

IMPLEMENTATION MANUAL
FOR
QUALITY ASSURANCE



**A Report of the
AASHTO Highway Subcommittee
on Construction**

February 1996

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INTRODUCTION

This Implementation Manual for Quality Assurance is published as a committee report of the AASHTO Highway Subcommittee on Construction. Because it has not been ballotted by the AASHTO Standing Committee on Highways and the AASHTO Board of Directors, it is not considered an official AASHTO guide or voluntary standard.

This Committee report was prepared by a Joint Construction/Materials Quality Assurance Task Force of the AASHTO Highway Subcommittee on Construction. The members of the Subcommittee voted during their August, 1995 meeting to publish the Committee Report and authorized its distribution. The AASHTO Highway Subcommittee on Materials passed a resolution in August, 1995 endorsing the report.

This Implementation Manual for Quality Assurance committee report is a companion to a separate report of the Subcommittee on Construction titled Quality Assurance Guide Specification, published concurrently with this report.

The Subcommittee on Construction welcomes comments on this Committee Report, and will consider all that are received. It is planned to continue development of the Committee Report, leading to its ultimate acceptance and publication as an official AASHTO guide.

Comments on this Committee Report should be sent directly to AASHTO at the address displayed below.

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TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
PROGRAM IMPLEMENTATION	1
LABORATORY ACCREDITATION	7
SAMPLING AND TESTING PERSONNEL	8
QUALITY CONTROL	9
ACCEPTANCE PROGRAM	13
INDEPENDENT ASSURANCE	20
DISPUTE RESOLUTION	23
APPENDICES	
APPENDIX A STATISTICAL METHODS, EVALUATING RISKS, AND OPERATING CHARACTERISTIC (OC) CURVES	A-1
APPENDIX B COMPOSITE PAY FACTORS	B-1
APPENDIX Ca PROCEDURE FOR MIX DESIGN FOR PORTLAND CEMENT CONCRETE	C-1
APPENDIX Cb PROCEDURE FOR MAINTAINING SPECIFIED LEVEL OF STRENGTH IN PORTLAND CEMENT CONCRETE	C-4
APPENDIX D QUALITY CONTROL PLANS	D-1
APPENDIX E PARTNERING AGREEMENT	E-1
APPENDIX F COMPARISON OF QUALITY CONTROL AND ACCEPTANCE TESTS	F-1
APPENDIX G PROCEDURE FOR EVALUATING QUALITY CONTROL TEST RESULTS OF AGGREGATE GRADATIONS, ASPHALT MIXES, AND PORTLAND CEMENT CONCRETE	G-1
APPENDIX H PROCEDURE FOR EVALUATING UNIFORMITY OF A COMPLETE PRODUCTION RUN	H-1
NOTES AND REFERENCES	



PROGRAM IMPLEMENTATION

INTRODUCTION

The term Quality Assurance, as defined in the companion committee report titled, Quality Assurance Guide Specification, is:

"All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality."

The term Quality Control/Quality Assurance (QC/QA) has often been used synonymously with Quality Assurance. The above definition considers Quality Assurance to be an all encompassing concept which includes quality control (QC), acceptance, and independent assurance (IA). Therefore, Quality Assurance is the proper term and is used in this manual.

The implementation of a statistically based Quality Assurance specification can be a big change for Agency and industry personnel. As with any change, resistance should be expected. However, Quality Assurance specifications have positive elements for everyone associated with construction. The Agency's manager should continually stress these positive points to help ensure an orderly transition. The following presents important considerations in developing and implementing a Quality Assurance program.

AGENCY MANAGEMENT SUPPORT

Support of upper Agency management is essential. Their prior knowledge of the program objectives and provisions will enable them to support the concept in instances where they are contacted by frustrated individuals. Their support is critical in the area of providing necessary personnel, equipment, and training for an effective and successful program. Management must understand that there will be initial implementation costs, particularly in training and certification, which are critical to the long-term success of the program.

INDUSTRY SUPPORT

Support of and involvement by industry associations in the development and implementation phases of the Quality Assurance program is equally as essential. Their involvement can be extremely valuable in the technical aspects of the program as well as assisting in promotion of the concepts. It may be suitable to form a joint Agency and industry task force to assist in developing specifications and programs. The Agency must, however, first outline required parameters such as acceptance procedures, information requirements for materials control systems, etc.

PROGRAM GOALS

The primary goal of a Quality Assurance program should be to improve quality and provide for the effective use of existing personnel. Agencies should not implement Quality

Assurance programs for the purpose of reducing personnel requirements. Many Agencies have lost personnel through the years and are now faced with a critical need to maximize the productivity of existing personnel. A well organized Quality Assurance program will help satisfy this need to more efficiently use existing personnel.

Minor incremental improvements in the quality and durability of individual highway projects can translate into large system-wide improvements through increased performance. Some within the contracting industry view Quality Assurance as unloading work and responsibility from the Agency to the Contractor. Quality Assurance should be approached as a partnership effort between an Agency and the Contractor, but with well defined and separate responsibilities.

GENERAL SPECIFICATION PRINCIPLES

One of the keys to success of a Quality Assurance program is the specification design itself. Contact with other Agencies that have implemented a Quality Assurance program can provide useful insight. Don't set out to "reinvent the wheel," but rather to improve upon what others have already learned. Many decisions will have significant impacts on Contractors so their input is important. In addition to industry input, experts in material testing, statistics, pavement engineering, contract administration, etc. should be consulted during specification development. Emphasis should be placed on QC during production and acceptance and payment provisions based on final in-place measurements and analysis.

OUTLINE THE IMPLEMENTATION PLAN

Establish a "critical path" for the implementation plan, showing mileposts as to what is to be accomplished from beginning to full implementation. Do not rush the implementation but rather stretch it out over a 4 or 5 year period. This time period will give everyone a chance to adjust to any new procedures. Begin with one or two projects. Evaluate the outcome of those projects before starting additional projects. Report the outcome to the engineering staff and the industry. Address resource impacts such as staff, costs, etc.

Consider running "dual procedures" during the early phases on those selected projects. Running parallel test procedures will let Contractors gradually adjust to new procedures and pay adjustment provisions. Simply calculating, but not applying, pay adjustments in the beginning may be desirable. Gradually increase the number of projects over the following years making sure all geographic areas have some exposure. Price adjustment provisions can also be gradually changed.

COMPREHENSIVE PRESENTATION OF THE PROGRAM

Jointly present the plan to Agency personnel, Contractors, and suppliers. They need to know that there is to be a structured system for handling payments on a "payment for value received basis." This is a strong point of the program because conservation of the tax dollar is a concern to all.

The presentation should have enough detail to show actual results of several "what if" scenarios. Agency and Contractor personnel must understand how the program works and what to expect. Some Agencies do not plan to extend Quality Assurance to all projects. Full implementation may be only for projects over certain quantities or on certain highway systems. The intent of the Agency should be made clear in the presentation.

Joint training sessions should be an integral part of the program and should include Contractors, suppliers, and Agency personnel. Technical training should be provided for both Agency and Contractor personnel to ensure that each group receives the same level of information. A certification program should be required for all testing personnel.

THE ENGINEERING PERSONNEL

Many Agency engineering personnel have been involved in construction management for many years. They may believe that there is no need to change and that you are trying to "fix something that isn't broken." Some may interpret the Quality Assurance program as a form of automation and believe that they are being stripped of responsibilities. They may feel that their only responsibilities are to "observe and record" test results and when the work is done, just apply the proper pay adjustment. The inspectors must realize that their responsibility has not changed and that inspection is still a critical element of acceptance. If a Contractor is producing unacceptable work, the Contractor must be notified as soon as possible.

Most Agencies have always had a pay adjustment provision for substandard work. However, it has always been a problem for the resident engineer/project manager to determine the proper amount of adjustment. With the Quality Assurance program, the adjustment is determined by specification which is one of the significant benefits. Another benefit is improved communication between Agency and Contractor personnel regarding performance and adjustments.

THE CONTRACTOR

Contractors and suppliers that have been in business for many years have tailored their operations to the current specifications. Any change will likely affect the way they pursue profit. This is all the more reason for moving slowly. Prime Contractors will have to reassess their relationship with subcontractors and suppliers.

All Contractors need to fully understand the mechanics of the Quality Assurance program so that the bidding process will be as equitable as possible. The goal of the program is quality work. There are opportunities for experienced Contractors to be more competitive by allowing more flexibility within the specifications as well as being better able to control their costs.

One of the major complaints from successful Contractors is that they are expected to provide a good quality product while others receive full payment for providing a "not-so-good" quality product. This complaint would be resolved by a well organized Quality Assurance specification. This aspect should be pointed out when presented to the industry. Some

Agencies report that, after a few years of Quality Assurance projects, the Contractors do not want to return to the old system.

The Contractors must understand that QC is their responsibility, and "Acceptance" is the Agency's responsibility. It is important to realize that some of the test results will not be identical; therefore, an Agency must address these instances in their specifications. Contractors should establish correlation factors between their QC tests and the Agencies acceptance testing.

SPECIFICATION DESIGN

Quality Assurance specifications can be applied to any product. These specifications should be based on characteristics that will adequately measure the quality of a piece of work. Much can be learned from the evaluation of past projects. Specifications should have a sound statistical basis.

DETERMINE THE LEVEL OF VARIABILITY OF THE MATERIALS AND TESTING

In designing specification limits consider the industry's past history. The use of the present level of variability from several projects is possible to set realistic, achievable limits as long as the data is based on unbiased data; i.e., that obtained in a random manner with all test data reported. Some Agencies have made a special study of variability on which to base the limits.

There are different philosophies on setting an acceptable range of values. As a rule, it is best to set tolerances in the beginning close to what will be the ultimate specification. The specifying Agency should study Contractor's capabilities, state-of-the-art recommendations, and actual product performance history and set acceptable ranges based on these factors coupled with the criticality of the item being specified.

PAY ADJUSTMENTS

Pay factors should be set to encourage quality. They should also relate the loss or gain in service life of the product. Pay adjustments should become more significant as quality levels severely drop off. This can be accomplished by basing the pay factor on a curvilinear relationship (i.e. parabolic) rather than a straight-line relationship. This will result in a small adjustment if the constructed product is only slightly out of allowable specification range but rapidly decline the further the quality level falls off.

Where there is value received, such as for smoothness, an Agency should consider incentives. If the parameters are properly set, the incentive payment will be returned many times in the form of greater longevity of the pavement. It is also important to set a maximum limit.

CONSIDER WHETHER TO MAKE QUALITY CONTROL A PAY ITEM

If the QC testing is made a separate pay item, it gives the Contractor a way to quantify the costs. This will also be helpful in determining the program costs. Agencies should move away from having QC as a separate pay item as Contractors obtain an understanding of costs related to QC. This should be addressed as a goal in the implementation plan.

EVALUATION AND FEEDBACK

Once a Quality Assurance specification has been implemented it is very important to evaluate the resulting constructed product. All tests results should be kept as a permanent record. These results should be statistically analyzed on a periodic basis to ensure that the specification limits are appropriate. Appropriate specification limits will take into account the normal variation inherent with most production processes. At the same time the Agency's and Contractor's risk will be minimized. Pay factors should be reviewed to assure that incentive/disincentive amounts applied to the Contract are fair and commensurate with the quality of the constructed product.

Statistical data gathering can also be useful in pavement management, maintenance management, and highway performance monitoring systems. This information can be used not only to evaluate long term performance of the highway product but also to evaluate the quality of the Contractor's capabilities and performance.

In addition to analyzing data, it is equally important that a reliable and effective communication/feedback system be in place that is accessible by all personnel involved in the Quality Assurance program.

SUMMARY

As stated earlier, the implementation of Quality Assurance specifications will be a significant change and like all major program changes there will probably be resistance from those within and outside the Agency. Typically this resistance is due to a misunderstanding of the basic concepts of Quality Assurance and statistical Quality Control and how they can be used to produce a consistent and high quality product.

The AASHTO Quality Assurance Guide Specification is intended as a model to be used by any Agency when developing their own specifications. It will need to be modified to suit their available resources, needs, and product performance history. Caution must be used to avoid vague and/or conflicting requirements. Also, combining "method type" specification requirements with Quality Assurance concepts will severely compromise the effectiveness of the program. Many aspects of construction specifications will need to continue as "method specifications" until such a time as a reliable "end-result" test can be developed.

The most important issue to be addressed prior to implementation will be that of training. It is extremely important that formal training be developed and provided to all Agency and Contractor personnel who will be working with the Quality Assurance program. The training

sessions should address all requirements of the specification. It is vital that all participants understand their respective roles. Specifications that require the Contractor's technicians meet certain qualifications should also apply to Agency technicians as well. The training sessions should be developed as a joint cooperative effort between the Agency and private industry.

Historically, the Contractors have depended on the acceptance testing and inspection to gage the quality of their product. QC has always been the Contractor's responsibility. It is only recently that the two areas have been well defined. This is one of the functions of the Quality Assurance program, to separate the areas of responsibility, and place the proper controls.

Experience indicates that the Quality Assurance specification will provide Contractors an opportunity to view their operations differently. Their level of attention to QC should increase and this should result in a high quality product.

LABORATORY ACCREDITATION

The AASHTO Accreditation Program (AAP) is used to provide a mechanism for formally recognizing the competency of a testing laboratory to carry out specific tests on construction materials (AASHTO R 18).

The AAP includes the in-depth laboratory inspections by AASHTO Materials Reference Laboratory (AMRL) and the Cement Concrete Reference Laboratory (CCRL) of equipment and testing procedures to ensure conformance to the standards. The on-site assessment by AMRL and CCRL includes a review of personnel qualifications. Minimum requirements are specified for the manager of the testing service and supervisory personnel.

The AAP considers proficiency testing results in its accreditation process. The accredited laboratories must participate in the AMRL and CCRL proficiency testing program. The laboratory's Quality Assurance system and calibration records are reviewed. The following are guidelines to the accreditation of laboratories.

Agency Central Laboratory:

The laboratory shall be accredited by the AAP.

Qualified Laboratories:

In many cases, the qualified laboratories perform a limited number of test procedures. A qualified laboratory can be an agency laboratory or contractor, consultant, or vendor owned facility. The agency shall establish an inspection program for these qualified laboratories. This program would be administered by the agency or the AAP.

Qualified laboratories which perform materials testing services for the agency should be approved by the agency or accredited under the AAP. If AAP is used, the report should be reviewed by the agency to ensure that all the appropriate testing procedures are covered.

Prior to the beginning of sampling and testing on a project, the agency or its designated agent should inspect and document the acceptability of the sampling and testing equipment that will be used on the project. This includes sampling and testing equipment owned by the agency, contractors and/or consultants. Checks on equipment during the life of a project should be accomplished by project sampling and testing personnel as well as the IA Program.

The agency's program should include a continuing program of proficiency testing. If the proficiency testing program indicates changes in the performance of the laboratory that could result in poor product performance, the laboratory should not be allowed to conduct testing for the agency until the matter is resolved.

SAMPLING AND TESTING PERSONNEL

TRAINING

The individuals performing any sampling and testing of materials to be used in the construction of an agency facility must be knowledgeable in the sampling and testing procedures that have been approved by the agency. In order for these individuals to have a basic understanding of the various materials that will be used and become knowledgeable in the principles of sampling and testing of their materials, a certain amount of training is required. The training must cover the correct procedures that are used in the sampling of each type of material. They must also receive training on the procedures required to run each type of test. It is also necessary that they be familiar with the equipment that is required for testing the material and to make sure it is correctly operated.

The following training levels are appropriate in achieving adequate sampling and testing capabilities:

- A basic knowledge of mathematics and reading comprehension is necessary and must be a prerequisite.
- On-the-job training is important to instill a basic understanding of the items to be sampled and tested as well as to develop experience with and understand the importance of the proper methods of sampling and testing.
- Formal training is necessary in order to gain the basic knowledge of principle: of sampling and testing, including the concepts of Quality Assurance.

CERTIFICATION

Any agency that is involved in a Quality Assurance program will require that individuals who perform one or more of the actual sampling, testing and inspection functions for the agency, contractor, vendor, or private laboratories be certified. In all cases, the certification programs help ensure the qualifications of sampling and testing personnel and increase pride in the work performed.

Certified sampling and testing personnel provide added assurance that the validity of the sampling and testing will be performed correctly. Options for the certification program recognized by the agency are one or more of the following:

- National Institute for Certification in Engineering Technologies;
- The American Concrete Institute or other trade association;
- Individually developed agency program; and
- Reciprocity between agencies.

QUALITY CONTROL

INTRODUCTION

The need for and use of a QC function cannot be overemphasized. Quality cannot be tested nor inspected into a product, it must be "built in." As discussed in the Program Implementation section, this will be done by the Contractor. Thus, it is imperative that the Contractor have a functional, responsive QC Plan. When a contractor's QC Plan is initially required, minimum requirements are helpful as a guide to the Contractor. This provides a uniform basis for bidding and ensures a minimum level of QC. An important feature of a QC Plan must address actions needed, including the frequency of testing to: a) keep the process in control; b) quickly determine when it goes out of control; and c) respond adequately to bring the process back into control.

A Quality Assurance specification should contain minimum requirements for the Contractor's QC system consistent with the agency's overall quality management system. A Contractor developed and documented QC Plan for each project is a preferred and practical part of the specification. General requirements should state that the following items be included:

- The Contractor will provide and maintain a QC system that reasonably ensures that all materials and work submitted for acceptance conform with the contract.
- The inspections and tests required to support conformance with the contract will be performed by the Contractor (or his designated agent) and made available to the agency for the period required by the contract.
- Standard equipment and qualified personnel will be used by the Contractor to perform the QC inspection, sampling, and testing required by the contract.
- Each required QC plan: a) documents the Contractor's policy for obtaining quality and the assignment of QC accountability and responsibility; b) has a statistically valid sampling, testing and analysis plan with frequencies, locations, and methods; c) details provisions for disposal or rework of non-specification materials or work; d) identifies the laboratory(s) to be used and its credentials; e) identifies the QC personnel and their qualifications; and f) has provisions for control charts.
- The QC Plan is submitted by the Contractor to the agency at the initial preconstruction conference. The Contractor's QC Plan may include QC plans obtained from subcontractors/vendors.
- The provisions of the QC Plan, when accepted by the agency, apply to the material and construction furnished under the contract.

ELEMENTS OF A QUALITY CONTROL PLAN

The Contractor's QC Plan for both production facilities and field operations should contain appropriate information identifying the contract for which the production and/or construction is intended. Typical examples of a Contractor's QC Plans that may be used as a guide in developing specifications concerning Contractor QC are published in the Quality Assurance Guide Specification, Appendix A and in Appendix D of this manual. Each of the items discussed below should be included in the plan when appropriate along with supporting documentation.

DESCRIPTIVE INFORMATION

For production facilities, descriptive information should contain such information as make, type, location, frequency of inspection of the facility, frequency and procedures used for calibration of weighing and metering devices, frequency and procedures used for verification of valid calibration, and any certification(s) that have been issued for the facility.

For field operations, descriptive information should contain such information as the equipment to be used such as make, type, frequency of inspection or maintenance, frequency and procedures used for calibration of control and metering devices, frequency and procedures used for verification of valid calibration, and any certification(s) that have been issued for the equipment.

PERSONNEL

A QC plan is applicable to both production facilities and field operations. It may be well designed and theoretically correct; however, its eventual success will depend on the people assigned by the Contractor to implement the plan. Employees qualified for the assignments should be carefully selected and provided full support by the Contractor's management and policy. The name, qualification, and telephone number of the employee designated to be responsible for the Contractor's QC Program, and the name, and certification number of employees designated to perform sampling, testing, and inspection that is required by the QC Plan should be included. Employees designated for any QC activities should be qualified in accordance with the contract.

MIX DESIGN

Many agencies require contractor mix designs. The following is applicable to those agencies. For production facilities, the mix design for items such as concrete and hot mix asphalt is a necessary and critical part of the effort to control the quality of items into which such materials are incorporated. The development of a mix design should be done in a qualified laboratory by qualified personnel. Tests should be performed during the mix design development to ensure that material manufactured in accordance with the mix design specifications will perform as required by the contract. It is mandatory that controls be imposed by the Contractor's plan to ensure that the material produced will comply with the accepted mix design for the contract. The type of mix, mix design identification, and

supporting test data should be part of the QC Plan. Mix designs that have been previously accepted by the agency may be resubmitted for use on other contracts when applicable. Only materials from sources acceptable to the agency should be used in the mix design. It is important that the mix produced in the plant be the same as that designed in the laboratory.

QC TEST FREQUENCY

During both production and construction operations, QC tests should be performed at or exceeding the minimum frequency set forth in the Contractor's QC Plan. As an aide to those agency's desiring guidance, typical schedules for QC test frequency are published in the Quality Assurance Guide Specification, Appendix A and in Appendix D of this manual. Frequency schedules for QC may be derived in terms of time, quantity, or a combination of the two. When an agency has a preference, it should be included in the contract. Statistically, schedules derived using either approach can be equally valid. Practically, a schedule based on quantity may yield more samples than desired when production or construction rates are high; on the other hand, fewer than desirable samples may be indicated when production or construction rates are low or intermittent. Conversely, schedules based on time tend to yield fewer sample numbers for high production and more samples for low or intermittent production. However, this is a desirable effect in many cases, since keeping a process in control may be more difficult under low or intermittent production or construction conditions than under high production conditions that are continuous.

NOTIFICATION OF PRODUCTION OPERATIONS

For both production and construction, at least 24 hours prior to beginning scheduled work, the Contractor should notify the agency that production or construction will begin, to allow appropriate agency personnel the opportunity to be present when start-up occurs.

CONTROL CHARTS

The QC Plan should contain the manner in which the Contractor will establish, display, and use control charts for both production facilities and field operations. The need for Contractors to use statistical control charts to control the process cannot be overemphasized. A control chart provides a visual indication of whether a process is in control. Timely reaction to the QC chart can prevent the production of nonconforming material.

QC TEST RESULT REPORTING

Timely evaluation and reporting of test results obtained on the QC samples is very important so that the Contractor's organization can react to the results and the agency can be kept fully informed. If a substantial delay occurs in reporting results, the Contractor should consider halting the operation until the testing "catches up" and the results become current. Timely reporting and evaluation should typically be completed on the same day of sampling. When this is impractical, reporting should be completed by noon the second day. Engineering judgement must be used to determine the value of QC tests that are not available in a timely manner. In cases where engineering properties are not available within a short period of

time but are judged to be useful, such as concrete strength, QC results should be obtained as quickly as current technology allows. As an example, concrete strengths can be determined in 24 hours using AASHTO T 276. However, when using accelerated tests, it must be determined that the precision and accuracy of the test are acceptable, particularly when they are used for acceptance purposes. The QC Plan should contain the target times when QC test results will be conveyed or made available to the agency. The Contractor should make adjustments to the plant production process when the QC data indicate an adjustment is necessary. If an adjustment is not made when warranted, the reason for the lack of action should be documented by the QC employee to the agency representative.

INSPECTION

Inspection is an activity that is as important to QC as it is to acceptance for both production facilities and field operations. It is necessary in order to minimize visually detectable problems in the production facility, such as stockpile or equipment maintenance practices or needs, that may eventually affect the quality of the material produced. The QC Plan should indicate inspection activities that will be performed by the Contractor's QC personnel. Agency personnel should be made aware of the importance of this part of the QC Program.

NONCONFORMING MATERIAL AND CONSTRUCTION

It is important that the occurrence of nonconforming material or work indicated by QC test data is addressed. Although such an occurrence is undesirable, it may happen. If the QC tests results are used for acceptance, the acceptance procedure will address the manner in which nonconforming material or work will be handled. If the QC tests are not used for acceptance, a plan identifying the defective material or construction and its disposition will be submitted for agency concurrence. Under any conditions, if nonconforming material or construction has been incorporated into the work, the agency will be notified immediately.

SAMPLE STORAGE AND RETENTION

When the contract requires that QC samples be stored and retained for a specific purpose during the contract period, the Contractor's QC Plan should contain a description and location of the facility where the samples will be held.

ACCEPTANCE PROGRAM

INTRODUCTION

The Acceptance Program defines a set of rational procedures to be used by the agency to determine the degree of compliance with contract requirements and value of product delivered by the Contractor. The intent is to use as much information as possible in reaching this determination. The results of the agency's acceptance tests and its on-going inspection activities form the heart of the program. Valid Contractor QC test results can be used to augment the agency's information. The validation of Contractor test results should be accomplished through a statistically valid comparison with agency test results. The agency may also rely on supplier/vendor testing or certification for the acceptance of some items.

All persons directly participating in acceptance activities must be qualified sampling and testing personnel for their assigned responsibilities. Only qualified laboratories will perform the required tests.

The objective of the Acceptance Program is to determine the degree of compliance with contract requirements and value of a product. It is recommended that this be accomplished by a Percent Within Limits (PWL) analysis that leads to the determination of a pay factor to be applied to the contract bid price in order to determine the final payment. The PWL approach, sometimes called quality level analysis, is presented in Section 110 of the Quality Assurance Guide Specification. If the payment determined varies from the contract price, disputes will occasionally arise. The Dispute Resolution process, discussed in a later section of this manual, addresses these issues.

Note: Other valid statistical procedures such as that described in "Development of New Criteria for control of HMA Construction," Transportation Research Record 1389, pages 1-8, may also be used by the Agency.

ELEMENTS OF AN ACCEPTANCE PROGRAM

ACCEPTANCE ACTIVITIES

An agency's Acceptance Program addresses the activities that enter into the agency's determination of the degree of compliance with contract requirements. There are a number of activities that an agency could use in this determination. Some of those activities are performed by the agency and some are performed by the Contractor.

Under the Quality Assurance concept, QC testing is the responsibility of the Contractor and acceptance testing is the responsibility of the agency.

Both the Contractor and the agency may delegate their responsibilities to a third party. The third party would be an expressly designated agent and the activities of that agent are as valid as the activities of the agency or Contractor. For the purposes of this manual, therefore, reference to the Contractor or the agency includes their designated agents.

Sampling and testing is a portion of the Acceptance Program. The establishment of the QA concept does not negate the need for a timely, thorough inspection. This is an important aspect of the program that must not be overlooked.

VALIDATION

Under the Quality Assurance concept, an agency has the prerogative of whether or not to include results of the Contractor's QC testing in the determination of compliance with the contract requirements.

If an agency elects not to use the Contractor's results, then acceptance is based only on the agency's testing and inspection activities. To be statistically ensured of the quality of the materials or construction processes, the agency needs sufficient information upon which to base its determination. This requires a relatively high frequency of sampling and testing.

If an agency decides to use the Contractor's QC results as a part of the Acceptance Program, there must be a system of checks and balances to ensure the reliability and accuracy of the Contractor's test results. Agency testing is required to form a basis for validating Contractor results. The required amount of agency testing, however, is less than would be necessary if the Contractor's results were not used.

Since an initial premise of this manual is that Contractor's test results are a legitimate source of data that can be used in the Acceptance Program, the validation methodology becomes an important decision for the agency.

ACCEPTANCE TESTING

Among the first determinations that an agency must make in developing an Acceptance Program for any product are those of a testing frequency and the definition of lot size. When making these determinations, practical considerations such as personnel and time constraints must be tempered with the fact that it is important to have a sufficient number of tests to statistically describe the product properties being measured. Lots and sublots can be defined as a quantity of production, e.g., a specific number of tons or square yards; or a time increment, e.g., a days production. Recommended testing frequencies and lot sizes are discussed in Section 110 of the Quality Assurance Guide Specification.

Although briefly discussed under QC TEST FREQUENCY, the advantages and disadvantages to the selection of lot size on either a quantity or time basis for acceptance testing are slightly different. If a quantity basis is used, the lots will all have the same amount of material in each acceptance decision. The testing frequency can easily be related to the subplot size and the same number of tests can generally be obtained for evaluating each lot. However, the lot may be comprised of material produced on several days, or there may be more than one lot per day. If the lot is based on time, such as one day's production, then the amount of material in each lot will vary. There must also be a policy developed and presented in the specifications to deal with situations where weather or plant problems cause the day's production to end before the required number of tests have been obtained. Both quantity and time based lot sizes have been widely used.

USE OF CONTRACTOR TEST RESULTS

The decision of whether or not to use the Contractor's QC test results as part of the acceptance decision is influenced by several factors. In some instances the Contractor QC tests will be different from the tests the agency is using for acceptance determination. For example, in asphalt mix production, the Contractor may use cold feed gradation samples for QC, while the agency uses extracted gradations for acceptance decisions. In this case, it is not possible to combine the Contractor and agency tests. The agency testing frequency will have to be sufficiently large to have adequate assurances that the materials or construction meet the contract requirements.

In many instances, however, the agency may require the Contractor to use the same QC tests that the agency is using for acceptance decisions. In this case, the agency must decide whether or not to combine the Contractor results with its own results in order to make the acceptance decision. If the agency chooses not to use the Contractor's tests, then its testing frequencies will, as just discussed, have to be sufficient to have adequate assurances that the materials or construction meet the contract requirements.

To have the best statistical estimate of the acceptance properties it is prudent to use all test results that are available. The source of these test results should not be of concern provided they are properly validated. Therefore, the agency may elect to use both the Contractor's QC test results as well as the agency's test results in developing the statistical estimate of a product property for determining the degree of compliance with contract requirements.

AGENCY TESTING FREQUENCIES

The frequency of agency testing is dependent upon whether it has decided to use Contractor test results as part of the acceptance decision. If the agency does not use Contractor results, then the agency's testing frequency will be relatively high and will remain the same throughout the project. If the Contractor QC test results are used for acceptance decisions, then the required amount of agency testing can be reduced to the amount necessary to validate the Contractor's results.

VALIDATION PROCEDURES FOR QC TEST RESULTS

As noted previously, the agency is responsible for determining the acceptability of the product. One major aspect of the acceptance decision is that of acceptance testing. It is desirable to have as many test results as possible when making an acceptance decision. One way to increase the amount of available data is to use the Contractor's test results as well as those of the agency. When an agency decides to make use of contractor developed test data, it must use some means to determine the validity of the Contractor's results. The validation procedures should be statistically valid if a meaningful decision is to be made. The agency should compare the Contractor's test results with those obtained by the agency, and then decide whether the results are consistent. This decision should be made using a statistically sound process.

SPLIT OR INDEPENDENT SAMPLES

When comparing the agency and Contractor test results, the agency can either use the test results from split samples or from samples that were independently obtained. This decision impacts what the agency is validating as well as whether or not the agency and Contractor tests can be combined.

It should be understood that test results are influenced by components of variability which consist of variability due to: a) material, b) sampling, and c) testing. Independently obtained samples contain all three components. Split samples contain only the component of testing.

If independently obtained samples are used for the agency/Contractor test result comparisons, then the agency tests are subject to the same overall variation as the Contractor tests. Since the agency test results are in this case independent pieces of information from the Contractor's results, the two can be combined to make the acceptance decision.

If split samples are used for agency/Contractor test result comparisons, then the comparison only considers the agency's and the Contractor's testing procedures, and does not consider the variability associated with material production, and sampling process. Also, if split samples are used, the agency tests become verification tests and cannot be combined with the Contractor's tests to make the acceptance decision. This is because the agency verification test and one of the Contractor's tests came from essentially the same sample and are, therefore, not two independent pieces of information. In this case, acceptance is based on the largest amount of data, i.e., the Contractor's QC test results, with the agency tests serving only to validate the Contractor testing procedures.

If split samples are used, the qualified agency testing personnel will witness the Contractor personnel when they obtain the sample and split it. The agency personnel will witness or assist in the sampling and splitting procedures and will take immediate possession of the agency portion of the split sample to ensure the validity of the split sample comparison.

STATISTICAL VALIDATION

The agency must understand that two tests, even tests on material from split-samples, will not always yield the exact same results. A valid procedure is necessary to be able to identify differences in test results that would indicate that the two results are not from the same population. This would indicate that the material came from different processes, or that the sampling and/or testing procedures were not the same. This could be the result of differences in procedures, failure to follow prescribed procedures, or incorrect or uncalibrated testing equipment.

It should be noted that what is being determined is whether or not the Contractor and agency tests are consistent. The fact that they are consistent does not necessarily mean that they are both correct. It does mean that the sampling and testing procedures that were employed produced results that were similar. If the two sets of results are consistent, then the agency

can use the Contractor results with some degree of assurance that the agency would have obtained results that were similar had it conducted the sampling and testing.

If the comparison indicates that the test results can not be assumed to be similar, it does not necessarily mean that the Contractor's results are wrong and the agency's results are correct. It does indicate that the sampling and testing procedures employed likely did not produce similar results. This may indicate that the agency results came from a different population than the Contractor results, or that the same sampling and testing procedures were not employed by the agency and the Contractor. The reason for the difference in the results should be investigated to determine how to proceed.

If it is determined that the Contractor's sampling and testing procedures or equipment were not in accordance with the contract requirements, then these results should not be used in the acceptance decision. In this event, the agency will have to base the acceptance decision on the tests that it conducted, and on additional testing if practical and necessary, to have sufficient data on which to base the decision. If the investigation indicates that the agency sampling and testing procedures or equipment caused the difference, then the agency can take additional tests to compare with the Contractor's initial test results. If this is not possible, then the acceptance decision may be based on the Contractor's test results, provided that previous validation comparisons had indicated consistent results between agency and Contractor testing.

As previously discussed, the agency may decide to require the Contractor to use split samples for its QC testing and to maintain the untested portion until after the final acceptance decision and payment determination have been made for the lot from which the sample came. In this way, material is available for additional testing if the agency and Contractor results are not consistent. If this is required, then the agency must specify procedures to follow to ensure the chain of custody of the untested split sample portion. This is necessary to ensure the validity of the sample material if it is subsequently used.

INITIAL VALIDATION

Appendices F and G of this manual contain two possible procedures for making the statistical comparison. Appendix F can be used when both data sets have two or more values. The approach in Appendix G allows the use of a single sample in one data set to be compared to five or more samples in the other data set. Procedures other than those presented in Appendices F and G may be used provided the procedures are statistically valid.

During the initial production (start-up) for any manufacturing process, it is important to obtain an early estimate of the quality of the product being produced. When the manufacturing process is one with which the agency has prior experience, previously developed data can be used to determine the probable level of process control and the corresponding probability of the initial production being within specification requirements. When there is no prior knowledge of the particular production process, it may be necessary to adjust testing frequencies to reduce the time required to produce a reliable early estimate of the degree of contract compliance. This will accomplish not only the desirable early estimate of contract compliance in a statistically valid manner, but will also, if statistical

analyses indicate that the agency's tests and Contractor's tests represent the same material population, produce confidence in the sampling and testing program. Otherwise, the source(s) of differences in test results should be determined and rectified as soon as possible.

Like any statistical procedure, the ability of the comparison procedure to identify differences between two sets of test results is dependent upon the number of tests that are being compared. The greater the number of tests, the greater the ability of the procedure to identify statistically valid differences. This is the reason for using a larger amount of agency testing early in a project. In this way, more data will be available to make a determination regarding whether the Contractor testing is consistent with the agency test results.

The type of samples taken for comparison depend upon the agency's objective.

- (1) If the agency's objective for this comparison is to simply identify discrepancies in testing procedures or equipment, then initial validation testing should be done on split samples.
- (2) If the agency's objective for this comparison is to identify discrepancies in the entire sampling and testing process, then initial validation testing should be done on independently obtained samples.

Whether split or independent samples are used, and until the initial validation testing has been done, it is recommended that only the agency's test results be used for contract compliance determination. Once the validation is successfully accomplished, the agency can then reduce its testing frequency.

CONTINUING VALIDATION

If split samples are used, the agency's test results can only be compared with the Contractor's test results for the other portion of the split sample. This reduces the number of tests that are available for the validation comparison.

If independent samples are used, the agency test results are still compared with the Contractor test results using the procedures in Appendices F or G of this manual or a similar statistically valid procedure. If the test results are consistent, then the agency and Contractor tests are combined for the contract compliance determination. It is not appropriate to combine test results from independently obtained samples with those from split samples.

CERTIFIED MATERIALS

A number of materials are typically accepted based on certified test results supplied by the supplier/vendor. It is desirable for the agency to also validate the certified testing procedures. This can be accomplished by the agency randomly testing the supplied materials to verify that they meet the contract requirements. The intent is to verify the certified testing process rather than to validate individual test results. Validation may consist of initial pre-qualification and subsequent re-qualification of the vendor's testing equipment and procedures, in addition to the random sampling and testing of delivered materials.

ACCEPTANCE AND PAYMENT DECISIONS

Agency acceptance decisions must be based on product properties that affect the performance and meet contract specifications. Section QA-110 in the Quality Assurance Guide Specification contains a listing of recommended properties which can be used for agency acceptance decisions. The actual properties to be used in the acceptance decision and the specified quality limits must be clearly stated in the contract documents.

Agency acceptance specifications should recognize that quality affects product performance. The specifications should establish pay adjustment procedures to compensate the Contractor for the completed product based on anticipated performance. It is recommended that a continuous, rather than discrete or stepped, payment schedule be used to eliminate relatively large differences in payment associated with relatively small differences in the measured quality level.

In order to determine how the specification will work, decision risks based on Operating Characteristic (OC) curves, as discussed in Appendix A, should be understood during specification development.

The results of agency acceptance tests, agency inspections, and validated Contractor test results, when applicable, are to be used by the agency to determine the degree of compliance with the contract requirements and the corresponding amount of Contractor payment for the lot of material. In the event that Contractor test results are determined to be invalid and the product does not meet contract specifications, the agency must establish procedures to address disposition of the lots in question.

INDEPENDENT ASSURANCE PROGRAM

INTRODUCTION

The IA Program is an independent verification of sampling and testing procedures and is designed to provide continuity to the Quality Assurance program. It involves a separate and distinct schedule of sampling, testing and observation.

Qualified sampling and testing personnel, other than those performing the acceptance and QC sampling and testing, should perform the IA. Likewise, equipment other than that used for acceptance and QC should be used for IA sampling and testing. The IA will be conducted by agency personnel or its designated agent.

Each agency should develop an IA Program to verify that the provisions of the Quality Assurance program are being adhered to and provide assurance of the reliability of the test results.

If contractor QC tests are used for acceptance purposes, the agency already has in place a method to verify or check the contractors sampling and testing schedule, personnel and equipment. Therefore, the IA program should be designed as a check on the verification system for the agency sampling testing schedule, personnel and equipment.

The IA Program should consider:

1. Establishing IA sampling and test frequencies;
2. Allowing a reasonable portion of the IA Program to be accomplished by observation when fully documented;
3. Establishing tolerances to be used for comparison of the IA tests with those of the agency tests;
4. Establishing procedures to address tolerance deviations;
5. Evaluating periodically the IA Program to verify that sampling and testing frequencies are adequate and tolerance limits are reasonable;
6. Delineating the documentation and reporting of IA results; and
7. Establishing provisions to monitor equipment used for agency tests.

Similar to the Acceptance Program, two different types of sampling can be used for IA; that is, independent samples or split samples. Also like acceptance, the decision of which type of sampling program should be used depends on the agency's desires. If independent samples are used, the system will collectively evaluate all sources of variability; including materials, sampling, and testing procedures and equipment. As such, the analysis cannot determine the

exact source of the variability. IA tests should be compared to the agency tests. Currently established precision and bias statements for tests methods cannot be used for comparison procedures since these tolerances are only valid for split samples. Therefore, other comparison tolerances that address all components of variability must be established. As previously discussed, when split samples are used, the materials and sampling variabilities are eliminated from the analysis and only the variability due to the testing procedures and the equipment are included.

FREQUENCY

The agency should establish the frequency for the sampling and testing of all materials. In general, the IA samples should be taken at the rate of 10 percent of the agency samples based upon the amount of verification/check sampling that is required. If agency sampling and testing frequencies are varied, based on the history of a material, the variation should be noted and data continually gathered to verify the adequacy of the deviation from a 10 percent ratio.

Where applicable, an alternative method to basing frequency on project testing frequencies is to base the IA frequency on source. In this case, the personnel and equipment would be verified on a systemic basis several times a year regardless of where the equipment and personnel is located. On this basis it is permissible to separate the verification of equipment and personnel, i.e., one method to check equipment is to require a calibration and inspection frequency.

TOLERANCES FOR SPLIT SAMPLE TESTS

The comparison of split sample test results should be based on established deviation values or tolerances that are representative of the testing procedures and materials used.

The AASHTO and ASTM have published precision statements for some test methods. These precision statements should be used when available. When precision statements are not available, the agency should develop tolerances from proficiency test data or round robin tests. Agencies find the use of historical data desirous because of large quantity that typically exists. Care must be taken when historical data are used in establishing these limits to ascertain that the data are not biased; i.e., they were obtained in a random manner and that all test results have been reported. Otherwise, the variability may be underestimated and the resulting limits too restrictive. Established tolerances should be periodically evaluated and modified to ensure that the goals of IA are being met; that is, it ensures the reliability of agency test results.

Most test methods generally incorporate precision statements that address the intrinsic variability. The multi-laboratory precision standard deviation can be used as a guide to establish tolerances. Tolerances can also be developed by round robin testing of split samples. Procedures for developing the precision of test methods are outlined in ASTM C 670.

COMPARISON OF RESULTS

The nature of an IA Program requires comparison* or evaluation of procedures and results in a timely manner to ensure continued reliability of agency results. It is not the purpose of IA, to compare the results from these tests to the specification requirements. Although as the agency's acceptance procedures are refined the IA samples provide another data set for overall specification performance.

As previously discussed, an IA verification test is designed to evaluate the sampling and testing procedures as well as the equipment used; this requires the use of independent samples. However, an agency may desire to evaluate only the testing procedure; in this instance, split samples can be used. The procedures described below for an IA Program allow independent or split samples.

1. Use of Independent Samples. A qualified sampling and testing person responsible for IA will obtain an independent sample. The sample will be tested independently of the agency sample. The results of the IA samples, taken in this manner, will be compared with agency test results. The test results being compared should be from samples obtained during a similar time period and at similar locations.
2. Split Samples Tested by an IA Tester. A qualified sampling and testing person responsible for IA will obtain a split sample in cooperation with the agency's qualified sampling and testing person responsible for acceptance. The sampling and splitting procedures and the adequacy of testing procedures and the equipment used should be documented. The samples should be tested independently by different technicians using different equipment. Test results from all the samples should be documented and reported.

RESOLUTION OF DISCREPANCIES

It is essential that an IA Program compare results and detect deficiencies in agency testing procedures in a timely manner. This improves the reliability of agency sampling and testing. The timely comparison of data may be restricted by the resources of an agency including personnel, facilities, and geographical constraints. These resource needs must be considered in an agency program.

When an agency is using the independent sample option, significant deviations from the established tolerances will require an engineering audit of the materials variability, the respective sampling and testing procedures, and the equipment used. When an agency is using the split sample option, significant deviations from the established tolerances will require an engineering audit of the respective sampling and testing procedures, and the equipment used. For either option, when comparison of test results reveals significant differences, the variables involved should be evaluated to determine whether further independent testing and investigation is needed to establish the source of the discrepancy.

Corrective actions should be incorporated as appropriate.

* Comparison, in this manual, connotes the determination of whether two sets of data, e.g., IA and agency, agree; this differs from the connotation of validation which, as addressed in the Acceptance Program, is used to determine that the Contractors tests come from the same population as the agency's tests.

DISPUTE RESOLUTION

INTRODUCTION

Dispute resolution is the procedure used to resolve conflicts resulting from discrepancies between the agency's and Contractor's results of sufficient magnitude to impact payment. Formalizing this concept should provide a means to minimize adversarial relationships and claims.

As part of the Quality Assurance program, both the Contractor and the agency will be performing tests independent of each other. Every effort should be made by the Contractor and the agency personnel to avoid any potential conflicts in the program prior to and during the project using partnering concepts, split sampling and testing, etc. After every avenue has been exhausted to avoid and resolve conflicts at the lowest possible level, if a dispute between some aspect of the Contractor's and agency's testing program does occur, a dispute resolution system needs to be provided to resolve the differences.

The following is presented as a guide to be considered and modified as needed for adoption by a particular agency to set out the procedure to be followed to resolve a dispute.

AVOIDANCE OF DISPUTES

Appropriate procedures should be taken to avoid disputes arising from differences in Contractor QC results as compared to agency results. A formal monitoring program should be established that will provide both the Contractor and the agency assurances that all data is reliable, unbiased and truly indicates the product quality. Typical elements of an effective monitoring program to be considered are:

- All sampling and testing should be performed by qualified testing personnel and laboratories;
- Pre-production correlation testing involving comparison of split samples between the QC lab and agency lab will provide each party a "comfort" level and minimize potential testing bias;
- It is desirable that all testing labs participate in a national or agency sponsored round robin sample testing program as a periodic check on reliability of testing;
- All samples obtained by either party should be selected under an approved random scheduling method;
- Agency observation of Contractor sampling and testing methods;
- Application of partnering concepts to resolve differences prior to formal dispute;