of a combustible nature for not less than 25 feet in all directions.

47. Broken bags or cartridges of blasting agents should be cleaned up and removed from the premises.

48. Blasting agents in bags or in cartridges should be stacked to allow free access by authorized persons and to permit circulation of air between and around stacks. (This does not apply to temporary van storage.)

49. If detonating fuse or any cap-sensitive material is added to a blasting agent composition, the entire package is a high explosive and should be handled accordingly.

50. All cartridges, bags, or other containers of blasting agents should be labeled to indicate their contents. If ammonium nitrate bags are used as containers for the mixed blasting agent, they should be relabeled to show their content.

51. Prolonged storage of AN-FO blasting agents should be avoided unless it has been demonstrated that segregation or evaporation of the oil does not occur. The principle factors affecting segregation are the type and density of ammonium nitrate, the kind and amount of coating, and the viscosity and vapor pressure of the fuel.

Transportation

52. The regulations of the Interstate Commerce Commission governing the transportation of blasting agents over public highways should be considered as minimum requirements.

53. Vehicles used for transporting blasting agents should be in a safe operating condition and should be driven by competent drivers who have a State driver's license valid for the type of vehicle driven. Drivers should also be familiar with applicable Federal, State, and local regulations and codes.

54. The construction of any truck or van used for transporting blasting agents should include a means for low-pressure venting in case the truck and its contents are involved in a fire.
55. Mobile processing equipment should not be used for mixing blasting agents while on public highways and other public thoroughfares.

56. No person should smoke or carry matches or any other flame-producing device or firearms while in or near a motor vehicle transporting blasting agents.

57. Any tarpaulin used to cover the load of blasting agents should be fire resistant.

58. Acids or other corrosive liquids should not be transported in any vehicle containing blasting agents.

59. Blasting agents should not be transported in any public vehicle carrying passengers for hire.

60. If an auger is used to deliver the blasting agent from the truck, the shell of the auger should be selected so as to minimize buildup of pressure internally.

61. All trucks transporting blasting agents should carry two 5-pound or larger carbon dioxide fire extinguishers or two 4-pound or larger dry chemical extinguishers. The extinguishers should be of an approved type and properly maintained. These extinguishers are effective against ordinary truck fires but not against fires involving the blasting agent.

62. Fires involving blasting agents should only be fought in the incipient stage. If all efforts in attempting to control the fire appears futile, then the area should be evacuated.

**Blasting Operations--General**

63. The relative safety of blasting agents may cause the blasting crew to disregard normal rules for handling explosives. All normal practices for safe handling of explosives should be observed. Smoking should not be tolerated in the vicinity of any explosives or blasting agents.

64. Jet-pierced or sprung holes should not be loaded before they have had adequate time to cool.

65. Excess oil in the blasting agents should be avoided because it has a desensitizing effect on both the primer charge and the blasting agent and decreases the chance for proper initiation.

66. Before entering a blast area, personnel should make certain that it is completely free of visible reddish-brown fumes, an indication of highly toxic concentrations of nitrogen dioxide gas.

67. Adequate priming should always be employed to guard against misfires, increased toxic fumes, and poor performance. The kind and amount of primer used should be governed by the sensitivity of the blasting agent, hole diameter, and other factors.
68. When a misfire occurs, no one should return to the face for at least 15 minutes when electric detonators have been used and for 30 minutes when cap and fuse have been used.

69. A misfire with a blasting agent should be handled in the same way as a misfire with a dynamite charge.

**Blasting Operations--Underground Mines (Additional Recommendations)**

70. Blasting agents should be excluded from underground coal mining operations. No blasting agent is approved by the Bureau of Mines as permissible for such use.

71. Ammonium nitrate blasting agents should be carefully prepared to a composition\(^7\) that will minimize the production of toxic fumes. Positive mechanical mixing should be used to aid in insuring consistently uniform compositions.

72. Mixing of blasting agents should not be done underground.

73. In small-diameter holes, the AN-FO or related agents should be loaded so as to provide a continuous column which completely fills the cross section of the borehole.

74. The potential hazard of static electricity causing premature initiation of the priming charge where pneumatic loading is employed should be evaluated in every type of blasting application before it is put into operation, and adequate steps should be taken to eliminate this hazard.\(^8\)

75. Pneumatic equipment used for loading blasting agents should be adequately grounded to dissipate any static charges that may be generated during the loading operation.

76. Water lines, air lines, rails, or the permanent electrical grounding systems should not be used to ground pneumatic loading equipment.

77. Any hose used in connection with the loading machine should be of the semiconductive type, having a total resistance low enough to permit the dissipation of static electricity and high enough to limit the flow of stray electric currents to a safe level.\(^9\) Wire-countered hose should not be used because of the potential hazard from stray electric currents.

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\(^7\) Approximately 5.7 percent of No. 2 diesel fuel marketed in the United States yields an oxygen-balanced mixture with pure ammonium nitrate which is ideal with respect to toxic fume production and efficiency of the blasting agent. Close control of composition is essential for use in underground operations.

\(^8\) The hazard from static electricity increases as the relative humidity decreases.

\(^9\) On the basis of presently available information it appears that semiconductive hose having a resistance of not less than 5,000 ohms per foot with no more than 2 megohms for the total length is satisfactory.
78. All loading should be stopped immediately when the presence of static electricity or stray current is detected. The condition should be remedied before loading is resumed.

79. Before holes containing water are charged, the water should be thoroughly removed. If water continues to flow into the boreholes, water-resistant explosive should be used rather than blasting agents. Plastic tubes should not be used to protect pneumatically loaded blasting agent charges against water unless a positive grounding system is provided to drain electrostatic charges from the hole.

80. Every reasonable precaution should be exercised to exclude moisture from the blasting agent. Water decreases the sensitivity of AN-FO mixtures and increases the production of toxic fumes on detonation.

81. Although information on the physical effects of both ammonium nitrate and fuel oil is limited, the possibility of irritating effects or other health hazards should not be overlooked. Protective equipment should be used where a need is indicated.

82. The hazard from cutoffs in multiple blasting can be minimized by careful design of the round and firing sequence.

83. Positive ventilation of the mine should be provided to remove toxic fumes from blasting operations.

84. Following blasting, a place should not be mucked out until the concentration of toxic gases is reduced to a safe level.

**RECOMMENDATIONS COVERING CAP-SENSITIVE COMPOSITIONS**

Cap-sensitive AN-FO compositions should be prepared and treated in the same way as dynamite and other similar explosives in every regard.
REFERENCES


### Table A-1. American Table of Distances for Storage of Explosives

<table>
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<tr>
<th>Explosives, pounds</th>
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*Explosives* means any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion, that is, with substantially instantaneous release of gas and heat, unless such compound, mixture, or device is otherwise specifically classified by the Institute of Makers of Explosives. It is not applicable to transportation of explosives, or to any handling or temporary storage necessary or incident thereto. It is not intended to apply to bombs, projectiles, or other heavily encased explosives.

*Table applies only to the manufacture and permanent storage of commercial explosives. It is not applicable to transportation of explosives, or to any handling or temporary storage necessary or incident thereto. It is not intended to apply to bombs, projectiles, or other heavily encased explosives.*

*All types of blasting caps in strengths through No. 8 cap should be rated at 1½ pounds of explosives per 1,000 caps. For strengths higher than No. 8 cap, consult the manufacturer.*

*The Institute of Makers of Explosives does not approve the permanent storage of more than 300,000 pounds of commercial explosives in one magazine or in a group of magazines that is considered as one magazine.*

*Barricaded* means that a building containing explosives is effectually screened from a magazine, building, railway, or highway, either by a natural barricade or by an artificial barricade of such height that a straight line from the top of any sidewall of the building containing explosives to the cave line of any magazine or building, or to a point 12 feet above the center of a railway or highway, will pass through such intervening natural or artificial barricade. "Natural barricade" means natural features of the ground, such as hills or timber of sufficient density that the surrounding exposures which require protection cannot be seen from the magazine when the trees are bare of leaves. "Artificial barricade" means an artificial mound or revetted wall of earth of a minimum thickness of 3 feet.

*When a building containing explosives is not barricaded, the distances shown in the table should be doubled.*

*Inhabited building* means a building regularly occupied in whole or in part as a habitation for human beings, or any church, schoolhouse, railroad station, store, or other structure where people are accustomed to assemble, except any building or structure occupied in connection with the manufacture, transportation, storage, or use of explosives.

*"Passenger railway" means any steam, electric, or other railroad or railway which carries passengers for hire.*

*"Highway" means any public street or public road.*

*"Magazine" means any building or structure, other than an explosives manufacturing building, used for the permanent storage of explosives.*

*When 2 or more storage magazines are located on the same property, each magazine must comply with the minimum distances specified from inhabited buildings, railways, and highways, and in addition, the magazines should be separated from each other by not less than the distances shown for "separation of magazines.* except that the quantity of explosives contained in cap magazines shall govern in regard to the spacing of said cap magazines from magazines containing other explosives. If any 2 or more magazines are separated from each other by less than the specified "separation of magazines* distances, then such 2 or more magazines, as a group, must be considered as 1 magazine, and the total quantity of explosives stored in such group must be treated as if stored in a single magazine located on the site of any magazine of the group and must comply with the minimum of distances specified from other magazines, inhabited buildings, railways, and highways.

Source: Institute of Makers of Explosives, revised and approved September 30, 1955.