# THE HISTORY OF INTRALINE DISTANCE IN THE UNITED STATES

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**Abstract**

In 2007 the US Army Technical Center for Explosives Safety (USATCES) funded the US Army Engineering and Support Center, Huntsville (USAESCH) to perform a historical study on intraline distance and how the explosives safety distance evolved over time. Through an extensive search of historical explosives safety standards, USAESCH developed a 60 page report entitled "The History of Intraline Distance Standards" that details the history of standards related to Intraline Distance including definitions, required separation distances, and permissible exposures.

Explosives safety requirements in the United States began in 1909 when the American Railroad Institute questioned explosives manufacturers regarding distances necessary to protect employees and property. In response to this inquiry, a group of explosives manufacturers collaborated to study over 200 explosive accidents. This study resulted in the 1914 American Table of Distances (ATD) published by the Institute of Makers of Explosives (IME). The 1914 ATD provided suggested separations between explosives and inhabited buildings, public highways, and public railways.

Intra-plant distance first appeared in explosives safety standards in the 1925 New Jersey State Law which would become the basis for explosive safety laws in the U.S. Intra-plant distance was defined as the distance required between various explosive operations on an explosives plant. The intra-plant distance defined in the New Jersey Law has since evolved into today's intraline distance.

Intraline distance today is specified in multiple explosives safety standards. However, the true intention of the separation distance has been lost or buried deep within the fine print of the standards. This paper will outline the history of intraline distance and describe how the use and perceptions of intraline distance have changed over the last 85 years.

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14. ABSTRACT
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## Introduction and Background

The US Army Technical Center for Explosives Safety (USATCES) is the Army approval authority for explosives safety site plans. In recent years, USATCES has noticed an increasing number of requests by DoD level approval authorities that protection be provided to workers sited at intraline distance although the protection is not required by DoD explosive safety standards. In response to these requests, USATCES funded the US Army Engineering and Support Center, Huntsville (USAESCH) to perform a historical study on intraline distance. The goal of the study was to discover the origins of intraline distance within DoD standards and investigate how the explosives safety distance evolved over time.

Within the most recent revisions of the DoD 6055.09-STD, *DoD Ammunition and Explosives Safety Standards,* (Change 2 dated August 2009 to the February 2008 revision) "Intraline distance (ILD)" is defined as the separation distances required between explosives and non-explosives buildings and sites within an explosives operating line." Though the definition is both clear and concise, the application and understanding of ILD varies greatly. While some explosives safety experts would argue that ILD is not intended to provide personnel protection, others would argue that personnel protection is a vital component of the requirement. This confusion is most likely due to the language used within the standard and the laundry list of items which may be located at ILD from a potential explosion site (PES).

This paper seeks to explain the progression of ILD from its first use within an explosives safety standard to its current state within the most recent DoD standard. Appendix A provides a complete summary of definitions, expected effects, permissible exposures, and ILD values for each standard examined in this study.

## Early Explosives Safety History of the United States

In 1909 the American Railway Association requested guidance from the Manufacturers of Powder and High Explosives of the United States, the forerunner of the Institute of Makers of Explosives (IME), related to the separation distance between buildings containing explosives and the property of railways. Specifically, the Railway Associated was interested in the distance necessary to provide reasonable safety to the railway property in the event of a detonation on an explosives plant. Thus, Col. B.W. Dunn, the Chief Inspector of the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, requested that the members of the IME attend a conference to discuss actions to be taken with respect to safe storage of explosives.

At the time, the only authoritative guidance known to the Chief Inspector was a portion of the British Government Regulation which mandated separation distances between explosives buildings and other property. Discussions at the conference resulted in the general agreement that the separation distances required by the British standards could not be verified and in many cases seemed unreasonable. Thus, a Special Committee was appointed to obtain all available information related to explosions causing serious injury or damage in the U.S. and abroad. The work, lasting more than one year, detailed over 200 separate explosions carefully tabulating data. After multiple meetings of the Manufacturers to consider and review the data, the Manufacturers

developed a table entitled “Proposed American Distances” which they believed would “provide reasonable safety”. With the approval of consumers and dealers of explosives in the United States, the proposed distance table became the first (1910) American Table of Distances (ATD). The 1910 ATD included separation distances for inhabited buildings, public railways, and magazines. Additional tables of distances were published in 1914 and 1919 adding separations for magazines from public highways and separations for blasting caps.

**The Origin of Intraline Distance**

In the earliest days of explosives safety standards in the US, today’s “intraline distance” was termed “intra-plant distance”. The earliest known reference to intra-plant distance was found in an IME timeline of unknown origin. Intra-plant distance was a topic of much discussion in 1917 as a Special Committee of the IME debated the appropriate distances to assign. Within meeting minutes dated January 1917, the chair of the committee which first presented the intra-plant table stated that the intention was to protect workers by preventing “serious injuries” and “preventing propagation”. By 1924, this committee had come to relative agreement on the distances and provided them to New Jersey state officials in January 1925 for incorporation into the 1925 New Jersey Law.

In March of 1925, the New Jersey Legislature passed a law related to manufacturing, handling, and storing explosives. This act was based largely on the ATD and includes the first confirmed use of ILD which within that document was termed “Intra-plant Distance”. The values found in this table did not vary greatly from those of today. Intra-plant distance within the law was defined as “the distance required between all factory buildings on an explosives plant, between factory buildings on an explosives plant and other buildings on the plant in which people were regularly employed, and between magazines and factory buildings and buildings on explosives plants in which people are regularly employed.”

In 1927, following the Lake Denmark explosion, the US Congress directed that the Secretaries of the War and Navy prepare a report on ammunition storage conditions. The Secretaries subsequently assigned a Joint Board on Ammunition to prepare a report. This board would later be known as the Joint Army Navy Ammunition Storage Board, the Army-Navy Explosives Safety Board, the Armed Services Explosives Safety Board, and eventually the Department of Defense Explosives Safety Board (DDESB). The recommendations of the board were that the New Jersey explosives law be incorporated as a federal standard for all government operations. Thus, in 1928, the US Congress adopted the New Jersey ATD-based standard for use on government facilities and intra-plant distance became a national standard.

**Changes From the Original Standards**

Until 1945, the New Jersey Law and the ATD would remain the basis of explosives safety criteria in the United States. Between 1928 and 1945, the Army published several standards under the title *Ordnance Safety Manual* which served to restate and clarify the 1925 New Jersey Law for use within Army operations. It is suspected that the Navy also had documents which served this purpose though none were located during the course of this study.

On May 3, 1945 the US Army Ordnance Department published another update to the *Ordnance Safety Manual*. Within this edition, the first use of the term "intraline" occurs. Intraline operations are defined as "those processes accomplished within one operating line." The 1945 manual also provided the first statement of expected effects by specifying, "Intraline distance is expected to protect buildings within an operating line from propagation of explosion due to blast effects, but not against the possibility of propagation due to missiles. Adjacent buildings in an operating line will have an even chance of substantial structural damage as determined by a study of many accidental explosions." The 1945 standard permitted two instances in which ILD could be applied: when hazards involved required dividing an operating line into separate buildings and when a service magazine needed to be located near an operating building it served.

In July 1945, July 1948, and April 1950, papers were written appraising and suggesting modifications to the explosives safety standards of the time. Officials at the time were concerned that the data in the original tables found in the ATD, based on explosions which occurred in the late 1800's to early 1900's, could not accurately represent the more powerful explosives developed in the first four decades of the twentieth century. The proposed solution was the result of re-evaluating the explosions which served as a basis for the ATD in addition to 66 more recent explosive accidents. The recommendation was to slightly modify quantity distances (QD) in order to base them on a "Risk Factor". This Risk Factor was the equivalent of today's K factor to be used as a multiplier to the cube root of the net explosive weight (NEW) in order to determine the appropriate separation distance. Lastly, the authors recommended changes to multiple types of explosives separations and permissible exposures. By 1950, the personnel protection aspect of ILD had been forgotten or lost as the April 1950 paper stated that ILDs are said to provide a high degree of protection against propagation of explosions from building to building but provide no protection against loss of life, severe injuries, building collapse, or from flying glass.

In 1950, the Armed Services Explosives Safety Board (ASESB) recommended development of the first standards to be used by all DoD Services. By December 1955, this recommendation had come to fruition as all three Services approved the document entitled *Quantity-Distance Standards for Manufacturing, Handling, and Storage of Mass-Detonating Explosives and Ammunition at Military Establishments*. In 1956, DoD Directive 4145.17 officially sanctioned the 1955 standard as the explosives safety requirement for use by all DoD Components. Within this document, ILD is relatively unchanged from its definition and use within the 1945 *Ordnance Safety Manual*. The main change is the statement of ILD as being equivalent to $9W^{1/3}$ ($3.57Q^{1/3}$) for barricaded buildings and $18W^{1/3}$ ($7.14Q^{1/3}$) for unbarricaded structures. In previous standards this relationship was not directly stated though required distance did include the relationship.

During the 1960's and 1970's the definition and use of ILD changed little. Notable changes in the 1961 *Ordnance Safety Manual* include permitting ILD to be used for protecting certain areas within airfields, heliports, and seadromes. Concurrent with this change, an expected effect was provided stating the extent of damage for those sites (see Appendix A). Within the 1966 DoD Instruction 4145.23 intraline separation was explicated for multiple

exposures which had previously been grouped under vague titles such as “auxiliary facilities” (see Appendix A). Within the 1969 DoD 4145.27-M, one of many new additions (see Appendix A) was that tactical facilities of multiple Services were permitted to be separated by ILD if the controlling Service accepted the hazard. Additions to permissible exposures which are first incorporated into the 1976 DoD 5154.4S include permitting parking areas for privately owned vehicles of workers at a PES and security personnel whose mission requires immediate response to be at ILD. In the 1978 DoD 5154.4S, additions were made which permit some waterfront utility facilities to be sited at ILD from explosives locations on piers and permit utility facilities which are essentially unmanned to be sited at ILD from explosives locations. Additionally, within the 1978 DoD 5154.4S, security facilities were permitted to be sited as close as $9W^{1/3}$ ($3.57Q^{1/3}$).

In 1984 the DoD published the first edition of the modern standard, the DoD 6055.9-STD. Within this standard, the definition of ILD changed from its 1945 version to the current definition, “the separation distances required between explosives and non-explosives buildings and sites within an explosives operating line”. Additionally, in this standard, the term “ILD” is for the first time associated with both the distances for K9 (3.57) and K18 (7.14) and the associated overpressures of 12 psi (82.7 kPa) and 3.5 psi (24 kPa) respectively. Previously, K9 (3.57) and K18 (7.14) were associated with ILD, and K9 (3.57) and K18 (7.14) were associated with 12 psi (82.7 kPa) and 3.5 psi (24 kPa). Never before were all three characteristics officially deemed synonymous. In addition, the standard received a new “bulletized” look and differentiated between barricaded and unbarricaded ILD. Most expected effects and permissible exposures within the document were already implied within previous standards, but the 1984 standard detailed the effects to various types of facilities and listed permissible exposures at various QD. The many changes made can best be viewed in the Summary of Changes (Appendix A).

During the 1990’s ILD changed only slightly from the 1984 standards. New editions of the DoD 6055.9-STD were published in 1992, 1997, and 1999. In 1992, parking lots for private vehicles were permitted to be sited as close as 100 ft (30.5 m) if certain conditions were met (see Appendix A) and construction personnel were permitted closer than intraline from a PES on a temporary basis. In 1997, burning grounds and control sites for EOD operations were added to the list of permissible exposures, and QD requirements between loaded combat aircraft and related facilities were removed provided the munitions meet certain criteria (see Appendix A).

No changes to ILD standards were made within suggested revisions dated 2002 – 2004 or in October 2004 when another revision of the DoD 6055.9-STD was published. In February 2008, the DoD published DoD 6055.09-STD, the current governing document within DoD. Within the February 2008 version and Change 1, issued March 2009, there were no changes to ILD standards. Change 2, issued August 2009, included two minor changes to intraline standards and two additions. The minor changes are listed in Appendix A. The additions to permissible exposure, also in Appendix A, include requiring that a hardened aircraft structure (HAS), used solely as a maintenance facility, be provided a minimum of ILD equivalent protection for personnel within the HAS if K30 protection isn’t provided. Additionally, locations used for collected material potentially presenting an explosive hazard (MPPEH) processing operations must not be sited a distances less than ILD from a PES.

**Perceptions of Intraline Distance**

As previously discussed, early IME meeting minutes indicate that the original purpose of intraline distance included some aspects of personnel protection. Unfortunately, without further research into early IME meeting minutes we cannot know the extent of the personnel protection intended. Additionally, early standards provide no statements of expected effects to people or structures located at intraline distance. The only known related to the intention of early intraline distance standards is that it was intended to separate buildings on an explosives plant.

By 1945, however, standard writers felt that the primary purpose of intraline distance was preventing propagation when they wrote that "Intraline distance is expected to protect buildings within an operating line from propagation of explosion due to blast effects, but not against the possibility of propagation due to missiles." No mention was made in the 1945 standard related to personnel protection provided at intraline distance. This belief was expounded upon in the 1950 standards which indicated that intraline distance provided a high degree of protection against propagation of explosions from building to building but provided no protection against loss of life, severe injuries, building collapse, or from flying glass.

Within the 1974 edition of the DoD 6055.9-STD, standard writers clearly stated that direct injury to personnel would be possible at unbarricaded intraline distance by pressure or translation. The 1984 DoD 6055.9-STD, which contained a bulletized list of expected effects, stated that severe injuries or death to occupants of the ES were expected at barricaded intraline distance and serious personnel injuries are likely at unbarricaded intraline distance. The expected effects listed in today's standard have not changed from the 1984 standard.

The authors of this paper cannot with confidence speak to the perceptions of the explosives safety community related to intraline distance outside of their own experience. However, in the experience of the authors of this paper, the explosives safety community as a whole is currently divided regarding whether or not intraline distance is intended to provide any personnel protection.

The belief that intraline distance provides personnel protection is reasonable. In fact, the authors of this paper are in agreement that intraline distance does indeed provide some level of personnel protection. However, it is the contention of the authors of this paper that the personnel protection provided at intraline distance is a secondary effect of the additional separation distance provided between the PES and ES. As clearly stated in the current DoD 6055.09-STD, at intraline distance personnel in open would most likely not receive fatal injuries from overpressure effect. At intraline distance, pressures are less than those which cause lung rupture and the probability of eardrum damage is 1 percent. The authors of this paper contend that if intraline distance were intended to provide personnel protection there would be some necessity to include a fragmentation requirement within the explosives safety standards. Currently, there is no fragmentation protection requirement at intraline distance.

It is the belief of the authors of this paper that intraline distance is, as stated in all DoD explosives safety standards since 1945, intended only to prevent propagation of explosions between operating lines. The authors of this paper believe that present-day perceptions straying from this statement of fact within explosives safety standards are a result of a muddying of the waters by standard writers.

Through the years, explosives safety standards have increased in both length and complexity. As DoD missions grew, standards had to expand to provide requirements for the new operations. With each new requirement, exceptions had to be made for special circumstances in which operational necessity required accepting some additional risk to personnel key to completion of the mission. This has resulted in the long list of permissible exposures permitted at intraline distance in today's standard. This list includes multiple types of personnel both related and unrelated to the mission. As this list of permitted exposures has increased, explosives safety experts have begun to request that personnel protection be provided at intraline even though a requirement is not specified within the standard. It is the contention of the authors of this paper that what explosives safety experts should be asking is not how site planners are protecting personnel at intraline distance but should the standards be changed to include personnel protection at intraline distance (including fragmentation protection). Unfortunately, that question remains to be answered.

**Conclusions, Questions, and Recommendations for Future Study**

Unfortunately, this study was too large an undertaking to complete in a single phase. Therefore, the scope of work, to date, was limited to compiling a list of changes to intraline distance requirements since explosives safety standards were first developed in United States.

Thus far, this study has left more questions than answers. What was the original basis for the intraline table in the 1925 New Jersey Law? What was the original intention of intraline distance? If we have moved away from the original intention of intraline distance, why? Why were so many additional exposures added and on what basis?

The authors of this paper have access to meeting minutes of both the Institute of Makers of Explosives (IME) and the Department of Defense Explosives Safety Board (DDESB) which date back to the early 1900s. It is the authors' belief that the answers to many questions can be found in these documents. Unfortunately many of these documents are in forms which make them exceptionally difficult to read or are poorly organized. Gleaning answers from these documents will be time consuming if not impossible.

Thus the authors of this paper have proposed much more work toward the completion of this study including: digitization of historical IME minutes, organization and cataloging of historical DDESB minutes, further searching these and other documents to find the basis of each change, and development of a formal report to compile and summarize all the information. Once these tasks have been completed, further investigation should be completed regarding the history of intraline distance including the origins of the distances provided in the original intraplant

table, reasons for the addition of exposures, and, potentially, the original purpose of the separation distance.

After full completion of the intraline distance study, the authors of this paper would propose following a similar path for other separation distance requirements. There is much to learn from the history of explosives safety requirements. Explosives safety is a relatively new science, and we are fortunate to have many records kept by the early practitioners. It is vital that this information be captured before these records are lost, destroyed, or made unusable through innovations in technology.

All information compiled during this study, to date, is contained in US Army Engineering and Support Center, Huntsville (USAESCH) report CEHNC-CS-09-01 entitled "The History of Intraline Distance Standards". This report has an open distribution and can be obtained by contacting the authors of this paper. Once the study has been completed in its entirety, the authors of this paper would propose developing a DDESB technical or white paper which would provide in detail a historical record of changes to intraline distance standards from 1925 to the present and would be updated as standards continue to change over time. This would ensure that the history of this science would be maintained and well documented for use by current and future scientists as they continue to strive toward striking the delicate balance between ensuring safety and meeting mission requirements.

# APPENDIX A – SUMMARY OF CHANGES

Intraline Distance has changed greatly since its first appearance in 1925. This summary attempts to consolidate all changes within the documents as they relate to intraline distance. Items shown in *italics* indicate that the item is the same as in the previous version. New items or items which are changed from previous versions are shown in standard type.

## DEFINITIONS

### INTRA-PLANT DISTANCE

**1925 New Jersey State Law, 1926 IME Pamphlet No. 3, 1928 US House Document 199, 1931 Ordnance Safety Manual, 1941 Ordnance Safety Manual**

Intra-plant distance is the distance required between all factory buildings on an explosives plant, between factory buildings on an explosive plant and other buildings on the plant in which people were regularly employed, and between magazines and factory buildings and buildings on explosives plants in which people are regularly employed.

**1945 Ordnance Safety Manual**

Intra-plant operations are defined as those operations accomplished within one ordnance establishment.

### LINE SEPARATIONS

**1945 Ordnance Safety Manual**

Line separation is defined as the distance required between the buildings of any two or more operating lines. Line separations require "inhabited building distance" between the buildings of separate operating lines.

### INTRALINE DISTANCE

**1945 Ordnance Safety Manual, 1951 Ordnance Safety Manual, 1961 Ordnance Safety Manual, 1956 DoD Directive 4145.17, 1966 DoD Instruction 4145.23, 1969 DoD Manual 4145.27-M, 1968 DoD Contractors' Safety Manual 4145.26-M, 1974 DoD 5154.4S, 1976 DoD 5154.4S, 1978 DoD 5154.4S**

Intraline distance is defined as the minimum distance allowed between any two buildings within one operating line where intraline operations are defined as those processes accomplished within one operating line.

**1984 DoD 6055.9-STD, 1992 DoD 6055.9-STD, 1997 DoD 6055.9-STD, 1999 DoD 6055.9-STD, Oct 2004 DoD 6055.9-STD, Feb 2008 DoD 6055.09-STD, Change 1 (March 2009) to Feb 2008 DoD 6055.09-STD, Change 2 (Aug 2009) to Feb 2008 DoD 6055.09-STD**

Intraline distance is defined as the separation distances required between explosives and non-explosives buildings and sites within an explosives operating line.

This standard is the first to define an overpressure and K values with various forms of intraline distance. Previously, overpressures were associated with K9 and K18, but no mention was made of intraline distance. Additionally, in previous standards, K9 and K18 were associated with intraline distance but only within tables for determining intraline distance of HD 1.1 explosives. Within the 1984 standard, the three descriptors of intraline distance (terminology, K values, and overpressure) are used together for the first time within Chapter 2 in Sections C.5 and C.7. For Barricaded intraline distance, airblast overpressure of HD 1.1 explosives is 12 psi and K is 9. At unbarricaded intraline distance, overpressure is 3.5 psi and K is 18.

## EXPECTED EFFECTS AT INTRALINE DISTANCE

**1945 Ordnance Safety Manual, 1951 Ordnance Safety Manual**

Intraline distance is expected to protect buildings within an operating line from propagation of explosion due to blast effects, but not against the possibility of propagation due to missiles. Adjacent buildings in an operating line will have an even chance of substantial structural damage as determined by a study of many accidental explosions.

**1956 DoD Directive 4145.17, 1966 DoD Instruction 4145.23**

The degree of safety afforded by the intraline distances and the risks involved if a mass detonation should occur in one building may be described generally as providing a high degree of protection against the propagation of explosions from building to building, however, there may be loss of life or severe injuries from partial collapse of buildings and from missiles and flying glass.

**1961 Ordnance Safety Manual**

*Intraline distance is expected to protect buildings within an operating line from propagation of explosion due to blast effects, but not against the possibility of propagation due to missiles. Adjacent buildings in an operating line will have an even chance of substantial structural damage as determined by a study of many accidental explosions.*

The magazine and intraline distances specified in the combat aircraft parking area Q-D table will provide protection only against the simultaneous detonation of mass-detonating explosives on adjacent aircraft. This distance does not provide protection against the propagation from the source of the explosions by blast, fragments, debris or fire to the ammunition and explosives on adjacent aircraft. Explosives loaded aircraft separated at magazine or intraline distances will

probably suffer structural damage so sever as to necessitate salvage or result in complete loss of the aircraft. If protection to aircraft is desired, inhabited building distance or some other means must be provided.

**1968 DoD Contractors' Safety Manual 4145.26-M, 1969 DoD Manual 4145.27-M**

*The degree of safety afforded by the intraline distances and the risks involved if a mass detonation should occur in one building may be described generally as providing a high degree of protection against the propagation of explosions from building to building, however, there may be loss of life or severe injuries from partial collapse of buildings and from missiles and flying glass.*

*The magazine and intraline distances specified in the combat aircraft parking area Q-D table will provide protection only against the simultaneous detonation of mass-detonating explosives on adjacent aircraft. This distance does not provide protection against the propagation from the source of the explosions by blast, fragments, debris or fire to the ammunition and explosives on adjacent aircraft. Explosives loaded aircraft separated at magazine or intraline distances will probably suffer structural damage so sever as to necessitate salvage or result in complete loss of the aircraft. If protection to aircraft is desired, inhabited building distance or some other means must be provided.*

**1974 DoD 5154.4S, 1976 DoD 5154.4S, 1978 DoD 5154.4S**

Same as 1968 DoD Contractors' Safety Manual 4145.26-M and1969 DoD Manual 4145.27-M with the following addition: at barricaded intraline distance overpressures may be high enough to injure personnel directly or by "translation".

**1984 DoD 6055.9-STD, 1992 DoD 6055.9-STD, 1997 DoD 6055.9-STD, 1999 DoD 6055.9-STD, Oct 2004 DoD 6055.9-STD, Feb 2008 DoD 6055.09-STD, Change 1 (March 2009) to Feb 2008 DoD 6055.09-STD, Change 2 (Aug 2009) to Feb 2008 DoD 6055.09-STD**

Barricaded Intraline (K9; 12 psi)

- Unstrengthened buildings will suffer severe structural damage approaching total destruction.
- Severe injuries or death to occupants of the ES may be expected from direct blast, building collapse, or translation.
- Aircraft will be damaged beyond economical repair both by blast and fragments. If the aircraft are loaded with explosives, delayed explosions are likely to result from subsequent fires.
- Transport vehicles will be damaged heavily, probably to the extent of total loss.
- Direct propagation of explosions between two explosives locations is unlikely when barricades are interposed between them to intercept high velocity low angle fragments.
- Improperly designed barricades or structures may increase the hazard from flying debris, or may collapse in such a manner as to increase the risk to personnel and equipment.

- Control – Barricading is required. Exposed structures containing equipment of high monetary value or of critical mission importance or wherein personnel exposure is significant may require hardening for necessary protection of personnel and equipment.

Unbarricaded Intraline (K18; 3.5 psi)

- Direct propagation of explosion is not expected.
- There is some possibility that delayed communication of an explosion may occur from fires, or as a result of equipment failure at the ES.
- Damage to unstrengthened buildings will be of a serious nature and approximate 50 percent or more of the total replacement cost.
- There is a 1 percent chance of eardrum damage to personnel.
- Personnel injuries of a serious nature are likely from fragments, debris, firebrands, or other objects.
- Cargo ships would suffer damage to decks and superstructure from being struck by fragments and having doors and bulkheads on the weather deck buckled by overpressure.
- Aircraft can be expected to suffer considerable structural damage from blast. Fragments and debris are likely to cause severe damage to aircraft at distances calculated from the formula $18W^{1/3}$ when small quantities of explosives are involved.
- Transport vehicles will incur extensive, but not severe, body and glass damage consisting mainly of dishing of body panels and cracks in shatter-resistant window glass.
- Control – Many situations arise in which control of pressure by suitably designed suppressive construction at the PES or protective construction at the ES are practical. Use of such construction to withstand blast overpressure is encouraged if it is more economical than distance alone, or if sufficient distance is not available to prevent the overpressure from exceeding this level.

## ES ALLOWED (PERMISSIBLE EXPOSURES) AT INTRALINE DISTANCE

**1945 Ordnance Safety Manual, 1956 DoD Directive 4145.17**

- Buildings forming an operating line shall be separated from each other by intraline distance
- Service magazines servicing an operating line are provided intraline separation from the buildings they service
- All AE operating buildings shall be located at intraline distance from other buildings within that line in which persons are regularly employed

**1951 Ordnance Safety Manual**

- *Service magazines servicing an operating line are provided intraline separation from the buildings they service*
- *Buildings forming an operating line shall be separated from each other by intraline distance*
- Adjacent operating lines when lines are producing the same explosives

- Normal maintenance, surveillance, and minor modification operations to be performed in the open are allowed at intraline distance from the nearest storage facility containing explosives but no closer than 100 feet
- Change houses, lunch rooms, dunnage preparation buildings, and lumber storage for magazine areas may be located at intraline distance from magazines
- Auxiliary facilities servicing an operating building (excluding service magazines) are allowed at intraline distance from the operating building but no closer than 100 feet

**1961 Ordnance Safety Manual**

- *Adjacent operating lines when lines are producing the same explosives*
- *Normal maintenance, surveillance, and minor modification operations to be performed in thee open are allowed at intraline distance from the nearest storage facility containing explosives but no closer than 100 feet*
- *Change houses, lunch rooms, dunnage preparation buildings, and lumber storage for magazine areas may be located at intraline distance from magazines*
- *Service magazines servicing an operating line are provided intraline separation from the buildings they service*
- *Auxiliary facilities servicing an operating building (excluding service magazines) are allowed at intraline distance from the operating building but no closer than 100 feet*
- *Buildings forming an operating line shall be separated from each other by intraline distance*
-

The following Q-D for airfields, heliports, and seadromes were added

- AE cargo areas (i.e. areas designated for AE loading/unloading cargo-type aircraft or parking loaded cargo-type aircraft containing AE as cargo) are allowed at intraline distance from AE operating facilities
- AE operating facilities are allowed at intraline distance from other AE operating facilities
- AE storage facilities are allowed at intraline distance from AE operating facilities
- Ready ammunition storage facilities are allowed at intraline distance from AE operating facilities

**1966 DoD Instruction 4145.23**

- Intraline separation was permissible for separating an operating building from storage magazines and other operating buildings regardless of whether or not line operations are involved, provided the degree of hazard of the operation did not exceed that normally associated with surveillance, check-out, inspection, minor retrofit, limited assembly operations, and packing and shipping operations
- Intraline separation was permissible for separating non-explosives operations from the explosive operations which they supported
- Intraline separation was permissible for separating operating buildings of various operating lines provided they presented similar hazards to their occupants

- Intraline separation was permissible for separating surveillance and inspection buildings, lunch rooms exclusively serving explosives areas, guard shelters, dunnage preparation buildings, and motor pools or dispatch areas exclusively serving explosive locations from the explosive locations they serve

**1968 DoD Contractors' Safety Manual 4145.26-M**

- *Intraline separation was permissible for separating an operating building from storage magazines and other operating buildings regardless of whether or not line operations are involved, provided the degree of hazard of the operation did not exceed that normally associated with surveillance, check-out, inspection, minor retrofit, limited assembly operations, and packing and shipping operations*
- *Intraline separation was permissible for separating non-explosives operations from the explosive operations which they supported*
- *Intraline separation was permissible for separating operating buildings of various operating lines provided they presented similar hazards to their occupants*
- *Intraline separation was permissible for separating surveillance and inspection buildings, lunch rooms exclusively serving explosives areas, guard shelters, dunnage preparation buildings, and motor pools or dispatch areas exclusively serving explosive locations from the explosive locations they serve*
- *Normal maintenance, surveillance, and minor modification operations to be performed in the open are allowed at intraline distance from the nearest storage facility containing explosives but no closer than 100 feet*

*The following Q-D apply for airfields, heliports, and seadromes*

- *AE cargo areas (i.e. areas designated for AE loading/unloading cargo-type aircraft or parking loaded cargo-type aircraft containing AE as cargo) are allowed at intraline distance from AE operating facilities*
- *AE operating facilities are allowed at intraline distance from other AE operating facilities*
- *AE storage facilities are allowed at intraline distance from AE operating facilities*
- *Ready ammunition storage facilities are allowed at intraline distance from AE operating facilities*

- Fences should not be placed closer to AE operating buildings than intraline distance
- Maintenance and tool rooms in an operating line shall be separated from explosives by intraline distance
- Rail cars and automotive equipment containing AE which are nearer than intraline distances to an explosives operation or operating building shall be included in computations as part of the explosives limits of the operation or operating building. This is not intended to permit cars or trucks containing AE to be used as service magazines and to be placed at less than intraline distances from the explosive operation or operational building. The total quantity within the cars and building shall not exceed the maximum permitted in the building or rail cars by the Q-D requirements.

- The storage of process water for operating facilities shall be separated from explosives facilities by intraline distance.
- Personnel evacuated during electrical storms shall be located within an approved protective shelter separated from the potential explosive site by intraline distance.
- When more than 70 lbs of black powder, tetryl, pentolite, explosives of similar sensitivity, and metal powders are to be screened and blended, all personnel and switch controls should be located a minimum of intraline distance from the operation.
- When blending military pyrotechnics, tracer, igniter, or incendiary mixture, all operating controls shall be located outside of the blending cubicle and protected by a "substantial dividing wall" or located at intraline distances from the blending cubicle.
- Where operational supplies of solid propellants are located in the loading wing, the quantity should be such that intraline distance is maintained from the explosives location to the non-explosive manufacturing portions of the building or to other wings containing explosives.
- When personnel protection is required for operations involving large quantities of explosives, providing a suitable protection shield at the operation often becomes impractical. In such cases the operator shall perform the work by remote control, from a barricaded position not closer to the operation than the appropriate barricaded intraline distance or be protected by a suitably constructed shelter designed with a safety factor of not less than 4 to withstand the overpressure from an equivalent amount of TNT.
- Where operational supplies of explosives or primers are located in a charging or pierce and prime wing of tracer and incendiary charging or primer inserting buildings, the quantity shall be such that intraline distances are maintained from the explosives location to the non-explosive manufacturing portions of the building or to other wings containing explosives.
- Temporary storage of primers (prior to removal to drying houses) should be outside the building in a shed or room, constructed for the purpose, or otherwise protected from a flash in the inspection room. The quantity of explosive material in the shed should be kept to the minimum practicable but in no case shall it exceed that permitted by the quantity-distance table for intraline separation.
- Wherever practicable, dry type explosives dust collection chambers, except portable units as specifically described in this document should be located outside operating buildings in the open or in buildings exclusively set aside for the purpose. In order to protect operating personnel from blast or fragments in event of an incident involving the collection chamber, an effective barricade (para. 304) or operational shield, depending upon the quantity to be collected, shall be provided between the operating building and the outside location or separate building where the collection chamber is placed. The protective barrier shall be placed at a minimum of intraline distance from the operating building. The collection chamber shall be located at least 3 feet from the wall.
- When material awaiting destruction is provided with adequate frontal and overhead protection, the material may be stored at intraline distance from the explosives being destroyed.

**1969 DoD Manual 4145.27-M, 1974 DoD 5154.4S**

- *Intraline separation was permissible for separating an operating building from storage magazines and other operating buildings regardless of whether or not line operations are involved, provided the degree of hazard of the operation did not exceed that normally associated with surveillance, check-out, inspection, minor retrofit, limited assembly operations, and packing and shipping operations*
- *Intraline separation was permissible for separating non-explosives operations from the explosive operations which they supported*
- *Intraline separation was permissible for separating operating buildings of various operating lines provided they presented similar hazards to their occupants*
- *Intraline separation was permissible for separating surveillance and inspection buildings, lunch rooms exclusively serving explosives areas, guard shelters, dunnage preparation buildings, and motor pools or dispatch areas exclusively serving explosive locations from the explosive locations they serve*

*The following Q-D apply for airfields, heliports, and seadromes*

- *AE cargo areas (i.e. areas designated for AE loading/unloading cargo-type aircraft or parking loaded cargo-type aircraft containing AE as cargo) are allowed at intraline distance from AE operating facilities*
- *AE operating facilities are allowed at intraline distance from other AE operating facilities*
- *AE storage facilities are allowed at intraline distance from AE operating facilities*
- *Ready ammunition storage facilities are allowed at intraline distance from AE operating facilities*
- Tactical facilities of one Service were permitted to be separated from the facilities of another Service by the appropriate intraline, inhabited building, or other criteria based hazards provided the degree of safety is acceptable to the controlling Service authorities
- Ships at explosives anchorages used for loading and unloading should be provided K18 protection when possible
- Loaded ships should be at K18 from one another
- Explosives piers should be at K18 from one another
- Classification yards should be at K18 from explosives loaded ships based on the NEW in the ship and the explosives loaded ships should be at IBD from classification yards based on the NEW in the yard.

**1976 DoD 5154.4S**

Same as 1974 DoD 5154.4S with the following additions:

- Parking areas for privately owned vehicles of workers are permitted at intraline distance from the PES provided they serve only workers assigned to a particular line or area
- Security personnel with a mission that requires an immediate response to a PES are permitted to be sited in a facility at intraline distance

**1978 DoD 5154.4S**

Same as 1976 DoD 5154.4S with the following additions:

- Utility manifolding or switching points and other similar waterfront utility facilities may be sited at intraline distance from an explosive locations on piers unless the utility facility exclusively supports a single pier or wharf in which case no specific quantity-distance separation is required
- Utility facilities which are essentially unmanned and provide auxiliary power generation or conversion, water and sewage treatment, environment monitoring, and other similar functions may be sited at intraline distance provided they do not present secondary hazards should they fail to function properly

Changed from 1976 D0D 5154.4S:

- Security facilities may be sited at a minimum of $D = 9W^{1/3}$. Peak incident overpressures to be expected from an explosion at this distance will be about 11 psi and are sufficient to render the alert force personnel within the building militarily ineffective. Strengthening the building to withstand small arms fire is considered to provide reasonable protection against fragments and building debris, but not necessarily against blast. Consideration should therefore be given to strengthening this building … to provide blast protection to the occupants.

**1984 DoD 6055.9-STD**

Barricaded Intraline (K9; 12 psi)

- Buildings housing successive steps of a single production, renovation, or maintenance operation.
- Security alert force buildings.
- Facilities of a tactical missile site where greater distances from the PES cannot be provided for technical reasons.
- Breakrooms and change houses if they are part of an operating line and are used exclusively by personnel employed in operations of the line.
- Temporary holding areas for trucks or railcars containing explosives to service production or maintenance facilities.
- Field operations in magazine areas when performing minor maintenance, preservation, packaging, or surveillance inspection.
- Unmanned auxiliary power facilities, transformer stations, water treatment and pollution abatement facilities, and other utility installations that serve the PES and are not an integral function in the PES, and loss of which would not create an immediate secondary hazard. These applications need not be barricaded. Exception: Unmanned auxiliary power generation or conversion facilities exclusively supplying power to the explosive storage area and security fence lighting may be located at fire distance from explosive facilities (50 feet for fire-resistant structures, 100 feet for nonfire-resistant structures).
- Dunnage preparation and similar support structures housing nonexplosives operations if used only by personnel employed at the PES**.**
- Service magazines that are part of operating lines. Distances are based on the quantity and type of ammunition or explosives in the service magazine or magazines, not the operating building.

- Exposures as indicated for unbarricaded intraline if blast suppression and structure hardening provide comparable protection for personnel and equipment involved.

Unbarricaded Intraline (K18; 3.5 psi)

- Workers engaged in construction in the vicinity of ammunition production areas, waterfront areas where ammunition is being handled or quantity-distance (Q-D). otherwise applies, or areas used for loading of aircraft with explosives.
- Surveillance, maintenance, and inspection buildings and labor intensive operations closely related to the PES.
- Comfort, safety, and convenience occupied buildings exclusively in support of the PES (such as lunchrooms, motor pools, area-offices, auxiliary fire stations, transportation dispatch points, and shipping and receiving buildings (not magazine area loading docks)).
- Parallel operating lines from one another, whether or not barricaded, provided ammunition and explosives involved in each operating line present similar hazards. The criticality or survivability of one or more of the operating lines may require that each line be given an inhabited building level of protection.
- Operations and training functions that are manned or attended exclusively by personnel of the unit operating the PES. This includes day rooms, squadron operation offices, and similar functions for units such as individual missile firing batteries, aircraft squadrons, or ammunition supply companies. Training functions permitted this level of exposure (3.5 psi) include organized classroom and field training of personnel who may be required to engage in explosives work at the PES. Maneuver areas, proving ground tracks, and similar facilities for armored vehicles also may be exposed to 3.5 psi (24 kPa) since the vehicle should provide adequate protection to the operators from fragments and debris.
- Maintenance of military vehicles and equipment when the PES is basic load or ready storage located outside the continental United States (OCONUS) areas, and is limited to 4000 kg or less net explosive quantity (NEQ) at each and when the maintenance work is performed exclusively by and for military personnel of the unit for which the basic load of ammunition is stored.
- Auxiliary power and utilities functions excluding "cold-iron" facilities, supply, and mechanical support at naval station waterfront areas when not continuously manned, when serving only the waterfront area, and when the PES is a ship or ammunition handling location on the waterfront. This category includes auxiliary power plants; compressor stations; electric power transformers; tool and consumable supplies storage and issue; and handling equipment service, battery charging, and minor repair. When such facilities serve an entire naval station or base complex, or when loss of the facility will cause an immediate loss of vital function, the exposure level must not exceed 1.2 psi (8.3 kPa).
- Minimum distance between separate groups of explosives loaded combat-configured aircraft or between aircraft and **a** pre-load or "quick-turn" site that serves to arm the aircraft. The use of intervening barricades is required to reduce further communication and fragment damage and eliminate the necessity for totaling net explosive weight (NEW). Loading ammunition and explosives

aboard aircraft can be accomplished with each group of aircraft without additional protection.

- Parking lots for privately owned automobiles belonging to the personnel employed at or stationed at the PES**.**
- Service-magazines that are part of operating lines. Distances are based on quantity and type of ammunition or explosives in the service magazines, not the operating building.
- Container stuffing and unstuffing operations that are routine support of PES. This applies only to main support functions set aside for support of ship-loading and unloading and the ES is an ammunition ship, the quantity at the container site shall govern. (Container stuffing and unstuffing in a magazine area are permitted at intermagazine distances.)
- Between explosives-loaded combat aircraft and those nonexplosives facilities that directly support the servicing and launching of a unit's armed aircraft (that is, activities and their operating facilities that handle ammunition and explosives on the flightline, prepare and service armed aircraft, and those that fly combat aircraft. Direct flightline combat aircraft associated facilities may contain field offices, breakrooms, unit training rooms, and equipment and supply rooms, as well as petroleum, oils, lubricants (POL) hydrant facilities and civil engineer (CE) fire protection stations). Specifically excluded are morale, welfare, and recreation (MWR) facilities; base civil engineering headquarters; industrial facilities, including central base supply; central maintenance control and associated critical shops such as engine buildup or central avionic repair.

**1992 DoD 6055.9-STD**

Same as 1984 DoD 6055.9-STD with the following changes:

- *Parking lots for privately owned automobiles belonging to the personnel employed at or stationed at the PES (Note: This is the same as 1984).* When a parking lot supports a single PES, it may be separated at less than intraline only from its associated facility. A minimum distance of 100 feet is required to the associated facility to protect it from vehicle fires. Access for emergency vehicles must be provided.
- Construction personnel who must, on a temporary basis, be near PESs to perform their job shall be provided the maximum practicable protection *(as opposed to K18 in 1984)* from the effects of an explosion should one occur at a PES.

**1997 DoD 6055.9-STD**

Same as 1992 DoD 6055.9-STD with the following changes:

- Locate burning grounds at intraline distance from other PESs.
- Control sites for ammunition and explosives destruction, demonstration, and EOD operations must be at intraline distance from other PESs based on the PES NEW.
- The 1997 standard removes the intraline QD requirements between combat aircraft loaded with munitions and related facilities provided the munitions are one of the three types shown below.
  a. Hazard Division (04) 1.2 – gun ammunition, 30 mm or less.
  b. Hazard Division 1.3 – tactical missiles or pyrotechnics.

c. Hazard Division 1.4 – munition.

**1999 DoD 6055.9-STD, Oct 2004 DoD 6055.9-STD, Feb 2008 DoD 6055.09-STD, Change 1 (March 2009) to Feb 2008 DoD 6055.09-STD**

No changes to ILD permissible exposures.

**Change 2 (Aug 2009) to Feb 2008 DoD 6055.09-STD**

Same as 1997 DoD 6055.9-STD with the following changes:

- *Parking lots for privately owned automobiles belonging to the personnel employed at or stationed at the PES. When a parking lot supports a single PES, it may be separated at less than intraline only from its associated facility. A minimum distance of 100 feet is required to the associated facility to protect it from vehicle fires. Access for emergency vehicles must be provided.* The minimum distance may be reduced from 100 ft to 50 ft if the PES is of non-combustible construction, a barrier sufficient to prevent the vehicle from rolling within 50 ft [15.2m] of the PES is located between the POV parking spaces and the PES, and the DoD Component has assessed the risk from debris (i.e., bumpers) projected directly toward the PES and implemented any required controls.
- A HAS used solely as a maintenance facility would normally be classified as a related facility and would require ILD separation from a supported PES. As an ES, a First, Second, or Third Generation Maintenance HAS will provide K30 equivalent protection at the reduced distances shown in Table C9.T26 with doors properly secured. If Table C9.T26 is not applied for aircraft survivability, then at a minimum, ILD equivalent protection will be provided to personnel within the maintenance HAS.
- Clarification added to the provisions for detached loading docks - when loading docks servicing operating buildings are separated from the operating buildings which they serve by ILD, the distance is based only on the explosives limit of the loading dock, not the operating building.
- Within Chapter 16, Section 16.3 has been added providing standards for collected material potentially presenting an explosive hazard (MPPEH). Locations used to collect MPPEH processing operations (e.g., consolidation, inspection, sorting, storage, transfer, release) must be sited per Chapter 9. Specifically, when sited as an ES, this material must not be sited a distances less than intraline distance from the surround PES.

## INTRALINE DISTANCE VALUES

**1925 New Jersey State Law, 1926 IME Pamphlet No. 3, 1928 US House Document 199, 1931 Ordnance Safety Manual, 1941 Ordnance Safety Manual, 1945 Ordnance Safety Manual, 1951 Ordnance Safety Manual, 1961 Ordnance Safety Manual**

Table(s) of required distances given.

**1956 DoD Directive 4145.17, 1966 DoD Instruction 4145.23**

The intraline separations are approximately those obtained from the formulas:

- Barricaded buildings and structures – $D = 9W^{1/3}$
- Unbarricaded buildings and structures – $D = 18W^{1/3}$

**1968 DoD Contractors' Safety Manual 4145.26-M, 1969 DoD Manual 4145.27-M**

ILD for Class 1 (high fire hazard, no blast hazard, very little fragmentation hazard) explosives is 100 feet.

ILD for Class 2 explosives (defined as vigorously burning with no propagating shock waves) is equivalent to magazine distance at $5W^{1/3}$.

ILD for Class 3: a value of 200 feet is specified which may not be reduced based on the presence of barricades.

ILD for Class 4: provide distances as specified in Table 7D which are approximately equivalent to $9W^{1/3}$ for barricaded values and $18W^{1/3}$ for unbarricaded values up to a maximum of 400 feet.
ILD for Class 5: provide distances as specified in Table 7D which are approximately equivalent to $9W^{1/3}$ for barricaded values and $18W^{1/3}$ for unbarricaded values up to a maximum of 600 feet.

ILD for Class 6: provide distances as specified in Table 7D which are approximately equivalent to $9W^{1/3}$ for barricaded values and $18W^{1/3}$ for unbarricaded values.

Class 7 explosives represent the mass-detonating or high explosives. For these types of explosives, intraline distance is specified in Table 7D. These table values are approximately equivalent to $9W^{1/3}$ for barricaded values and $18W^{1/3}$ for unbarricaded values.

Additionally, tables are provided for separation distances from liquid propellants

**1974 DoD 5154.4S**

ILD for Class 1 (fire hazard only) was stated as being the "appropriate fire protection distance" but was not permitted to be less than 100 feet for regular construction or 80 feet for fire-resistive construction.

ILD for Class 2 explosives (vigorously burning with no propagating shock waves) intraline distance is equivalent to magazine distance at $5W^{1/3}$.

ILD for Classes 3 through 5 explosives (combined hazards) the values specified are equivalent to the ILD values provided in Table 5-6.3 (K9 and K18 values) up to maximum values of 200, 400, and 600 feet, respectively.

Class 6 and Class 7 explosives required the application of Table 5-6.3 (K9 and K18 values).

Values are also provided for intraline distance for propellants in chapter 8.

**1976 DoD 5154.4S, 1978 DoD 5154.4S**

ILD for Class 1, Division 1 explosives, intraline distance is defined as previously defined for Class 7 explosives as being equivalent to $9W^{1/3}$ for barricaded values and $18W^{1/3}$ for unbarricaded values.

ILD for Class 1, Division 2 explosives four categories exist: Category 04, Category 08, Category 12, and Category 18. Intraline distances for 1.2 explosives in Categories 04-12 are the same as those previously defined for Classes 3 through 5. These values are the K9 and K18 values up to maximums of 200, 400, and 600 feet for Category 04, 08, and 12 respectively. Intraline distances in Category 18 are equivalent to K9 and K18 with no specified maximum.

ILD for Class 1, Division 3 explosives, intraline distance is defined as previously defined for Class 2 explosives or equivalent to magazine distance of $5W^{1/3}$.

ILD for Class 1, Division 4 explosives, intraline distance is defined as previously defined for Class 1 explosives as the appropriate fire protection distance.

**1984 DoD 6055.9-STD**

ILD for Class 1.1 explosives are equivalent to values determined by the equation $D=KW^{1/3}$ where K equals 9 and 18 for barricaded intraline and unbarricaded intraline respectively.

ILD for Class 1.2 explosives are as shown in Table 7.1.4.

Table 7.1.4 – Class 1.2 Intraline Distances as specified in 1984 DoD 6055.9-STD

| **Class 1, Division 2 Category** | **Standard Intraline Distance[1] (feet)** | **Intraline Distance (feet) NEW ≤ 5,000 lbs** |
|---|---|---|
| 04 | 200 | 200 |
| 08 | 400 | 200 |
| 12 | 600 | 200 |
| 18 | 900 | 900 |

Notes: [1] Standard intraline distances allow Any NEW for Categories 04 and 08. Standard intraline distances allow up to 500,000 lbs for Categories 12 & 18.

ILD for Class 1.3 explosives are equivalent to aboveground magazine distances at $D=5W^{1/3}$.

There are no ILD requirements for limited quantities of Class 1.4 items and larger quantities (no upper limit) require 50 feet of 100 feet if combustible construction is present.

**1992 DoD 6055.9-STD, 1997 DoD 6055.9-STD, 1999 DoD 6055.9-STD**

Same as 1984 DoD 6055.9-STD with the following two changes:

Changes from the K9 and K18 distances to account for attenuation/focusing effects of Earth Covered Magazines (ECM) (see Table 7.2.4).

Table 7.2.4 – K-Value Adjustments for Earth Covered Magazine Intraline Distances in 1992 DoD 6055.9-STD C9.C.1.c

| Exposure | NEW Range (lbs) | Vice K9 | Vice K18 |
|---|---|---|---|
| Front | 1-300,000 | 10 | 18 |
| | 300,000-500,000 | 10-9 | 18 |
| Side | 1-300,000 | 7 | 16 |
| | 300,000-400,000 | 7-9 | 16-18 |
| | Over 400,000 | 9 | 18 |
| Rear | 1-100,000 | 6 | 12 |
| | 100,000-300,000 | 6 | 12-14 |
| | 300,000-400,000 | 6-9 | 14-18 |
| | Over 400,000 | 9 | 18 |

Addition of HD 1.6 resulted in Q-D distance requirements for new Hazard Division. ILD for HD 1.6 is equivalent to aboveground magazine distances of K5.

**Oct 2004 DoD 6055.9-STD**

No changes from 1999 DoD 6055.9-STD.

**Feb 2008 DoD 6055.09-STD, Change 1 (March 2009) to Feb 2008 DoD 6055.09-STD**

No changes to ILD distances.

**Change 2 (Aug 2009) to Feb 2008 DoD 6055.09-STD**

Intraline Distance for HD 1.4 explosives changed slightly within Change 2 to the February 2008 edition of the DoD 6055.09-STD. Within the notes for Table C9.T14, a statement has been added stating that ILD is 0 feet from the sides and rear of an ECM, from an AGS (H), an AGS (H/R), and an ECM front that meets the definition of AGS (H)

# THE HISTORY OF INTRALINE DISTANCE IN THE US

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US Army Corps of Engineers
**BUILDING STRONG®**

# Purpose of Study

- Misunderstanding of intention of Intraline Distance (ILD)
  - Army noticed a prevalent belief that ILD protects personnel
  - Original and current definition are similar
  - Explosives Safety experts do not agree whether or not ILD is intended to protect personnel.
- Application and understanding of intraline distance varies greatly from definition
  - Definition of Intraline Distance in current DoD 6055.09-STD

  *"the distance to be maintained between any two [Ammunition and Explosives] AE-related buildings or sites within an AE related operating line."*

  - However, many other sites may now be located at intraline distance
- **Goals of the Study**
  - **Discover origins of ILD (including original purpose)**
  - **Explain progression of intraline from first use to its current state**

# Early Explosives Safety History

- 1909 – Manufacturers of Powder and High Explosives of the US (forerunner of IME) recognized need for standards
  - Separation between explosives and property of railways
  - Col. B.W. Dunn requested a conference of Manufacturers to discuss
- 1909 – Conference to discuss explosives storage
  - Only authoritative guidance was a British Government Regulation (deemed unverifiable)
  - Committee appointed to develop a table of distance to provide “reasonable protection”
- 1910 – First American Table of Distances (ATD) published following a study of over 200 explosions (updates in 1913, 1914, and 1919)

# Origins of Intraline Distance

- 1917 – First known use of intra-plant distances
  - January IME Meeting Minutes: the special committee on intra-plant's intention is to protect workers by preventing "serious injuries" and preventing propagation.
- 1924 –Intra-plant distance tables agreed upon and provided to State of New Jersey (January 1925)
- 1925 - New Jersey Law
  - Based largely on the ATD
  - First confirmed use of ILD (Intra-plant Distance) in a standard
  - Values in law are not very different from ILD values of today
  - Intraplant – distance required between:
    - all factory buildings on an explosives plant,
    - factory buildings on an explosive plant and other buildings on the plant in which people were regularly employed, and
    - between magazines and factory buildings and buildings on explosives plants in which people are regularly employed.

# Origins of Intraline Distance

- 1927 - Secretaries of War and Navy directed by Congress to prepare a report on ammunition storage conditions
  - Response to Lake Denmark explosion of 1926
  - Secretaries assigned a Joint Board on Ammunition to prepare the report
  - Board recommended 1925 New Jersey Law be enacted for use on government facilities
- 1928 – House Doc 199 of 70th Congress
  - Adopted New Jersey Law for US Government Use
  - Intra-plant became a national standard
  - Extended the charter of the Joint Board on Ammunition, renaming it the Joint Army-Navy Ammunition Storage Board (JANASB) which would later become the Department of Defense Explosives Safety Board (DDESB)

# Changes from Original Standards

- 1929-1944: New Jersey Law and ATD remained basis for explosives safety criteria
  - Army published several standards under the title *Ordnance Safety Manual*
    - Restated and clarified the 1925 New Jersey Law
    - Suspect that the Navy published similar documents, but none were located during the study
- 1945 *Ordnance Safety Manual*
  - First use of term “intraline” to separate “processes accomplished within one operating line“
  - First stated expected effects:
    - “protect buildings within an operating line from propagation of explosion due to blast effects, but not against the possibility of propagation due to missiles”
    - “adjacent buildings in an operating line will have an even chance of substantial structural damage”
  - ILD permitted for use when
    - Hazards required dividing an operating line into separate buildings
    - Service magazine needed to be near an operating building it served.

# Changes from Original Standards

- 1945-1950 – Officials suggested modifications to standards
  - Concern
    - Tables based on detonations primarily involving black powder
    - More potent explosives developed since table was published
  - Explosions were re-evaluated
  - Recommendation – use K factor
- 1950's – First standards to be used by all DoD services (DoD 4145.17)
  - ILD = $9W^{1/3}$ (barricaded) or $18W^{1/3}$ (unbarricaded)
  - Expected effects:
    - high level of protection against propagation
    - no protection against loss of life, severe injury, building collapse, or from flying debris
- 1960's and 1970's – A few new exposures
  - Tactical facilities of multiple Services
  - some waterfront utility facilities
  - Areas within airfields, heliports, and seadromes (and expected effects for these areas)
  - POV parking areas
  - security personnel
  - unmanned utility facilities

# Changes from Original Standards

- 1984 DoD 6055.9-STD – A new look for the standard
  - ILD redefined as “the separation distance required between explosives and non-explosives buildings and sites within an explosives operating line”
  - Definitions, K-values, and overpressures are combined
  - New “bulletized” look
    - Listed expected effects explicitly for a variety of facility types
    - Explicitly listed permissible exposures at various QD
- 1990s - Present – Very few significant changes
  - Minor revisions and clarifications
  - Major changes to exposures provided ILD protection included:
    - Burning grounds and control sites for EOD operations
    - Locations for collecting material potentially presenting an explosive hazard (MPPEH)
    - Personnel within a HAS used as maintenance facility if K30 protection is not provided

# Perceptions of Intraline Distance

- The Original Intention???
  - Early IME meeting minutes - intra-plant distance was intended to protect personnel from serious injury and prevent propagation
  - Without further research we cannot know to what extent personnel protection was intended
  - Early standards provide no statement of purpose or expected effects
- Mid-Century Beliefs
  - By 1945 standard writers felt primary purpose of intraline distance was to prevent propagation
  - 1950 standard – intraline provided a high degree of protection against propagation but no protection from fatalities, serious injuries, building collapse, or flying glass

# Perceptions of Intraline Distance

- Moving Toward Current Standards
  - 1974 standard - direct injury possible by pressure or translation
  - 1984 - Present – bulletized list of effects
    - Serious injuries are likely
    - Fatalities unlikely in open
      - Pressures too low for lung rupture
      - 1% probability of eardrum rupture
- Current Perceptions are Polarizing

# Perceptions of Intraline Distance

- Validity of Personnel Protection Concept
  - ► Some level of protection is provided
    - Increased distance from the detonation
    - Is this protection intentional or a secondary effect?
  - ► Fatal injuries are unlikely in open
    - Pressure too small for lung rupture
    - 1% probability of eardrum rupture
  - ► Fragmentation Requirement
    - Not in current standards
    - Personnel protection theory would mandate this
- Best guess - Intraline distance is intended to prevent propagation (as stated since 1945)

# Perceptions of Intraline Distance

- How did these perceptions develop?
  - DoD missions expanded
  - Standards became much longer / more complex
  - Site planners are mission focused
- Are we asking the right questions?
  - Probably not
  - Ask not how we are protecting personnel but should we be protecting personnel

# Conclusions Questions & Recommendations

- Conclusions
  - Again, best guess is that ILD was intended to prevent propagation (but it is a guess)
  - Thus far, study resulted in more questions than answers
  - Until we find the answers we should...
    - Focus on actual words in standards
    - Systemically evaluate whether or not personnel protection *should* be provided at Intraline Distance
    - Write standards which are clear and concise.
    - Professionally challenge incorrect assumptions and assertions

# Conclusions Questions & Recommendations

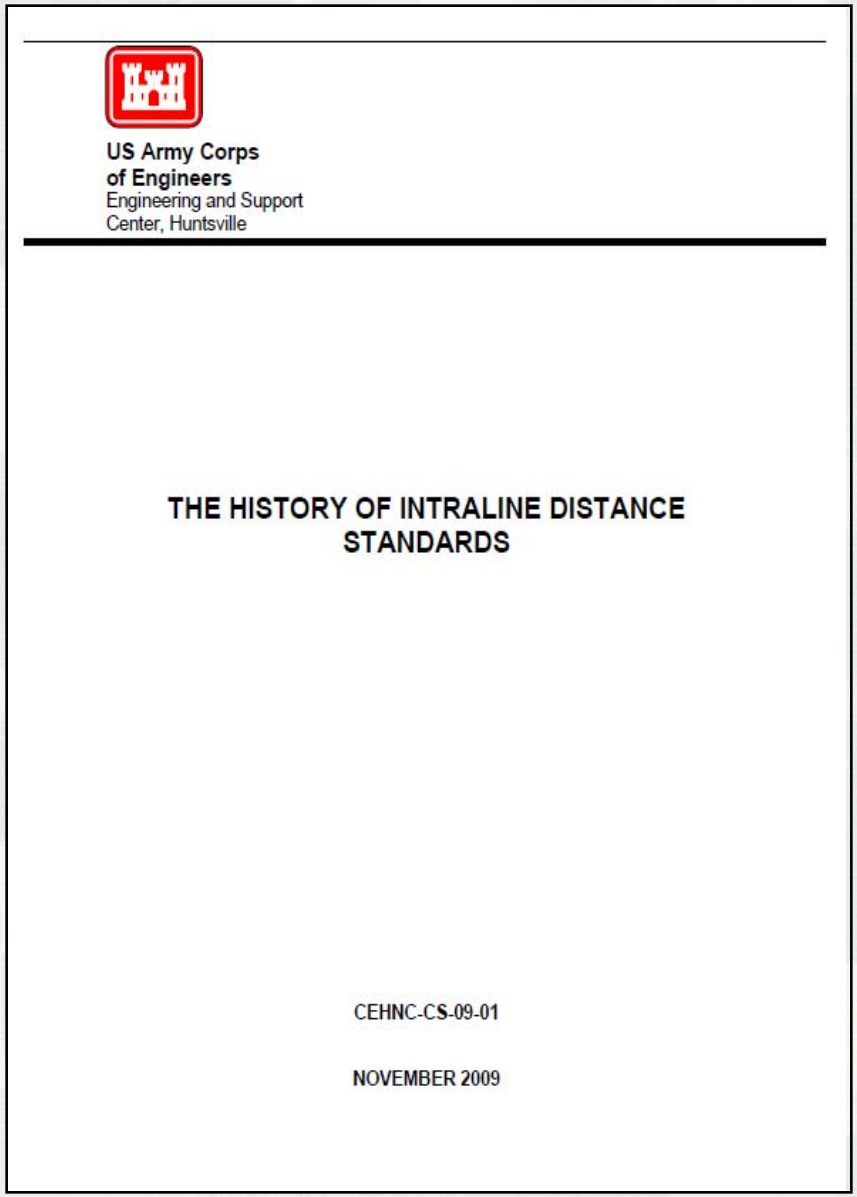
- Questions, Questions, & More Questions
  - What was original basis for intraline?
  - What was the original intention of intraline?
  - Have we moved away from the original intention? If so, why?
  - Why were so many exposures added and on what basis?
- Can these questions be answered?
  - IME meeting minutes
  - DDESB Board minutes

# Conclusions Questions & Recommendations

- Recommendations for Continued Work
  - Digitize historical IME minutes
  - Organize and catalog historical DDESB minutes
  - Search historical minutes and other documentation to gather the why's for each change and the origins / basis of intraline
  - Develop a formal report to compile data gathered
  - Repeat the study for IBD, PTRD, IMD, etc.

# Our Sincere Thanks Goes To…

- Lon Santis and the Institute of Makers of Explosives (IME)
- US Army Technical Center of Explosives Safety (USATCES)
- Department of Defense Explosives Safety Board (DDESB)




# Questions???

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# Items Reviewed for Study

- Attempted to gather the preeminent explosive safety standard of the time for all explosives safety standards in the US
  - 1910 – first explosives safety standards developed, very simple tables for all scenarios
  - Present – many standards for various uses, complex standards based on specific ES-PS combinations
- Became necessary to omit certain documents to focus the study

# Intraline Definition

- 1925 New Jersey Law:  Intra-plant Quantity and Distance Table – All factory buildings shall be located one from the other and from other buildings on explosives plants in which persons are regularly employed and all magazines shall be located from factory buildings and buildings on explosives plants in which persons are regularly employed in conformity with the Intra-Explosives Plant Quantity Distance Table
- Current:  The distance to be maintained between any two AE-related buildings or sites within an AE related operating line.

# Intraline Distance Values

## 1925 New Jersey Law

- Table values roughly approximate K18 values
- Values may be halved when barricades exist

| EXPLOSIVES | | DISTANCE |
|---|---|---|
| Pounds Over | Pounds Not Over | Feet Separate building or within substantial dividing walls |
| .... | 10 | 40 |
| 10 | 25 | 60 |
| 25 | 50 | 80 |
| 50 | 100 | 100 |
| 100 | 200 | 120 |
| 200 | 300 | 130 |
| 300 | 400 | 140 |
| 400 | 500 | 160 |
| 500 | 750 | 180 |
| 750 | 1,000 | 210 |
| 1,000 | 1,500 | 230 |
| 1,500 | 2,000 | 260 |
| 2,000 | 3,000 | 280 |
| 3,000 | 4,000 | 300 |
| 4,000 | 5,000 | 320 |
| 5,000 | 6,000 | 340 |
| 6,000 | 7,000 | 360 |
| 7,000 | 8,000 | 380 |
| 8,000 | 9,000 | 400 |
| 9,000 | 10,000 | 420 |
| 10,000 | 12,500 | 450 |
| 12,500 | 15,000 | 470 |
| 15,000 | 17,500 | 490 |
| 17,500 | 20,000 | 530 |
| 20,000 | 25,000 | 560 |
| 25,000 | 30,000 | 590 |
| 30,000 | 35,000 | 620 |
| 35,000 | 40,000 | 640 |
| 40,000 | 45,000 | 660 |
| 45,000 | 50,000 | 680 |
| 50,000 | 55,000 | 700 |
| 55,000 | 60,000 | 720 |
| 60,000 | 65,000 | 740 |
| 65,000 | 70,000 | 770 |
| 70,000 | 75,000 | 780 |
| 75,000 | 80,000 | 790 |
| 80,000 | 85,000 | 800 |
| 85,000 | 90,000 | 820 |
| 90,000 | 95,000 | 830 |
| 95,000 | 100,000 | 900 |
| 100,000 | 125,000 | 950 |
| 125,000 | 150,000 | 1,000 |
| 150,000 | 175,000 | 1,050 |
| 175,000 | 200,000 | 1,100 |
| 200,000 | 225,000 | 1,150 |
| 225,000 | 250,000 | |

# Intraline Distance Values

- Approx 1984 – Present DoD 6055.09-STD
  - ► Intraline Distance is equivalent to…
    - Class 1.1 – ILD=$18W^{1/3}$ (unbarricaded intraline)
    - Class 1.2

| Class 1, Division 2 Category | Standard Intraline Distance[1] (feet) | Intraline Distance (feet) NEW ≤ 5,000 lbs |
|---|---|---|
| 04 | 200 | 200 |
| 08 | 400 | 200 |
| 12 | 600 | 200 |
| 18 | 900 | 900 |

Notes: [1] Standard intraline distances allow Any NEW for Categories 04 and 08. Standard intraline distances allow up to 500,000 lbs for Categories 12 & 18.

    - ILD for Class 1.3 explosives are equivalent to aboveground magazine distances at D=5W1/3.
    - There are no ILD requirements for limited quantities of Class 1.4 items and larger quantities (no upper limit) require 50 feet of 100 feet if combustible construction is present.

Note: There are many tables with many footnotes in addition to these requirements

# Intraline Permissible Exposures

- 1925 New Jersey Law (ILD used to separate)
  - Factory buildings from factory buildings
  - Factory buildings from other buildings on explosives plants in which persons are regularly employed
  - All magazines from factory buildings
  - All magazines from buildings on explosives plants in which persons are regularly employed

# Intraline Permissible Exposures

Note: this list is not all encompassing

- Approx 1984 – Present DoD 6055.09-STD
  - Permissible Exposures (first bulletized format in 1984)
    - Construction personnel who must, on a temporary basis, be near PES to perform their job shall be provided the maximum practicable protection *(K18 in 1984)* from the effects of an explosion should one occur at a PES.
    - Surveillance, maintenance, and inspection buildings and labor intensive operations closely related to the PES.
    - Comfort, safety, and convenience occupied buildings exclusively in support of the PES
    - Parallel operating lines from one another, whether or not barricaded, provided AE involved in each operating line present similar hazards.
    - Operations and training functions manned or attended exclusively by personnel of the unit operating the PES.
    - Maintenance of military vehicles and equipment when the PES is basic load or ready storage located outside the continental United States (OCONUS) areas, and is limited to 4000 kg Auxiliary power and utilities functions.
    - Minimum distance between separate groups of explosives loaded combat-configured aircraft or between aircraft and a pre-load or "quick-turn" site that serves to arm the aircraft.
    - Parking lots for privately owned automobiles belonging to the personnel employed at or stationed at the PES**.**
    - Service-magazines that are part of operating lines.
    - Container stuffing and unstuffing operations that are routine support of PES.
    - Between explosives-loaded combat aircraft and those non-explosives facilities that directly support the servicing and launching of a unit's armed aircraft
    - Locate burning grounds at intraline distance from other PES.
    - Control sites for ammunition and explosives destruction, demonstration, and EOD operations must be at intraline distance from other PES based on the PES NEW.