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NEW DoD QUALITY ASSURANCE PRACTICES

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August 1994

Prepared for
Office of the Assistant Secretary of Defense for Economic Security

INSTITUTE FOR DEFENSE ANALYSES
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Contract MDA 903 89 C 0003
Task T-B6-946

PREFACE

The work reported in this document was performed for the Office of Industrial Engineering and Quality within the Production Resources Office in the Office of the Assistant Secretary of Defense for Economic Security under the technical cognizance of the Armament Research, Development, and Engineering Center at Picatinny Arsenal, NJ, Quality Assurance Directorate under Contract MDA 903-89C-0003. The objective of the task, *Government-Industry Standardization of Product Acceptance Based on Process Data*, was to help devise a new Department of Defense (DoD) approach to quality assurance practices, including the development of a standard acceptable to both DoD and industry to move DoD away from accepting product by end-item inspection to accepting product based on the contractor's quality system and use of process controls.

Reviewers of this report were Mr. Chris Jehn and Dr. David Graham of the Strategy, Forces and Resources Division of the Institute for Defense Analyses (IDA), and Dr. Donald Ermer, Professor of Mechanical and Industrial Engineering at the University of Wisconsin-Madison and holder of the first Proctor and Gamble Bascom Professorship in Total Quality.

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EXECUTIVE SUMMARY

Under increasing pressure to change its way of doing business and adopt commercial products, practices, specifications, and standards, DoD approached the Institute for Defense Analyses (IDA) to conduct a study that would ultimately lead to new quality assurance practices for Defense. IDA was approached because of its vast previous experience with concurrent engineering and quality management practices within industry and the Government. The subject was controversial because of high Congressional visibility and a public perception, based on sampling inspection standards still in place, that DoD was willing to accept defective product. Objectivity and independence were required to develop a new standard practice that both DoD and industry would be comfortable with.

IDA set out to analyze the best commercial practices, specifications, and standards and prepare a draft of a new standard that provided a replacement for the current sampling inspection standards, required manufacturing process and statistical process controls for the most critical characteristics of the product, and provided an incentive to all producers to use effective quality practices. IDA enlisted the help of recognized acceptance sampling and quality assurance experts. Dr. Edward G. Schilling, a professor at the Rochester Institute of Technology and author of numerous books on acceptance sampling, and Mr. Seymour J. Lorber, retired Deputy Chief of Concurrent Engineering for Army Materiel Command (AMC), were hired as consultants. IDA also worked with a recognized industry association Statistical Process Control (SPC) committee with industry, academia, and DoD participants to develop the standard and get it accepted.

In addition to developing the standard, IDA recommended changes to DoD quality assurance practices in general throughout the course of the study. In particular, IDA recommended that DoD not only authorize use of the International Organization of Sandards, ISO 9001, *Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation, and Servicing*, but aggressively plan for its full adoption over a reasonable period of time. With this authorization, IDA recommended that DoD not endorse or require certification by a third independent party. This restriction would not prevent the contractor from using consultants or other services to implement a quality program. With regard to this recommendation, it is noted that OSD, on

14 February 1994, authorized the use of the ISO 9000 and its American National Standards Institute/American Society of Quality Control, ANSI/ASQC Q90, series of quality standards for new programs and as appropriate for ongoing programs.[1]

A. RECOMMENDATIONS TO IMPROVE DEFENSE QUALITY ASSURANCE ACTIVITIES

Efforts by DoD during the past several years to improve its acquisition quality assurance operation have resulted in many significant improvements. In the interest of further improvement, IDA recommends that DoD continue to increase procurement of commercial products, reduce government oversight of contractors, utilize commercial specifications and standards wherever possible, strive for the prevention of defects by the implementation of integrated product and process development (IPPD), and accommodate dual-use, commercial/military integration in production lines. Specifically, IDA recommends the following:

- Replace MIL-STD-105, *Sampling Procedures and Tables for Inspection by Attributes*, with its commercial equivalent, ANSI/ASQC Z1.4-1993.
- Continue to use ANSI/ASQC Z1.4 plans for products that are of relatively simple design, described by standard Technical Data, and for which experience has demonstrated no problems.
- Replace MIL-STD-414, *Sampling Procedures and Tables for Inspection by Variables for Percent Defective,* with its commercial equivalent, ANSI/ASQC Z1.9-1993.
- Request ASQC to develop an ANSI/ASQC standard to replace MIL-STD-1235 and cancel MIL-STD-1235.
- Replace MIL-I-45208, *Inspection System Requirements* with the new draft standard, *DoD Preferred Methods for Acceptance of Product* (Appendix D to this paper).

B. RELATED ACTIVITIES IN DOD

While this effort was initiated in 1991, it has dovetailed with recommendations in two recent activities. The joint Military and National Aeronautical and Space Administration (NASA) Handbook, *Interim Guidance on the Application of ISO*

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[1] John Deutch, Under Secretary of Defense, Memorandum for Secretaries of the Military Departments, Directors of Defense Agencies, *Use of Commercial Standards in the Department of Defense (DoD),* 14 February 1994.

9000/ASQC Q90 Series Quality Systems in Standards, was issued on 4 February 1994. Its purpose is "to assist contracting activities that have decided to use Q91 or Q92 quality system standards with domestic contracts and seek guidance for doing so."

In April 1994, the *Report of the Process Action Team on Military Specifications and Standards* was also issued. It makes recommendations for a process focus, AQL elimination, and reduced contractor inspection and test. Specifically, under *Oversight*, the report recommends two specific tasks related to the draft standard and the recommendations in this paper:

- "Deputy Secretary of Defense issues a policy memorandum emphasizing greater use of process controls in lieu of development and production testing and inspection."[2]
- "Develop a priority action list of military specifications containing fixed allowable defect level measures such as acceptable quality levels or lot tolerance percent defect. Initiate action to eliminate requirements for these defect measures."[3]

And under *Contractor Test and Inspection*, the report states: "The contractor shall certify to the government that the item or items offered for acceptance and delivery satisfy the requirements of the specifications through process controls and inspections."[4]

The draft standard in Appendix D fits with these two recent activities and should be approved as a military or commercial standard with the recommended elimination of the other documents listed in Section A.

C. SUMMARY OF RECOMMENDATIONS

1. Sampling Inspection Requirements

- Cancel MIL-STD-105, MIL-STD-414 and MIL-STD-1235, *Single- and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes, Functional Curves of the Continuous Sampling Plans.*
- Use ANSI standards equivalent with canceled standards.
- Urge ASQC to prepare an ANSI standard to replace MIL-STD-1235.

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2 *Report of the Process Action Team on Military Specifications and Standards*, Office of the Under Secretary of Defense for Acquisition and Technology, April 1994, p. 100.

3 Ibid.

4 Ibid, p. 107.

2. Quality Management Standards

- Implement aggressive efforts to replace MIL-Q-9858 with ANSI/ASQC Q91.
- Replace MIL-I-45208 with a new standard, *DoD Preferred Methods for Acceptance of Product* (Appendix D to this report).

D. "DEFECT ANTICIPATION" FOLLOW-ON EFFORT

This study had as its focus the encouragement of improvements in defect prevention and process control as a means for improved quality in DoD. To make truly significant quality (both performance and cost effectiveness) gains, the challenge is for DoD to develop *defect anticipation* practices. These are efforts that influence the product designs to improve their robustness and tolerance to the vagaries of the production floor as well as the battlefield environment. When defect anticipation and variability reduction come together, the prospects of *Process Based Acceptance* may become real.

I. CHANGING INDUSTRIAL ENVIRONMENT

The new national security environment embodies elements that previously were absent. It now includes national *economic* security that functions within an integrated, commercial/military national industrial base. This new mission for the Department of Defense (DoD) and the austere budget constraints it faces lead to the need for high quality products at an affordable cost utilizing best commercial products, facilities, and practices, including commercial specifications and standards. This paper addresses the Quality Assurance function of DoD in this new environment, and this first chapter discusses the changing commercial industrial environment with which DoD practices will be contrasted.

A. PRIOR TO 1980s: QUALITY BY INSPECTION

Products that are mass produced are manufactured by "lots." A lot is a specified homogeneous collection of production runs or shifts on a single line. Inspection is the process by which characteristics of the product coming off the line (end items) are inspected for conformance to the product's specification. Inspection can encompass 100 percent of the items or a random sample of the lot—a less costly process incurring some calculated risk. The latter process, called sampling inspection, is based on standards that are indexed by the amount of tolerable risk as dictated by Acceptable Quality Levels (AQLs) and Lot Tolerance Percent Defectives (LTPDs). Sampling plans include the lot size with related sample size and the accept/reject criteria. End items can be inspected by *attributes*, for which either a *go* or *no go* decision is made often by simple gages (e.g., the outer diameter of a bolt), or by *variables*, for which a precise measurement is taken of the characteristic that has to be within a certain tolerance of the product specification (e.g., thread width).

Prior to World War II, during the 1920s and 1930s, the general industry practice was 100 percent inspection of a lot or of some sample of the lot (e.g., 10 percent). Western Electric introduced the Dodge-Romig inspection sampling plans for internal use in the 1920s. These plans provided single or double sampling tables categorized to achieve (1) minimum inspection labor or (2) a limit on the amount of defective product.

After World War II, industry applied inspection sampling extensively as a result of war time experience and the efforts of the new American Society for Quality Control (ASQC). The Dodge-Romig attributes sampling tables for lot-by-lot inspection were made commercially available in 1959.[1] Many companies used MIL-STD-105, *Sampling Procedures and Tables for Inspection by Attributes*, which was first published as MIL-STD-105A in 1950. The commercial equivalent to MIL-STD-105D (1963) was issued as American National Standards Institute/American Society for Quality Control (ANSI/ASQC) Z1.4 in 1981. MIL-STD-414, *Sampling Procedures and Tables for Inspection By Variables for Percent Defective*, was first published in 1957, with its commercial equivalent, ANSI/ASQC Z1.9, in 1980. Many companies devised their own versions of the published plans. The aircraft industry employed 100 percent inspection because of its stringent safety requirements.

B. MID-1980s: U.S. DISCOVERS DEMING

During the mid 1980s, U.S. industry was in an upheaval. U.S. producers who complacently held the market share for so long were now starting to lose market share to the Japanese. U.S. manufacturers could no longer afford the expensive scrap and rework necessary to achieve a certain level of quality when Japanese manufacturers were eliminating scrap and rework and achieving a higher level of quality. Television shows engrossed viewers with titles like *Japan Can, Why Not America*? This crisis forced senior management to embrace the "Deming" approach and become fully aware of the Total Quality Management (TQM) philosophy, including improved customer and supplier relationships and a focus on continuous improvement and control of the processes through statistical process control (SPC). The leaders in the quality movement, Philip B. Crosby and Dr. W. Edwards Deming,[2] were in great demand as speakers both for television shows and in workshops and seminars across the nation. Many companies devised their own quality programs, such as Motorola's 6 Sigma approach, Ford's Quality First (Q101), and Boeing's D1-9000. Quality management and process controls—a focus on prevention and improvement—were being recognized worldwide for the competitive advantage they offered. Instead of "inspecting quality in" after production, resulting in rework and scrap

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1 H.F. Dodge. and H.G. Romig, *Sampling Inspection Tables*, 2nd. ed., John Wiley and Sons, New York, 1959.

2 Philip B. Crosby, *Quality is Free*, 1979; W. Edwards Deming, *Out of the Crisis*, MIT, 1982.

and the additional costs they entail, process controls aim to minimize scrap and rework by the *prevention* of defects.

During the latter part of the 1980s, the International Organization of Standards (ISO), ANSI, and the ASQC were in final coordination with the ISO 9000 series of Quality System Standards and Guidelines, as follows:

- 9000: *Quality Management and Quality Assurance Standards—Guidelines for Selection and Use*
- 9001: *Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation and Servicing*
- 9002: *Quality Systems—Model for Quality Assurance in Production and Installation*
- 9003: *Quality Systems—Model for Quality Assurance in Final Inspection and Test*
- 9004: *Quality Management and Quality System Elements—Guidelines*

The ANSI/ASQC Q90 series of documents (Q90, Q91, Q92, Q93, Q94) are the U.S. equivalents of the ISO series. Commercial application of the ISO 9000 series began expanding in the United States and the world. Industry was voluntarily changing its approach to quality by using ISO 9001 or ISO 9002 as the model for operations. The European Community (EC) announced it would require an ISO 9000 series Quality System in any company it did business with. Industry recognized that prevention was a means to control cost as well as to meet the requirements of major customers.

C. 1990s: HIGH QUALITY AT LOWER COST BEING ACHIEVED THROUGH NEW MANAGEMENT PRACTICES

Into the 1990s commercial industry continued its trend toward using TQM principles, and the defense industry followed. In 1992, the prestigious Malcolm Baldrige National Quality Award went to the Defense Systems and Electronics Group at Texas Instruments, Incorporated. DoD itself began pursuing such advanced quality concepts as quality in source selection; specification streamlining; leadership and management commitment; employee participation; quality improvement training and development; quality performance measurement and recognition; prevention-based quality, variability reduction, key supplier involvement; line-proofing; identification of key process characteristics; and manufacturing risk management.

DoD was beginning to see that the use of best commercial practices by defense contractors could improve quality and reduce costs—but not without many changes in the way DoD does business. Customer satisfaction and involvement resulting in a quality product meeting the user's needs at lower cost requires an Integrated Product and Process Development (IPPD) environment with close prime/subcontractor arrangements and a relationship of trust between the contractors and DoD.

II. PRESSURES FOR DOD TO CHANGE

A. HISTORY OF QUALITY ASSURANCE PRACTICES IN DOD

Defense acquisition quality assurance (QA) practices consist of three basic activities: Sampling Inspection Standards, Quality Management System Specifications, and Government Quality Assurance Oversight of Contractor Operations. The sections below describe the three current military sampling inspection standards, the two military specifications for a quality management system, and the DoD efforts to change the customer/supplier relationship.

1. Sampling Inspection Standards

Prior to World War II, in the 1920-1930 time frame, Government inspectors inspected 100 percent of military products for conformance with specification requirements and returned defective product to the producer for repair or replacement. Sampling inspection procedures were introduced in 1942, when the U.S. Army published sampling tables including single and double sampling plans indexed by Acceptable Quality Levels (AQLs). These tables—

- Considered AQLs to be the desired process average.
- Protected the producer from rejection of lots better than AQL.
- Imposed more stringent requirements when quality history was poor.
- Imposed more stringent criteria for serious defects.
- Provided economies when quality history was good.
- Set sample size requirements based on lot size.

By 1945, several similar plans were available. For example, the Navy had multiple sampling plans in *Tables and Procedures* by the Statistical Research Group. In 1950, MIL-STD-105A, *Sampling Procedures and Tables for Inspection by Attributes*, was published, and in 1963 it became an ABCA (America, Britain, Canada, and Australia) Standard. The initial benefits to the DoD of this approach during WW II included

improved quality of product received and a substantial reduction in the number of government inspectors required.

a. Military Inspection Engineering Activities, 1940s

The introduction of sampling during WW II required Army and Navy engineering activities to specify inspection standards and to classify the AQLs. Standard Inspection Procedures (SIPs) were developed in which product characteristics were defined and classified by their importance (Critical, Major, Minor). The SIPs provided standards for "good" or "bad," were not contractual, and were issued for the government inspectors to use. Special product training for government inspectors included sampling practices and use of inspection equipment. Inspection equipment was issued for the government inspectors as a means of performing government inspection.

b. Sampling Practices, 1950–1970

Within DoD, MIL-STD-105[1] and supporting sampling standards, such as MIL-STD-414, *Sampling Procedures and Tables for Inspection by Variables for Percent Defective*,[2] and MIL-STD-1235, *Single and Multi-Level Continuous Sampling Procedures for Inspection by Attributes, Functional Curves of the Continuous Sampling Plans*,[3] were used extensively. In the mid-1950s, an Instruction was issued to abolish the SIPs and instead include the classification of defects, the AQLs, and the required inspection equipment in Section 4 of the Item Specification. All inspection was to be performed by the contractor unless reserved for the exclusive action by the Government.

c. Technical Data Package

The Product Specification serves as the principal element of the Technical Data Package (TDP) and includes a Section 3, *Technical Requirements*, and Section 4, *Quality Assurance Requirements*. Section 3 of the Product Specification contains all product technical requirements including drawings and parts list, and excluding packaging, which is in Section 5. Section 4 of the Product Specification contains all the test, inspection, and examination requirements and the specification quality system requirements.

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1 First published as MIL-STD-105A in 1950.

2 First published in 1957.

3 MIL-STD-1235A published in 1974.

Since the 1950s, MIL-STD-105 has served as the basis for prescribing required product sampling and level of risk to be tolerated in defense Product Specifications. Based on specification language, the producer is required at a minimum: (1) to perform the sampling prescribed in the contract; (2) to take appropriate disposal action on the basis of the inspection results and the sampling plan accept/reject criteria; and (3) to submit the product that meets requirements together with the supporting inspection results to the government representative for acceptance purposes.

2. Quality Management System Specifications

Two military specifications, *Quality Program Requirements* and *Inspection System Requirements*, currently provide a two-tier system for the procuring activities to specify quality management system requirements.

The Air Force pioneered requirements for contractor quality program requirements during the early 1950s when it issued MIL-Q-5923 AF. These requirements were aimed at major contractors engaged in the development, production, and selected service tasks for aircraft and missile systems. Following the Air Force example, the other Services initiated similar requirements for their products of similar complexity. Finally, the OSD staff brought all parties together in the late 1950s to establish a coordinated approach: Military Specification MIL-Q-9858, *Quality Program Requirements*. The Air Force experience demonstrated that control of the engineering and production processes at the facilities of the prime contractors and subcontractors was necessary to assure delivery of acceptable product. The traditional practice of end item inspection simply would not provide sufficient evidence of a quality product.

As the requirement for a quality system was imposed by contract, many contractor senior managers in the defense industry believed it to be an unnecessary burden or an overhead cost that led to increased costs and, therefore, needed to be applied on a restricted basis. Allowable quality assurance costs were frequently set by negotiation between the contractor and Government. Independent surveys of military contractors to identify cost drivers or unnecessary requirements always included *Quality Program Requirements* high up on resulting survey reports. The extensive use of 100 percent inspection throughout the manufacturing operation due to the critical safety and high performance requirements for aircraft and missile products also held back the application of process controls and Statistical Quality Control (SQC) methods. While the application of *Quality Program Requirements* may not have been efficient, the resulting product performed as expected.

The other Military Specification, MIL-I-45208, *Inspection System Requirements*, originally prepared by the Army in the late 1950s, was intended as a simple quality system requirement for contractors producing product to a fully developed Technical Data Package. Design of the product was complete and no additional design was required. The product specification included full disclosure of the inspection and test required to determine product acceptability. Product engineering was not an element of the contract, and standard inspection procedures were available. *Inspection System Requirements* is less stringent than *Quality Program Requirements*. Very often it is the producer's first experience with a contract requirement for quality management.

3. Oversight of Contractor Quality Activities

As the U.S. commercial industry was changing in the mid-1980s, so too was the DoD. Total Quality Management (TQM) had an office in OSD, and each Service implemented its own version of TQM. Past performance started to become a selection factor, and one saw such programs as Exemplary Facility and Contractor Performance Certification Program $(CP)^2$. There was increased use of *Quality Program Requirements* and an effort to improve customer/supplier relations between the government and the contractor.

Defense Quality Assurance oversight essentially involves on-site government personnel performing quality surveillance or audits of the contractor's production activities related to contract requirements. The recent consolidation of all in-plant quality assurance oversight resources into the Defense Contract Management Command (DCMC) and the introduction of In-Plant Quality Evaluation (IQUE) practice provides for a modern and competent capability to meet the challenge in the next century. The IQUE system encourages the contractors to adopt modern quality practices and innovative means of preventing poor quality.

B. THE PROBLEM

Current DoD Sampling Inspection Standards include the following:

- MIL-STD-105E, *Sampling Procedures and Tables for Inspection by Attributes*, 10 May 1989.
- MIL-STD-414, *Sampling Procedures and Tables for Inspection by Variables for Percent Defective*, 11 June 1957.

- MIL-STD-1235C, *Single and Multi-Level Continuous Sampling Procedures for Inspection by Attributes, Functional Curves of the Continuous Sampling Plans*, 15 March 1988.

MIL-STD-105 is the primary document. It is employed worldwide by many nations and has extensive use in industry. However, its need was established on what is now 50-year-old production technology and techniques. There has been a significant change in defense products: They are more complex and costly, they contain a greater percentage of electronics, and they are produced on automated production lines with shorter lead time. The sampling plans in MIL-STD-105 are also based on AQLs, which are out of step with best commercial practices such as process controls, prevention objectives, continuous improvements, and parts' reliability of defect rates measured in parts per million.

Sampling plans indexed by AQLs often had accept/reject criteria that allowed acceptance of a lot if, say, three defects were found, and rejection on four defects. Over the years, the use of these plans led industry to believe that DoD would tolerate less than required performance and gave the public and Congress the perception that DoD would willingly accept and pay for defective product. The term *acceptable* quality level became onerous and led to tremendous activity in the past eight years on the issue of AQLs and the intent to eliminate them from specifications (Table II-1).[4] The Office of the Secretary of Defense (OSD), in June 1987, directed the removal of AQL and Lot Tolerance Percent Defective (LTPD) criteria from military specifications while continuing to use sampling procedures with only accept-on-zero (AoZ)-defects criteria. In February 1989, OSD directed any military specifications containing AQLs or LTPDs not be published. OSD modern quality policies allow only AoZ sampling plans. Problems have developed, however, because the engineering and acquisition activities of defense had to change the way they had been doing business for almost 40 years. The lack of guidance on using AoZ plans has driven contractors and government QA personnel to costly 100 percent inspection as a choice of "what to do instead." Woe be it to someone who accepted product based on samples containing defects and the media found out about it. Additional guidance was required.

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[4] A complete list of the memoranda issued is also contained in the Bibliography of Appendix E.

Table II-1. Previous Efforts to Eliminate Acceptable Quality Levels in Specifications

Date	Action	Issues
16 Oct 86	Memorandum issued on "Achieving Continuous Quality Improvement" directed all DoD specification preparation activities to remove AQLs/LTPDs	
11 Mar 87	Memorandum issued reaffirming the 16 Oct 86 memo	
16 Jul 87	Memorandum directed the removal of AQLs/LTPDs from Government specifications while continuing to use sampling techniques	Raised concern in the military departments, the Defense Logistics Agency (DLA), the Government Supply agency (GSA), and industry. Wanted alternative guidance before arbitrary removal of AQLs/LTPDs.
20 May 88	Publication of MIL-STD 961C, *Military Specifications and Associated Documents, Preparation of*	Specified that AQLs and LTDPs "shall not be included as specification requirements."
13 Jul 88	Final Report of the Joint Services Working Group on the Elimination of Fixed Defect Levels, which was chaired by George Thielen	
8 Nov 88	MIL-STD-961C, Notice 1 issued	Revised statement on AQLs, LTPDs: "Specifications may state that sampling inspection for the purpose of determining compliance is acceptable. Fixed AQLs and LTPDs with associated specific sampling plans, however, shall not be included as specification requirements."
12 Jan 89	Memorandum from George Thielen with OSD's response to working group's final report	
20 Jan 89	Memorandum from HQ AMCCOM, AMSMC-QAH(D), "Recommendations of Working Group on Elimination of Fixed Defect Levels from Military Specifications"	
21 Feb 89	Jack Katzen, OASD TQM/SDM, memo, "Elimination of Acceptable Quality Levels (AQL's) and Lot Tolerance Percent Defectives (LTPD's) from Military Specifications," Memorandum for Assistant Secretaries of the Services and Director, DLA	Orders compliance by 30 June 1989. Deadline later postponed and formation of DoD-wide Process Action Team (PAT) on AQL/LTPD removal directed.
3 Mar 89	Seymour Lorber, AMCQA-E, memo setting up AMC Task Force chaired by Geza Pap	
16 Jun 89	Seymour Lorber memo: "AMC First-Stage Policy for the Elimination of Acceptable Quality Levels/Lot Tolerance Percent Defectives (AQLs, LTPDs) from Military Specifications"	Eliminates AQLs/LTPDs. Specifies interim measures. Refers to Task Force working on long-range plan (to improve this first-stage action). Supports OASD position on eliminating AQLs/LTPDs.

Table II-1. Previous Efforts to Eliminate Acceptable Quality Levels in Specifications (Continued)

Date	Action	Issues
Dec 89–May 90	DoD-wide Process Action Team (PAT) on AQL/LTPDs removal, chaired by Stan Beitsch	
24 Sep 90	Final report of DoD-wide PAT on AQL/LTPDs removal	Recommendations: Revise MIL-STDs 961, 962, and 490 to prohibit AQL and LTPD expressions of nonconformance in new and revised specs. Eliminate AQLs and LTPDs from Mil Specs during the normal document review cycle (5 years).
05 Oct 90	Memorandum, Peter Yurcisin, Director Standardization and Data Management, OASD(P&L)	Directing handbook be prepared for specification writers and Quality Assurance users. Action: Acting Director, Industrial Productivity and Quality (John Todaro). Refers to DoD PAT convened by DASD for TQM. Their final report —> recommendations + methodologies — basis for handbook.
15 Oct 90	Memorandum, John Todaro, OASD(P&L)PR/IPQ	Rejects Yurcisin idea as impractical in era of cutting OSD documents. Suggests each Service carry out Process Action Team's requirements.
30 Apr 91	General McCausland's letter, DLA-Q, "Nonconforming Material"	Recommends incremental reduction of AQLs, starting with all Existing acceptance numbers greater than 3 to be reduced by 1/3, all 2s reduced to 1s.
17 May 91	Memorandum. Joseph Pucilowski, acting Deputy Chief of Staff (DCS) for Concurrent Engineering	For Commander, U.S. Army LABCOM, Materials Technology Laboratory. Confirmed previous AQL/LTPD policy and effort to introduce SPC based schemes into industry standardization picture.

The efforts to have better supplier relationships were not in line with the adversarial posture that 100 percent inspection implies. Also, increased budget pressures preclude a more expensive end-item inspection practice that entails scrap and rework. The focus must be on inspection of the process, the institution of process controls, the prevention of defective product, and an attitude of continuous improvement on the part of both government and industry.

During the latter part of the 1980s, DoD and many defense contractors discussed the possibility of using the new ISO 9000-ANSI/ASQC 90 series of quality standards in lieu of the military specifications. But DoD representatives did not see any significant benefit in changing to the 1987 version of the ISO 9000 series. Many contractors shared the same doubts as the military. As a result, no changes were made at that time.

III. DEVELOPING NEW QUALITY ASSURANCE PRACTICES FOR DOD

Spurred by increasing pressure to change its way of doing business, DoD approached the Institute for Defense Analyses (IDA) to conduct a study that would ultimately lead to new quality assurance practices for Defense. IDA was approached because of its vast previous experience with concurrent engineering and quality management practices within industry. The subject was controversial because of high Congressional visibility and a public perception, based on sampling inspection plans still in place, that DoD was willing to accept lots that contained defects. Objectivity and independence were required to develop a new standard practice that both DoD and industry would be comfortable with.

A. IDA APPROACH AND FINDINGS

IDA set out to analyze the best commercial practices in order to recommend changes to DoD quality assurance practices. IDA also enlisted the help of recognized acceptance sampling and quality assurance experts. Dr. Ed Schilling, a professor at the Rochester Institute of Technology and author of numerous books on acceptance sampling, and Mr. Seymour Lorber, retired Deputy Chief of Concurrent Engineering for Army Materiel Command, were hired as consultants.

1. Sampling Inspection Standards

IDA collected information on quality standards and systems used in both defense and commercial industry. Appendix A contains a list of the more prominent documents and activities in this area, and Appendix E contains the entire bibliography of literature reviewed during this study. IDA spoke to quality assurance professionals in both commercial and defense industry and sent questionnaires to industrial organizations dealing with product standards, asking about their use of AQLs for product acceptance sampling in their standards and their views on the use of nongovernment standards (NGSs) by the DoD. Their responses are recorded in the documented briefing in Appendix B. This information related to the AQL elimination initiatives within DoD and its move toward greater use of

industry standards. IDA also documented the series of activities in DoD to eliminate the use of AQLs in military standards, as was shown in Table II-1 of the last chapter. The current mandate is that inspection sampling be conducted using only accept-on-zero-defects plans. IDA found that the best commercial practices in industry have demonstrated that high quality and lower cost can be achieved not by end-item inspection but by control of the processes that produce the end-item. Instead of "inspecting quality in" after production, resulting in rework and scrap and the additional costs they entail, process controls aim to minimize scrap and rework by the *prevention* of defects.

One could reasonably ask, "Does DoD require sampling inspection inspection procedures at all?"—a question to which the answer is clearly "yes" when one considers DoD as a customer. It buys large quantities of many items from many producers and many suppliers. DoD policies require competition, interchangeability, standardization, and repair parts for the life of the systems. In this environment, a uniform means of establishing characteristics is required, but minimum verification costs are desired. Some formula for government-prime-subcontractor communications needs to be devised.

Some initial IDA findings and observations about sampling inspection procedures included the following:

- For selected commodities, there may be no need to change the sampling inspection practices; however, the military standards could be replaced with their commercial equivalent.
- The description of the characteristics of the product (Critical, Major, Minor) should be retained in the product specification.
- A standard sampling procedure could be prepared using selected zero-defects acceptance plans.
- A new procedure based on Statistical Process Control (SPC) concepts for selected application could then be phased in.

These findings led IDA to prepare a draft of a new quality assurance standard for DoD and work with a recognized industry association SPC committee with industry, academia, and DoD participants to develop the standard and get it accepted.

2. Quality Management System Specifications

As discussed in Chapter I, quality management and process controls have been recognized worldwide for the competitive advantage they offer. Commercial application of the ISO 9000 series has expanded in the U.S. and the world. Industry has voluntarily

changed its approach to quality, no longer viewing a quality system as an onerous military requirement. Contractors have recognized the benefit of prevention for controlling costs as well as meeting major (including military) buyers' requirements for quality systems. If DoD were to continue to insist that all defense contractors comply with the military specification, these contractors would then have to maintain documentation for *Quality Program Requirements* as well as for ISO 9000 in order to do business commercially or internationally. This would be a costly process, limiting the cost advantages DoD might obtain by encouraging dual use facilities.

Comparing *Quality Program Requirements* with the requirements of ISO 9001 revealed minimal differences except for paragraph 4.4, *Design Control*, which covers quality system requirements during design phases. *Quality Program Requirements* does not mention design control. However, all defense contractors doing development and engineering respond to a wide variety of technical requirements for contract management of product development.

For these reasons, IDA recommended that DoD not only authorize use of the ISO 9000 series but aggressively plan for its full adoption over a reasonable period of time. With this authorization, defense should not endorse or require certification by a third independent party. The restriction does not prevent the contractor from using consultant or other services to implement a quality program. With regard to this recommendation, it is noted that OSD, on 14 February 1994, authorized the use of the ISO 9000-ANSI/ASQC Q90 series for new programs and as appropriate for ongoing programs.[1] The use of a single quality system in a facility "provides for cost effective, high quality products and services and improved process capability."[2]

IDA found that the ISO series currently does not provide a document comparable to *Inspection System Requirements*. ISO 9002, *Quality Systems—Model for Quality Assurance in Production and Installation,* is essentially similar to 9001 except that paragraph 4.4, *Design Control*, is not included. The similarity between 9001 and 9002

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1 John Deutch, Under Secretary of Defense, Memorandum for Secretaries of the Military Departments, Directors of Defense Agencies, *Use of Commercial Standards in the Department of Defense (DoD)*, 14 February 1994.

2 Walter B. Bergmann II, Acting Assistant Secretary (Production Resources), *MIL-HDBK-9000, Guidance in the Application of ISO 9000-ANSI/ASQC Quality System Requirements*, Memorandum for Assistant Secretary of the Army for Research, Development and Acquisition, Assistant Secretary of the Navy for Research, Development and Acquisition, Assistant Secretary of the Air Force (Acquisition), and Directors of Defense Research, 14 February 1994.

suggests that in the future, 9002 may be abandoned and contractors will be catalogued as 9001 with or without design control as appropriate. ISO 9003, *Quality Systems—Model for Quality Assurance in Final Inspection and Test*, is essentially equivalent to the standard inspection clause required to be included in all U.S. government contracts.

Inspection System Requirements is not able to meet the current demand for improved manufacturing pra[illegible]es and does not take advantage of the current quality management environment. It is an inspection document that does not provide an emphasis on prevention and control. The number of contractors currently using *Inspection System Requirements* is substantial, and the number can be expected to grow as industry generally upgrades their quality system. For example, a DCMC review found that in the plants where they perform in-plant quality assurance activities, 800 facilities meet *Quality Program Requirements*, 7200 facilities meet *Inspection System Requirements*, and nearly 8000 facilities work to the simple standard inspection clause requirements. Using ISO 9002 or ISO 9003 in place of *Inspection System Requirements* does not produce the desired result and, unfortunately, places a significant burden on the majority of industry supplying DoD (much of the this industry is small business). IDA determined that the standard should not only provide a replacement for the current sampling standards, with a new approach to accomplish strict sampling inspection, and require manufacturing process and statistical process controls for the most critical product characteristics, but also provide an incentive to producers to use effective quality practices and process controls.

3. Oversight of Contractor Quality Activities

One of the IDA findings on best commercial practices is that relationships with suppliers should be based on trust with audit rather than on extensive product inspection. The consolidation of all in-plant quality assurance oversight resources into the DCMC and the introduction of IQUE practice have substantially improved relations with defense contractors. Early in the task, IDA met with Mr. Ernest Ellis, Deputy Executive Director, Quality Assurance, and his staff at the Defense Logistics Agency (DLA) and presented a approach for the IQUE program to move from inspection sampling to acceptance of product based on a producer's SPC data. This approach, called the "ABC" process, was developed by Carmen Liuzza and Paul Roediger of the Quality Assurance Directorate of the Armament Research, Development, and Engineering Center at Picatinny Arsenal, NJ, and Ed Shilling of the Rochester Institute of Technology. The briefing given to DLA was well received and is contained in Appendix C, *A Three-Stage Sampling Plan to Attain Process Control and*

Capability. It was originally thought that this ABC process could be developed into the recommended standard. Although useful to the IQUE people at DLA, the standard took a different approach. In its present form, however, the draft standard is compatible with the IQUE approach.

B. NEW DRAFT STANDARD

IDA developed the original concept of an SPC quality assurance plan on the basis of contractor requirements in *Quality Program Requirements* and the use of SPC in accordance with the American Society for Quality Control and American National Standards Institute ANSI Z1.1-1985, *Guide for Quality Control Charts*, ANSI Z1.2-1985, *Control Chart Method of Analyzing Data*, and ANSI Z1.3-1985, *Control Chart Method of Controlling Quality During Production*. Processes were to be established to meet full production capabilities, and when a process fell below requirements, an aggressive effort to improve was to be required. Production may have been restricted until required levels were achieved. The procurement contracting officer (PCO) and the acquisition contracting officer (ACO) were to cooperate with the contractor to achieve required levels. The proposed process capability indices (C_{pk}s) and types of sampling required at the various stages for critical, major, and minor characteristics of the product that were to be required are as shown in Table III-1.

Table III-1. Cpk Values for Critical, Major, and Minor Characteristics at Different Phases

	Initial Plan	Initial Production	Full Production
Critical	1.33 (100% Screening)	1.66 (A-o-Z Sampling)	2.00 (0 Sampling)
Major	1.33 (A-o-Z Sampling)	1.33 (A-o-Z Sampling)	1.66 (0 Sampling)
Minor	1.00 (A-o-Z Sampling)	1.00 (A-o-Z Sampling)	1.33 (0 Sampling)

The draft standard underwent many changes. IDA began working with the American Defense Preparedness Association (ADPA) SPC Division Technical Committee in an effort to get industry, academia, and government support for the standard. The quality assurance professionals on this committee are listed in Table III-2. Concepts for the standard changed along the way as consensus was reached within the committee. IDA also sent the various versions out to additional government and industry quality assurance and standards personnel for further informal coordination. Appendix D contains the new draft

standard developed under this task. This document was developed as a possible way to move DoD procurement quality assessment requirements from lot-by-lot sampling toward process controls and continuous improvement. Following current mandate, it contains accept-on-zero-defects sampling tables, but that is not its primary objective.

Table III-2. ADPA SPC Technical Committee Members

Name	Organization
Mr. Geza Pap, Chair	U.S. Army ARDEC, Picatinny Arsenal, NJ
Mr. James Childress	Army Management Engineering College, Rock Island, IL
Mr. Robert M. Chvatal	COMARCO, Bloomfield, IN
Mr. Ray Edlund	U.S. Army HQ, AMCCOM, Rock Island, IL
Dr. Donald S. Ermer	University of Wisconsin, Madison, WS
Mr. Bob Formella	ARMTEC Defense Systems, Coachella, CA
Mr. Raymond Hamblin	Alliant TechSystems, Brooklyn Park, MN
Dr. Anand Joglekar	Alliant TechSystems, Brooklyn Park, MN
Mr. Dan Kedzie	COMARCO, Bloomfield, IN
Ms. Jennifer Kibiger	Olin Ordnance, St. Petersburg, FL
Mr. Carmen Liuzza	U.S. Army ARDEC, Picatinny Arsenal, NJ
Mr. Seymour Lorber	Consultant, Institute for Defense Analyses, Alexandria, VA
Mr. Bill Mitrik	Olin Ordnance, St. Petersburg, FL
Mr. Harlan Patterson	Hughes Aircraft Co., El Segundo, CA
Dr. Karen J. Richter	Institute for Defense Analyses, Alexandria, VA
Mr. Greg Stein	BMY-Combat Systems, HARSCO Corp, York, PA
Dr. Ken Tiernan	Loral Aeronutronic, Newport Beach, CA
Mr. Rich Zerilli	Defense Logistics Agency, Alexandria, VA

The document is intended to replace the AQL-based existing military standards, and intentionally avoids the usual statistical details and methodologies. It provides a sampling procedure based on zero acceptance criteria for attributes sampling and comparable plans for variables and continuous sampling. The hundreds of pages in the three primary inspection sampling standards are reduced to three simple accept-on-zero-defects tables with straightforward examples. Detailed rules for switching between plans are provided, based on the results of the inspection. The objective is to create an atmosphere where every nonconformance is an opportunity for corrective action and improvement rather than one where AQLs are the contractually sufficient goals.

The two key features of this document are its Alternate Acceptance Provisions, which establish incentives for initiating preventative quality programs, and fairly high sampling producer's risks. They are intended to complement each other, such that suppliers of high quality goods can gain product acceptance on the methods they are using to achieve the quality (SPC, etc.), while suppliers of marginal quality are confronted by increased screening and administrative costs. The underlying theme is a partnership between the supplier and DoD, with the requisite competence of both parties, and a clear mutual benefit for processes capable of consistently high quality product.

The draft standard was put into the required format[3] and is now undergoing formal coordination among the Services as a MIL-STD, sponsored by the Army at Picatinny Arsenal. The draft standard is also being considered as a commercial standard.

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3 Yes, there is a standard on how to write standards, *Preparation of Military Standards, Handbooks, and Bulletins*, MIL-STD-962B, 20 May 1988.

IV. CONCLUSIONS

This task demonstrated an approach toward acquisition reform that involved government, industry, and academia working together with IDA's help to do something that OSD can tackle on its own without requiring Congressional action. IDA is continuing to work for the acceptance of the new standard by analyzing final review comments and is assisting in the development of a handbook to accompany the standard with the ADPA SPC Division. This handbook must address both how to develop a Technical Data Package (TDP) with the standard and what the government and contractor must do when the contract cites the standard. And, of course, IDA continues to advise OSD on execution of the new quality assurance/management practices.

A. RESULTS AND CONSEQUENCES

Adoption of the draft Standard under the recommendations given below and the authorization of the ISO 9000-ANSI/ASQC Q90 series together help facilitate a common approach and DoD use of best commercial specifications and practices. The use of a single quality system helps allow the dual use of facilities in the move toward the commercial/military integration and the development of a national industrial base. The lower cost products capable under this new quality management approach will help to have globally competitive defense contractors and a government/contractor relationship that encourages improved process control and a culture of continuous improvement.

B. RECOMMENDATIONS

1. Improving Defense Acquisition Quality Assurance Activities

Efforts by DoD during the past several years to improve its acquisition quality assurance operation have resulted in many significant improvements. In the interest of further improvement, IDA recommends that DoD continue to increase procurement of commercial products, reduce government oversight of contractors, utilize commercial specifications and standards wherever possible, strive for the prevention of defects by the implementation of integrated product and process development (IPPD), and accommodate dual-use, commercial/military integration in production lines.

Specific to the task described in this paper, IDA recommends the following:

- Replace MIL-STD-105, *Sampling Procedures and Tables for Inspection by Attributes*, with its commercial equivalent, ANSI/ASQC Z1.4-1993.
- Continue to use ANSI/ASQC Z1.4-1993 plans for products that are of relatively simple design, described by a complete specification, and for which experience has demonstrated no problems.
- Replace MIL-STD-414, *Sampling Procedures and Tables for Inspection by Variables for Percent Defective*, with its commercial equivalent, ANSI/ASQC Z1.9-1993.
- Request ASQC to develop an ANSI/ASQC standard to replace MIL-STD-1235 and cancel the MIL-STD.
- Replace MIL-I-45208, *Inspection System Requirements* with the new draft standard, *DoD Preferred Methods for Acceptance of Product* (Appendix D to this paper).

2. Related Activities in DoD

While this effort was initiated in 1991, it has dovetailed with recommendations in two recent activities. The joint Military and National Aeronautical and Space Administration (NASA) Handbook, *Interim Guidance on the Application of ISO 9000/ASQC Q90 Series Quality Systems in Standards*, was issued on 4 February 1994. Its purpose is "to assist contracting activities that have decided to use Q91 or Q92 quality system standards with domestic contracts and seek guidance for doing so."

In April 1994, the *Report of the Process Action Team on Military Specifications and Standards* was also issued. It makes recommendations for a process focus, AQL elimination, and reduced contractor inspection and test. Specifically, under *Oversight*, the report recommends two specific tasks related to the draft standard and the recommendations in this paper:

- "DepSecDef issues a policy memorandum emphasizing greater use of process controls in lieu of development and production testing and inspection."[1]

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1 *Report of the Process Action Team on Military Specifications and Standards*, Office of the Under Secretary of Defense for Acquisition and Technology, April 1994, p. 100.

- "Develop a priority action list of military specifications containing fixed allowable defect level measures such as acceptable quality levels or lot tolerance percent defect. Initiate action to eliminate requirements for these defect measures."[2]

And under *Contractor Test and Inspection*, the report states: "The contractor shall certify to the government that the item or items offered for acceptance and delivery satisfy the requirements of the specifications through process controls and inspections."[3]

The draft standard in Appendix D fits with these two recent activities and should be approved with the recommended elimination of the other documents listed in Section B.1.

3. Summary of Recommendations

a. Sampling Inspection Requirements

- Cancel MIL-STD-105, MIL-STD-414 and MIL-STD-1235, *Single- and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes, Functional Curves of the Continuous Sampling Plans.*
- Use ANSI standards equivalent with canceled standards.
- Urge ASQC to prepare an ANSI standard to replace MIL-STD-1235.

b. Quality Management Standards

- Implement aggressive efforts to replace MIL-Q-9858 with ISO 9001-ANSI/ASQC Q91.
- Replace MIL-I-45208 with a new standard, *DoD Preferred Methods for Acceptance of Product* (Appendix D to this report).

4. "Defect Anticipation" Follow-On Effort

This study had as its focus the encouragement of improvements in defect prevention and process control as a means for improved quality in DoD. To make truly significant quality (both performance and cost effectiveness) gains, the challenge is for DoD to develop *defect anticipation* practices. These are efforts that influence the product designs to improve their robustness and tolerance to the vagaries of the production floor as well as the

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2 Ibid.

3 Ibid, p. 107.

battlefield environment. When defect anticipation and variability reduction come together, the prospects of *Process Based Acceptance* may become real.

Appendix A

QUALITY AND INSPECTION SAMPLING STANDARDS

CONTENTS

Appendix A
QUALITY AND INSPECTION SAMPLING STANDARDS

A. DEFENSE STANDARDS

MILITARY STANDARDS (MIL-STDS)

MIL-STD-105 — *Sampling Procedures and Tables for Inspection by Attributes*

Inspection by attributes is inspection whereby either the unit of product is classified simply as defective or non-defective or the number of defects in the unit of product is counted with respect to a given requirement or set of requirements.

Attributes sampling plans have the advantage of greater simplicity, of being applicable to either single or multiple quality characteristics, and of requiring no knowledge about the distribution of the continuous measurements of any of the quality characteristics.

MIL-STD-109 — *Quality Assurance Terms and Definitions*

MIL-STD-414 — *Sampling Procedures and Tables for Inspection by Variables for Percent Defective*

The variables sampling plans apply to a single quality characteristic that can be measured on a continuous scale and for which quality is expressed in terms of percent defective. The theory underlying the development of the variables sampling plans, including the operating characteristic (OC) curves, assumes the measurements of the quality characteristics are independent, identically distributed, normal random variables.

In comparison with attributes sampling plans, variables sampling plans have the advantage of usually resulting in considerable savings in sample size for comparable assurance as to the correctness of decisions in judging a single quality characteristic or, for the same sample size, greater assurance is obtained using variables plans.

MIL-STD-1235 — *Single, and Multi-level Continuous Sampling. Procedures and Tables for Inspection by Attributes.*

MILITARY SPECIFICATIONS (MIL-SPECS)

MIL-I-45208 — *Inspection System Requirements*

MIL-Q-9858 — *Quality Program Requirements*

MILITARY HANDBOOKS (MIL-HDBKS)

MIL-HDBK-53-1 — *Guide for Attribute Lot Sampling Inspection and MIL-STD-105.* Portions copied from ISO 2859-1974, Addendum 1 (1977).

MIL-HDBK-53-2	*Guide for Attribute Continuous Sampling Inspection and MIL-STD-1235*
MIL-HDBK-53-3	*Guide for Variables Lot Sampling Inspection and MIL-STD-414*

TECHNICAL REPORTS

TR-7	Factors and Procedures for Applying MIL-STD-105D Sampling Plans to Life and Reliability Testing.
	DoD Quality Control and Reliability Assurance Tech Report, OASD (Supply and Logistics), 1965.

B. COMMERCIAL STANDARDS

AMERICAN NATIONAL STANDARDS INSTITUTE/AMERICAN SOCIETY FOR QUALITY CONTROL (ANSI/ASQC)

ANSI Z1.1/ASQC B1 (1985)	*Guide for Quality Control Charts*
ANSI Z1.2/ASQC B2 (1985)	*Control Chart Methods of Analyzing Data*
ANSI Z1.3/ASQC B3 (1985)	*Control Chart Method of Controlling Quality During Production*
ANSI Z1.15 (1979)	*Generic Guidelines for Quality Systems*
ASQC Z1.4 (1981)	*Sampling Procedures and Tables for Inspection by Attributes.* Equivalent to MIL-STD-105.
ASCQC Z1.9 (1982)	*Sampling Procedures and Tables for Inspection by Variables. for P[ercent Nonconforming.*
	Equivalent to MIL-STD-414.
ANSI/ASQC A1 (1987)	*Definitions, Symbols, Formulas and Tables for Control Charts*
ANSI/ASQC A2 (1987)	*Terms, Symbols, and Definitions for Acceptance Sampling*
ANSI/ASQC A3 (987)	*Quality Systems Terminology*
ASQC C1 (1968)	*General Requirements for a Quality Program*
ASQC E3 (1984)	*Guide to Inspection Planning*
ASQC Q90 (1987)	*Quality Management and Quality Assurance Standards—Guidelines for Selection and Use*
	Provides guidelines for the selection and use of Standards Q91, Q92, Q93, and Q94.
ASQC Q91 (1987)	*Quality Systems—Model for Quality Assurance in Design/Development, Production, Installation and Servicing*
	Specifies quality system requirements for use where a contract between two parties requires the demonstration of a supplier's capability to design and supply product.

ASQC Q92 (1987) *Quality Systems—Model for Quality Assurance in Production and Installation*

Specifies quality system requirements for use where a contract between two parties requires the demonstration of a supplier's capability to control the processes that determine the acceptability of a product supplied.

ASQC Q93 (1987) *Quality Systems—Model for Quality Assurance in Final Inspection and Test*

Specifies quality system requirements for use where a contract between two parties requires the demonstration of a supplier's capability to design and control the disposition of any product nonconformity during final inspection and test.

ASQC Q94 (1987) *Quality Management and Quality System Elements—Guidelines.*

Describes a basic set of elements by which a Quality Management System can be developed and implemented internally.

AMERICAN NATIONAL STANDARDS INSTITUTE/INSTITUTE FOR INTERCONNECTING AND PACKAGING OF ELECTRONIC CIRCUITS (ANSI/IPC)

ANSI/IPC-PC-90 (1990) *General Requirements for Implementation of Statistical Process Control*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME FAP-1 (1990) *Quality Assurance Program Requirements for Fastener Manufacturers and Distributors*

AMERICAN SOCIETY FOR TESTING MATERIALS (ASTM)

ASTM STD 15D *Manual on Presentation of Data and Control Chart Analysis*

ASTM E105 (1958) *Recommended Practice for Probability Sampling of Materials*

ASTM E122 (1972) *Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process*

ASTM E141 (1969) *Recommended Practice for Acceptance of Evidence Based on the Results of Probability Sampling*

ASTM E456 (1983) *Terminology for Statistical Methods*

AMERICAN NATIONAL STANDARDS INSTITUTE/ELECTRONICS INDUSTRIES ASSOCIATION (ANSI/EIA)

ANSI/EIA-557 (1989) *Statistical Process Control Systems*

ANSI/EIA-584 (1991) *Zero Acceptance Number Sampling Procedures and Tables for Inspection by Attributes of a Continuous Manufacturing Process*

ANSI/EIA-585 (1991) *Zero Acceptance Number Sampling Procedures and Tables for Attributes of Isolated Lots*

ANSI/EIA IS-17 (1985) *Assessment of Outgoing Defective Levels in PPM*

JEDEC No, 19 (1988) *General Standard for Statistical Process Control (SPC)*

BOEING

DI-9000 (1991) *Advanced Quality System*

FORD

Q-101 (1990)	*Worldwide Quality System Standard for Manufacturing Operations and Outside Suppliers of Production and Service Products*
	Quality System Survey and Scoring Guidelines, 15 Apr 90.
	Worldwide Supplier Quality Rating System, 15 Apr 90.
	The Initial Sample Review Process for Suppliers to Ford Motor Company, 15 Apr 90.
	Planning for Quality, 15 Apr 90.
	Q1 01Preferred Quality Award for Suppliers to Ford Motor Company, 15 Apr 90.
	Facilities and Tools, Quality System Standard, May 1991
Q-101W (1991)	*Worldwide Quality System Standard, Warehouse and Distribution*

FORD, CHRYSLER, AND GENERAL MOTORS

	Fundamental Statistical Process control, Reference M-anual-1991
	Measurement Systems Analysis, Reference Manual-1990
	Quality System Standard (Draft)-1993

INDUSTRIAL FASTENERS INSTITUTE

	Recommended Practices for Statistical Process Control

INTERNATIONAL STANDARDS ORGANIZATION (ISO)

ISO 3534 (1977)	*Statistics—Vocabulary and Symbols*
ISO 8402 (1986)	*Quality—Vocabulary*
	Referenced in all of ANSI/ASQC 90 series
ISO 9000 (1987)	*Quality Management and Quality Assurance Standards—Guidelines for Selection and Use*
	Equivalent to ASQC Q90 series.
ISO 9001 (1987)	*Quality Systems—Model for Quality Assurance in Design/Development, Production, Installation and Servicing*
ISO 9002 (1987)	*Quality Systems—Model for Quality Assurance in Production and Installation*
ISO 9003 (1987)	*Quality Systems—Model for Quality Assurance in Final Inspection and Test*
ISO 9004 (1987)	*Quality Management and Quality System Elements—Guidelines*
ISO 2859 (1974)	*Sampling Procedures and Tables for Inspection by Attributes, Parts 1 and 2*
	International version of MIL-STD-105D
ISO 3951	International graphical version of MIL-STD-414

IEC

IEC 410 (1973) (Recommendation)	*Sampling Plans and Procedures for Inspection by Attributes*
IECQ	*IEC Quality Assessment System for Electronic Components*

QC 001001 (1981)	*Basic Rules of the IEC Quality Assessment System for Electronic Component*

TECHNICAL COMMITTEES

ISO/TC 176	*Quality Assurance*
	Wrote ISO 9000 series
ISO/TC 69	*Applications of Statistical Methods*
	Wrote ISO Standards Handbook 3, Statistical Methods, as well as other standard guides and codes of practice
ANSI/ASQC Z-1	*Quality Assurance*

Appendix B

INFORMATION ON INDUSTRY USE OF ACCEPTABLE QUALITY LEVELS (AQLs) AND NONGOVERNMENT STANDARDS

CONTENTS

INTRODUCTION

For many years DoD has relied on a philosophy of defect detection using sampling inspection as the basis for acceptance of manufactured product. The principal military sampling standards that have been cited in military specifications are indexed using Acceptable Quality Levels (AQLs) for selecting appropriate sampling plans. Implied in this approach is the notion that the DoD is willing to accept some level of defective product and, as a result, suppliers are not driven to provide quality levels beyond that which the sampling plan permits. Recent demonstrated successes in obtaining quality products has shifted industry focus to defect prevention through the control of manufacturing processes. This change in philosophy drove DoD to issue repeated policy statements that nonconforming products will not be accepted, and AQLs will no longer be cited in military specifications. As a result, valid modes of acceptance sampling are limited to 100% inspection and accept-on-zero (A-o-Z) defects sampling plans. These plans can be costly and still do not motivate or reward the defect-prevention thrust.

AQL ELIMINATION EFFORTS

In conjunction with the sponsors, IDA has been working on a new standard for product acceptance based on statistical process control and the supplier's demonstrated quality program that encourages continuous improvement of the supplier's manufacturing processes and protects DoD from accepting defective product. The information contained in this document was collected to provide background for this standard. IDA has been working with the sponsors to ensure that this standard becomes accepted as an industry standard to be cited in specifications in lieu of the military standards still referencing AQLs. This intent complements the efforts under way in DoD to reduce the acquisition process paperwork and enable the use of commercially available products by using industry standards in place of those once unique to the military.

This slide shows the amount of time and effort that has gone into eliminating the use of AQLs and Lot Tolerance Percent Defectives (LTPDs) from the military specifications.

AQL Elimination Efforts

October 1986: OASD(P&L) Memorandum on "Achieving Continuous Quality Improvement" directed all DoD spec preparation activities to remove AQLs/LTPDs .

Mar 87: OASD(P&L) memo, as above, to Quality Assurance community.

July 1988: Final Report of the Joint Services Working Group on the Elimination of Fixed Defect Levels.

February 1989: OASD(P&L) TQM/SDM orders compliance to 16 Oct memo by 30 June 1989, Deadline later postponed and formation of DoD-wide Process Action Team (PAT) on AQL/LTPD removal directed.

June 1989: Memorandum, "AMC First-Stage Policy for the Elimination of Acceptable Quality Levels/Lot Tolerance Percent Defectives (AQLs, LTPDs) from Military Specifications" eliminates AQLs/LTPDs, specifies interim measures, supports OASD position on eliminating AQLs/LTPDs.

September 1990: Final report of DoD-wide PAT on AQL/LTPDs removal recommends revising MIL-STDs 961, 962, and 490 to prohibit AQL and LTPD expressions of nonconformance in new and revised specs and eliminate AQLs and LTPDs from specs during the normal document review cycle (5 years).

May 1991: Memorandum, AMC acting DCS for Concurrent Engineering for Commander, U.S. Army LABCOM, Materials Technology Laboratory confirmed previous AQL/LTPD policy and effort to introduce SPC-based schemes into industry standardization picture.

INDUSTRY STANDARDS ASSOCIATIONS QUERIED

The list of industry standards associations from which to solicit information was derived from the listing of industry groups in the Standardization Directory (SD-1) of the Defense Standardization and Specification Program. Industry groups were chosen if their name implied that they might be more product than process oriented and more likely to have standards or specifications for product inspection. The list is as follows:

Abrasive Grain Association
Acoustical Society of America
Aerospace Industries Association
Aluminum Association, Inc.
American Association of Government Industrial Hygienists
American Dental Association
American Gear Manufacturers' Association
American Hot Dip Galvanizers Association
American Institute of Aeronautics and Astronautics (AIAA)
American Institute of Timber Construction
American Petroleum Institute
American Plywood Association
American Society of Agricultural Engineers
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society of Quality Control
American Society for Testing and Materials
American Welding Society
Anti-Friction Bearing Manufacturers Association
Association for Information and Imaging Management
Association for Manufacturing Technology
Cast Iron Soil Pipe Institute
Construction Specifications Institute
Dairy Food Industries Supply Association
Diamond Wheel Manufacturers Institute
Electronic Industries Association
Facing Tile Institute
Institute of Electrical and Electronics Engineers
International Association of Plumbing & Mechanical Officials
Magnetic Materials Producers Association
Material Handling Institute, Inc.
McGill Manufacturing Co., Inc.
National Association of Corrosion Engineers
National Electrical Manufacturers Association
National Fire Protection Association
National Hardwood Lumber Association
National Institute of Oilseed Products
National Wood Window and Door Association
Rack Manufacturers Association
Rubber Manufacturers Association
SKF USA, Inc.
Society of Automotive Engineers, Inc. Air & Space
Society of Automotive Engineers Land & Sea
Solar Energy Industrial Association
Southern Pine Inspection Bureau
Steel Door Institute
Steel Window Institute
Tire and Rim Association, Inc.
Tile Council of America, Inc.
Torrington Co.
Truck Manufacturers Association (TMA)
Underwriters Laboratories, Inc.
Variable Resistive Components Institute

Industry Standards Associations Queried

- **Letter sent to all organizations listed in SD-1 whose name implied they may have product standards (as opposed to process)**
- **53 Organizations**
- **22 Responses**

QUESTION #1 RESPONSES

Question #1: *Do your standards and specifications make reference to acceptance sampling? If so, please state any acceptance sampling documents referenced (e.g. MIL-STD 105).* There were 12 "yes" responses and 10 "no." Specific responses (not single word answers) are listed below.

Yes, MIL-STD-105. Sampling procedures are in accordance with MIL-STD-105 and to the AQLs as stated in the specification. Many of our part standards reference a military procurement specification.

Yes. MIL-STD-105D or Chrysler Motor's Sampling Plan, Table II

Yes, for lot verification of E-rated lumber, the principles in MIL-STD-105 were adopted.

Yes, ANSI/ASQC Z1.4-1981 (MIL-STD-105), ANSI/ASQC S1.1987

Yes, over 25 listed under Sampling—hundreds more under Acceptance Testing, Quality Control, etc.

Yes, MIL-STD-105D. All of our Government and aircraft use MIL-STD-105 plans. Our internal documents use c = 0 inspection plans.

Yes, MIL-STD-105, Zero Acceptance Sampling Plans, c = 0 developed from N.L. Squeglia.

Yes. We use c = 0 for all plans and refer to MIL-STD-105E for sample size.

Yes, MIL-STD-105.

Yes, we utilize MIL-STD-105 when dictated by Defense Contractors as part of the Purchasing Contract. Otherwise, we use the standard tables of c = 0 sampling plans as formulated by Nicholas L. Squeglia.

Yes. Our own, MIL-STD-105. For Sampling Guide only—not specified AQL.

No. Our industry's products are high value, low volume. Generally, they do not lend themselves to acceptance sampling, which was developed primarily for the high volume, low-to-medium value items.

No, we recommend 100 percent inspection at this time.

In general, no. Possibly one document (which I can't identify at the moment) out of 200 references a sampling document.

Question #1

- **Do your standards and specifications make reference to acceptance sampling?**
- **If so, please state any acceptance sampling documents referenced (e.g. MIL-STD 105).**

Responses:

- **12 yes**
- **10 no**

QUESTION #2 RESPONSES

Question #2: *Are your acceptance sampling plans indexed by Acceptable Quality Levels (AQLs)? If possible, please list your standards and specifications that use AQLs.* The specific answers follow.

Yes. Specifications: NAS 1289, 1290, 4002, 4003, 4004, NA 007, 008, 0026, 0057, 0071, 0072, 0154, 0161

Specifically referenced in Form and Style for ASTM Standards, Section B15, Sampling. Would have to look at each standard—probably Vol. 14.02 E11 committee—also ASTM Standards on Precision and Bias for Various Applications.

Yes, AITC Test T124.

Yes, Aircraft Product: Receiving Inspection c = 0, 0.65%, 1.0%, 4.0%, 10%; In Process Inspection MIL-STD-105, 0.65%, 1.0%; Final.

Commercial Product: Receiving Inspection c = 0, 0.65%, 1.0%, 4.0%, 10%; In Process Inspection, MIL-STD-105, 1.0%; Final Inspection, MIL-STD-105, 1.0%.

Incoming inspection standards. Some in-process toll gate inspection.

MIL-STD-105D (required to use by the government).

Yes, our standards and specs don't specifically list AQL levels, but our basic level is 0.65% with more stringent AQL levels for critical characteristics and less stringent levels for insignificant characteristics.

ANSI 137.1—1988 Para 4.2 Sampling Plan

Yes, we use 0.65, 1.0, and 2.5 AQL. By Government requirement our QC-IN-76 is based on various AQLs. Normally parts that do not receive 100% inspection are 0.04% AQL. All commercial plans AR c = 0 at various AQLs.

No. We use c = 0 for all plans.

Question #2

- **Are your acceptance sampling plans indexed by Acceptable Quality Levels (AQLs)?**
- **If possible, please list your standards and specifications that use AQLs.**

Responses:

- **9 yes—approximately 20 listed**
- **9 no**
- **2 not applicable**

QUESTION #3 RESPONSES

Question #3: *Have you published any continuous improvement or statistical process control documents? If so, please list them.* Specific answers follow.

Internal documents only. We utilize SPC through control charts, histograms, lot plots, capability analysis, pareto analysis, and DoE.

AITC Inspection Bureau Memo #8—SPC for End Joint Production

ISO-9000 internally and at key suppliers. SPC on all critical/major parameters. Design review encompassing: C_p Studies; FMEA (Design and Process); Team Problem Solving.

ANSI/ASQC Q90-Q94 distributed by ASTM.

No. We do use SPC and now ISO-9000. We use a training manual developed in house for SPC and continuous improvement.

We have published a comprehensive continuous improvement document patterned to the spirit of the ISO 9000 series standards. This document titled "Management Handbook for Quality Systems Development in Machine Tool and Related Industries" contains specific information, suggestions and recommendations for the implementation of continuous quality improvement in a typical machine tool company.

We are currently revamping our SPC system to fall within the guidelines of Boeing D1-9000, Advanced Quality System Program.

Yes, samples attached

We have only published internally. We have documents on SPC, Capabilities Studies and our Quality Assurance manual.

We have published for our own use, and as examples for our customers and suppliers, the following:
TPS-7000 The Torrington Co.—Quality Systems
TPS-70001 The Torrington Co.—SPC Reference Document

Question #3

- **Have you published any continuous improvement or statistical process control documents?**
- **If so, please list them.**

Responses:

- **10 yes—ISO 9000 and Boeing D1-9000 listed frequently, many internal documents also cited**
- **10 no**

REQUEST FOR ADDITIONAL COMMENTS—AQL ELIMINATION

Further information was requested as follows: *Please add any comments you may have regarding either objective—AQL elimination or government use of nongovernment standards (NGS).* The responses on AQL elimination are as follows.

Both objectives are good and should be pursued.

It's about time AQLs are eliminated. We actually operate on c = 0. Any defects require a lot to be 100 percent sorted.

We would like to use smaller sample lots with 0 reject (not MIL-STD-105—bigger lots and accept on 1, reject on 2).

Excellent idea. The thought of accepting lots that contain known defectives is quickly becoming out of step with worldwide industry.

The DoD's AQL should be gradually phased out and replaced with existing civilian standards like ANSI/ASQC A2, ANSI/ASQC B1, B2 and B3, ANSI/ASQC Q3, ANSI/ASQC S1 and similar. Most of these documents were developed only recently by some of the same authors that were involved in the writing of the Government Quality Specifications.

We seldom see AQL levels specified by contract, but we frequently see MIL-STD-105 as a requirement. Since industry as a whole has switched to the c = 0 sampling plans (as an adjunct to SPC), we would like to see the Government do likewise. We are not ready to give up sampling even though we are using SPC extensively, and would not expect anyone else to do so until they have achieved a consistent level of quality (approximately 60 ppm defect level).

The need for AQLs will never be eliminated.

Seems like the AQL should be set for each part of a whole for a product that is manufactured from parts.

AQL acceptance methods are still valid—until all key processes have $C_p \geq 1.33$—for visual defects.

I am uncertain from the initiative how risk (producer/consumer) would be quantified vis-a-vis attributes sampling.

Request for Additional Comments—AQL Elimination

- Please add any comments you may have regarding either objective—AQL elimination or government use of nongovernment standards (NGS).

Responses on AQL elimination:

- 5 thought it an idea whose time had come
- 5 objected to or were uncertain about the feasibility or implementation of the idea

REQUEST FOR ADDITIONAL COMMENTS—NGS USE

The responses on the use of NGS by the government are shown below.

Military sampling standards tend to be outdated as compared to progressive industry approach to continuous quality improvement stressing process control. Control of processes through statistical methods targeting to achieve 1.0 C_{pk} seems to present higher reliability of product quality (100% inspection is only 80-85% reliable). Automotive programs and concepts such as Boeing D1-9000 are more intuned to today's manufacturing objectives of improved quality, efficiency and service.

AIAA is beginning an appraisal of the value of ISO 9000 to aerospace, both civil and military. Because of its forward-looking approach, it seems likely that any conformity assessment included in AIAA standards would be oriented in this direction.

The use of non-government standards and participation by the government in ASTM follows the criteria established in OMB Circular 119. The continued involvement and active participation by DoD in ASTM will provide DoD with the opportunity of adopting standards acceptable to DoD needs.

The Department of Defense and Standardization Office has listed all 3-A Sanitary Standards (for equipment) and 3-A Accepted Practices (for systems) in their Standardization Directory, SD-1.

I feel the government should move towards the use of more modern standards. MIL-Q-9858 should be replaced by ISO-9001/9002. MIL-I-45208A should be replaced by ISO-9003.

I agree with government use of nongovernment standards. However, most quality control, sampling/analysis systems are found within third party certification and testing programs. The government could be well serviced by products "certified" to meet industry standards.

The above questions are appropriate for product standards but not installation, use, and maintenance standards in general. Use of non-government standards for procurement of products and services is a major step forward.

Voluntary, consensus standards available in the private sector should be used whenever possible.

Government quality systems standards should be eliminated in lieu of ISO-9000 series standard.

We support the use, by the government, of nongovernment standards wherever feasible.

We support to the fullest extent possible the use of best commercial industry standards for non-uniquely military items.

In the aerospace industry, the government standards and the nongovernment standards (NGS) together make a complete set of documents, i.e., they are not duplicative. Therefore, for the government to use NGS, the NGS would have to be developed. This only adds unnecessary expense to the standardization process.

Request for Additional Comments—NGS Use (Cont'd)

Responses on NGS use:

- **12 favorable responses**
- **Only 1 negative reply**
- **ISO-9000 series mentioned often**

INTERESTING RESULTS

When the comments are seen attributed to the specific standards organization, it appears as though those with the greatest defense application are those most in favor of keeping AQLs. Almost all organizations favored the greater use of NGSs by DoD.

Name of Organization	Additional Comments
Aerospace Industries Association	The need for AQLs will never be eliminated.
	In the aerospace industry, the government standards and the nongovernment standards (NGS) together make a complete set of documents, i.e., they are not duplicative, therefore, for a government to use NGSs—the NGSs would have to be developed. This only adds unnecessary expense to the standardization process.
Aluminum Association, Inc.	Both objectives are good and should be pursued.
American Gear Manufacturers' Association	It's about time AQLs are eliminated. We actually operate on c = 0. Any defects require a lot to be 100 percent sorted.
	I feel the government should move towards the use of more modern standards. MIL-Q-9858 should be replaced by ISO-9001/9002. MIL-I-45208A should be replaced by ISO-9003.
American Institute of Aeronautics and Astronautics (AIAA)	AIAA is beginning an appraisal of the value of ISO 9000 to aerospace, both civil and military. Because of its forward-looking approach, it seems likely that any conformity assessment included in AIAA standards would be oriented in this direction.
American Institute of Timber Construction	Seems like the AQL should be set for each part of a whole for a product that is manufactured from parts.
American Society of Agricultural Engineers	Voluntary, consensus standards available in the private sector should be used whenever possible.
American Society of Quality Control	Government quality systems standards should be eliminated in lieu of ISO-9000 series standard. AQL acceptance methods are still valid, until all key processes have $C_p \geq 1.33$ for visual defects.
American Society for Testing and Materials	The use of non-government standards and participation by the government in ASTM follows the criteria established in OMB Circular 119. The continued involvement and active participation by DoD in ASTM will provide DoD with the opportunity of adopting standards acceptable to DoD needs.
Anti-Friction Bearing Manufacturers Association	We would like to use smaller sample lots with 0 reject (not MIL-STD-105—bigger lots and accept on 1, reject on 2). Excellent idea. The thought of accepting lots that contain known defectives is quickly becoming out of step with worldwide industry.
Association for Manufacturing Technology	The DoD's AQL should be gradually phased out and replaced with existing civilian standards like ANSI/ASQC A2, ANSI/ASQC B1, B2 and B3, ANSI/ASQC Q3, ANSI/ASQC S1 and similar. Most of these documents were developed only recently by some of the same authors that were involved in the writing of the Government Quality Specifications.

Interesting Results

When the comments are seen attributed to the specific standards organization, it appears as though:

- **Those with the greatest defense application are those most in favor of keeping AQLs.**
- **Those with the greatest defense application are those least in favor of using NGS.**

INTERESTING RESULTS (Cont'd)

Name of Organization	Additional Comments
McGill Manufacturing Co., Inc.	Military sampling standards tend to be outdated as compared to progressive industry approach to continuous quality improvement stressing process control. Control of processes through statistical methods targeting to achieve 1.0 C_{pk} seems to present higher reliability of product quality (100% inspection is only 80-85% reliable). Automotive programs and concepts such as Boeing D1-9000 are more intuned to today's manufacturing objectives of improved quality, efficiency and service.
National Fire Protection Association	Use of non-government standards for procurement of products and services is a major step forward.
National Wood Window and Door Association	I agree with government use of nongovernment standards. However, most quality control, sampling/analysis systems are found within third party certification and testing programs. The government could be well serviced by products "certified" to meet industry standards.
Rack Manufacturers Association	I am uncertain from the initiative how risk (producer/consumer) would be quantified vis-a-vis attributes sampling. We support to the fullest extent possible the use of best commercial industry standards for non-uniquely military items.
Rubber Manufacturers Association	We support the use, by the government, of nongovernment standards wherever feasible.
SKF USA, Inc.	We recommend the elimination of AQLs with replacement by "0" defects. This means, in all cases, if one reject is found, then the lot should be 100 percent sorted.
Torrington Co.	We seldom see AQL levels specified by contract, but we frequently see MIL-STD-105 as a requirement. Since industry as a whole has switched to the c = 0 sampling plans (as an adjunct to SPC), we would like to see the Government do likewise. We are not ready to give up sampling even though we are using SPC extensively, and would not expect anyone else to do so until they have achieved a consistent level of quality (approximately 60 ppm defect level).

Interesting Results (repeated)

When the comments are seen attributed to the specific standards organization, it appears as though:

- **Those with the greatest defense application are those most in favor of keeping AQLs.**
- **Those with the greatest defense application are those least in favor of using NGS.**

CONCLUSION

To follow on the general comments made by the standards organizations, IDA conducted phone conversations with quality assurance personnel from various commercial and defense companies and organizations, including Texas Instruments (TI) Defense Electronics Group (Malcomb Baldrige winner), Ford Motor Company, Motorola, SEMATECH, National Center for Manufacturing Sciences (NCMS), and TRW. The questions asked were:

- Do you use AQLs in inspection sampling for your suppliers?
- How does the use of AQLs relate to your process improvement and quality?

The answers can be summarized as follows:

- If AQLs are used, it is only where they are still required in a government contract.
- AQLs are seen as out-dated and contradictory to quality programs for achieving continuous process improvement.

Typical responses were:

- We still have to deal with the Mil-Spec AQLs and AOQLs at the commodity level with our suppliers. These ought to be out, but we still have them in our contracts...But in relationship with its suppliers, TI "anticipates and expects no nonconformance."
- AQLs imply a willingness to expect achieving a given level of quality, not continuous improvement. "AQLs represent a missed opportunity for improvement." (TRW)

Conclusion

Modern quality practices stressing the need for continuous improvement are driving the move away from specifying an acceptable level of quality.

Appendix C

A THREE-STAGE SAMPLING PLAN TO ATTAIN PROCESS CONTROL AND CAPABILITY

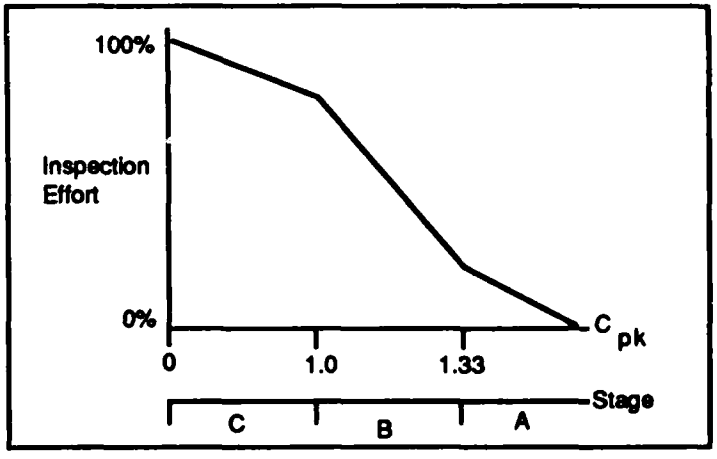
CONTENTS

A THREE-STAGE SAMPLING PLAN TO ATTAIN PROCESS CONTROL AND CAPABILITY

The Stages of the Plan

The switching and discontinuation rules of MIL-STD-105 and MIL-STD-414 embody the correct notion that the amount of inspection required varies in direct relation to the current quality of the process being sampled. Put another way: "...these methods (sampling) together with control charts (SPC) can eventually lead to sufficient knowledge of the producer's quality to allow inspection to be dropped in favor of SPC techniques."[1] ABC utilizes both Statistical Process Control (SPC) and traditional sampling techniques to accept product and allows inspection reduction as a result of increased C_{pk}. The plan incorporates three successive stages (C, B, and A) to move from an uncontrolled process to a process under control with capability index C_{pk} of at least 1.33. Feedback from the control charts and sampling results determines how subsequent product is accepted and the proper stage of the plan. Until SPC yields a favorable assessment of the process, ABC utilizes sampling and screening to assure that the average outgoing quality is no worse than a specified Average Outgoing Quality Limit (AOQL) (stages C and B). As quality improves and the process stabilizes, the need to rely on sampling lessens. ABC adjusts the amount and type of inspection accordingly. Progress in ABC is accompanied by a gradual elimination of sampling inspection when stage A is reached, the stage of excellence.

Switching from stage to stage is through stringent requirements in terms of capability and control. Increasing C_{pk} is primarily the result of reducing sigma. When the process is under control, sigma, estimated from the range chart, determines the required level of inspection. Otherwise, it is prudent to assume sigma is large and inspect accordingly. The three line segments, from left to right, illustrate the stages C, B, and A situations, respectively. The C_{pk} thresholds to gain entry into stages B and A are set at 1.0 and 1.33, respectively. These assignments are consistent for use with major characteristics and have historical precedence.[2] Since capability should not be estimated from an out-of-control process, switching rules also consider demonstration of control and total conformance of sampled units to the specification.



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1 Schilling, Edward G., "New ANSI Versions of MIL-STD-414 and MIL-STD-105D," Naval Research Logistics Quarterly, Volume 32, Number 1, February 1985.

2 Juran, J.M., F.M. Gryna, and R.S. Bingham, *Quality Control Handbook*, McGraw-Hill, New York, Third Edition, 1974, Ch. 9, p. 22.

Stages of the Plan

Stage C: Uncontrolled process

Inspection by accept-on-zero attributes plan with screening of all rejected lots

Stage B: Controlled process

Inspection by mixed variables/attributes plan with screening of all rejected lots

Stage A: Controlled and capable process

Inspection by auditing SPC charts

The Value of the Plan

Protection is afforded the customer in terms of the AOQL of sampling plans run in parallel with the implementation of SPC. At the same time, latitude is provided the supplier in application of SPC. Switching rules between the stages in the plan provide fallback procedures that allows the product to be accepted without line stoppage.

The plan is also structured to be of maximum educational benefit to the user in promoting continual improvement.

Value of the Plan

- Guaranteed quality level to the customer as process is being brought under control
- Reduction of inspection effort as control and capability are established
- Recovery procedure if control is lost
- Flexibility given supplier in implementation of the SPC program
- Maximum education benefit to the user in promoting SPC

Prerequisites for ABC

For the sake of expediency, ABC was tailored for a major, normally distributed characteristic, to which variable-SPC is planned. It also requires that screening is feasible, lots are large, production rates are high, and contract duration is long. The contractor-generator quality plan and Department of Defense (DoD) approved SPC plan must define terms and delineate procedures to be followed that are consonant with ABC precepts. To gain entry into ABC, processes are subjected to a one time screening phase. The screening phase is likely to bar processes incapable of making progress in ABC. Though not part of ABC per se, the quality plan and screening phase are essential prerequisites to it.

ABC requires that lots consist of an integer number of PIs. Stage C and level B1 accept on either a lot or PI basis; stage A and level B0 accept only on a PI basis. If, while accepting on a lot basis, the requirements to begin accepting on a PI basis are satisfied, and the contractor wants to begin, he must accept the truncated lot on a lot basis and begin immediately accepting subsequent PIs on a PI basis. The contractor may, however, choose to remain on a lot basis for that lot. In so doing, he jeopardizes the opportunity to accept on a PI basis. ABC offers no other guidance in this area, except to point out that lot (N)/PI (n) affects the average fraction inspected.

Prerequisites for ABC

- Major, normally distributed characteristic
- Variable SPC planned for the characteristic
- Screening must be feasible
- Large lots, high production rates
- Quality plan
- Screening phase

Illustrative Example

The contractor produces 2400 bolts per day (3 shifts) at a production rate of 100/hour. Product has been being accepted using an attributes 125-0-1 sampling plan. The contractor is instituting a new quality program and wants to use SPC on this line. The contractor requests that the product be accepted based on the results of the SPC program. The customer agrees to initiate the ABC process.

Illustrative Example

- Purchase of bolts from supplier
- Production rate of 100/hour
- Three shifts, 2400 produced per day
- Critical characteristic is outside thread diameter
- Supplier has begun an SPC program
- Supplier requests that product be accepted based on an audit of his X-bar and R charts
- Customer agrees to initiate ABC process

The Quality Plan

The contractor's quality plan should contain a detailed description of his proposed procedures to develop and maintain control at the desired capability, and identify the specific processes and products to which they apply. ABC requires that the quality plan address the following points and be in accord with ABC precepts, which appear below within braces { }.

- What constitutes a lot, a sublot, a PI? What is the sampling frequency from which the n control chart samples are taken? {n=5}
- What constitutes establishing initial control {for both charts, 20 points in a row must be within [LCL, UCL] ending at least a 5 shift minimum, subject to independent verification as deemed necessary}, and going out-of-control? {A current value falls out of [LCL, UCL]}
- What criteria will be followed in updating the center lines {X-doublebar and R-bar} and UCL and LCL?
- How does C_{pk} get evaluated initially {upon establishing initial control) and when will it be updated? {Whenever X-doublebar or R-bar change}
- What corrective action procedure will be followed in the event of going out-of-specification/control? {Stop production (critical only), isolate and screen current PI and the next PI (out -of-specification only), find and document cause (all situations), eliminate cause and document solution (all situations), and request to restart (critical only)}
- What conditions warrant consideration for exemption? E.g., an inconsequential out-of-specification/control condition that occurs occasionally, for which a routine adjustment corrects.

Quality Plan

- Contains SPC plan
- Contractor generated/Government approved
- Defines
  - —Lot/Sublot
  - —Production interval (PI)
  - —Control chart n, UCL, LCL
  - —Control, capability
  - —Corrective action procedures
  - —Special conditions

Initial Screening

Prior to entering ABC, product is subjected to a one-time screening phase. This highlights the important role that screening plays in ABC, and the requirement that screening really be feasible. It also enables a quick assessment of the situation and provides a quick decision as to whether the process has the potential of making progress in ABC. The screening phase requires finding 125 acceptable units in a row, before inspecting 459 units. Any process whose process average is at most 1 percent nonconforming will, 90 percent of the time, pass through the screening phase into ABC.

Initial Screening

Goal: Establish reasonable probability of success with ABC plan.

SPC actions by contractor	Product acceptance actions
• Sample of five bolts taken each hour • X-bar and R charts • Corrective action to gain control	• Continuous attribute inspection until 125 clear before 459 total

Contractor enters stage C if product passes the screening.

Stage C

The first stage represents the *inspect quality into the product* approach. This represents screening and stage C.

For simplicity, stage C was chosen to consist of an attribute AoZ sampling plan, whereby rejected product is screened. Screening allows computation of an AOQL. For a given AOQL, an AoZ sample size is easily computed. This fits nicely with the idea that, to leave stage C, a C_{pk} requirement must be met: just match the stage C AOQL to what the AOQ would be if the process was in fact in-control with the specified C_{pk}. Accordingly, having specified a C_{pk} of 1.0 or more to leave stage C, which corresponds to an AOQL of 0.3 percent or less, the stage C AoZ sample size is found to be 125 (rounded up slightly).

Stage C applies to accepting product on a lot, sublot, or production interval (PI) basis, and requires no assumption about the control or capability of the process involved. It represents a safe place for the buyer, by providing 0.3 percent AOQL protection, and for the contractor to perform the work required to establish initial control, improve the process, maintain control, and demonstrate capability to qualify to move to stages B or A. It is a place to occasionally revisit when the process has been out-of-specification and/or control long and often enough to be of concern.

Stage C

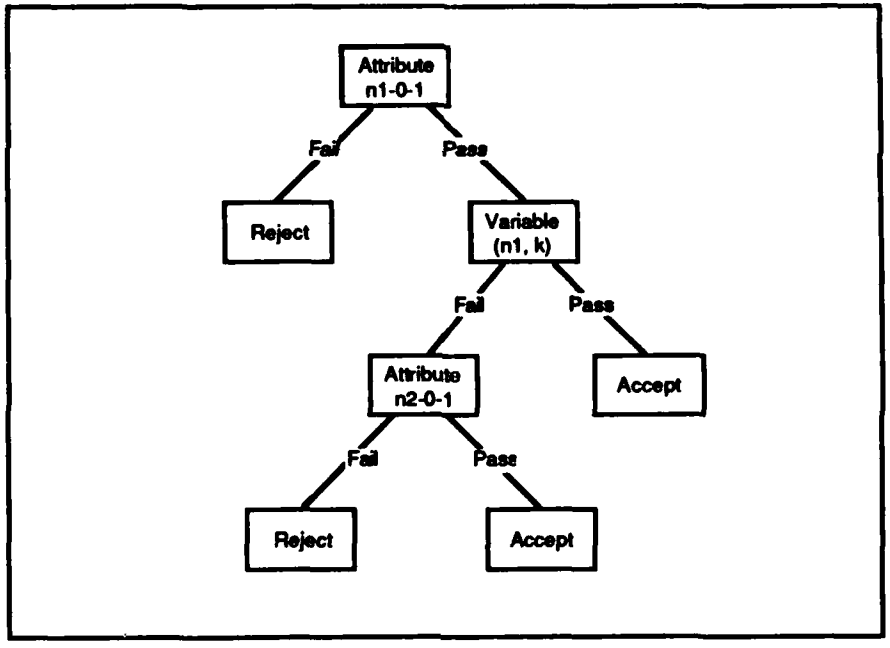
Goal: Guarantee quality level to customer while control is being established (AOQL=0.3)%

SPC actions by contractor	Product acceptance actions
• Continue 5/hr sampling • X-bar and R charts • Corrective action to gain control • After 20 points in control calculate Cpk	• Random sampling • Lotting of production intervals • Accept on zero attributes plan, 125-0-1 • Screening of all rejected lots

Contractor enters stage B if Cpk≥1.0 and last lot had no defects

Stage B

Stage B takes the form of a mixed variable-attribute plan, the mechanics of which are depicted in the figure. The terms "accept" and "reject" refer to disposition of the product inspected, whereas "pass" and "fail" refer to status of the sampling plan inspection results. This mixed plan differs from the norm[3] in that the variable sample (size n1) is viewed first as an attribute, and allows the possibility of rejection based on it. If the product passes the attributes inspection, it can then be accepted based on the small variable sample. If the sample n1 fails the variables plan, then the lot , sublot, or production interval is subjected to an attribute AoZ plan based on a larger sample, n2. Both mixed plans yield an AOQL of 0.3 percent nonconforming or less. The variable component of the mixed plan comes in two forms: sigma known, and sigma unknown. Whether sigma is known or not depends on whether the range chart is in control or not.



3 Schilling, Edward G. and Harold F. Dodge, "Procedures and Tables for Evaluating Dependent Mixed Acceptance Sampling Plans," Technometrics, Volume 2, Number 2, May 1969.

Stage B

Goal: Reduce inspection as control is established and capability improved (AOQL=0.3%).

SPC actions by contractor

- **Continue 5/hr sampling**
- **X-bar and R charts**
- **Improving process**
- **After 20 points in control calculate Cpk**

Product acceptance actions

- **Mixed variables / attributes plan**
- **Screening of all rejected lots or PIs**

Two levels to Stage B with different mixed plans.

Level B1

Level B1 is entered when C_{pk} is calculated as ≥ 1.0 but ≤ 1.2. Calculation of Cpk requires that the last 20 points on the X-bar chart have been in control, but it is assumed at this level that the range is not yet in control and therefore sigma is unknown. An unknown sigma mixed plan can provide a safe fall-back when control chart conditions do not warrant using the known sigma plan. Comparable protection can be afforded by matching the operating characteristic (OC) curves of the two variable components of the mixed plan via Wallis' formula[4] and keeping n1+n2 fixed at 125. This yields n1=30 for the matching unknown sigma mixed plan. The samples in level B1 are random samples and inspection is of lots.

Stage B is designed to ease the transition from accepting lots based upon a random sample (level B1) to accepting PIs based only on the relatively smaller nonrandom control chart sample (level B0). It provides, again, a *safe* place to take the risks of tinkering with the process that might have to be taken to improve capability.

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4 Schilling, Edward G., *Acceptance Sampling in Quality Control*, Marcel Dekker, Inc., New York, NY, 1982, pp. 237-238.

Level B1

Enter from stage C when 1.0≤Cpk≤1.2, sigma unknown.

SPC actions by contractor

- **Cont' ue 5/hr sampling**
- **X-bar and R charts**
- **Establishing control on R chart**
- **After 20 points in control calculate Cpk**

Product acceptance actions

- **Random sampling**
- **Lotting of production intervals**
- **Variables n1=30, k=3.3 plan**
- **Attributes n2=95, c=0 plan**
- **Screening of all rejected lots**

Advance to level B0 when Cpk≥1.2, R chart in control.

Level B0

A known sigma mixed plan is ready made for control chart application. Knowledge of sigma comes from the R chart. As long as sigma and mu are fixed, the control chart sample, taken in a brief period of time (snapshot), is like a random sample. As such it may serve as the variable sample in a known sigma mixed plan. This is the crux of defining stage B. The ABC control chart sample size (n1) is taken as 5, and the k value of the mixed plan is 3.3. A smaller value of k introduces, in our opinion, too much risk. The combined sample size (n1+n2) is set equal to the stage C AoZ sample size, here 125.

Level B0

Enter from stage C or B1 when Cpk≤1.2, sigma known.

SPC actions by contractor

- **Continue 5/hr sampling**
- **X-bar and R charts**
- **Improving process**
- **After 20 points in control calculate Cpk**

Product acceptance actions

- **Production intervals instead of lots**
- **Variables n1=5 (rational subgroup), k=3.3 plan**
- **Attributes n2=120, c=0 plan**
- **Screening of all rejected production intervals**

Advance to stage A when Cpk≥1.33.

Stage A

The final stage is to accept product by simply being in-control. This represents stage A, which is arrived at by reducing sigma, or increasing capability. Acceptance of product in stage A is accomplished entirely on the basis of the control chart sample. The criteria for acceptance are that both X-bar and R charts remain in control, and that the control chart samples fully conform.

Stage A

Goal: Accept product on control chart samples.

Enter from stage B1 when Cpk≤1.33.

SPC actions by contractor	Product acceptance actions
• Continue 5/hr sampling • X-bar and R charts • Improving process	• Audit contractor's SPC charts • Screen immediate and next production interval if point goes out of control

Must be in control with Cpk≥1.33 to remain in A.

Rules

ABC switching rules are based on three factors: capability, control, and whether all sample units meet the specification. Capability is measured in terms of C_{pk}, which is taken to be a process parameter, not a lot-to-lot sample statistic. Thus, C_{pk} is calculated only under specific circumstances—when the last 20 points have been in control. Switching due to change in capability is based on C_{pk}.

Control, by itself, is unsuited for use in ABC switching. An additional concept is required because control is memoryless in that it may conceivably flip-flop in and out with each PI. *AQL elimination* policy prescribes that a timely, positive, nontrivial response be made in the event a defective unit is found (e.g., any unit from the control chart sample is out-of-specification). Thus, conformance to specification is an additional concept to consider in the switching rules. Due to the similarity in corrective actions to take upon being out-of-control and out-of-specification, the two factors were combined into one: specification/control. The specification/control value (In, Out) depends upon whether the control chart samples are within specification, whether the X-bar and R charts are in control, AND whether any associated randomly drawn samples are within specification.

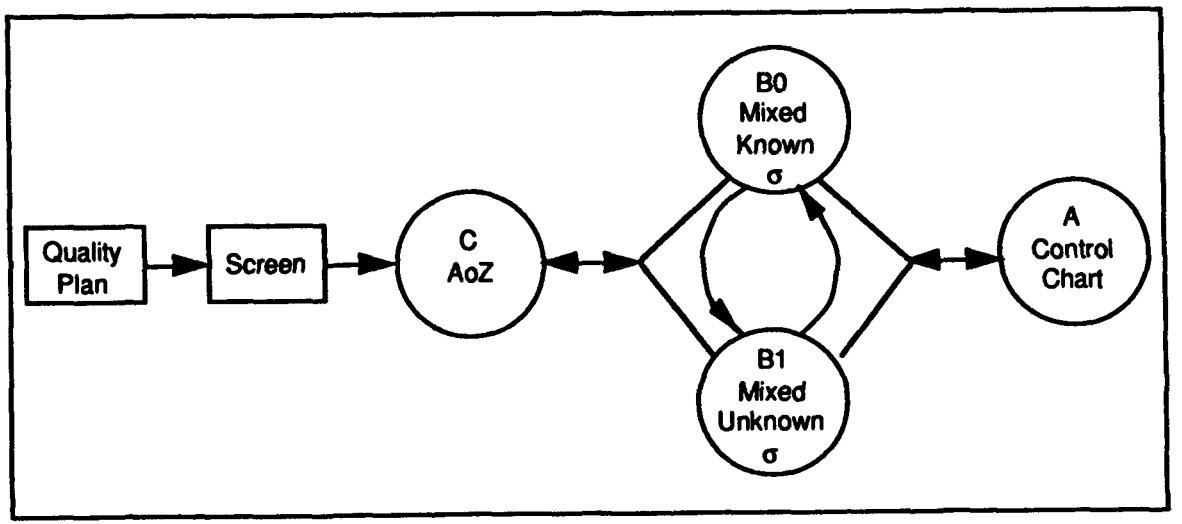
Opportunities to switch from stage to stage in ABC depend on C_{pk} and the current value of the specification/control condition. This value is updated upon completion of each PI. To progress in ABC (C to B to A direction), BOTH specification/control and C_{pk} requirements must be met (logical AND); to regress (A to B to C) failing ONE requirement suffices (logical OR). Opportunities to switch from level to level in stage B depend upon C_{pk}, the specification/control condition, and the condition of the range chart. To progress in stage B (B1 to B0 direction), BOTH requirements must be met (logical AND); to regress in stage B (B0 to B1 direction) failing ONE requirement suffices (logical OR).

Rules

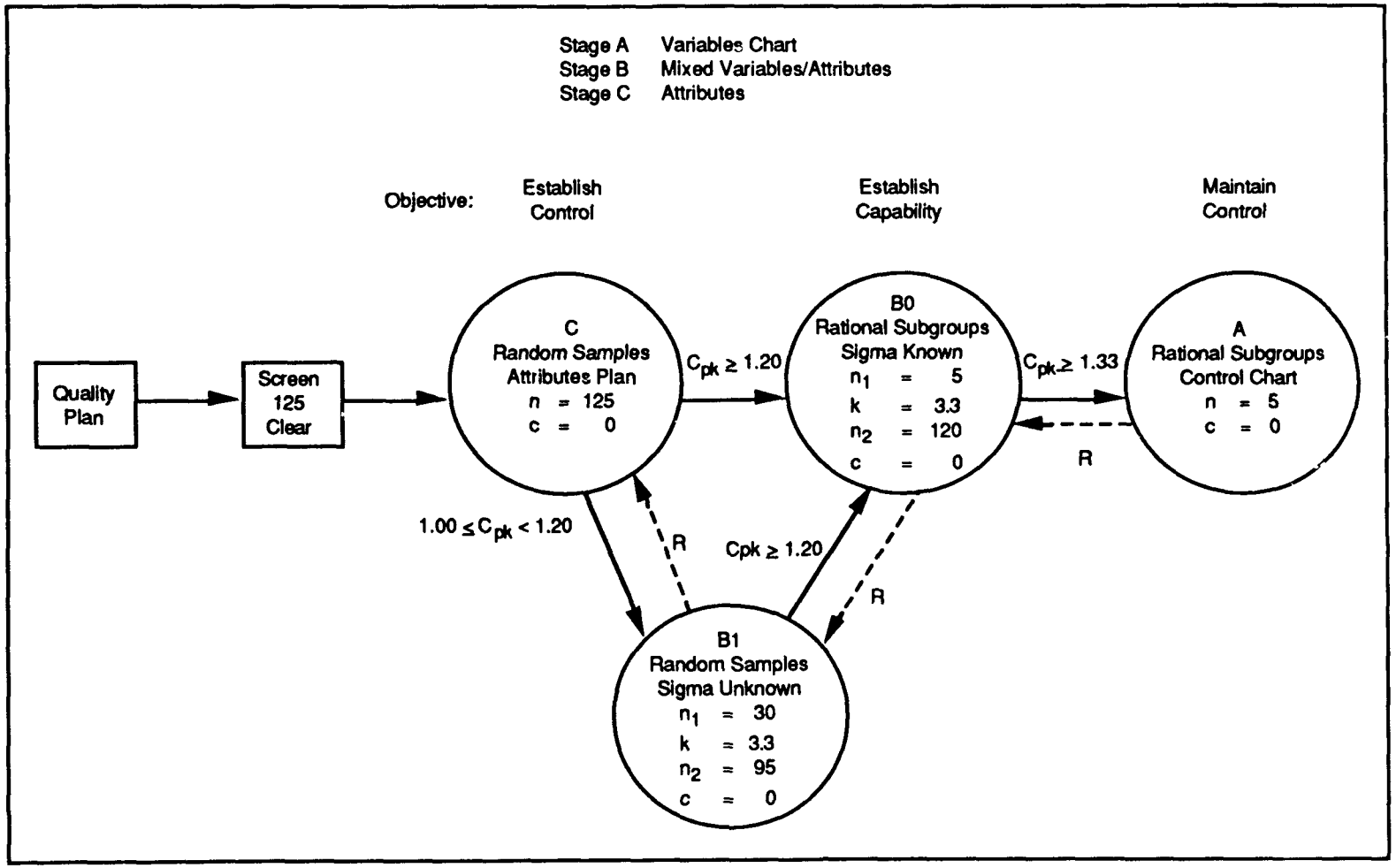
- **Screen the immediate and next lots when either of the following 2 conditions occur:**
  - **— A point is out of control**
  - **— A defect is found**
- **When a point goes out of control in stage B or A, the last 10 of the next 20 points must be in control or revert to previous stage of inspection**
- **Recalculate Cpk any time control limits are changed and move to appropriate stage**

ABC Summary

Armed with a quality plan and preceded by the screening phase, ABC looks like the figure.



ABC Summary


Stage A Variables Chart
Stage B Mixed Variables/Attributes
Stage C Attributes
Objective:
Establish Control
Establish Capability
Maintain Control
Quality Plan
Screen 125 Clear
C
Random Samples
Attributes Plan
n = 125
c = 0
Cpk ≥ 1.20
B0
Rational Subgroups
Sigma Known
n1 = 5
k = 3.3
n2 = 120
c = 0
Cpk ≥ 1.33
A
Rational Subgroups
Control Chart
n = 5
c = 0
R
1.00 ≤ Cpk < 1.20
R
Cpk ≥ 1.20
R
B1
Random Samples
Sigma Unknown
n1 = 30
k = 3.3
n2 = 95
c = 0

Appendix D

STANDARD XXX

DOD PREFERRED METHODS FOR ACCEPTANCE OF PRODUCT

CONTENTS

ANNEXES

TABLES

FOREWORD

1. This standard is approved for use by the Department of Defense, Defense Contractors, and other commercial organizations.

2. This standard provides a set of sampling plans and procedures for planning and conducting the inspection of product to assess quality and conformance to contract requirements. This standard complies with the Department of Defense (DoD) policy of eliminating acceptable quality levels (AQLs) and associated practices.

3. The following points provide the basis for this standard:

   - Defense contractors are required to submit product that conforms to requirements and to generate and maintain sufficient evidence of conformance.
   - Contractors are responsible for establishing their own manufacturing and process controls to produce product in accordance with requirements.
   - Contractors are expected to use common industrial practices such as process controls and statistical techniques.
   - Department of Defense (DoD) procurement practices encourage industry innovation and provide flexibility to achieve the benefits of improvement.

4. Sampling inspection is a common industrial practice for demonstrating the conformance of product to the requirements of the contract and its technical data package. The application of sampling plans for acceptance involves both consumer and producer risks. Increased sampling is one way of reducing these risks, but it also increases costs. Producers can reduce risks by employing effective processes with appropriate process controls. To the extent that such practices are employed and are effective, risk is controlled and, consequently, product inspection, including testing, can be reduced.

5. Manufacturing process controls and statistical control methods are the preferable means of preventing nonconformances, controlling quality, and generating information for product improvement. An effective process control system may also be used to provide information to assess the quality of product submitted for acceptance. The suppliers are encouraged to use process control and statistical control procedures for their internal control and to consider submitting effective process control procedures in place of prescribed sampling requirements to the government for approval.

1. SCOPE

1.1 PURPOSE

This standard establishes the DoD preferred set of sampling plans and procedures for the acceptance of product.

1.2 APPLICABILITY

This standard, when referenced in the contract, specification, or purchase order, is applicable to all suppliers at the contractor, subcontractor, or vendor facilities. The sampling plans shall be applied as specified in the contract documents, and product may be submitted for acceptance if the requirements of this standard have been met.

1.3 PRODUCT REQUIREMENTS

The contractor is required to submit product that meets all contract and specification requirements. The application of sampling plans in this standard does not relieve the contractor of responsibility for meeting all contract product requirements. The contractor's quality system, including manufacturing processes and quality control measures, shall be established and operated to consistently produce products that meet all requirements. Absence of any inspection or process control requirement in the contract shall not relieve the contractor of responsibility for assuring that all products or supplies submitted to the government for acceptance conform to all requirements of the contract.

1.4 APPLICATIONS AND LIMITATIONS

1.4.1 Applications

Sampling plans and procedures in this standard when appropriate may be used to assess conformance to requirements of the following:

- End items
- Components or basic materials
- Operations or services

- Materials in process
- Supplies in storage
- Maintenance operations
- Data or records
- Administrative procedures

1.4.2 Limitations

The sampling plans and procedures of this standard are not intended for use with destructive tests or where product screening is not feasible or desirable. In such cases, the sampling plans will be stated elsewhere in the contract or product specifications.

2. APPLICABLE DOCUMENTS

2.1 MILITARY STANDARDS

MIL-STD-109, *Quality Assurance Terms and Definitions*

2.2 COMMERCIAL STANDARDS

ISO 8402, *Quality-Vocabulary*

3. DEFINITIONS AND TERMS

The definitions and terms in ISO 8402 and the following are applicable. When terms and definitions listed below or in the contract and supporting reference requirements differ from those in ISO 8402, they will take precedence over ISO 8402.

3.1 DEFINITIONS FROM FEDERAL ACQUISITIONS REGULATION (FAR) 46.101

3.1.1 Acceptance

The act of an authorized representative of the Government by which the Government, for itself or as agent of another, assumes ownership of existing identified supplies tendered or approves specific services rendered as partial or complete performance of the contract.

3.1.2 Contract Quality Requirements

The various functions, including inspection, performed by the Government to determine whether a contractor has fulfilled the contract obligations pertaining to quality and quantity.

3.1.3 Government Contract Quality Assurance

The various functions, including inspection, performed by the Government to determine whether a contractor has fulfilled the contract obligations pertaining to quality and quantity.

3.1.4 Inspection

Examining and testing supplies or services (including, when appropriate, raw materials, components, and intermediate assemblies) to determine whether they conform to contract requirements.

3.1.5 Off-The-Shelf Item

An item produced and placed in stock by a contractor, or stocked by a distributor, before receiving orders or contracts for its sale. The item may be commercial or produced to military or Federal specifications or description.

3.1.6 Subcontractor

(see 44.101)

3.1.7 Testing

That element of inspection that determines the properties or elements, including functional operation of supplies or their components, by the application of established scientific principles and procedures.

3.2 DEFINITION FROM DEPARTMENT OF DEFENSE FEDERAL ACQUISITION REGULATIONS

3.2.1 Metrology

The science of weights and measures used to determine conformance to technical requirements including the development of standards and systems for absolute and relative measurements.

3.2.2 Quality

The composite of material attributes including performance features and characteristics of a product or service to satisfy a given need.

3.2.3 Quality Assurance

A planned and systematic pattern of all actions necessary to provide adequate confidence that adequate technical requirements are established; products and services conform to established technical requirements; and satisfactory performance is achieved.

3.2.4 Quality Audit

A systematic examination of the acts and decisions with respect to quality in order to independently verify or evaluate the operational requirements of the quality program or the specification or contract requirements of the product or service.

3.2.5 Quality Program

A program which is developed, planned, and managed to carry out cost effectively all efforts to effect the quality of materials and services from concept through validation, full-scale development, production, deployment, and disposal.

3.3 CLASSIFICATION OF CHARACTERISTICS

The enumeration of characteristics of product, classified according to their importance. Characteristics will normally be grouped into classes of critical, major, or minor; however, they may be grouped into other classes or subclasses within these classes.

3.4 CRITICAL CHARACTERISTIC

A characteristic that judgment and experience indicate must be met to avoid hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product; or that judgment and experience indicate must be met to assure performance of the tactical function of a major item such as a ship, aircraft, tank, missile, or space vehicle.

3.5 MAJOR CHARACTERISTIC

A characteristic, other than critical, that must be met to avoid failure or material reduction of usability of the unit of product for intended purpose.

3.6 MINOR CHARACTERISTIC

A characteristic, other than critical or major, whose departure from its specification requirement is not likely to reduce materially the usability of the unit of product for its intended purpose or whose departure from established standards has little bearing on the effective use or operation of the unit.

3.7 NONCONFORMANCE

A departure from a specified requirement for any characteristic.

3.8 NONCONFORMING UNIT

A unit of product that has one or more nonconformances.

3.9 CRITICAL NONCONFORMING UNIT

A unit of product that fails to conform to specified requirements for one or more critical characteristics.

3.10 MAJOR NONCONFORMING UNIT

A unit of product that fails to conform to specified requirements for one or more major characteristics, but conforms to all critical characteristics.

3.11 MINOR NONCONFORMING UNIT

A unit of product that fails to conform to specified requirements of one or more minor characteristics, but conforms to all critical and major characteristics.

3.12 SCREENING INSPECTION

An inspection process where every unit is checked and all nonconforming units are removed; also referred to as 100 percent inspection.

3.13 PRODUCTION INTERVAL

Normally is a single shift; it can be a day if it is reasonably certain that shift changes do not affect quality of product, but shall not be longer than a day.

3.14 VERIFICATION LEVEL (VL)

Prescribes the level of significance or utility of a characteristic to the user. The amount of effort to assure conformance can be allocated on the basis of importance to the user. (Major characteristics will require more verification effort than minor characteristics.) VL-VII requires the highest level of effort, and the effort decreases as the VL decreases to the lowest level, VL-I.

4. SAMPLING INSPECTION REQUIREMENTS

4.1 PREFERRED SAMPLING PLANS

This standard establishes three sets of matched sampling plans for the sampling inspection of product submitted to the government for acceptance. These sampling plans provide for inspecting the samples from lots or batches by attributes or variables measurement and for continuous sampling by attributes measurement. The three sets of matched sampling plans are indexed by seven specified verification levels (VL) and five code letters (CL), which are determined by the lot or production interval size. The sampling plans are matched between corresponding VL and CL combinations to result in essentially similar producer's risk. The contractor may utilize the type of plan, at the same verification level, that best complements the production process.

4.2 FORMATION AND IDENTIFICATION OF LOTS OR BATCHES

The product shall be assembled into identifiable lots, sublots, or batches, or in such other manner as may be prescribed. Each lot or batch shall, as far as practicable, consist of unit of product of a single type, grade, class, size, and composition, manufactured under essentially the same conditions, and at essentially the same time. The lots or batches shall be identified by the contractor and shall be kept intact in adequate and suitable storage space. Although lot or batch size is not used to select a continuous sampling plan, the formation of lots or batches may remain desirable for reasons of homogeneity, shipping convenience, and facilitation of payment.

4.3 DETERMINATION OF SAMPLING PLAN

A sampling plan is determined by:

- Verification level (VL) as specified.
- Type of sampling (attributes, variables, or continuous).
- Lot or production interval size code letter (CL) from Table 1, Section 4.8.1.
- Switching procedure (normal, tightened, reduced).

For lot acceptance situations (attributes or variables), the occurrence of one or more nonconformances shall result in withholding acceptance of the product submitted and initiation of corrective action. When continuous sampling is in effect, the occurrence of a nonconforming unit while in a sampling phase results in withholding acceptance of that unit, a return to screening, and initiation of corrective action. If a nonconforming unit is found while in a screening phase, acceptance is withheld for that unit and screening is continued until the requirements of paragraph 4.9.3.2 are satisified.

4.4 SAMPLING OF LOTS OR BATCHES

4.4.1 Selection of Units

Units of product drawn from a lot for a sample shall be selected at random from the lot without regard to their quality. Random sampling requires that each unit in the lot, batch, or production interval have the same probability of being selected for the sample.

4.4.2 Representative (Stratified) Sampling

When appropriate, the number of units in the sample shall be selected in proportion to the size of sublots or subbatches, or parts of the lot or batch, identified by some rational criterion. When representative sampling is used, the units from each sublot, subbatch, or part shall be selected at random.

4.4.3 Process of Sampling

A sample may be drawn after all units comprising the lot or batch have been assembled, or sample units may be drawn during assembly of the lot or batch, in which case the size of the lot or batch will be determined before samples are drawn. When the lot or batch passes the sampling plan, such lots or batches are acceptable and may be submitted to the government. When sample units are drawn during lot or batch assembly and nonconforming units are found, the contractor shall withhold from acceptance that portion of the lot completed and all additional production occurring prior to the initiation and verification of corrective action. For lots or batches withheld from acceptance, the contractor shall take the following actions:

- Screen the lots or batches and dispose of all nonconforming units in accordance with paragraph 4.5.
- Determine the cause of the nonconformances and implement appropriate process changes.

- Initiate the switching requirements of paragraph 4.8.3.
- Advise the government representative of actions taken and submit the screened lot or batches to the government.

4.5 DISPOSITION OF NONCONFORMING PRODUCT

All units of product found to be nonconforming by the contractor shall be removed and kept apart from the flow of production or otherwise identified or segregated to preclude submission to the government. The contractor may rework or repair these units unless the contract excludes such activities. Corrected product will be screened by the contractor and resubmitted to the government apart from the regular flow of the product.

4.6 SPECIAL RESERVATIONS FOR CRITICAL NONCONFORMANCE

When a critical nonconformance is discovered at any phase of production or during any inspection, the following immediate action is required: prevent delivery of critical nonconforming units to the government, notify the government representative, screen all available units, and take corrective action. Records of corrective actions shall be maintained and made available to the government representative.

4.7 CRITICAL CHARACTERISTICS

For each critical characteristic, the contractor is required to implement an automated screening or a fail safe manufacturing operation and apply sampling plan VL-VII to verify the performance of the screening operation unless otherwise specified in the contract or product specifications. The occurrence of one or more critical nonconformances requires corrective action as specified in paragraph 4.6.

4.8 SAMPLING INSPECTION

4.8.1 Verification Level Specification

The VLs are specified in the contract or product specifications. A VL may be specified for individual characteristics, for a group of characteristics, or for subgroups of characteristics within the group. The VL and code letter (CL) from Table 1 determine the sampling plan required to assess product compliance to contract and specification requirements. Contractors are expected to produce and submit product in full conformance to all requirements. Lots, batches, or production intervals of product that consistently meet

or exceed all requirements will be accepted by the sampling plans of this standard and will result in qualifying for reduced sampling levels.

Table 1. Code Letters (CL) for Entry Into the Sampling Tables

Lot or Production Interval Size	Verification Levels						
	VII	VI	V	IV	III	II	I
2–170	A	A	A	A	A	A	A
171–288	A	A	A	A	A	A	B
289–544	A	A	A	A	A	B	C
545–960	A	A	A	A	B	C	D
961–1632	A	A	A	B	C	D	E
1633–3072	A	A	B	C	D	E	E
3073–5440	A	B	C	D	E	E	E
5441–9216	B	C	D	E	E	E	E
9217–17408	C	D	E	E	E	E	E
17409–30720	D	E	E	E	E	E	E
30721 and larger	E	E	E	E	E	E	E

4.8.2 Sampling Procedures

Unless otherwise described, the VL specified in the contract shall be considered the normal level of inspection and will be used at the start of inspection. Normal, tightened, or reduced sampling inspection shall continue unchanged for each group of characteristics or individual characteristic except where the switching procedures given in paragraph 4.8.3 require change. The switching procedures shall be applied to each group of characteristics or to individual characteristics.

4.8.3 Switching Procedures

The sampling plan criteria for normal, tightened, and reduced inspection are given in Tables 2, 3, and 4 (Note 2 to the respective table) of Section 4.9.

The switching procedures are independent of the results of any remedial action, such as screening, additional samples, etc., resulting from the occurrence of sample nonconformances and withholding of acceptance.

Some Table 4 switching criteria depend upon a corresponding Table 2 entry. These entries have been denoted by $n_a(N)$ and $n_a(T)$ in the descriptions that follow. $n_a(N)$ represents the Table 2 sample size used for normal sampling at the VL and CL currently in effect. Likewise, $n_a(T)$ represents the tightened sample size.

4.8.3.1 Normal to Tightened

When normal inspection is in effect, tightened inspection shall be instituted when one of the following conditions occurs, depending on the type of sampling plan being used.

- Lot or batch sampling (Tables 2 and 3):
  - — 2 lots/batches have been withheld from acceptance within the last 5 or fewer lots/batches.
- Continuous sampling (Table 4):
  - — 2 nonconforming units are found within the last 5 segments of size $n_a(N)$, or fewer, units inspected.

4.8.3.2 Tightened to Normal

When tightened inspection is in effect, normal inspection may be instituted when the following conditions are both satisfied.

- The cause for producing the nonconformances is corrected.
- Lot or batch sampling (Tables 2 and 3):
  - — 5 consecutive lots/batches are accepted.

  Continuous sampling (Table 4):
  - — The last 5 segments of size $n_a(T)$ units inspected contain only consecutive conforming units.

4.8.3.3 Normal to Reduced

When normal inspection is in effect, reduced inspection may be instituted when the following conditions are all satisfied.

- Lot or batch sampling (Tables 2 and 3):
  - — 10 consecutive lots/batches are accepted while on normal inspection.

  Continuous sampling (Table 4):
  - — The last 10 segments of size $n_a(N)$ units inspected contain only consecutive conforming units.
- Production is at a steady rate.
- The contractor's quality system is considered satisfactory by the government.
- Reduced inspection is considered desirable by the government.

4.8.3.4 Reduced to Normal

When reduced inspection is in effect, normal inspection shall be instituted when the following conditions occur.

- Lot or batch sampling (Tables 2 and 3):
  - — A lot/batch is withheld from acceptance.

  Continuous sampling (Table 4):
  - — A nonconforming unit is found.
- Production becomes irregular or delayed.
- The contractor's quality system is unsatisfactory.
- Other conditions warrant that normal inspection be instituted.

4.8.3.5 Discontinuation of Acceptance

If sampling inspection of lots or batches remains in tightened inspection due to discovery of nonconformances or when, on continuous sampling plans, there are long periods of screening due to discovery of nonconformances, the government reserves the right to discontinue acceptance of the product until the causes of nonconformances are eliminated or other means acceptable to the procuring agency have been instituted. When sampling inspection is restarted after discontinuation of acceptance, it shall be at the tightened inspection level.

4.9 PREFERRED SAMPLING INSPECTION TABLES

See Appendix A for methods of computing sampling results, using switching rules, and determining compliance with requirements using the attributes, variables, and continuous sampling plans contained in this section.

4.9.1 Attributes Sampling Plans for Lot or Batch Inspection

The preferred attributes sampling plans for lots or batches are described in Table 2 for normal, tightened, and reduced inspection.

Table 2. Attributes Sampling Plans

Code Letter	Verification Levels								
	T	VII	VI	V	IV	III	II	I	R
	Sample Size (n_a)								
A	3072	1280	512	192	80	32	12	5	3
B	4096	1536	640	256	96	40	16	6	3
C	5120	2048	768	320	128	48	20	8	3
D	6144	2560	1024	384	160	64	24	10	4
E	8192	3072	1280	512	192	80	32	12	5

NOTES:

(1) When the lot size is less than or equal to the sample size, 100 percent attributes inspection is required.

(2) One verification level (VL) to the left/right of the specified normal VL is the respective tightened/reduced plan. Tightened inspection of VL-VII is T, reduced inspection of VL-I is R.

(3) The lot acceptability criteria is that the sample shall contain nonconformances.

4.9.2 Variables Sampling Plans for Lot or Batch Inspection

The preferred variables sampling plans for lots or batches are described in Table 3 for normal, tightened, and reduced inspection.

4.9.2.1 Limitations on Use of Table 3

Table 3 is not to be used indiscriminately. Its use shall depend upon evidence, provided by graphical or statistical analyses, that the assumptions of independence and normality are being met. Table 2 shall be used whenever the evidence fails to warrant use of Table 3.

4.9.2.2 Nonconforming Unit

For the purposes of variables sampling, a unit of product for which the variables measurement exceeds the specified tolerance is considered as a nonconforming unit. One or more nonconforming units in the sample shall be cause for withholding acceptance of the lot or batch.

Table 3. Variables Sampling Plans

Code Letter	T	Verification Levels							R
		VII	VI	V	IV	III	II	I	
	Sample Size (n_V)								
A	113	87	64	44	29	18	9	4	2
B	122	92	69	49	32	20	11	5	2
C	129	100	74	54	37	23	13	7	2
D	136	107	81	58	41	26	15	8	3
E	145	113	87	64	44	29	18	9	4
	k Values (One- or Two-Sided)								
A	3.51	3.27	3.00	2.69	2.40	2.05	1.64	1.21	1.20
B	3.58	3.32	3.07	2.79	2.46	2.14	1.77	1.33	1.20
C	3.64	3.40	3.12	2.86	2.56	2.21	1.86	1.45	1.20
D	3.69	3.46	3.21	2.91	2.63	2.32	1.93	1.56	1.20
E	3.76	3.51	3.27	3.00	2.69	2.40	2.05	1.64	1.21
	F Values (Two-Sided)								
A	.136	.145	.157	.174	.193	.222	.271	.370	.707
B	.134	.143	.154	.168	.188	.214	.253	.333	.707
C	.132	.140	.152	.165	.182	.208	.242	.301	.707
D	.130	.138	.148	.162	.177	.199	.233	.283	.435
E	.128	.136	.145	.157	.174	.193	.222	.271	.370

NOTES:

(1) When the lot size is less than or equal to the sample size, 100 percent attributes inspection is required.

(2) One verification level (VL) to the left/right of the specified normal VL is the respective tightened/reduced plan. Tightened inspection of VL-VII is T, reduced inspection of VL-I is R.

(3) The lot acceptability criterion is that the sample shall contain no nonconformances and shall also meet the applicable k and F acceptability criteria described in Appendix A (Examples 2 and 3).

4.9.3 Continuous Attributes Sampling Inspection Plans

The preferred continuous sampling plans for inspection by attributes are described in Table 4 for normal, tightened, and reduced inspection.

Table 4. Continuous Sampling Plans

Code Letter	T	Verification Levels							R
		VII	VI	V	IV	III	II	I	
	Screening Phase: Clearance Numbers (i)								
A	3867	2207	1134	527	264	125	55	27	NA
B	7061	3402	1754	842	372	180	83	36	NA
C	11337	5609	2524	1237	572	246	116	53	NA
D	16827	8411	3957	1714	815	368	155	73	NA
E	26912	11868	5709	2605	1101	513	228	96	NA
	Sampling Phase: Frequencies (f)								
A	1/3	4/17	1/6	2/17	1/12	1/17	1/24	1/34	1/48
B	4/17	1/6	2/17	1/12	1/17	1/24	1/34	1/48	1/68
C	1/6	2/17	1/12	1/17	1/24	1/34	1/48	1/68	1/96
D	2/17	1/12	1/17	1/24	1/34	1/48	1/68	1/96	1/136
E	1/12	1/17	1/24	1/34	1/48	1/68	1/96	1/136	1/192

NOTES:

(1) Use of other i and f combinations are permitted provided they are computed in accordance with Appendix A, Example 5.

(2) One verification level (VL) to the left/right of the specified normal VL is the respective tightened/reduced plan. Tightened inspection of VL-VII is T, reduced inspection of VL-I is R.

(3) Sample units shall be chosen with frequency (f) so as to give each unit of product an equal chance of being inspected. The inspector should allow the interval between sample units to vary somewhat rather than draw sample units according to a rigid pattern.

4.9.3.1 Conditions for Continuous Sampling Procedures

The following conditions must exist before the continuous attributes sampling procedures of this section may be used for inspection.

- Moving product.
- Ample space, equipment, and manpower at or near the inspection station to permit 100 percent inspection when required.
- A process that is producing or is capable of producing material whose quality is stable.

4.9.3.2 Continuous Sampling Inspection Procedure

At the start of production, all units are inspected. Sampling inspection may be initiated at frequency *f* when the following conditions are satisfied:

(a) All units of product are of the same configuration and produced under stable conditions.

(b) At least *i* consecutive units inspected are free of nonconformances.

Sampling inspection shall be terminated and 100 percent inspection resumed if either or both of the following conditions occur:

(1) The production process is interrupted for more than three operating days, or the requirement of (a) above is otherwise not satisfied.

(2) A unit having any nonconformance is found during sampling.

5. ALTERNATE ACCEPTANCE PROVISIONS

5.1 GENERAL

This standard, when referenced in the contract or product specifications, requires the contractor to perform sampling inspection in accordance with Section 4 and the product specification. However, it is recognized that sampling inspection alone does not control or improve quality. Product quality comes from proper product and process design and process control activities and when they are effective, sampling inspection is a redundant effort and an unnecessary cost. Contractors that have an acceptable quality system and proven process controls on specific processes are encouraged to consider submitting alternate acceptance methods for one or more contractually specified characteristic. In addition, contractors that have a successful quality system and a history of successful process controls throughout the company are encouraged to consider submitting a systemic alternate acceptance method for all the contractual sampling inspection requirements associated with Section 4.

Submissions will describe the alternate acceptance methods, the sampling inspection provision to be replaced, and an evaluation of the protection provided by the alternate methods as compared with the inspection requirement to be replaced. The alternate acceptance method shall include evidence of process control and capability during production together with adequate criteria, measurement, and evaluation procedures to maintain control of the process. The acceptability of the alternate acceptance methods is dependent on the existence of a quality system, the demonstration of its process focus, and the availability of objective evidence of effectiveness.

5.2 REQUIREMENTS AND PROCEDURES

Contractors currently operating quality systems in accordance with such models as MIL-Q-9858 enhanced with Statistical Process Controls (SPC), ANSI/ASQC Q94, or others that are deemed satisfactory to the government representative are qualified to apply for alternate acceptance methods if demonstration of process focus and objective evidence of effectiveness exists.

The contractor will include in his request for alternate acceptance method approval an assessment plan to periodically verify process stability, capability, and other conditions under which the alternate acceptance method was developed. The current target values of process capability are equivalent to a C_{pk} of 2.00 for critical characteristics, 1.33 for major characteristics, and 1.0 for minor characteristics. Upon approval of the assessment plan, the contractor may reduce or eliminate inspection sampling when the plan criteria are met or exceeded.

Appendix B provides criteria and considerations that may be used if the contract does not otherwise establish procedures for alternate acceptance methods.

5.3 SUBMISSION AND INCORPORATION

There are two ways of submitting alternate acceptance methods:

1. Submission of individual alternate acceptance methods for one or more contractually specified sampling inspection requirements to the Government quality assurance representative (QAR) for approval at any time during the contract period of performance.
2. Submission of a systemic alternate acceptance method to the procuring contracting officer (PCO) prior to contract being awarded. This pre-approval allows the contractor to adopt alternate acceptance methods throughout the length of the contract. After contract award, submissions of a systemic alternate acceptance method should be made through the administrative contracting officer (ACO) to the PCO.

All approved alternate acceptance methods shall be incorporated into the contractor's manufacturing and quality program plans or other vehicles acceptable to the contracting agency, as applicable.

5.4 WITHDRAWAL OF APPROVAL OF ALTERNATES

The government reserves the right to withdraw approval of alternate acceptance methods that are determined to provide less assurance of quality than the inspection requirements originally specified or when the inability to maintain process stability and capability over time becomes apparent.

6. NOTES

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Annex A

EXAMPLES OF SAMPLING PLAN USE

CONTENTS

FIGURES

Annex A
EXAMPLES OF SAMPLING PLAN USE

1. Attributes Sampling

Wing nuts are to be inspected for missing thread. A verification level IV (VL-IV) has been specified. The producer chooses to use attributes sampling plans from Table 2. Lot sizes may vary as a result of production decisions. A segment of the producer's experience is shown in Figure A-1.

Lot #	Lot Size	Code Letter	Sample Size	Non-conform-ances	Lot Disposition	Stage T/N/R	Action
1	5000	D	160	2	Withhold Acceptance	N	Begin with normal sampling, VL-IV.
2	900	A	80	0	Accept	N	
3	3000	C	128	1	Withhold Acceptance	N	2 lots out of 5 fail to pass. Switch to tightened VL-IV.
4	1000	B	256	0	Accept	T	
5	1000	B	256	0	Accept	T	
6	900	A	192	0	Accept	T	
7	2000	C	320	0	Accept	T	
8	2500	C	320	0	Accept	T	
9	3000	C	128	0	Accept	N	5 consecutive lots accepted. Process corrected. Switch to normal VL-IV.
10	5000	D	160	0	Accept	N	

Figure A-1. Attributes Sampling Inspection Log

2. Variables Sampling (Single Specification Limit Case)

The maximum temperature of operation for a certain device is specified as 209 (measured in degrees F). Verification level I (VL-I) has been specified. A lot of 40 items is submitted for inspection in accordance with variables sampling. Table 3 requires a sample size of $n_v = 4$ for code letter A (CL-A). Suppose the measurements obtained are as follows: 197, 188, 184, and 205; and compliance with the acceptability criteria is to be determined. Computations are shown in Figure A-2.

Line	Information Needed	Symbol	Formula	Result	Explanation
1	Sample size	n_v		4	See Table 3
2	Sum of measurements		ΣX	774	
3	Sum of squared measurements		ΣX^2	150034	
4	Correction factor	CF	$(\Sigma X)^2/n_v$	149769	$(774)^2/4$
5	Corrected sum of squares	SS	ΣX^2-CF	265	150034-149769
6	Sample variance	V	$SS/(n_v-1)$	88.333	265/3
7	Sample standard deviation	s	$\sqrt{V}$	9.399	$\sqrt{88.333}$
8	Sample mean	$\bar{X}$	$\Sigma X/n_v$	193.500	774/4
9	Lower specification limit	L		Not applicable	
	Upper specification limit	U		209	
10	Lower quality index	Q_L	$(\bar{X}-L)/s$	Not applicable	
	Upper quality index	Q_U	$(U-\bar{X})/s$	1.649	(209-193.5)/9.399
	Quality Index = Min(Q_L, Q_U)	Q	$\min(Q_L,Q_U)$	1.649	
11	Sample F value	$\hat{F}$	s/(U-L)	Not applicable	
12	Number of nonconformances	C		0	
	k value	k		1.210	See Table 3
	F value	F		Not applicable	See Table 3
13	C acceptability criterion		C = 0?	Yes	
	k acceptability criterion		$Q \geq k$?	Yes	1.649 ≥ 1.21
	F acceptability criterion		$\hat{F} \leq F$?	Not applicable	

NOTES: The k value is the minimum allowable value for the quality index, Q.
The F value is the maximum allowable value for the sample F value, $\hat{F}$.

Figure A-2. Computations for Single Specification Limit Case

The lot is accepted because it meets all applicable acceptability criteria.

3. Variables Sampling (Double Specification Limit Case)

The minimum temperature of operation for a certain device is specified as 180 (measured in degrees F). The maximum is 209. Verification level I (VL-I) has been specified. A lot of 40 items is submitted for inspection in accordance with variables sampling. Table 3 requires a sample of size $n_v = 4$ for code letter A (CL-A). Suppose the measurements obtained are as follows: 197, 188, 184 and 205; and compliance with the acceptability criteria is to be determined. Computations are shown in Figure A-3.

Line	Information Needed	Symbol	Formula	Result	Explanation
1	Sample size	n_v		4	See Table 3
2	Sum of measurements		ΣX	774	
3	Sum of squared measurements		ΣX^2	150034	
4	Correction factor	CF	$(\Sigma X)^2/n_v$	149769	$(774)^2/4$
5	Corrected sum of squares	SS	$\Sigma X^2\text{-}CF$	265	150034-149769
6	Sample variance	V	$SS/(n_v\text{-}1)$	88.333	265/3
7	Sample standard deviation	s	$\sqrt{V}$	9.399	$\sqrt{88.333}$
8	Sample mean	$\bar{X}$	$\Sigma X/n_v$	193.500	774/4
9	Lower specification limit	L		180	
	Upper specification limit	U		209	
10	Lower quality index	Q_L	$(\bar{X}\text{-}L)/s$	1.436	(193.5-180)/9.399
	Upper quality index	Q_U	$(U\text{-}\bar{X})/s$	1.649	(209-193.5)/9.399
	Quality Index = Min(Q_L, Q_U)	Q		1.436	
11	Sample F value	$\hat{F}$	s/(U-L)	0.324	9.399/(209-180)
12	Number of nonconformances	C		0	
	k value	k		1.210	See Table 3
	F value	F		0.370	See Table 3
13	C acceptability criteria		C = 0?	Yes	
	k acceptability criteria		Q ≥ k?	Yes	1.436 ≥ 1.210
	F acceptability criteria		$\hat{F} \leq F$?	Yes	0.324 ≤ 0.370

NOTES: The k value is the minimum allowable value for the quality index, Q.
The F value is the maximum allowable value for the sample F value, $\hat{F}$.

Figure A-3. Computations for Double Specification Limit Case

The lot is accepted because it meets all applicable acceptability criteria.

4. Continuous Sampling

A visual inspection of stamped metal parts for the presence of a spot weld will be performed immediately after units pass through a spot welding station. Verification level II (VL-II) has been specified. The product will be submitted for continuous attributes sampling inspection. The production interval size is an 8-hour shift, which initially will consist of between 700 to 800 welded parts. With VL-II and code letter C (CL-C) from Table 1, the i and f values (Table 4) are found to be 116 and 1/48, respectively. A segment of sampling experience is shown in Figure A-4.

Product Item Number	Code Letter	Frequency or 100%	Stage T/N/R	Event/Action
1	C	100%	N	Start production: Begin screening phase with $i = 116$.
8	C	100%	N	Find a defective unit: Reset counter.
124	C	100%	N	$i = 116$ consecutive conforming units cleared: Begin sampling phase with $f = 1/48$.
170	C	1/48	N	First random sample selected: Found it to conform.
9697	C	1/48	N	200 consecutive conforming sampled units observed: Switch to reduced inspection with $f = 1/68$. Here, 200 equals 10 times the Table 2 sample size entry for CL-C and VL-II.
9769	C	1/68	R	Next sample randomly selected with $f = 1/68$.
13982	C	1/68	R	Production interval size tripled (2100 to 2400 units): End CL-C and begin CL-E sampling phase, $f = 1/136$, since VL-II and reduced sampling inspection are in effect.
14121	E	1/136	R	First random sample taken with new $f = 1/136$: Found it to conform. Continue random sampling.
16290	E	1/136	R	A nonconforming unit observed: Switch to normal inspection. Initiate screening phase with $i = 228$, since CL-E and VL-II are in effect.
16518	E	100%	N	$i = 228$ consecutive conforming units cleared: Begin sampling phase with $f = 1/96$.

Figure A-4. Continuous Sampling Inspection Log

5. Continuous Sampling (Producer Alternate)

The producer may opt to use another continuous sampling plan instead of the one specified in Table 4. The only restrictions are that such a change is not allowed while inside a screening sequence and that the new plan be derived in accordance with the procedure described below.

Certain circumstances make such choices desirable. Sometimes the selection of a clearance number or frequency is application dependent, e.g., if it matters that i or $1/f$ be a multiple of pallet size. Availability and capability of screening and sampling crews are yet further considerations.

The plan cited in Table 4 consists of the largest i number and the smallest f number combination. Plans whose i is larger than the tabulated i, or whose f is smaller than the tabulated f, are not permitted. Producers willing to sample at rates larger than f can reduce i substantially.

The procedure that allows choice is presented by way of the preceding continuous sampling example situation as initially described, subject to one modification: the producer prefers to start with a plan having an i of 50 instead of the 116 specified. The procedure to determine a valid f is as shown in Figure A-5.

Line	Information Needed	Symbol	Formula	Result	Explanation
1	Clearance number	i		116	Table 4
2	Target i number	i_t	$i_t < i$?	Yes	50 < 116
3	Attribute Sample Size	n_a		20	Table 2, same VL, CL
4	Compute f_0:				
	Step 1	S1	$(n_a+1)(1+1/n_a)^{n_a}$	55.7193	
	Step 2	S2	$(i_t+1)(1+1/i_t)^{i_t}$	137.2710	
	Step 3	S3	$[S1/(S1-1)]^{i_t}$	2.4732	
	Step 4	f0	(S1-1)/[(S2)(S3)]	0.1612	
5	Valid f		Any $f > f_0$	1/6	1/6 > 0.1612

Figure A-5. Procedure to Determine a Valid *f*

Therefore, an i of 50 may be used in lieu of 116 if f is increased from 1/48 to 1/6.

If it is f that is preselected, the corresponding i may be found by trial and error, that is, by iterative implementation of the procedure described.

The printed numerical results have been rounded to 4-decimal accuracy. However, use of the procedure requires that all calculations be performed with at least 6-digit precision. Evidence supporting the validity of numerical results shall be maintained and be available for review upon request. Proper execution of the procedure ensures Tables 4 and 2 are comparable with respect to the average fraction inspected and the average outgoing quality limit.

Annex B

ALTERNATE ACCEPTANCE PROVISIONS—REQUIREMENTS AND PROCEDURES

CONTENTS

Annex B
ALTERNATE ACCEPTANCE PROVISIONS— REQUIREMENTS AND PROCEDURES

1. QUALITY SYSTEM

In order for an alternate acceptance method to be considered, the contractor shall establish and utilize an internal quality system as a means of ensuring that all products conform to requirements specified by the contract and associated specifications and standards. The quality system shall be documented and shall be subject to on-site government review throughout the contract. It shall include, at a minimum, a description of the organizational structure, responsibilities, procedures, processes, and resources. Such documentation is hereinafter called the quality system plan. The contractor shall maintain, disseminate, update, and improve the quality system plan in order to ensure its continued use and accuracy. The design and documentation of the quality system plan shall allow for ease of use, review, and audit by internal as well as government personnel.

The quality system shall be prevention-based. Common quality system models that reflect this philosophy include the ISO 9000 series, MIL-Q-9858 enhanced with SPC, and many industry specific total quality standards and programs. The quality system shall also reflect additional needs in accordance with the requirements of this standard. Regardless of the model chosen, the quality system shall demonstrate its effectiveness by meeting the following objectives throughout all areas of contract performance:

- The quality system is understood and executed by all personnel having any influence on product or process quality.
- Products and services meet or exceed customer requirements.
- Quality is deliberately and economically controlled.
- Emphasis is on the prevention of process discrepancies and product nonconformances.
- Discrepancies and nonconformances that do occur are readily detected, and root cause corrective actions are taken and verified.

- Sound problem solving and statistical methods are employed to continuously reduce process variability and, in turn, improve process capability and product quality.
- Records are maintained and indicate implementation process of the quality plan and effectiveness of the control procedures.

The acceptability of the quality system as part of the request for alternate acceptance method(s) is dependent on its compliance with an industry accepted quality system model, demonstration of its process focus, and the availability of objective evidence of its effectiveness as described below.

2. PROCESS FOCUS OF QUALITY SYSTEM

To demonstrate a process focus, the contractor shall show that the manufacturing process and its related processes have been studied and are understood, controlled, and documented in such a manner that they are

- Consistently producing conforming product.
- Controlled as far upstream as possible.
- Robust to variation in equipment, raw materials, and other process inputs, and designed to yield a quality product.
- Operated with the intent to constantly strive to reduce process/product variability.
- Designing or procuring manufacturing equipment with objectives of minimum variability around targeted values.
- Managed for continuous improvement.
- Designed and controlled using a combination of manufacturing practices and statistical methods in order to ensure defect prevention and process improvement.

3. OBJECTIVE EVIDENCE OF QUALITY SYSTEM IMPLEMENTATION AND EFFECTIVENESS

3.1 Examples of Evidence Regarding Process Improvement

- Process flow charts showing the key control points where action is taken to prevent the production of defective product.

- Identification of process improvement techniques and tools used, e.g., Plan-Do-Check-Act (PDCA) cycle, Failure Modes and Effects Analysis (FMEA), Pareto Analysis, and Cause and Effect Analysis.
- Identification of the measures used, e.g., trend analysis, cost of quality, cycle time reduction, defect rates, 6 sigma capability.
- Results of the improvements from the use of these process improvement tools.
- Results of properly planned experiments that led to reduced common cause variability of a process and improved productivity.

3.2 Examples of Evidence Regarding Process Control

- Identification of the scope of use of process control techniques, e.g., SPC, automation, gages, set-up verification, preventative maintenance, visual inspection.
- Process control plans, including the improvement goals and statements of management commitment to SPC.
- Approaches and supporting data used to determine if suppliers have adequate controls to assure defective product is not produced and delivered.
- Descriptions of the required training in SPC and/or continuous improvement, i.e., the number of courses, their content, courses required for personnel at each organizational level and function associated with the quality plan, the qualifications of the instructors or trainers for SPC classes, support by management to attend such courses, and information demonstrating the effectiveness of the training.
- Identification and definition of the interrelations of all departments (e.g., production, engineering, purchasing, marketing, administration, etc.) involved in SPC and quality improvement, their responsibilities, and the use of teams.
- When applying control charts, the basis for criteria on establishing rational subgroups, the frequency of sampling, and the proper procedures for establishing and updating control limits.
- Identification of key parameters, placement of their control points in the manufacturing process, and method of verifying the correlation of such parameters when they are used in lieu of one or more specified characteristics.
- Basis for criteria on determining out-of-control conditions, and identification of personnel responsible for process-related corrective action.
- Proper gage measurement studies showing measurement variations relative to the total variation.

- Traceability of the product and process corrective action(s) taken when the process went out of statistical control, showing how the root cause was identified and eliminated.

3.3 Examples of Evidence Regarding Product Conformance

- Control charts showing the process to be in statistical control.
- Records of product and process corrective action(s) taken when nonconformances occur.
- Process capability studies consisting of the correct calculation and interpretation of indices, such as C_p and C_{pk}.
- History of product inspection results reinforced by statistical data and analysis.
- Results from in-process control methods, such as 100 percent automated assembly and/or inspection.

Appendix E
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Appendix E
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Gunter, B.H., "The Use and Abuse of C_{pk}," *Quality Progress*, Volume 22, Number 1, 1989, pp. 72-73.

Hall, Thomas D., Amerock Corporation, "How Close is s to σ," *Quality*, December 1991, p. 45.

Hare, Lynn B., Statistical Services, Thomas J. Lipton, Inc., "In the Soup: A Case Study to Identify Contributors to Filling Variability," *Journal of Quality Technology*, Volume 20, Number 1, January 1988, pp. 36-43.

The use of a planned experiment in a plant process which is controlled using Shewhart control charts is discussed. The response is the filling variation among packets of dry soup mix. It was desired to minimize this variation to provide more product uniformity and increase consumer acceptance. The experimental design is discussed as are summary statistics derived from control chart data and the analysis and interpretation of these summary statistics. The results are analyzed graphically, without the use of formal statistical tests. They illustrate the power of planned experimentation in identifying opportunities for quality and productivity improvement.

Harry, Mikel J., "The Nature of Six Sigma Quality," Motorola, Inc., Government Electronics Group.

This booklet highlights the six sigma product quality concept and its relationships to Motorola's position in the marketplace.

The discussion zeros in on the concept of six sigma, which advocates that there are strong relationships between product nonconformities or *defects* and product yield, reliability, cycle time, inventory, schedule, and so on. As the number of defects found during manufacture increases, the number of sigmas decreases. In other words, the larger the sigma value, the better the product quality--and vice versa. Although the ultimate aspiration is zero defects, the threshold of excellence is six sigma quality.

Interestingly, six sigma quality is estimated assuming *typical* shifts and drifts in the average. In this sense, 99.99966 percent capability at the *part* and *process step* levels is an intermediate target toward the ideal of perfection. This may be illustrated by considering a product that contains 300 parts and the related manufacturing process that consists of say, 500 individual steps. A six sigma capability at the part and process step levels would ensure a final *rolled throughput* yield of 99.73 percent. This would be to say, out of every 10,000 units of product manufactured, there would be 9973 units that would be produced completely free of nonconformities. Of course, this example assumes that each part and process step possesses

only one opportunity for nonconformance, that all parts and steps are independent, and that nonconformities are randomly distributed.

The notion of variation is presented as the number one enemy of quality, yields, and costs. It must be arrested and ultimately eliminated in order to achieve *best in class*. By attacking variation during the design phase, within suppliers' processes, and within our own processes, six sigma product quality can be achieved. In doing so, the foundation of excellence is laid.

The discussion also focuses on a more statistically based understanding of the six sigma program. It describes the arithmetic mean (μ), standard deviation σ and practical uses of the normal distribution. In particular, the rationale for making quality and yield estimates under the assumption of a 1.5 σ shift in the mean is emphasized. Based on the statistical perspective, the product and process engineering viewpoints are brought into focus by means of analytical examples. Through the discussion and examples, insights are developed as to the objectives of the six sigma program: enhanced product quality, yield, and cost--all of which, in turn, improve customer satisfaction.

Index and Directory of U.S. Industry Standards, Volume I, "Subject Index," and Volume II, "Society/Numeric Listing ANSI Number Concordance Society Directory," Information Handling Services, Englewood, CO, 1985.

Industrial Fasteners Institute, pamphlets.

"Industry Survey to Measure Quality Management," *Defense Daily*, 6 February 1992, p. 202.

Price Waterhouse and AAI Corporation today announced the start of a joint survey of aerospace and defense companies on the issue of quality management.

Called TQM/100, the study seeks to identify and measure total quality management standards and trends across a broad range of business activities while giving participating companies confidential access to the survey's findings to compare their quality efforts with those of first-rank and other companies in the study.

The study is expected to encompass 30 to 50 aerospace and defense companies with DoD or NASA sales of more than $100 million. So far, about 20 companies, including Grumman, TRW, Northrop, and General Electric, have agreed to participate. The cost per participant is $25,000.

Kane, Victor E. (Ford Motor Company), "Process Capability Indices," *Journal of Quality Technology*, Volume 18, Number 1, January 1986, pp. 41-52.

The capability indices Cp, CPU, CPL, k and Cpk are presented and related to process parameters. These indices are shown to form a complementary system of measures of process performance, and can be used with bilateral and unilateral tolerances, with or without target values. A number of Japanese Industries currently use the five indices and the U.S. automotive industry has started using these measures in a number of areas. Various applications of the indices are discussed along with statistical sampling considerations.

Kilpatrick, Philip S., Alliant Techsystems, Inc., "Benefits of SPC Application to Program Management for 120mm Tank Ammunition," viewgraphs, *American Defense Preparedness Association, 2nd Annual Statistical Process Control Symposium*, Hunt Valley, MD, 4 March 1992.

Kowalick, Jim, "QFD, DOE and Producibility," Renaissance Leadership Institute, Renaissance, CA.

Lamprecht, James L., "ISO 9000 Implementation Strategies," *Quality*, November 1991, pp. 14-17.

The race is on here in the U.S. for ISO certification in Europe.

Lang, Ron, "Achieving Manufacturing Excellence," viewgraphs, National Center for Manufacturing Science (NCMS), 1993.

Levi, Raffaello (Polytechnical University of Turin, Italy), "Cautions for Tachuchi Lovers," *Manufacturing Engineering*, March 1993, page 16.

Lindley, Dennis V.(retired) and Nozer D. Singpurwalla (The George Washington University), "On the Evidence Needed to Reach Agreed Action Between Adversaries, With Application to Acceptance Sampling," Journal of the American Statistical Association, Volume 86, Number 416, December 1991.

Two decision makers disagree about a quantity of interest to them both. One of them, the "consumer," has a choice of two decisions that are affected by the quantity. The other, the "manufacturer," offers to perform an agreed type of experiment that it is hoped will change the consumer's view of the quantity and hence the decision. This article is devoted to the evaluation of how much experimentation should be done. Binomial, Poisson, and normal likelihoods, together with their conjugate utilities and probabilities, are considered and illustrated by numerical cases. The scenario considered here arises in applications to quality control, bidding, drug testing, marketing, and sales.

Liuzza, Carmen J. and Paul A. Roediger, "ABC, Joint AMC/ADPA SPC Meeting," viewgraphs, ARDEC, 22 October 1991.

Liuzza, Carmen J., Paul A. Roediger (Picatinny Arsenal), and Edward G. Schilling (Rochester Institute of Technology), "ABC: A Sampling Plan to Attain Process Control and Capability."

Lorber, Si and Bill Kracov, "Quality Program Requirements for the 90's," May 1992.

Lorber, Si and Bill Kracov, *DoD Quality Program Requirements for the 90's*, viewgraphs, Spring 1992.

Lowell, Steve, "DoD Non-Government Standards Adoption Program Tutorial, Past, Present, and Future," viewgraphs, Office of the Assistant Secretary of Defense for Production and Logistics, Washington, DC.

MacDonald, B.A. and M.V. Petty, "List of Quality Standards, Specifications and Related Documents," 10 February 1987.

Marusich, Kerry, Alliant Techsystems, Inc., "Managing With Control Charts," *Second Annual American Defense Preparedness Association, Statistical Process Control Symposium*, Hunt Valley, MD, 1-4 March 1992.

> Management data varies over time just as data relating to product quality characteristics in a production environment does. Dr. W. Edwards Deming says that great opportunities exist for the use of Shewhart control charts in areas of supervision and management, and that the job of management is one of prediction. Yet, managers make critical decisions (predictions) with intuition or 'gut feel' being the rationale, rather than by analyzing data in time series. This method of operation causes lost opportunities for improvement and/or damage to the system, resulting in lower quality and increased costs. The purpose of this paper is to demonstrate the importance using Shewhart control charts for analyzing management data, as well as the importance of viewing production globally, rather than as a set of independent processes.

National Center for Manufacturing Sciences, "Standards Come to the Fore as a World-Class Competitive Force," *Focus*, March 1992.

National Institute for Standards and Technology (NIST), "Standards Developing Organizations (Abbreviations and Directory)," January 1991.

Naval Surface Warfare Center, Crane Division, *Procurement Quality Handbook*, June 1993.

Ott, Ellis R. (The State University of New Jersey, Rutgers), and Edward G. Schilling (Rochester Institute of Technology), "On Sampling to Provide a Feedback of Information," Chapter 6, *Process Quality Control*, McGraw-Hill Publishing Co., Second Edition, pp. 123-129.

Pap, Geza M., "Measuring to AQL Ineffective," letter, *Quality Progress*, April 1992.

Pap, Geza M., "AQL Elimination, IDA Task and Related Activities," viewgraphs, Picatinny Arsenal, NJ, 17 March 1992.

Pap, Geza M., AMSMC-QAH (D), Picatinny Arsenal, NJ, "Elimination of Acceptable Quality Levels (AQLs) from Military Specification," viewgraphs, presented to AMCCOM, 28 January 1992.

Pecht, Michael (University of Maryland) and Edward Hakim (Fort Monmouth, NJ), "The Future of Military Standards, A Focus on Electronics."

> With cut-backs in the military and the changing international economic environment, there is a growing perception that the military must rely on commercial industries in order to afford the next generation of high performance and high reliability military systems. What is not clear is whether an industrial base for the defense can be provided and maintained without dramatic changes in the operation of both the government (DoD) and commercial industry. This paper examines one issue associated with this question—whether commercial standards can effectively supplant military standards and still provide high performance and reliability for military missions.

Pennueel, Nicholas J. (Calcomp, Anaheim, CA), "What are C_p and C_{pk}?," *Quality*, August 1986.

> Once a process is in statistical control, it doesn't mean the work is done. It is only the first step. The next question is, "Will the product meet the spec, and how well will it meet the spec?," C_p and C_{pk}, respectively, can provide the answers.

Placek, Chester, "Fasteners Group Issues Guide to Recommended SPC Practices for Fastener Industry," *Quality*, April 1991, p. 13.

> Statistical Process Control (SPC) guide published by industrial Fasteners Institute should help manufacturers of fasteners and formed parts achieve a common basis for assuring product quality.

Process Action Team, *Draft Charter on Military Specifications and Standards*, AMCRD-IC CON Engineering, August 1993.

Process Action Team, *Elimination of Fixed Defect Levels (Acceptable Quality Levels/Lot Tolerance Percent Defective) from Military Specifications*, Final Report, MCRDAC PS, 24 September 1990.

> This report summarizes the efforts of a joint-service/agency Process Action Team (PAT) formed to determine the most effective approach to remove Acceptable Quality Levels (AQLs) and Lot Tolerance Percent Defective (LTPDs) from military specifications as acceptance criteria. In addition, the PAT recommended:
>
> > Standard methods to replace such statements,
> >
> > Uniform methods to convey expectations of total compliance to specification requirements, and
> >
> > Methods to measure quality of product without specifying risk statements.
>
> The PAT effort embodied the basic concepts of Total Quality Management (TQM) as implemented within OSD. The PAT initiated its task with a review of previous efforts which had addressed the same subject; in particular, the final report of the Joint Services Working Group on Elimination of Fixed Defect Levels dated 13 July 1988. Subsequently, the PAT conducted an in-depth analysis of the history, use and misuse of AQLs and LTPDs, so that appropriate benefits of their use would not be lost while the negative aspects were being removed.
>
> The PAT recommends a fundamental shift of focus of verification and acceptance activities from end-of-line inspections and tests to in-line or off-line manufacturing process controls. The desired outcome is to convey clearly an expectation of 100 percent compliance to well defined, specified requirements while preserving the right of Government to use appropriate verification, including in-plant sampling to establish confidence in meeting required quality. Specific recommendations include:
>
> > Remove AQL/LTPD terminology and similar expressions from military specifications. The use of sampling plans and statistical techniques is not prohibited by the removal of such terminology.
> >
> > Immediately revise MIL-STDs 961, 962, and 490 to permit accomplishment of the first recommendation.

In a phased orderly manner, require that new or newly revised product specifications meet these requirements prior to publication.

Sponsor further action to develop acquisition language and techniques such that DoD can successfully implement the quality policy with long term focus on process control and continuous improvement.

"The Quality Glossary," *Quality Progress*, February 1992, pp. 20-29.

Rade, Leonard G. (Peripheral Components International), "Enhance Product Development by Using Capability Indexes," *Quality Progress*, April 1989, pp. 38-41.

Reiss, Fred J., GEC-Marconi Electronic Systems Corporation, "Graphical Analysis Using Probability Paper," *2nd Annual Technical Workshop on Quality Control and Statistics*, Princeton University, Princeton, NJ, 4 December 1971.

Rogers, Lee, P.E., *The Rationale and Plan for Eliminating Fixed Allowable Levels of Defects from Military Specifications (MIL-specs) and DoD Procurements*, 6 June 1991, Draft.

Riddell, Frederick R., "Notes—Meeting With Ed Schilling," Rochester Institute of Technology, Rochester, NY, 28-29 October 1991.

Rydeski, James A., Alliant Techsystems, "Management and SPC," viewgraphs, presented at *American Defense Preparedness Association, Second Annual Statistical Process Control Symposium*, Hunt Valley, MD, 3 March 1992.

Rydeski, James A., Alliant Techsystems, "A SPC Rating System, An Effective Communication Tool," presented at The Third Annual SPC Division of ADPA's SPC Symposium "SPC: A Management Strategy, 17 March 1993.

Schilling, Edward G. (Rochester Institute of Technology, Rochester, NY), "The Transition from Sampling to SPC," *Quality and Statistics: Total Quality Management*, ASTM STP 1209, Milton J. Kowalsewski, Jr., Ed., American Society for Testing and Materials, Philadelphia, 1994.

Modern quality control practice emphasizes the importance of process control in the creation of quality product. When the process is in control, it is possible to characterize the product forthcoming from the process, for the particular characteristic controlled, at the point in the process at which the control is instituted. When the process is out of control, the relationship between product and process is lost. It is then necessary to go rely on acceptance sampling procedures to characterize the process. By combining the power of process control with the assurance of acceptance sampling, the process experimentation necessary for continual improvement can be undertaken with minimal risk to the consumer. An approach has been developed to transition from a process lacking control and/or capability to a controlled process with a C_{pk} value 1.33 indicating that the process is operating at an average level four sigma from the specification(s).

Schilling, Edward G., Letter, ABC for IQUE, 1 February 1992.

Schilling, Edward G., Scientific Services Program, "An ABC Sampling Plan to Attain Process Control and Capability," Armament Research, Development and Engineering Center, Picatinny Arsenal, NJ, 28 February 1991.

An ABC Sampling Plan for acceptance of products and processes is presented which incorporates three successive stages to move from an uncontrolled process to a process under statistical control with $Cp_k = 1.33$.

Protection is afforded in terms of the AQQL of sampling plans run in parallel with implementation of statistical process control. Switching from state to stage is in terms of stringent requirements in terms of capability and control. The plan is structured to be of maximum educational benefit to the user in promoting continual improvement.

Schilling, E.G., Rochester Institute of Technology, "New ANSI Versions of MIL-STD-414 and MIL-STD-105D," *Naval Research Logistics Quarterly*, Volume 32, 1985, pp.5-9.

When acceptance sampling plans are applied to measurement characteristics, a choice between application of a variables or an attributes plan must be made. With the recent revision by the American Society of Quality Control for the American National Standards Institute of the ANSI/ASQC Z1.9 variables system and the ANSI/ASQC Z1.4 attributes system, the standards have now been matched so that it is possible to move between them. This article discusses exploitation of the resulting synergistic relationship to achieve more rational and more effective acceptance sampling.

Schilling, Edward G., General Electric Company, "Revised Attributes Acceptance Sampling Standard—ANSI/ASQC Z1.4 (1981)," *Journal of Quality Technology*, Volume 14, Number 4, October 1982, pp. 215-219.

The United States National Standard ANSI/ASQC Z1.4 (1981) is a revised version of the military attributes sampling system MIL-STD-105D. This standard has undergone revisions to modernize terminology and to emphasize the system aspect of the procedure. In addition, it has been made even more compatible with its variables counterpart ANSI/ASQC Z1.9 (1980), which was derived from MIL-STD-414. The development and nature of these revisions are described.

Schilling, Edward G., General Electric Company, "Two New ASQC Acceptance Sampling Standards," *Quality Progress*, March 1983, pp. 14-17.

Two recently revised standards now fit together to allow more effective sampling.

Schilling, Edward G., Rochester Institute of Technology, "Product Oriented Quality Control and Assurance," invited paper from *Proceedings of the 35th EOQ Annual Conference*, 17-21 June 1991, Prague, Czechoslovakia, pp. 376-382.

This paper describes the advantages and desirability of the use of statistical process control techniques in characterizing the product, while pointing out the areas in which such techniques are inappropriate. Strategies are proposed which incorporate both process control and acceptance sampling to achieve the efficiencies offered by proper application of both procedures.

Schilling, Edward G., Paul A. Miller (Rochester Institute of Technology), and Dan J. Sommers (General Electric Company), "Section 25, Acceptance Sampling," reprinted by permission from *Quality Control Handbook*, edited by J. M. Juran and Frank M. Gryna, Jr., McGraw-Hill Book Company, 1988.

Schilling, E.G. (Rochester Institute of Technology) and H.F. Dodge (Rutgers University), "Procedures and Tables for Evaluating Dependent Mixed Acceptance Sampling Plans," *Technometrics*, Volume 11, Number 2, May 1969.

This paper gives procedures and tables for evaluating the operating characteristic curves and associated measures of dependent mixed

acceptance sampling plans for the case of single specification limit and known standard deviation, assuming a normal distribution. Joint probabilities necessary for evaluating these measures are derived and methods to facilitate their computation are provided. A useful generalized dependent plan is also presented, using two attributes acceptance numbers rather than one. Tables of joint probabilities necessary for evaluation of mixed plans are presented for first sample sizes of 4, 5, 8, and 10, acceptance numbers of 0, 1, and 2 and various percentages defective.

Schilling, Edward G., Rochester Institute of Technology, "Acceptance Sampling in Quality Control," *ASQC Quality Press*, Marcel Dekker, Inc., New York and Basel, Milwaukee, pp. 76-107.

Schilling, Edward G., "The Role of Statistics in the Management of Quality," based on the Shewhart Medal acceptance speech made at the Honors and Awards Breakfast at the 38th Annual Quality Congress, *Quality Progress*, August 1984, pp. 32-35.

Schweiker, Jane, Independent Consultant, "ASTM and the Department of Defense," *ASTM Standardization News*, September 1991.

Shainin, Dorian and Peter D. Shainin, "Statistical Process Control," Juran's *Quality Control Handbook*, Section 24, 4th Edition, McGraw Hill, 1988.

Singpurwalla, Nozer D., The George Washington University, "Design by Decision Theory: A Unifying Perspective on Taguchi's Approach to Quality Engineering," to appear in *Reliability and Decision Making*, Elsevier Science, pp. 267-272.

We argue that an encompassing perspective on Taguchi's approach to quality engineering is provided by statistical decision theory. This theory deals with decision making in the face of uncertainty, with or without partial information, and prescribes that an optimum decision is one that maximizes (minimizes) expected utility (loss). The role of experimental design is to enable one to obtain partial information about unknown quantities in an efficient manner. When viewed as such, much of what Taguchi advocates, including his proposals for tolerance design, gets streamlined and integrated as a comprehensive package. An advantage of the proposed perspective is a better delineation, and possible elimination of some areas of controversy. Furthermore, it helps us focus on issues additional to those pertaining to experimental design and thereby provides opportunities for new research to expand and to build upon Taguchi's sensible plan.

Singpurwalla, Nozer D., The George Washington University, "A Bayesian Perspective on Taguchi's Approach to Quality Engineering and Tolerance Design," IIE Transactions, Volume 24, Number 5, November 1992, pp. 18-27.

An impetus for the new revolution in quality technology has been Professor Genichi Taguchi's approach to quality engineering, best exemplified by his call for *off-line quality control*. However, much of the literature on this topic appears to be fragmented between engineering, statistics and quality control journals, each emphasizing a point of view that is pertinent to its readership. A consequence of the above is that there has been some difficulty in developing an appreciation for the totality of the approach, its key ingredients, and the several excellent contributions of many others in this important subject. In this paper, we attempt to help alleviate this difficulty by pointing out that an encompassing perspective on Taguchi's philosophy can be provided by *statistical decision analysis*. The subject

deals with decision making in the face of partial or no information, and prescribes that an optimum decision is one that *maximizes expected utility*. The role of experimental design is to obtain partial information about the unknown quantities in an efficient manner. When viewed as such, much of what Taguchi prescribes, including his proposals for *tolerance design*, gets streamlined and integrated as a comprehensive package.

Society of Automotive Engineers (SAE), *Report to Aerospace Industry*, 1991 SAE Cooperative Engineering Program, January 1991.

Standardization Management Activity Seminar, information, 17 March 1994.

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Stratton, John H., "What is the Registrar Accreditation Board?," *Quality Progress*, January 1992, pp. 67-69.

Third Party Accreditation: Acceptance, Applications, and Implications, Bulletin from The Performance Review Institute's First Conference, Holiday Inn, Washington, DC, 15 October 1991.

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Department of Defense, The Deputy Secretary, *Use of Commercial Quality System Standards in the Department of Defense (DoD)*, Memorandum for Secretaries of the Military Departments Directors of Defense Agencies.

Ellis, Ernest D., Deputy Executive Director, Quality Assurance, Defense Logistics Agency. "MIL-Q-9858, Quality Program Requirements," with Enclosure, Memorandum for Nicholas M. Torelli, Jr.. 11 December 1992.

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Miller, Ken, Department of the Air Force (SAF/AQX), "MIL-Q-9858A Proposed Amendment 3—Action Memorandum," Memorandum for Acting Deputy Assistant Secretary of Defense (Production Resources) (Mr. Walter B. Bergman II), 22 February 1994.

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Pucilowski, Joseph J., Jr., Acting Deputy Chief of Staff for Concurrent Engineering, Department of the Army, Headquarters, U.S. Army Materiel Command, AMCCE-QE, "AQL/LTPD Policy," Memorandum for Commander, U.S. Army Laboratory Command, Materials Technology Laboratory, Alexandria, VA, 17 May 1991.

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Letter to be Attached to all Picatinny Solicitations/Contracts Which Have AQL Free TDPs (0-1 Plans), Fourth Draft, U.S. Army Armament Munitions and Chemical Command, 3 December 1991.

Todaro, John B., Industrial Productivity and Quality, PR/IPQ, "Fixed Allowable Level of Defects Handbook," Memorandum for Director, Standardization and Data Management, 15 October 1990.

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American Society for Quality Control, *ANSI Z1.1-1985 Guide for Quality Control Charts, ANSI Z1.2-1985 Control Chart Method of Analyzing Data, ANSI Z1.3-1985 Control Chart Method of Controlling Quality During Production*, Milwaukee, WI.

American Society for Quality Control, ASQC Standard Project 43, American National Standard, *Introduction to Attribute Sampling*, Milwaukee, WI.

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Quality Management and Quality Assurance Standards—Guidelines for Selection and Use, ANSI/ASQC Q90-1987, American Society for Quality Control, Milwaukee, WS, approved 8 June 1987, American National Standards Institute, Inc.

> *Quality Management and Quality Assurance Standards—Guidelines for Selection and Use* provides guidelines for the selection and use of Standards Q91, Q91, Q91, and Q94.

Quality Systems—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing, ANSI/ASQC Q91-1987, American Society for Quality Control, Milwaukee, WS, approved 19 June 1987, American National Standards Institute, Inc.

> *Quality Systems—Model for Quality Assurance in Design/Development, Production, Installation, and Servicing* specifies quality system requirements for use where a contract between two parties requires the demonstration of a supplier's capability to design and supply product.

Quality Systems—Model for Quality Assurance in Production and Installation, ANSI/ASQC Q92-1987, American Society for Quality Control, Milwaukee, WS, approved 15 June 1987, American National Standards Institute, Inc.

> *Quality Systems—Model for Quality Assurance in Production and Installation* specifies quality system requirements for use where a contract between two parties requires the demonstration of a supplier's capability to control the processes that determine the acceptability of a product supplied.

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> *Quality Systems—Model for Quality Assurance in Final Inspection and Test* specifies quality system requirements for use where a contract between two parties requires the demonstration of a supplier's capability to design and control the disposition of any product nonconformity during final inspection and test.

Quality Management and Quality Systems Elements—Guidelines, ANSI/ASQC Q94-1987, American Society for Quality Control, Milwaukee, WS, approved 15 June 1987, American National Standards Institute, Inc.

Guidelines describes a basic set of elements by which a Quality Management System can be developed and implemented internally.

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Appendix F
DEFINITIONS AND ACRONYMS

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Quality means the composite of material attributes including performance features and characteristics of product or service to satisfy a given need (DFAR 246.101).

Government Contract Quality Assurance means the various functions, including inspection, performed by the Government to determine whether a contractor has fulfilled the contract obligations pertaining to quality and quantity (FAR 46.101).

ABCA	America, Britain, Canada, Australia
ADPA	American Defense Preparedness Association
AF	Air Force
ANSI	American National Standards Institute
AoZ	Accept-on-Zero (Defects)
AQL	Acceptable Quality Level
ASQC	American Society for Quality Control
DCMC	Defense Contract Management Command
DFAR	Defense Federal Acquisition Regulations
DLA	Defense Logistics Agency
DoD	Department of Defense
FAR	Federal Acquisition Regulations
IDA	Institute for Defense Analyses
IPPD	Integrated Product and Process Development
IQUE	In-plant Quality Evaluation
ISO	International Organization of Standards
LTPD	Lot Tolerance Percent Defective
NASA	National Aeronautical and Space Administration
OSD	Office of the Secretary of Defense
QA	Quality Assurance
SPC	Statistical Process Control
SQC	Statistical Quality Control
TDP	Technical Data Package
TQM	Total Quality Management

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13. ABSTRACT ***(Maximum 200 words)***

This paper reports the results of a three-year study by the Institute for Defense Analyses (IDA) called *Government-Industry Standardization of Product Acceptance Based on Process Data.* The purpose of the study was to help devise a new Department of Defense (DoD) approach to quality assurance practices. The paper includes a new standard developed under the task, acceptable to both DoD and industry, that allows DoD to move away from accepting product by end-item inspection to accepting product based on the contractor's quality system and use of process controls. The paper recommends the elimination of three military standards and a specification, and discusses IDA's role in DoD's decision to authorize the use of the ISO 9000 series of quality system standards.

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Quality Assurance, Quality System Standards, Statistical Process Control (SPC), inspection sampling, Acceptable Quality Levels (AQLs), ISO 9000, product acceptance, Total Quality Management (TQM)

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