

2900 Refractory Inspection

Abstract

This section discusses inspection of newly installed refractory linings, including repair work. The discussion includes: use of third party inspectors and testing services; prequalification testing of materials, including the kinds of tests that are usually performed on various refractory material; and prequalification of contractors' procedures and work crews. Specific guidelines are given for inspecting the application of monolithic lining systems, refractory ceramic fiber systems, and brick and special shapes. For help in evaluating existing linings for possible tear-out, see Section 2800.

Contents	Page
2910 Introduction, Background and Scope	2900-3
2920 Third-Party Inspection and Testing	2900-3
2921 Selection of a Company	
2922 Duties of Third-party Company	
2930 Prequalification Testing	2900-4
2931 Material Prequalification	
2932 Refractory Contractor Prequalification	
2933 Time Allowance for Prequalification Testing	
2940 Installation Inspection of Monolithics	2900-13
2941 Material Storage and Handling	
2942 Tear-out	
2943 Surface Preparation	
2944 Anchor Inspection	
2945 Forming (Casting and Cast Vibrating)	
2946 Inspection of Work Area	
2947 Installation of Monolithics	
2948 Preparing Production Test Samples	
2950 Inspection of RCF	2900-18

2951 Tear-out

2952 Surface Preparation

2953 Anchor Layout and Installation

2954 Vapor Barrier

2955 Installation of RCF

2960 Inspection of Brick and Shapes

2900-22

2961 Tear-out

2962 Surface Preparation

2963 Installation of Brick and Shapes

2970 Refractory Inspection Checklist

2900-23

2910 Introduction, Background and Scope

Inspection of refractory systems requires a combination of activities all leading to the approval of a refractory lining. Many types of refractory products and installation methods are used in refineries and chemical plants, but all programs to ensure a quality installation will have 3 elements:

- Material prequalification (certification),
- Contractor and crew qualification, and
- Installation inspection.

The emphasis placed on each element will depend on the scope of work and nature of the application (i.e., for IFB applications, certifying the refractory material will need less emphasis than crew or contractor prequalification, which will need less than the actual installation inspection. Monolithic refractory applications will emphasize all three elements).

A good inspection program must set hold points and acceptance/rejection criteria. Such a program allows the inspector to perform his job and gives the contractor firm guidelines to follow.

2920 Third-Party Inspection and Testing

The use of a third party to inspect and test refractory materials and application methods has become a significant factor in a successful refractory installation. This practice has resulted from increased emphasis on quality refractory work and material.

Several companies specialize in the testing and inspection of refractories and their application. In early 1992, the Company entered into a refractory inspection partnering alliance with the R. J. Jenkins Company of Webster, TX. A more detailed description of the alliance contract and how to initiate it are described in Section 4100, Contracting Plans.

The refractory inspection partnering alliance with Jenkins Company should be considered wherever third party refractory inspection is needed. The Company can benefit from strong contributions to unit reliability from the Jenkins team.

These companies provide quality control programs that ensure the Company that everything has been performed in a professional manner and is consistent with the appropriate Company specification. Testing is either witnessed by experienced technicians or is performed in the third-party laboratory. Sometimes a mobile lab is brought to the installation site to facilitate prequalification of the crew and to test production samples.

Inspectors typically are experienced installers that watch the refractory installations. Generally it is important to witness the installation process, since inspection afterward is not sufficient to determine the quality of a lining.

Independent or third-party inspection and testing is a good way to supplement the Company's inspection capabilities. The Company's inspection force is not generally

experienced in refractory work. Two areas in which it has little experience are 1) marking areas of refractory to be torn out and 2) inspecting refractory installation. Third-party inspection companies use inspectors who specialize in refractory installation and have experience from numerous applications.

2921 Selection of a Company

Any company considered to perform inspection and testing associated with refractory applications should be examined very closely. Guidelines for selection of these companies should include:

1. Standard pricing for testing and inspection services
2. Project experience (look at a project listing for the past 3 years)
3. Experience of inspection personnel (check resumes)
4. Standard lab practices
5. Inspection of laboratory facilities (visit the lab, when possible)
6. Outline of inspection and testing plan for individual projects

Currently, no formal requirements exist for qualifying inspectors nor are there schools designed to help with inspection of refractory applications. Therefore, it is important to screen the potential inspection force and request certain persons.

Proper testing of refractory products is also very important, and each independent lab should be reviewed. A good way to review a company's credentials is to examine its lab practices and talk to other oil companies about their experience.

Consult with the Materials Division refractories specialist for help in this area.

2922 Duties of Third-party Company

The function of any third-party inspection and testing company should be to supplement the inspection efforts of the Company. This will take on different meanings for each job and may include inspection of existing lining for potential repairs, monitoring tear-out, monitoring anchor and refractory placement, and monitoring dryout.

In all cases the third party is acting as a consultant and is not authorized to make engineering decisions on behalf of the Company. They are to observe, report and advise the Company so that sound engineering decisions can be made.

2930 Prequalification Testing

Prequalification testing includes testing the refractory material (certification), approving the contractor's written procedures, and testing members of the installation crew. The methods for administering these tests are given in the Company's purchase and installation specifications for refractory systems. Those in charge of

scheduling an installation job must allow time for each stage of testing (and retesting, if needed).

2931 Material Prequalification

Material prequalification is the process of certifying a refractory product. For monolithic refractory material this process is needed to ensure that the material has the required properties specified on Standard Drawing GB-N1268. All products can and should receive some form of certification. The degree of prequalification depends on the type of product and variables of the manufacturing process. It also depends on the nature of the application and assessment of the failure risk. The project engineer may elect to amend the extent of prequalification.

Types of Tests

Figure 2900-1 shows the types of qualification tests associated with the different product groups. Not all tests are performed for each and every purchase of refractory. The Company's refractory purchase specification IRM-MS-4785 provides minimum testing requirements.

Fig. 2900-1 Qualification Tests for Various Refractory Material

Refractory Type	Prequalification Testing
Insulating Firebrick (IFB)	Density, Permanent Linear Change (PLC), Cold Crushing Strength (CCS), Dimensional Accuracy, Thermal Conductivity (TC) ⁽¹⁾
Firebrick (High Al ₂ O ₃ & Super Duty)	Density, PLC, Modulus of Rupture (MOR), Hot Load, ⁽²⁾ Dimensional Accuracy
Refractory Ceramic Fiber (RCF)	Density, Dimensional Accuracy, TC, ⁽¹⁾ Shrinkage
Insulating Castables	Density, Strength (CCS), PLC, TC ⁽¹⁾
Dense Castables	Density, Strength (CCS), PLC, Erosion Loss ⁽³⁾
Plastic Refractories	Density, CCS, PLC, Erosion Loss ⁽³⁾
Mortars	None

(1) Tests of thermal conductivity are done infrequently. Discuss requirements with the Materials Division.

(2) Hot load tests are performed for divider walls only.

(3) Erosion loss tests are performed as required for the application.

Density is a weight per unit volume usually reported in pounds per cubic foot. This property is very helpful in assessing the product and its installation. It also helps explain problems with a product.

Strength is the most widely used index of quality for refractory products. The cold crushing strength (CCS) is the most popular and is determined by crushing a 2-inch cube. This property is expressed in pounds per square inch (psi). Modulus of rupture (MOR) is also reported in psi and is a measure of bending strength of a 9 × 2 × 2-inch bar. Both of these tests are helpful in assessing the quality of the

bond in a product. Testing should be performed in accordance with ASTM C-133, with the exception of sample size.

Erosion loss as described by ASTM C-704 is an accelerated test to determine wear characteristics of a product. This property is reported as a volume loss (cubic centimeter), where the lower the loss, the better. Section 2123 describes the test. For *in situ* testing, a portable tester is available from the J. Jenkins Co. Initial experience is very favorable.

Permanent linear change (PLC), more commonly known as shrinkage, is a measure of the change in length of a $9 \times 2 \times 2$ -inch bar after firing to 1500°F, reported in percent.

Porosity is a measure of the pore volume as a percent of the volume of a sample. It is determined in accordance with ASTM C-20, which is for apparent porosity. Sample size and shape are not important in this test, although 2-inch cubes are convenient.

Thermal conductivity (TC) is a measure of the ability of heat to travel through a material. This test should be used sparingly because of cost, but it can be helpful in confirming heat transfer data for a system. There are numerous techniques used to test for TC. The method used must always be reported and must be a part of the evaluation, since the different methods develop somewhat different results.

Sample Preparation

Testing, including sample preparation, requires a prescribed procedure to eliminate variables introduced by individual technicians. The procedure should develop an unbiased set of data that will describe the quality of a refractory product. Sample preparation is more important in monolithic refractories than in other types and is especially important in plastic refractories. Cement-bonded castables are sensitive to water content, placement method, and temperature conditions.

Splitting Bags. For monolithic refractories such as castables (this includes gunite products) bagged material is identified and then split (using a splitter). Splitting of the sample material compensates for any segregation or irregularities of the product.

Mixing. Method of sample preparation greatly influences results, and the method should follow the guidelines of ASTM C-862. The dry material is usually mixed in a Hobart (or equal) mixer. After mixing for 30 to 60 seconds, water is added over a 30-second period. The manufacturer's recommendation for amount of water should be followed, although the amount may be varied slightly to achieve the desired consistency. Consistency should be measured according to ASTM C-860's ball-in-hand test.

Forming. The mix is then placed into the molds and either vibrated into place, cast into the mold or handtamped. The method of forming in the mold should always match the method to be used in the field. (If the field method is gunning then the sample should be gunned. After curing, samples of the required size are then cut from the gunned piece and tested.)

The Company's Standard Drawing GD-N1271 shows the various molds used. A cube mold (Detail 5A) is used for preparing samples for strength tests (CCS and MOR). Shoe box or plate molds (Details 5B and 5C) are used to prepare samples for erosion tests. A bar mold (Detail 5D) is used to prepare samples for PLC tests.

Different materials require different methods of placement. The inspector should ensure that nothing has been done to enhance the performance of a product. For example, low water content can produce excellent properties, but the material may need to be gunned at the jobsite.

Curing, Drying, and Firing. After samples are cast, they are covered with a thin plastic film to allow proper curing. Curing at the laboratory should be at ambient temperature. The use of curing cabinets is disallowed.

After 24 hours of ambient temperature curing, the samples are stripped from the molds, cut into desired specimens, and placed into driers operating at 230°F for a minimum of 12 hours. After drying, dimensions and weights of samples are measured for density, PLC and cold crush strength tests.

Firing should follow the procedures specified in ASTM C-865. The samples are heated to 1500°F at rates not to exceed 300°F per hour and held at that temperature for 5 hours. The cool-down rate cannot exceed 500°F per hour.

Because the drying and firing procedure can rarely enhance the performance of a product, the inspector can sometimes perform an abbreviated examination of the procedure.

Plastic refractories are sensitive to the drying rates and drying temperatures. A gradual dryout with forced air is helpful in preparing representative samples of plastic. Drying at ambient temperature (70 to 90°F) is desirable for at least one day. In all phases of drying good air circulation is very important.

Testing

Testing of Monolithic Refractories. Testing is then performed in accordance with ASTM C-133 (cold crush and MOR) and ASTM C-704 (erosion), or the appropriate Company specification. The inspector should be familiar with the test procedures and should disallow any that would enhance physical property development.

For erosion testing, when samples are cut from shoe box samples (see Detail 5B of GD-N1271), the test should be performed on the cut face. For samples individually formed (Detail 5C of GD-N1271), the erosion test should be performed on the rammed face. Avoid testing on molded surfaces because the results will be influenced by the collection of fines on the surface.

Testing will require 3 to 4 days to complete. Taking less time than this could influence the performance of a product and cause false results.

Testing of Plastic Refractories. Plastic refractories are rammed into the molds. They should be dried at 100 to 175°F to minimize damage during handling. This may be done before or after the samples are stripped from the mold. Drying is the

critical part of testing plastics. Drying must be slow, and forced air is necessary. A 3-day dryout is preferred, which extends testing to a 5-day procedure.

Ways to Accomplish Material Prequalification

Four methods are generally available to certify products. Each method will have advantages and the one chosen will depend on many factors. These factors include: the service (i.e., furnace, FCC regenerator, cyclones, stack, etc.), timeliness, cost and, in some cases, the Company's experience with a product and/or the manufacturer. The four methods are:

1. Manufacturer's quality control
2. Third-party witnessing of manufacturer's quality control procedures
3. Third-party testing
4. Combination of methods 2 and 3

Method 1, Manufacturer's Quality Control. Most refractory manufacturers engage in some type of quality control of their products. The testing is generally thorough but not done frequently, i.e., each batch. The manufacturer uses his quality assurance data to certify the properties of his products. If the job requirements are minimal, the manufacturer's QC program alone may be acceptable. Method 1 alone does not add to the cost of the refractory material.

In some cases, the manufacturer will certify a percentage of the physical property data shown on the data sheet (i.e., manufacturer may certify a cold crushing strength of 5000 psi for a product when the data sheet reports 6500 psi). For this type of certification, there is no need for third-party involvement. The Company simply requests certification and the manufacturer provides it based on previously agreed criteria.

Method 2, Third-party Witness Certification. This method is the most expensive of the four because the inspectors must travel to the manufacturer's location and spend 3 to 4 days to witness all phases of certification. It is the most common method currently used by the Company and has the least risk.

In a program of this type, an independent testing and inspection company will assume responsibility for monitoring the manufacturer's production of a refractory material for a particular project. The inspection company may or may not have participated in developing the criteria for acceptance or rejection of the products. In most cases, these inspection company is given the requirements and simply monitor the certification as follows:

1. Witness the manufacturing (this has been used infrequently and has often been omitted from most programs).
2. Examine the material manufactured for a specific order and select sample material as required by the user. It is also the inspector's responsibility to ensure that all pallets designated for the project are properly identified and verifiable.

3. Witness the preparation of samples from the selected sample material. The inspector assures that sample preparation is performed in an accepted manner so nothing is done to enhance the performance of the samples. Any irregularities are resolved prior to proceeding.
4. Witness testing. The inspector witnesses all tests to ensure that all testing requirements are met (i.e., results of erosion tests, per the ASTM C-704 procedure, can be greatly influenced by the techniques used). Any irregularities are resolved prior to proceeding.
5. Report the results of this program in writing.

The Company reserves the right to accept or reject any material. This right is sometimes delegated to the inspection firm, but these firms should advise the Company of the results. The Company in turn evaluates not only the product quality but such things as how acceptance or rejection impacts on the installation schedule.

Method 3, Third-party Testing. In this method, the independent firm will begin with steps 1 and 2 of Method 2. After selecting the sample material and ensuring proper identification of all material, the test material is forwarded to the independent testing lab. Upon receiving the sample, the lab proceeds as follows:

1. Sample preparation. As prescribed by the manufacturer and or user. The manufacturer is encouraged to witness the sample preparation.
2. Testing. Accomplished in accordance with the appropriate ASTM procedure or generally accepted lab practice. Again, the manufacturer is encouraged to witness this stage of the program.
3. Reporting. The same procedure applies as in the previous section.

Method 4, Combined Effort Between Manufacturer and Third Party. This procedure is likely to develop the most unbiased set of quality control data available. The method combines Method 2, items 1, 2, and 3 and Method 3, items 2 and 3:

1. Witness manufacturing (optional).
2. Examine the material and select sample material. Identify all pallets for future verification.
3. Witness sample preparations at the manufacturer's lab. The independent inspector ensures that all criteria for sample preparations are met.

All samples are dried to 230°F and fired to 1500°F (optional). The samples are then shipped to the independent lab.

4. Samples are tested in accordance with prescribed standards. The manufacturer is encouraged to witness this part of the program.
5. Report and recommend.

All of these methods of material prequalification have been used successfully in the industry. The most popular are Methods 2 and 3. The proper choice of method

depends on the nature of the project, its size, and scheduling requirements. Methods 2, 3, or 4 will all provide satisfactory results.

2932 Refractory Contractor Prequalification

Contractor prequalification has two phases. The first is to be sure that the contractor understands the scope of work and the Company's refractory specifications and develops a plan to accomplish that work (procedure qualification). The second phase is to provide a means of testing or qualifying personnel selected for the job.

Contractor prequalification is very important and should receive proper attention. Many inconsistencies in placement can be identified here. It also establishes criteria for acceptance and/or rejection of work.

Specifications IRM-MS-4786, -4787, -4788 and -4789 address contractor prequalification requirements for various types of refractory.

Procedure Review and Approval

The Company's installation specifications require the contractor to submit written procedures for all anticipated work for approval. In this phase, inconsistencies in a contractor's refractory placement procedures can be discovered and corrected. Contractors do not intentionally develop bad habits. However, through repetition and the absence of anyone challenging their methods, incorrect procedures are fostered and presumed to be correct.

The Company's refractory specifications are intended to supplement contractors' procedures. Prior to the start of a job, a thorough review of the specifications is important. The contractor will have an opportunity to demonstrate his understanding of the specification and its individual requirements. Contractors rarely have the opportunity to evaluate their work; therefore, it is difficult to identify improper practices and correct them.

Crew Prequalification

In this phase of inspection, the contractor's crew or individuals demonstrate their ability to install the selected material. This will be shown by the use of mock-ups to simulate the actual work to be performed. Typical mock-ups for the various types of monolithic refractories are shown in Details 1, 2 and 3 of Standard Drawing GD-N1271.

A Casting and guniting mock-up is a panel with anchors as seen in Detail 1. (In some instances for guniting, such as small vessels or lines, the mock-up may be designed to closely simulate the actual installation, i.e., inside a 40-foot diameter riser.) A mock-up for vibration casting is a 3-foot cylinder with inner form for 4-inch lining (Detail 2). Mock-ups for hand packing and pneumatic ramming vary as required. A mock-up for ramming refractory plastics is shown in Detail 3. Mock-ups for ramming Resco's AA-22 are the same as for plastic.

Crew qualification for installation of RCF and insulating firebrick is not as important as it is for monolithics. Any requirements for mock-up with these materials

will be covered in the appropriate specification. In many cases, the procedural review will be sufficient to approve a contractor for work with these materials.

Workers who install anchors must be prequalified by passing a welding test. This test will normally be administered by boiler shop welding inspectors. The requirements of ASME Section IX, Paragraph QW-180 must be met.

For monolithic applications individual craftsmen are required to demonstrate their skills when successful placement depends on quality of their individual efforts. The crew and the procedure are both tested for applications where coordination of the crew is more important than the individual's efforts.

In either case, to successfully demonstrate its techniques for approval, the crew must pass three milestones:

1. The crew or installer must pass a visual inspection of the installation process. Most specifications allow the inspector to reject a procedure or individuals strictly on the basis of their installation technique.
2. The second milestone is the examination of the mock-up after a 24-hour curing period. The mock-up panels are disassembled and examined. Most mock-up panels are partially destroyed in this examination. Gunned panels are broken into many pieces to examine the anchors, lamination, and trapped rebound. Plastics and Resco's AA-22 panels are examined to ensure that the material was satisfactorily rammed into all areas and that no voids exist. Cast and vibration cast mock-ups are broken to ensure that the linings are solid and free of large voids or honeycombing (due to insufficient vibration and/or the presence of dry material).
3. The third milestone is actual testing of samples that the work crew prepared. This phase determines the effectiveness of the crew's installation techniques. The samples are sent to a laboratory where they undergo the same tests described in Section 2930.

The test results must meet predetermined minimum requirements of Standard Drawing GB-N1268. Workers who prepared samples that pass are then authorized to perform the work for the designated project.

Casting and Vibration Casting. The success of these two methods depends on the joint effort of the entire crew. Inspection should confirm the procedures and verify that the individuals comprising the crew understand the requirements. A checklist (a sample of which follows Section 2970) is useful to guide the inspector during observation.

Guniting. Success of guniting depends on good individual effort combined with good support from the crew members. The nozzleman's effort is the most important because he actually installs the lining and must tell the crew the requirements (i.e., more or less air, more or less material, etc.). The crew's effort to support the nozzleman can greatly influence the nozzleman's success. The crew predampens the material and operates the gun. A good gun operator is critical to the success of the nozzleman. Both aspects of this placement technique should be investigated

thoroughly. A checklist can be used to assist in this phase of the inspection. See Section 2970.

Hand Packing and Pneumatic Ramming. Assuming the use of properly mixed material, the success of these two methods is largely dependent on the skill of the applicator. Therefore, the applicator is the one tested.

Ramming Type C Plastic Refractory. Plastic refractories are shipped ready to install. The lining quality is completely dependent on the skill of the applicator.

Ramming Type B Castables (Resco's AA-22). Skill of both individual installer and crew can affect successful installation. How well the crew mixes the material is very critical to a good installation, but the applicator has the most difficult task.

2933 Time Allowance for Prequalification Testing

Ideally, the schedule of a successful, smoothly run shutdown will take into account the time required to prequalify materials, procedures and installers. In reality, several variables make accurate prediction difficult. These variables are:

- Amount of tear-out required and, therefore, amount of refractory material to order (you will not know exact amount until the unit is shut down)
- Time required for manufacture of refractory material
- Quality of material manufactured (retesting is sometimes needed)
- Time required to order, prequalify and receive additional material, if needed
- Age of refractory material at installation time (if it has passed its shelf life, material may need to be rejected or retested)
- Quality of the installation contractor's written procedures (sometimes procedures must be changed and retested)
- Expertise of the crew (crew members may need retraining or replacing before the crew can qualify)
- Weather-caused delays

With these variables in mind use the information below to guide your time estimate.

Depending on the type of material being tested and the method of testing chosen, materials prequalification can take three to five days. The time needed for contractor prequalification is less easily predicted. However, the Company recommends that as early as possible you check the contractor's written procedures for agreement with the Company's refractory installation specifications. Ask questions early to clear up potential conflicts in the procedure. Also, find out if the contractor has several crews and if one is considered better than another for certain types of refractory installation. Anticipate what can happen and have alternative plans.

Referring to the shutdown timeline in Section 4100 may also be helpful.

2940 Installation Inspection of Monolithics

The inspection of monolithic refractory installations will generally include witnessing preinstallation work and the actual placement of refractory. Witnessing both is important, and sufficient time should be given to perform them properly.

Preinstallation inspection will include all things leading to placement, such as storage of material, anchor layout, anchor attachment, forming, tear-out of old refractory, inclement weather provisions and equipment examination. Inspection during placement will include monitoring the actual placement, sampling, and curing procedures.

See also Section 2700, which briefly discusses visible changes to refractory surfaces during dryout, and what they mean. For example, some amount of surface cracking is to be expected.

2941 Material Storage and Handling

Monolithic refractory material, except for plastic refractories, contains a cementitious binder that must be kept dry until placement. Allowing water, like rain or condensation, to collect on the bags will cause portions of the material to “set” in the bag. This causes lumping, which ultimately affects the placement and material quality. Inspection of refractory installations should include ensuring that the materials are stored in a dry place and off the ground. No refractory material should be stored directly on the ground.

When examining stored materials the inspector should:

1. Record all code dates and pallet numbers
2. Ensure that all material is off the ground and covered properly
3. Ensure that storage temperatures comply with specification requirements

2942 Tear-out

Tear-out of any refractory, in the field or the shop, must be performed in a manner to minimize or eliminate damage to the metal shell, existing anchor structure and adjacent lining material. Existing linings should be “squared” or preferably undercut slightly such that the refractory edge is perpendicular to the metal shell.

The inspector should examine the torn out area to ensure that conditions of the appropriate specification are met. He should examine the shell and anchors for any damage and report problems. The existing lining should be “sound” and capable of additional service. Tear-out can damage adjacent refractory which then must also be removed.

2943 Surface Preparation

Surfaces should be cleaned prior to installation of anchors. For new shop work, the condition of the metal is usually satisfactory and cleaning is not needed. In the

field, or for metal that has rust or oil present, cleaning will be required. Abrasive blasting is appropriate where large areas are involved. Small areas may be cleaned with wire brushes or by grinding, provided adequate cleaning is accomplished.

The refractory installation specification will outline details for surface preparation. The inspector should examine the specification early to avoid confusion and potential delays.

2944 Anchor Inspection

The inspector should examine anchors before they are installed, verifying proper metallurgy, diameter, and length. He must also oversee anchor layout and welding.

Anchor Layout. Anchor layouts will be identified on the appropriate drawings, work orders, or in the specification. Because of varying interpretation on anchor layouts, the inspector needs to ensure that the proper layout is used. This means the inspector should be present during the initial stages of the layout and welding. The inspector should help “spot” anchors in areas that are irregular, where breaks in the lining exist (manways), around corners, or other areas not covered by the normal pattern.

Anchor Welding. Anchor welding requires a certified welder. The welding rod must be checked to assure compliance with the appropriate specification. Proper welding procedures must be observed and a bend test will help identify problems. The frequency for the bend test will vary for different styles of anchors and will be outlined in the appropriate specification.

All new anchors should be struck with a hammer to help determine the quality of the weld. A properly welded anchor will have a distinct ring when struck. Anchors not providing that ring should be examined more closely or bend tested. Old or existing anchor systems must also be checked thoroughly. These anchors should also have a distinct ring when struck.

When additional anchors are required for repairs, the pattern should be close to that specified for new linings. In many cases, the inspector will mark locations for new anchors. Inspection of these anchors must be consistent with that used for new anchors.

2945 Forming (Casting and Cast Vibrating)

Forms should be rigid and nonabsorbent. They should be of suitable materials to withstand any pressure exerted by the casting process. They must be secured to prevent movement during casting, especially cast vibrating. Centering or positioning for proper refractory thickness must be checked and approved. Sealing of all cracks is also necessary to avoid loss of material and development of voids.

2946 Inspection of Work Area

The condition of the work area will greatly influence the quality of refractory placement. The lighting, scaffolding, and ventilation must help provide a safe area for people to work.

Scaffolding needs to be erected in a manner not to interfere with placement and must provide adequate access to the work area. Ladders need to be available in sufficient quantity to allow repeat and/or follow-up inspection without their having to be moved. Achieving access throughout the unit as soon as possible after shutdown and cleaning allows work definition to progress and tear-out to begin in a timely fashion.

Ventilation is necessary to reduce dust and the potential of accumulating harmful vapors. The inspector is responsible for checking that safe practices are followed whenever workers may be exposed to dust from or must handle regulated or potentially hazardous materials. Refer to Section 500, Safe Handling, for guidance.

A clean work area promotes good work. In a dusty environment, it is difficult to see the work area, which can lead to poor installation.

It is partially the responsibility of the inspector to bring inconsistencies in the work area to the attention of the Company representative.

2947 Installation of Monolithics

This section tells how to inspect the four methods most commonly used for installing monolithic refractory linings in refinery and chemical plants: casting, cast vibrating, gunning, and hand packing or ramming. Methods of preparing production test samples are discussed also.

The inspector should have a good working knowledge of refractory products and of the installation techniques. Refer to Section 2500 for a discussion of installation techniques for monolithic refractories.

For all four methods, the inspector should be sure that the ambient temperature, as well as the temperature of the material and the water, is within the range given in the Company's specification. If temperatures outside the set limits are anticipated, the Company should be advised.

Casting and Cast Vibrating

These two methods are similar and require very similar inspection techniques. The inspector should have an inspection checklist to follow (see Section 2970). The most important factors of these installation techniques are:

1. Water content of mixture
2. Forming (no leaks)
3. Number and arrangement of vibrators
4. Method of attaching vibrators

5. Duration of pour
6. Work stoppage contingency

All equipment needs to be clean at the start and cleaned frequently throughout the casting process. Dirty mixing equipment can lead to problems that the contractor's crew may not recognize.

The inspector should observe the casting procedure and assure proper consolidation, without overvibrating. Curing compounds are to be used on all exposed monolithic refractory surfaces.

Guniting

This technique is the most difficult process to inspect. The many variables associated with placement can cause significant problems. The material is mixed and placed into a gun in one location and applied in another area as much as 300 feet from the gun. Some of the more important variables are:

- Type of material
- Expertise of the nozzleman
- Expertise of the gun operator
- Air pressure
- Feed rate
- Mixing: time, prewet, cleanliness, "preset"
- Type and condition of equipment
- Ambient conditions
- Distance from gun to work area

Due to the critical nature of the gunning operation and the variability of results, an inspector should observe all material being placed. A checklist is extremely important because of the many variables (see Section 2970). General guidelines for an inspector observing guniting include the following:

1. The air pressure/feed rate ratio should result in a minimum of rebound.
2. The nozzleman must gunite so as to eliminate trapped rebound, laminations, and voids.
3. The nozzleman should gun normal to the work area.
4. Proper water content can be judged by the appearance of the gunned surface, which should have a slight temporary "sheen" from the water. A dull appearance usually indicates that the application is too dry.
5. Work stoppages generally require cutting back or squaring of the lining. All lining areas not at full thickness should be removed (the specifications will define when this is required).
6. Curing compound must be applied within 1 hour on most jobs and sooner when a high ambient temperature causes quick setting of the lining.

Hand Packing or Ramming

This method of installing castables is very difficult. Inspectors need to observe the consolidation of the material very closely. The lining must be built up gradually because it is difficult to move large masses of refractory. The surface being “worked” will consolidate and form a void-free mass. However, poor consolidation will occur toward the back of the lining if this building-up process is not followed.

Inspection of Plastic Refractory Installation

The installation of plastic refractories does not require the same attention as castable products. Because there is no mixing, many of the variables present with casting and guniting are absent. Inspectors need to ensure that the plastic is thoroughly compacted and that it extends to the edge of the anchors (thin linings). Good consolidation is the key to an acceptable plastic refractory installation.

2948 Preparing Production Test Samples

Sampling during installation should be performed at the frequency outlined in the appropriate specification. The inspector should ensure that each sample is taken in a manner that best represents the lining. For example, when guniting, a sample should be taken in a sample box as the lining is being installed.

The treatment of samples after they are taken is also critical to developing representative results. The inspector should ensure that the samples have curing compound applied, where appropriate, are not allowed to freeze, and are not disturbed prior to setting. The inspector must also be aware of all samples taken and ensure their identity.

Cast and Vibration Cast Samples. It is suitable to cast a sample in a shoe box mold like Detail 5B of Standard Drawing GD-N1271. The mold must be nonabsorptive, made of either plexiglas, metal or painted wood.

Guniting Samples. Sample molds should be like the one shown in Detail 4 of Standard Drawing GD-N1271. They can be constructed of plywood, with the sides made of expanded metal mesh. The inspector should not allow the contractor to prepare gunite samples outside the vessel. The sample should be cured with the lining, i.e., *in* the vessel. After 24 hours, the samples can be tested as described in Section 2930.

Hand Packing or Ramming Samples. These samples can be collected in shoe box molds also.

Plastic Refractory Samples. Sampling of plastic refractory is like that for castable refractories. Individual specimens must be prepared (i.e., 2-inch cubes for crushing strength and plates for erosion loss). Typical molds used for sampling of plastic are shown in Details 5A and 5C of Standard Drawing GD-N1271. Samples should be stripped from their mold shortly after forming or according to the manufacturer's recommendation. Air drying for 24 hours with a subsequent slow heat-up is desirable. The use of forced air to help dry the plastic samples is very helpful and important. Care should be taken to maintain the shape of the plastic samples.

Testing of Production Samples

Except for method of sample preparation, production samples are tested the same way laboratory-prepared samples were tested during material qualification (see Section 2931).

2950 Inspection of RCF

Many of the considerations for RCF inspection are the same as for cast and gunned linings in vessels as described in Sections 2930 and 2940. However, inspection programs for RCF will emphasize the installation, with minimal attention to prequalification of the material or crew and application method.

RCF lining systems for new equipment will have drawings showing the proposed anchor layouts and installation details. These drawings are generally very detailed and should reflect any requirements of the Company's specifications. Any inconsistencies should be resolved prior to the start of work.

2951 Tear-out

Inspectors should show what old material needs to be torn out and the method to be used. Tear-out of RCF systems should be performed to minimize any damage to adjoining ceramic fiber. Ceramic fiber blanket can be cut with a large knife. Boards and modules can easily be trimmed or cut with knives. In all cases, tear-out should be performed to allow proper installation of the repair material (i.e., blanket or blanket/board construction will require staggered joints, board lining will require proper anchoring, and modules must be installed tightly).

RCF linings fired above 1800°F will have significant devitrification, which causes the fiber to lose resilience and become somewhat brittle. Tear-out must be performed with caution to avoid damage to acceptable lining material. Due to the presence of ceramic fibers and silica dust, this work is normally done wet, and appropriate respiratory protection equipment must be worn. **Inspectors should be aware of the hazards to personnel and should see that safe handling practices outlined in Section 500 and Specification IRM-MS-4775 are followed.**

2952 Surface Preparation

Anchors for RCF systems are installed by stud welding. It is important to have a clean surface to work with. The surface should be free of oil, scale, dirt, etc., for good stud welding. Abrasive blasting is the best cleaning method. Other techniques would be permissible, assuming the surface is clean. The inspector should be convinced that proper stud attachment can be accomplished prior to approving the surface cleaning.

2953 Anchor Layout and Installation

Anchoring for RCF systems is very critical. Anchor patterns will be dictated by the RCF system outlined in Section 2600, RCF Installation. This pattern should also be well defined in the drawings for the project.

Anchor layout is very important to the success of an RCF system. It should constitute a hold point, to avoid serious delays, and inspectors should monitor layout closely. On large areas, accumulative error must be avoided. Accumulative error occurs when individual anchor or stud locations are measured independently; i.e., if studs are to be 9 inches apart and each location is measured separately, a tolerance of 1/8 inch can easily lead to errors of more than one inch in a row of studs. This error can be avoided by using long tape measures.

The inspector should examine anchors before they are installed, verifying proper metallurgy and dimensions. He must also oversee anchor layout and welding.

Welding techniques should be verified and each installer should weld three good anchors to a test plate. This procedure should be repeated after each work stoppage. Guidelines for acceptance of welding are covered in Part II of Specification IRM-MS-4789. Proper stud welding is described in Section 2600 of this manual.

Anchors are usually stud welded. This technique is convenient and fast. However, setting for current and dwell time are critical to the weld quality. A bend test should be performed on 25% of the long studs. On shorter studs, for modules, several bend tests at the beginning of each shift, or after each work stoppage will be sufficient. Visual inspection and hammer testing (100%) should be performed on the remainder of short studs. In repair areas or for irregular configurations, the inspector should assist in identifying location for replacement studs.

2954 Vapor Barrier

The inspector should be sure that a vapor barrier coating is installed after completion of anchor welding. Stud threads should be covered to prevent damage. Surface preparation in accordance with IRM-MS-4789 is important.

2955 Installation of RCF

Shrinkage is a common problem in RCF systems and good installation techniques are important to minimize the effect of shrinkage.

Layered RCF

The principles of installing layered RCF systems are basically the same for new construction and repairs. The inspector should pay special attention to the techniques used to mate repair linings to existing refractory material.

Installation of blanket RCF follows simple principles. Characteristics that the inspector should look for include:

1. Joints should always be offset to avoid alignment of any joint.
2. The stud pattern should be installed to accommodate the hot face.
3. Edges of top blanket should be approximately 2 inches from an anchor row for overlap construction.
4. Additional anchors may be required around burner block, view ports, hangers, etc., to provide adequate support.
5. All joints should be tight.
6. Blankets should not be stretched.
7. Special areas such as corners, termination joints, burner block, and penetrating members require additional inspection to ensure proper installation. The blanket must be properly anchored for these areas.

Details of installation for layered RCF construction are discussed in Section 2600.

Blanket/Board Systems

The installation of board/blanket linings requires considerable preplanning. The installation drawings will identify the best orientation of the boards and best stud locations, but details of construction should be reviewed prior to starting.

The studs and stud pattern are designed for the hot face board which is the ceramic fiber board. The stud pattern suggested by the manufacturer and by the Company's specification should not be altered by the contractor. Improper anchoring of boards can cause the boards to break and fail. All joints should line up between anchor rows.

Back-up blanket should be installed in the same manner as layered RCF. The joints should be staggered and tight.

The inspector must check that the boards fit loosely against the back-up lining. The boards should not be used to compress the back-up. By compressing the back-up, considerable stress is exerted onto the board, and when the binder is burned out, and other thermal stresses are introduced, cracking will be likely.

Modules

The installation of RCF modules is covered thoroughly in Section 2600. Inspectors should be familiar with that section.

Inspection of the layout and welding should be consistent with Section 2953. Module systems will require anchor layout and prewelding of anchors. Systems which require stud welding as the lining is installed are not permitted.

In all cases, the modules must be tightly installed against the adjacent modules. Special techniques are used to join corners, or modules against different refractory systems. A tight lining is vital.

Modules are shipped in a compressed condition. After installation, the banding must be removed and the modules tamped on the face to further tighten the lining and close small openings. Tamping also helps to tighten the module against the shell.

Inspection of module installations should be performed to ensure that acceptable techniques are used and that all details of the drawings are followed. The inspector should check that:

1. Lining installation follows the drawing
2. Surface preparation is properly done
3. Anchor layout is correct
4. Anchor welds and welding procedure are tested
5. Modules are tightly installed
6. Vapor barriers are not disturbed
7. Orientation of modules (parquet vs. soldier course, etc.) is correct
8. Corners, peepsites, manways, and penetrating members are correctly anchored and lined
9. Lining is tamped and all small openings are filled
10. Batten strips are used properly
11. Proper closure or installation methods are used on the last row of modules

Inspecting repair areas for modules will not differ greatly from original installations. The same principles apply. However, more emphasis is placed on surface preparation and anchor welding. The modules must also fit tightly against the existing RCF or refractory, and final seam closure around edges is important.

RCF Veneering

Though not used often, veneering with RCF has been used successfully to reduce heat loss through existing refractory linings. There are two methods used to veneer with RCF. One uses blanket installed (layered) on metal studs secured into the refractory lining. The second method uses modules, cemented to the existing lining.

Studs or anchors installed into existing refractory must be tight and capable of holding the RCF. Installation of the blanket follows the same guidelines for layered RCF covered in Section 2614.

For the cementing of modules over existing refractory, the inspector must be positive the modules are secure. The refractory surface must be free of dust, oil, etc., and the cementing mortar must have the proper consistency. The technique of installing the modules should be reviewed thoroughly before work begins.

Sprayable RCF

Sprayable RCF is designed to allow pneumatic placement of an RCF system. Its use is limited, and special equipment is required for application.

It is designed to be fast and can be effective when circumstances are right.

Anchoring is important and the guidelines suggested by the manufacturer should be followed. It is very important that the lining be homogeneous and laminations eliminated.

2960 Inspection of Brick and Shapes

The installation of brick and shapes generally follows common-sense principles. Brick walls should be straight, level, and properly anchored. The proper brick shapes should be used to turn curves, and the lining needs to be tight to the shell (casing). Inspection of brick installations combines knowing the plan and ensuring that generally accepted practices are followed.

2961 Tear-out

Unsound brick and other prefired shapes should be torn out gently to minimize damage to sound lining. Any damaged anchoring system should also be removed.

2962 Surface Preparation

Surface preparation should be consistent with the techniques described in Section 2943. The metal casing must be clean enough to produce acceptable anchor welding.

2963 Installation of Brick and Shapes

Anchoring for brick systems, like other refractory systems, is critical to the success of a lining. The inspector should ensure that the anchor system complies with requirements of the job, which are typically outlined in drawings for the project. He should also verify anchor metallurgy and dimensions.

Mortar joints should be controlled to minimize their thickness. Thin mortar joints (less than 1/16 inch) are generally required. The brick should be free of dust to allow the mortar to bond properly. The inspector should systematically check this by removing mortar from a brick. If the mortar “wets” the brick, the bond will be satisfactory. The mortar must be of the proper consistency. The consistency will vary depending on the application method (dipping vs. troweling).

Expansion joints are designed to allow thermal expansion without affecting the lining. The inspector should confirm their proper location. Joints should also be clean of debris to allow freedom of movement. The inspector must ensure that these expansion joints are installed properly and must not allow the contractor to alter their placement without permission from the Company.

Inspection of brick systems should include a systematic review of the dimensional accuracy of the work. Walls must be plumb and floors level. Rows in the walls must also be level, and thick mortar joints are not an accepted way to level the rows.

Bridgewalls are self-supporting and must be constructed of brick with controlled dimensional accuracy to avoid instability during firing. These walls must also have proper expansion provisions.

The final inspection of brick should ensure that all criteria for the lining were met. These include:

1. Dimensions match design drawings
2. Lining is tight
3. Uniformity of brick dimensions and installation pattern
4. Rings are properly keyed (cylindrical linings)
5. Expansion joints are packed (as required)
6. Mortar thickness is proper

2970 Refractory Inspection Checklist

This checklist can be used during shop and field inspection. It can also be amended to include hold points as well.

Preparation Before Installation

The following items should be obtained and reviewed prior to the start of work.

Materials

- Types and Data Sheets, including Material Safety Data Sheets (MSDS) ()
- Prequalification test results: match all materials with prequalification records; pallet numbers, code date, etc. ()
- Special installation requirements ()

Documents

- Drawings ()
- Company specification ()
- Contractor's written installation procedure ()

Inspection Responsibilities: defines degree and quality of:

- Tear-out ()
- Surface preparation ()
- Anchor layout and welding. Review procedure () and material requirements such as rod alloy.

Inclement Weather Provisions (per Company specifications)

Rain	()
Cold	()
Heat or hot weather	()
Storage of materials	()

Equipment**Mixers**

Number & type	()
Back-up	()
Location relative to work	()
Cleanliness	()
Rubber wipers	()

Guniting Rig

Number	()
Type	()
Operating condition	()
Cleanliness	()
Sufficient hose	()
Nozzle type	()

Vibrators

Number	()
Type	()
Attachment method	()
Operating condition	()
Back-up	()

Curing Compound Applicators

Type and size	()
Cleanliness	()
Number	()
Working condition	()

Air Compressors

Size	()
Operating condition	()
Back-up	()
Contingencies	()

Sample Molds

Cube	()
Gunit	()
“Shoe Box”	()
Plate for erosion testing	()

Air Hammers Wrecking

Size	()
Operating condition	()
Number	()

Pneumatic Rammers

Number	()
Operating condition	()
Size	()

Miscellaneous Tools and Equipment

Trowels	()
Screen boxes for metal fibers	()
Lights	()
Tape measures	()
Rubber mallets	()
Hammers	()
Spare parts	()
Thermometers	()

Installation**Conditions**

Ambient meets specs	()
Provisions to meet spec	()
Weather protection	()

Forming

Strength of forms	()
Form release	()
Positioned for proper thickness	()
Sealed	()
Bracing	()
Secured	()

Mixing

Water source	()
Storage containers	()

Introduction of metal fibers	()
Mixer cleanliness	()
Method of adding water	()
Water temperature	()
Mixing time	()
Mix temperature	()
Water percent	()

Surface Preparation and Anchoring

Surface preparation meets spec.	()
Welding procedure	()
Anchor weld (no cracks)	()
Squaring of old refractory	()
Anchor layout	()
Hammer test	()
Weld rod alloy	()

Scaffolding and Lighting

Adequate lighting	()
Scaffolding is safe (see <i>Safety in Designs Manual</i>)	()
Positioning (not too close to lining)	()
Back-up lighting	()
Crew to maintain lights	()

Guniting

Competence of gun operator	()
Material feed rate	()
Sampling	()
Rebound management	()
Curing compound applied	()
Maintenance of gun	()
Gunning technique	()
Air pressure	()
Thickness	()
Cut-back	()
Construction joints	()
Prewet	()

Casting or Vibration Casting

Vibrator frequency	()
Movement of material	()
Time from mixing to placement	()
Mixing per checklist	()
Forms per checklist	()
Curing compound applied	()
Total casting time	()
Water content	()
Vibration arrangement	()
Batch size	()
Anchor loss	()

Ramming (Plastics, Resco's AA-22, etc.)

Proper rammer size	()
Material fills area properly	()
Technique of stopping work relative to anchors	()
Compaction	()
Cut-back	()

Production Sampling

Proper molds and sizes	()
Frequency	()
Sampling procedure matches installation procedure	()
Curing	()
Handling	()

Inspection After Curing

Cracking	()
Construction joints	()
Hammer test	()

Dryout

Firing equipment	()
Burner locations—relative to refractory	()
Dryout schedule	()
Thermocouple location	()
Recording equipment	()

Reporting

Daily log	()
Map of placement	
• Dates	()
• Materials	()
• Applicators	()
• Equipment	()
• Log of samples	()