 Practical Considerations and Tools for Successful Implementation of Owner Verification Testing Programs on Large Construction Projects

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ABSTRACT

23 CFR 637 (CFR) has opened the door to contractor acceptance while requiring adequate checks and balances to ensure the quality of materials is not compromised. Specifically, the CFR contains regulations that must be followed and FHWA (Federal Highway Administration) has provided guidance on how owner verification testing (OVT) should be performed. This paper provides a general framework for establishing and implementing an OVT program for large design-build projects. It is based primarily on the authors’ successful experience on the State Highway 130 project in Central Texas but also includes lessons learned from other projects.

There are two primary phases in setting up an OVT program. In the initial program setup, it is critical to understand and follow all applicable federal regulations, state practices, and contractual requirements applicable to the project. Business rules are needed to address the collection, organization, analysis, and interpretation of data used in the acceptance decision (i.e. the owner verification and contractor acceptance test results).

Laboratory and personnel qualifications should be completed prior to starting work on the project. Split sample testing and higher initial OVT testing frequency will provide the owner with confidence in the contractor’s test results. Proactive management of the statistical validation process is critical in reducing the time spent resolving the lack of validation. An overarching key to success in the development and execution of an OVT program is the establishment of good communication and trust between the vested parties early in the project.
Practical Considerations and Tools for Successful Implementation of Owner Verification Testing Programs on Large Construction Projects

In the 1980s, contractors began to assume testing and inspection responsibilities associated with quality control (QC) for project produced materials. This created a perception that the testing effort was being duplicated since the contractor performed QC testing and the state transportation agency (STA) performed acceptance testing. A revision of FHWA’s sampling and testing regulation titled “Quality Assurance Procedures for Construction” was published on June 29, 1995 as Title 23, Code of Federal Regulations, Part 627 (henceforth referred to as CFR). This regulation permits the use of contractor test results in the acceptance decision “provided that adequate checks and balances are in place to protect the public investment (1).” FHWA provided guidance and recommendations for the use and validation of contractor’s test results for acceptance in FHWA Technical Advisory T 6120.3 (2).

The purpose of the CFR is “to prescribe policies, procedures, and guidelines to assure the quality of materials and construction in all Federal aid highway projects on the National Highway System (3).” Included in this document are policies related to verification sampling and testing and random samples. It states that “verification sampling and testing are to be performed by testing personnel employed by the STA or its designated agent, excluding the contractor or vendor.” It also states that all samples used for contractor and verification sampling and testing shall be random samples. The requirements for a quality assurance program (QAP) and qualifications for sampling and testing personnel are also contained in the CFR. In the requirements for quality assurance programs, contractor sampling and testing results may be used as part of the acceptance decision provided that the following conditions are met:

1. Sampling and testing has been performed by qualified laboratories and qualified sampling and testing personnel,
2. Quality of material is validated by verification sampling and testing performed on samples taken independently of the contractor’s sampling and testing, and
3. Contractor sampling and testing is evaluated by an independent assurance (IA) program.

Information contained in FHWA Technical Advisory T 6120.3 supersedes earlier FHWA direction and stands as the most current guidance on this subject matter. The advisory discusses the use of contractor tests results for acceptance, requirements for verification sampling and testing, and validation procedures on independent samples. In the discussion on validation procedures performed on independent samples, it recommends the use of the F-test and t-test because “they have more power to detect actual differences.” More information on statistical procedures can be found in course material for NHI (National Highway Institute) Course No. 134042 (4), other FHWA publications (5, 6, 7) or regular statistics textbooks or handbooks. A review of current state construction quality assurance programs can be found in NCHRP Synthesis 346 (8).

This paper is written from the perspective of an owner’s representative in responsible charge of owner verification testing (OVT). This person has been called the Materials Manager on some projects and henceforth will be referred to as such for the remainder of this paper. It should be noted that that the owner’s Construction Manager or Resident Engineer may also play this role in lieu of a dedicated person serving in this capacity. However this may prove difficult
on a fast-paced large highway project where the Construction Manager or Resident Engineer has many other responsibilities.

This paper will discuss practical considerations and tools for establishing and executing a successful owner verification testing (OVT) program on large design-build highway projects that receive federal aid. The concepts and tools presented are primarily based on the success on the State Highway 130 project but also include lessons learnt from other projects.

The process can be divided into two stages or steps. The first step is the initial set-up. This involves understanding federal requirements, state practices, and contractual agreements between the owner and the contractor. Once an understanding has been reached, a system/process for managing and analyzing owner (verification) and contractor test results has to be developed. The second step relates to daily operations and proactive measures taken to head off disagreement between owner and contractor test results (also referred to as non-validation). An overarching key to success in both stages of this process is communication. Its importance cannot be overemphasized. This will become apparent as the two stages of this process are discussed in further detail below.

INITIAL PROGRAM SETUP

Understanding Federal Requirements, State Practices, and Contractual Requirements

The purpose for this section is to highlight some specific considerations that apply to OVT and the acceptance of contractor test results on a large highway project. It is not meant to provide an exhaustive list of all federal and state requirements. For example, it will not discuss any regulations that pertain to environmental, design, or right-of-way acquisition regulations mandated by the FHWA or STA.

The first step is to understand federal requirements, state practices, and contractual agreements. The primary source for federal requirements is 23 CFR 637. For the purpose of this paper, it is assumed that the use of contractor test results for acceptance is employed and that the recommended guidance in FHWA Technical Advisory T 6120.3 will be followed. It is also assumed that the Materials Manager will be in responsible-charge of OVT and that this is a large design-build highway project. Further it is assumed that the owner verification (OV) testing and inspection oversight is performed by two separate groups of personnel. While they will work closely in the field, all responsibility for performing tests lies with the testing arm of the team.

Each state already has a QAP that meets the CFR. However, a modified QAP may be required for large design-build projects since the project scope may be sufficiently different, making the traditional acceptance methodology impractical for the project. An example would be design-build projects where contractor test results are used for acceptance in a state where owner-performed acceptance is the norm. If a separate QAP is required, communication between the FHWA and STA personnel is critical in developing a program. It would be beneficial for the Materials Manager and/or Construction Manager or Resident Engineer to be involved in developing the QAP. The QAP is a vital OVT document because it is an FHWA-approved document that is the record of commitments that the STA made to the FHWA regarding how the project will comply with the CFR requirements.

The STA also has specific state practices that apply to the project. This will work in concert with the contractual requirements and agreements outlined for the specific project. The contract should outline which test methods will be used on the project. There may be a requirement to use state-specific test methods or the contractor may be allowed to use test methods that are dictated by the contractor’s design team. For example, the contractor’s design
team may be more familiar with ASTM (American Society for Testing and Materials) or AASHTO (American Association of State Highway and Transportation Officials) test methods and specify them over state-specific test methods for materials acceptance during construction. This could be a possibility if the contract permits.

The STA also has established testing frequencies for accepting traditional projects within the state and may even have identical or different requirements for stand-alone large projects. The STA may also have tolerances for split-sample test results, developed through its IA program. These tolerances will probably be applicable to the project if the state’s test methods are employed on the project. Each state also has laboratory and testing personnel qualification procedures for acceptance testing on traditional projects. These procedures may be part of the state’s independent assurance program. In each of these areas, the contract will define whether the state’s traditional practices apply to the project or if an alternate process is to be used.

Establishing Business Rules for Statistical Analysis

With the FHWA, STA, and contractor onboard with the requirements that apply to the use of contractor test results for acceptance, it is now time to develop a plan to meet those requirements. Business rules are processes and procedures that are agreed-upon by the STA and contractor for use on the project. These procedures include how the released for construction (RFC) documents are reviewed and distributed, how uncertainties in the construction process are clarified, and how all project document are transmitted and saved for future use. However, only business rules pertaining to OVT will be discussed in this section.

Many business rules must be developed to support the collection, organization, analysis and interpretation of data (test results). Fortunately, there are guidelines which can be followed to ensure that these steps are correctly carried out so that valid inferences can be made from the resulting statistical analyses.

The collection of data refers to the “planned process of obtaining a relatively small number of measurements (sample data) from a fairly large quantity of material (lot or population) (4).” In the context of this paper, collection of data refers to sampling and testing material to represent the material being incorporated into the project. As required in the CFR, all contractor acceptance and owner verification sampling and testing shall be performed on random samples. Additionally, the verification sampling and testing samples will be taken independently of the contractor’s sampling and testing. Only test results that meet these two criteria should be used in the statistical validation process. Owners may be concerned that this requirement limits their ability to take tests at specific (i.e. not random) locations where the quality is question. This is not the case. The owner always has the authority to take test(s) at any specific location(s) to demonstrate the material there does or does not meet specifications and require the contractor to bring it into compliance if necessary. However, these tests should be designated in a manner to exclude them from the statistical analysis. Owners may also be concerned about the restriction on running split-samples (i.e. non-independents samples) to check the contractor’s proficiency in performing a test. Again, the split-sample tests are permitted but should not be included in the statistical analysis.

The goal of statistical analysis is to ensure that the quality of material and workmanship presented through contractor’s test results are confirmed by verification test results. Therefore only test results that represent material incorporated into the project should be analyzed in the statistical analysis. Test results representing material that has been reworked or removed from the project should not be included in the statistical analysis. Occasionally, there may be test results (either from the owner or contractor) that do not appear to correctly represent the material
incorporated. In such cases, ASTM E 178-02 (9) may be used to determine if the outlying test results should be considered an outlier and removed from the analysis.

The organization of data refers to the “assembling of data into systematic groups or classifications from which logical conclusions can be drawn (4).” In the context of this paper, organization of data refers to the categorization of test results into specific groups so that statistical analyses can be performed within each group to determine if the owner’s test result validate the contractor’s test results. It is common knowledge that apples should be compared to other apples, and not oranges. Similarly, it is critical to establish criteria that only put test results generated from materials obtained under controlled conditions (i.e. construction material produced under essentially the same conditions) in the same material category for statistical analysis. The most basic distinction can be made by material type. Most basic highway construction materials can probably be placed into one of the following six categories:

1. Portland Cement Concrete,
2. Hot-Mix Asphalt Concrete,
3. Manufactured Materials,
4. Treated Materials,
5. Offsite Borrow, and

Within each material type, separate materials must be put into distinct categories. For example, different Portland cement concrete mix designs should be put into distinct categories so that they will not be analyzed together. Each Portland cement concrete mix design would have its own material category. Similarly, aggregate base meeting the same specification requirement from two different sources (suppliers) should be placed in separate material categories and analyzed separately.

While it is important to compare apples to apples, it is equally important not to call an apple and orange. With the large volumes of work being performed at any one time on a large project, it is critical that a list of CVLs (controlled vocabulary language) be developed to ensure standardization in the use of terms. This includes standardized labels for highways, suppliers, mix designs, features of work, etc. Since the Materials Manager is ultimately responsible for the statistical analyses performed on the project, he/she should have the primary responsibility of ensuring that the agreed-upon (by the owner and contractor) CVLs are properly used by both the contractor and verification testing personnel. CVL data entry errors may cause test results to be placed in an incorrect material category for analysis or even left out of all analyses completely. For example, if Supplier A is mistakenly labeled as Supplier B, then the test results meant for inclusion in the Supplier A statistical analysis will be short this test result and the statistical analysis for Supplier B will have an additional test result that should not be included.

The analysis of data refers to the “numerical determination of statistical measures that describe the important characteristics of the data (4).” In the focused context of this paper, analysis of data refers to the determination of the mean, variance and sample size for owner and contractor test results within each material category. Other statistical measures include range, median, coefficient of variation, etc.

The interpretation of data refers to the use of “basic sample results to infer broader statements about the total quantity of material (lot or population) (4).” In the context of this paper, interpretation of data refers to the performance of the F-test and t-test to determine if the
owner’s verification test results validate the contractor test results. Specific details pertaining to the interpretation of data is covered in course material for NHI Course No. 134042 (4) or regular statistics textbooks or handbooks and will not be covered in this paper. Some discussion regarding actions that the Materials Manager could take in response to the interpretation of data will be presented later in the paper.

Electronic Data Management System (EDMS)
In today’s day and age, the use of electronic data is widely accepted and employed in highway engineering applications. For large fast-track projects, this becomes all the more critical because of the large volumes of data that need to be processed, stored, and analyzed. While this paper will not address the use of specific software applications, it will discuss some basic principles involved in the use of an EDMS and software-based engineering/analysis tools that are useful in managing OVT operations.

From a materials testing standpoint, data review prior to final use is a basic tenant for ensuring the quality of test results. This may be achieved electronically where the technician would enter his data into an electronic worksheet and submit it through a workflow to the reviewer for approval using an EDMS. It may also be achieved using pen-and-paper technology where a technician records the test data on a paper worksheet and submits it to the reviewer for approval. In either scenario, it is critical to review the test results for completeness and accuracy as well as for the use of agreed-upon CVLs.

Since the responsibility of performing statistical analysis lies with the owner, the contractor’s data must transmit to the owner in a timely manner. On a large project, it is only practical to transmit such volumes of test data in electronic format. Once the contractor’s data is received and reviewed, the Materials Manager may perform the statistical analyses (F-test and t-test) to compare the two sets of data. On a large project, there may easily be tens or even one to two hundred categories to perform such analyses on. It would be extremely time consuming, if not impractical, for the Materials Manager to manually isolate the test results by test method and material category and then perform the statistical analyses on all of them. Therefore it is essential to have an automated system in place to perform this task. It should be noted that there are tools in Microsoft Excel® (as well as other software packages) that can perform the F-test and t-test. There are also tools in Microsoft Access® to import and save test data.

The primary EDMS functionality required for the OVT group is the ability to enter the owner’s verification data, receive the contractor’s acceptance test data, and perform statistical analyses in an expedient manner. Other useful EDMS functionality could include the following features:

1. Automated data transmission mechanism to automatically transfer contractor test data into the owner’s database,
2. Robust data search capabilities,
3. Trend graphing ability (e.g. 7-day concrete cylinder compressive strength against time),
4. Data graphing ability (e.g. 7-day concrete cylinder compressive strength against concrete slump),
5. Use of PDAs (personal digital assistant) to collect field test data, and
6. Web-based EDMS that allows for use anywhere internet access is available.
START-UP AND REGULAR OPERATIONS

Up to this point, various forms of communication between the FHWA, STA, and contractor staff has occurred to understand the federal and state requirements as well as to agree upon the necessary tasks and roles involved in successfully using contractor’s test results for acceptance. Many issues have successfully been negotiated and construction activities are about to begin. With everyone in agreement and the business rules tied down, it is now time to start operations and “get things going down the road to success.”

Communication

Communication becomes even more important as the project kicks off. On a large project there are some key players involved in the OVT portion of the project. While the Materials Manager has the primary responsibility for the success of the program, the contractor’s lead testing manager as well as other owner and contractor inspection managers also play important roles in the coordination and implementation process.

The primary involvement of the inspection managers and personnel in the OVT program is to provide accurate and timely updates to unexpected changes in the project schedule. In most cases, the owner’s testing technicians will not be dedicated to a specific construction crew nor will they be available to perform testing on very short notice. More often than not, they will traverse the entire project (or parts of the project, depending on the project’s magnitude and length) in order to meet their testing obligations. Therefore timely updates on changes to the scheduled testing times is vital in ensuring that the technicians’ time is spent efficiently. These updates can be provided by on-site inspection staff who are knowledgeable of these changes.

The contractor’s Testing Manager plays a critical role in the OVT program. Depending on the size of the project, this responsibility may be taken on by the contractor’s Construction Manager or Resident Engineer. Either way, he/she serves as the Materials Manager’s counterpart on all testing-related issues and will be in frequent contact with the Materials Manager to agree on new CVLs, coordinate testing activities (e.g. split sample testing), and resolve differences in test results when the statistical analysis indicates that the owner’s test results do not validate the contractor’s test results. For efficiency in operations and quick resolution to non-validation issues, it is vital that the Materials Manager and the contractor’s Testing Manager establish a strong relationship built on trust and cooperation. The importance of trust and cooperation at all levels of both organizations cannot be overemphasized and should be developed early on in the project.

Another important chain of communication is within the OVT team itself. While most technicians have worked on projects in the acceptance testing role for the owner or in a quality control role for the contractor, most have not worked in the OVT role. It is important to provide training to highlight the differences. One of the most significant challenges for technicians unfamiliar with the OVT role is the need to maintain the required test frequencies for each material category in his/her purview. Unlike traditional acceptance testing where the technician responds to every request for testing and performs tests on every lot to check for specification compliance, the OVT technician’s role is not testing for acceptance per se. Instead the OVT technicians performs a fraction of the contractor tests as a whole with each OVT technician responsible for covering large geographical area covered by several contractor technicians. To reduce driving time, OVT technicians may be assigned specific geographical areas to cover a variety of testing needs. Even so, he/she will have to plan his/her day carefully in order to cover all the required OVT tests in each material category adequately and efficiently.
In a fast-paced project, crews may be shifted from one location to another based on weather conditions, availability of materials, and other construction related factors. OVT testing obligations may be difficult to maintain without constant coordination and communication between OVT technicians and project construction personnel. Certain material categories may not validate and require additional independent or split sample testing to investigate the discrepancy. The OVT team must be alert enough to identify these changes and sufficiently versatile to remobilize staff to focus in on problem areas. Some suggested tools to identify these changes will be discussed later in this paper.

**Laboratory/Personnel Qualifications and Training**

Laboratory and personnel qualification should be defined in the QAP for the project. At the onset of the project, both the owner and contractor testing laboratory and personnel need to be qualified to perform testing on the project.

Laboratory qualification may be based on AASHTO, state, or project-specific programs. AASHTO laboratory accreditation is a nationally recognized standard for laboratory qualification. However, many states have their own qualification programs that meet the CFR requirements. If a project-specific program is used, it is important for all parties to fully understand the requirements. In addition to the initial qualification, laboratories may be required to participate in scheduled follow-up inspections and/or proficiency programs to maintain their qualifications.

Personnel qualifications are also required for the OVT program. Unlike laboratory qualifications, each individual is required to pass a qualification test (for each test method) prior to performing it on the project. Once again, qualified technicians may be required to re-qualify at scheduled intervals and/or participate in proficiency sample programs to maintain their qualifications.

**Split Sample Testing**

The beginning of the project is the best time to ensure that the owner and contractor laboratories and technicians are synchronized in technique and procedures. To be synchronized means that an owner-performed test on a sample gives the same result as a contractor-performed test on the same sample. This is often referred to as split-sample testing. At the beginning of the project, split-sample testing should be performed on as many test methods as practical.

Through the life of the project, new technicians may be added on to the project as the volume of work increases or due to turnover. In order to maintain consistency in the performance of tests, split-sample testing should be performed periodically. This frequency can be determined based on the number of technicians performing the test, the frequency at which the test is performed, and status of validation for a specific test method. If there are more technicians performing a particular test and only a percentage of the technicians participate in each round of split-sample testing, then the frequency of split sample testing could be increased to cover all qualified testing personnel.

Differences in test results can stem from material variability and testing variability. Testing variability can be further broken down into sampling variability and test method variability. If a material category is not validating for a specific test method, split sample testing is one way to narrow down the causes for the lack of validation. For example, if the contractor’s results on a split sample are the same as the owner’s test results, this may point to differences in sampling techniques.
Higher Initial Testing Frequency

A typical testing frequency for statistical materials validation is one owner test to every ten contractor tests. However, a higher initial testing frequency is recommended to build the sample population (i.e. number of tests that may be used in the statistical analysis) so that meaningful conclusions can be drawn with respect to validation of the contractor’s test results earlier in the process. If the number of owner tests is too low, then the statistical analysis may not provide very meaningful conclusions. The additional testing early on helps the owner develop confidence in the contractor’s test results if his/her own (verification) test results validate the prior. If the test results do not validate, steps can be taken early in the project to resolve the differences.

PROACTIVE MANAGEMENT TOOLS

So far, practical considerations for the initial set-up and daily operations have been discussed. Another key to success is proactive management of the validation process. Performing the statistical analyses on a regular basis provides the Materials Manager with timely feedback on the status of validation in each material category. This input can be tracked to monitor progress with respect to testing frequency (the number of owner verification tests relative to the contractor tests), $\Delta F$ (validation status for the comparison of variances), and $\Delta t$ (validation status for the comparison of means) for each material category. The minimum recommended testing frequency is 0.10 which represents one verification test for every ten contractor tests. “$\Delta F$” represents the result of deducting the calculated F-value from the critical F-value in the F-test. “$\Delta t$” represents the result of deducting the calculated t-value from the critical t-value in the t-test. A positive “$\Delta F$” indicates that the variances are equal and a positive “$\Delta t$” indicates that the means are equal. If both these values are positive, then the owner verification test results validate the contractor’s test results. Example plots showing the trackers for frequency and “$\Delta t$” are shown in Figures 1 and 2, respectively. A tracker for “$\Delta F$” would look very similar to the tracker for “$\Delta t$” and is not presented herein. In the two examples below, it is also assumed that the variances validate throughout the year for both Material Categories A and B. Therefore the focus of the following discussion will be on testing frequency and the tracker for “$\Delta t$.”

For Material Category A, the trends in both plots show a relatively “ideal” scenario. The higher initial frequency slowly decreases to the long-term target frequency (i.e. just above the minimum testing frequency). While it may appear mediocre rather than ideal to aim for a target frequency just above the minimum testing frequency (i.e. testing frequency = 0.10), it should be noted that since validation is achieved (i.e. $\Delta t = t_{\text{crit}} - t_{\text{value}} > 0$), the contractor’s test results are used for acceptance. It is important to remember that the objective of OVT is not to perform as many tests as possible but rather to perform sufficient test to verify that the quality of material represented by the contractor’s test results. Available resources would be better spent working on material categories that do not validate or are heading towards non-validation.

Material Category B shows a slightly quicker drop in testing frequency and an initial lack of validation with respect to equality of means (i.e. $\Delta t < 0$). When the initial lack of validation was discovered, a joint review of the test results and procedures was conducted by the Materials Manager and the contractor’s Testing Manager. It revealed that the contractor’s technician was unfamiliar with the soils being tested and did not select appropriate proctors for performing the field density tests. With additional training by contractor staff and collaboration with the OVT staff, the level of validation gradually improved and the category validated after eight weeks. No work was performed in this category over the next ten weeks due to the reassignment of the crew.
working in that area. Therefore there was no change in the testing frequency or “Δt.” When work resumed, the means returned to a non-validating status and the testing frequency dropped in spite of efforts to try to maintain it. An internal review by the Materials Manager indicated that the OVT technician had slacked off and did not recognize the importance of maintain the minimum testing frequency. Furthermore, he/she had continued to use “old” proctors that represented embankment material placed prior to the beginning of April while the contractor’s technician was using proctors that represented the material currently encountered along the alignment. With additional training for the OVT technician, partnering between the owner and contractor, and a temporary increase in OVT testing frequency the category came back into validation. Subsequently the testing frequency was gradually reduced to the “ideal” long-term testing frequency.

The tracking tool described above is simple to understand and use. It takes the output of the statistical analysis and provides some simple guidelines on the status of validation. More robust tracking mechanisms may be developed. However, it is important to remember the target audience for this tool and not develop something that may cause more confusion than assistance.

Since it is may not be possible for the OVT technician to keep track of all the contractor testing performed by his/her counterparts, the frequency tracker can be use to develop guidance for the OVT technicians performing testing in the field. The Materials Manager may provide a weekly or biweekly frequency guidance sheets that shows the required testing frequency for each material category. An example frequency guidance sheet is shown in Table 1. The numbers in the cells represent the current testing frequency and the color indicates that target testing frequency over the next two weeks. Looking at the entries for August 26, 2000 the frequency guidance sheet indicates that the OVT technician should try to achieve a testing frequency of one owner test for every four to six (yellow color background) contractor tests for Material Category X and a testing frequency of one owner test for every two to three (orange color background) contractor tests for Material Category Y from August 26 through September 8.

SUMMARY AND CONCLUSIONS

23 CFR 637 (CFR) has opened the door to contractor acceptance while requiring adequate checks and balances to ensure the quality of materials is not compromised. Specifically, the CFR contains specific regulations that must be followed and FHWA (Federal Highway Administration) has provided guidance on how owner verification testing (OVT) should be performed to ensure that the quality of material represented by the contractor’s test results is indeed accurate. This paper specifically discussed the establishment and implementation of an OVT program for large design-build projects based on the State Highway 130 project in Austin, Texas.

There are two primary phases in setting up an OVT program. In the initial program setup, it is critical to understand and follow all applicable federal regulations, state practices, and contractual requirements applicable to the project. Once all the requirements are understood, business rules have to be established to accomplish the statistical analysis recommended in FHWA Technical Advisory T 6120.3. Specifically, the business rules need to address the collection, organization, analysis, and interpretation of data used in the acceptance decision (i.e. the owner verification and contractor acceptance test results). With the large volume of data anticipated on a large project, the use of an EDMS is essential to success. Manual review and analysis of such voluminous data is impractical.
Once the initial set-up is complete, it is important to get the required laboratory and personnel qualifications completed prior to starting work on the project. Split sample testing and higher initial OVT testing frequency will provide the owner with confidence in the contractor’s test results. Proactive management of the statistical validation process is critical in reducing the time spent resolving the lack of validation.

An overarching key to success in the development and execution of an OVT program is communication between the vested parties. Trust and cooperation needs to be developed early in the project so that statistical validation issues can be worked out quickly and efficiently. Once the initial setup is completed, start-up

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TABLE 1 Example of Frequency Guidance Sheet for OVT Technicians

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<td>0.18</td>
</tr>
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*** Legend ***

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<th>Color</th>
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<tbody>
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</tr>
<tr>
<td>Yellow</td>
<td>1/4 to 1/6</td>
<td>Intermediate Frequency</td>
</tr>
<tr>
<td>Orange</td>
<td>1/2 to 1/3</td>
<td>Start-Up or Catch Up Frequency</td>
</tr>
<tr>
<td>Red</td>
<td>1/1</td>
<td>Critical Testing Frequency</td>
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</table>
FIGURE 1 Example of Testing Frequency Tracker for OVT Technicians.
Figure 2: Example of Comparison of Means Tracker for OVT Technicians.