

Product Evaluation, Application, and Testing of Stage Cementing Collars

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Product Evaluation, Application, and Testing of Stage Cementing Collars

1 Scope

This document provides requirements, guidelines, and recommended practices for stage cementing collars used in cementing applications in the petroleum and natural gas industry. Information is included on the types, application, specification, validation, manufacturing, job planning and execution, and preventing and diagnosing problems. Use of stage cementing collars for non-cementing applications or annulus casing packers, or both, are outside the scope of this document.

Products covered under another API or international specification are not included. This document does not cover the connections to the well conduit.

2 References

This document contains no normative references. For a listing of other articles associated with this publication, refer to the bibliography.

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1

annulus

The space between the open hole and tubulars, or between tubulars, where fluid can flow.

NOTE The annulus designation between the production tubing and production casing is the "A" annulus. Outer annuli between other strings are designated B, C, D, etc. as the pipe sizes increase in diameter.

3.1.2

baffle plate

A landing seat wholly contained within a tubular string and placed at a predetermined location for the purpose of landing a shutoff or bypass plug.

3.1.3

ball

A spherical device used to actuate downhole tools or release sub-surface darts or plugs.

3.1.4

bypass plug

Device designed to allow fluid to flow through or around itself once landed on a seat.

3.1.5

cancellation device

cancellation plug

A device dropped through the casing to fully cycle the stage collar from the run-in position to the closed position in a single operation.

3.1.6

cementing plug

plug

A device used to separate fluids and wipe the internal surface of the pipes as it is pumped from one location in the pipe to another or to operate downhole tools, or both.

3.1.7**static gel strength**

Shear strength (stress) measurement derived from force required to initiate flow of a fluid.

NOTE 1 The static gel strength of the cement slurry results in the decay of hydrostatic pressure.

NOTE 2 Critical static gel strength (CSGS) is its value to the point at which pressure is balanced (hydrostatic equals pore pressure) at a point adjacent to the potential flowing formation(s). API Recommended Practice 10B-6 contains additional information on CSGS.

3.1.8**dart**

A device dropped or pumped through the casing or work string to launch plugs, operate downhole equipment, and/or shutoff or divert flow.

NOTE Darts can be free-fall or wiper type.

3.1.9**dogleg severity****DLS**

Change in inclination or azimuth, or both, of a wellbore as a function of measured depth.

NOTE Typically expressed in degrees per 30 m or 100 ft.

3.1.10**equivalent circulating density****ECD**

The effective density of the circulating fluid in the wellbore resulting from the sum of the hydrostatic pressure imposed by the static fluid column and the friction pressure.

3.1.11**float equipment**

Casing accessories that contain one or more check valves and become part of the lower section of a casing string for the purpose of preventing the flow of fluid from the annulus into the casing.

3.1.12**hydraulic stage collar****hydraulic stage tool**

A non-workstring operated stage cementing collar that opens with a predetermined differential pressure between casing and annulus at the tool (collar).

NOTE The tool opens when internal pressure applied to the casing acts on a differential area between the top and bottom of the opening seat.

3.1.13**mechanical stage collar****mechanical stage tool**

A non-workstring operated stage cementing collar that opens with a predetermined differential pressure inside the casing above and below the tool (collar).

3.1.14**opening device**

Used to open a non-workstring operated stage cementing collar.

3.1.15**shutoff plug**

A device used to terminate flow when landed on a seat.

3.1.16**stage cementing collar****stage cementing tool**

A device that can be selectively opened and closed to allow communication between the inside of the casing or liner to the annular space.

3.1.17**sub-surface launch plug set****sub-surface release plug set**

An integrated set of plugs installed in the liner hanger or casing running tool.

NOTE The individual plugs found in the assembly are usually released by dropping balls or darts from the surface through a work string—either drill pipe or tubing.

3.1.18**well barrier**

A component or practice that contributes to the total system reliability by preventing liquid or gas flow if properly installed.

NOTE API Standard 65-2 contains information on well barriers and zonal isolation.

3.1.19**well barrier system**

Well barrier system is two or more well barriers that act in series to prevent flow.

NOTE 1 Well barriers that do not act in series are not considered part of a single well barrier system, as they do not act together to increase total system reliability.

NOTE 2 API Standard 65-2 contains information on well barriers and zonal isolation.

3.1.20**workstring**

Drill pipe, tubing or coiled tubing string used to convey a treatment or manipulation of downhole tools for well activities.

3.2 Abbreviations

BOP	Blow out preventer
DLS	dogleg severity
ECD	equivalent circulating density
FEA	Finite Element Analysis
ID	internal diameter
LCM	loss circulation material
MASP	maximum allowable surface pressure
OD	outside diameter
QMS	Quality Management System
TOC	top of cement
WOC	wait on cement

4 Purpose and Applications of Stage Cementing Collars

4.1 General

Stage cementing collars allow communication between the inside of the casing or liner to the annular space at a predetermined distance above the bottom of the casing or liner string.

Stage cementing collars may be used in primary cementing of casing and liners in vertical, deviated, and horizontal wells. They may also be used as a contingency if the cement is not placed in the desired portion of the well.

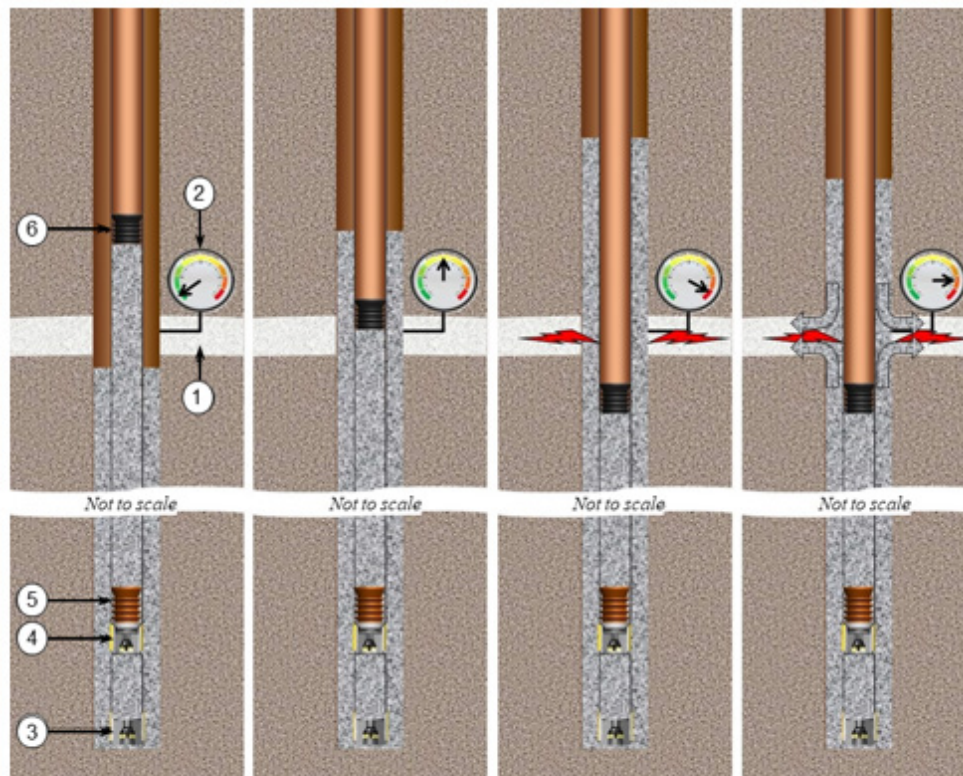
Applications of stage cementing collars include:

- a) cementing across a potential flow loss zone;
 - 1) two-stage cementing, and
 - 2) three- or more stage cementing.
- b) discontinuous cement interval;
- c) reducing post-cementing annular flow potential;
- d) off-bottom cementing above open hole completions;
- e) placing specialty fluids in the top section of the annular space;
- f) contingency cementing.

4.2 Cementing Across a Potential Loss Zone

Cementing across a potential weak zone (a zone lacking the integrity to withstand the equivalent circulating density (ECD) required to achieve the desired top of cement (TOC) in a single stage) is one application where stage cementing tools are effective. Figure 1 illustrates the main challenge in cementing across weak zones.

When displacing cement into the annular space, pressure across a weak zone will begin to increase as the cement is pumped past that zone. As the height of the cement column increases, ECD at the weak zone may prevent cement from reaching the desired depth.



Key

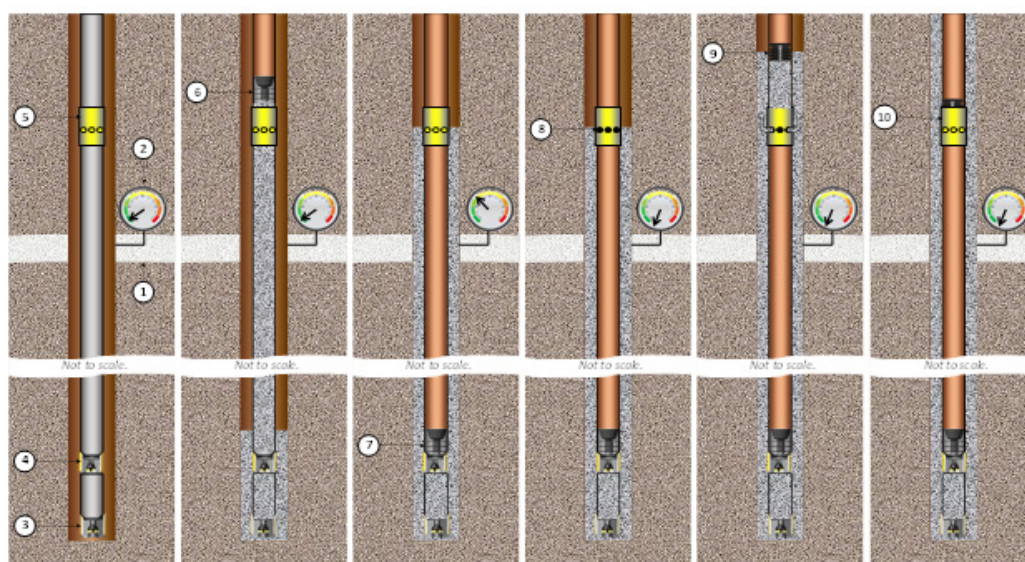
- | | |
|-------------------------|-------------------------|
| 1 Weak zone | 4 Float collar |
| 2 Pressure at weak zone | 5 Bottom cementing plug |
| 3 Float shoe | 6 Top cementing plug |

Figure 1—Formation Fracture during Single-stage Primary Cement Job

4.3 Two-stage Cementing

4.3.1 Two-stage Cementing Principle

In this application, the cement job is performed in stages, so that the maximum ECD during each stage never exceeds formation fracture pressure. A typical two-stage cement job is illustrated in Figure 2.



Key

- | | |
|--------------------------|--|
| 1 Weak zone | 6 First stage plug |
| 2 Pressure at weak zone | 7 First stage plug landed on landing baffle or seat |
| 3 Float shoe | 8 Apply pressure or drop opening device to open stage collar |
| 4 Float collar | 9 Second stage displacement plug-closing device |
| 5 Stage cementing collar | 10 Closed stage cementing collar |

Figure 2—Preventing Formation Fracture with Two-stage Primary Cement Job

A stage cementing collar is made up to the casing string and run to total depth. The setting depth of the stage cementing collar is typically above the weak zone. An optional inflatable annulus casing packer can be run immediately below the stage cementing collar to further protect the weak zone from the hydrostatic forces of the second-stage cementing.

The first-stage would be pumped conventionally through the float equipment using a single or double plug system. The plugs shall be compatible with the stage collar to ensure they do not cause the stage collar to function when passing through the seats.

When the first-stage plug lands on the float equipment or landing collar or baffle, the cement column in the annular space will not exceed the formation fracture pressure of the weak zone. At that point, the casing string is effectively closed at the float collar or landing collar or baffle.

After pumping the first-stage cement, the following operations are performed:

- Open the stage collar to allow communication between the casing and the annular space so that the excess cement from the first-stage can be circulated out to prevent premature cementation of the outside of the stage collar.
- Isolate the weak zone to prevent further transmission of pressure when pumping the second-stage cement. This can be done by waiting on first-stage cement to set, or by using an annular casing packer.
- Pump cement down the casing, through the stage collar ports, and into the annular space. The second-stage can be pumped using a single or double plug system. After second-stage is completed the stage collar is then closed.

NOTE The above illustrations show the stage collar being operated (opened and closed) by applying pressure using darts or plugs, or both. Other stage collar types are available and described in Section 5.

4.3.2 Two-stage Cementing Procedure

Sample operational procedure for two-stage cement job (manufacturer's recommendations should be followed when applicable) should be as follows:

- a) Load the plugs on the cement head or plug launcher, and ensuring the plugs are not damaged in the process and loaded in the proper sequence.
- b) Install first-stage plug landing seat (float equipment, landing collar, or baffle) at the top of the shoe track.
- c) Install tool on casing string, observing manufacturer's recommendations related to tong area.
- d) Monitor flow rates and displacement pressure while pumping and record any pressure anomalies or deviations from pumping schedule.
- e) Mix, pump, and displace first-stage cementing fluids (including spacers and preflushes).
- f) Determine flow-back volume.
- g) Open stage cementing collar.
- h) Circulate through stage cementing collar as per program.
- i) Mix, pump, and displace second cement stage.
- j) Close stage cementing collar.
- k) Determine flow-back volume.
- l) Confirm stage cementing collar closure.

4.4 Three-stage Cementing or More Stages

In three or more stage operations the process is similar to two-stage operations. However, there are specific equipment considerations to consider for plug or hydraulic operated stage collars for these applications. Some of these considerations are referenced in Sections 6, 8, and 9.

4.5 Discontinuous Cement Intervals

In this application, cement is placed in two separate intervals with a non-cemented interval between. In case of a two-stage cementing operation, first-stage TOC is deeper than the stage collar. Operations are similar to multiple-stage cement jobs as in 4.3 and 4.4.

4.6 Reducing Post-cementing Annular Flow Potential

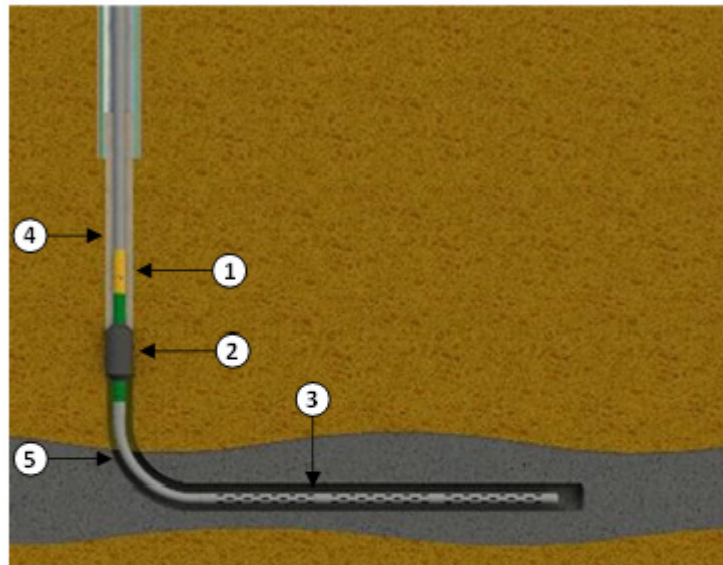
The hydrostatic pressure of a cement column decreases as cement gains gel strength, increasing the potential for annular flow. Hydrostatic pressure loss increases with cement column length. Therefore, reducing cement column length will mitigate this effect. Stage collars can be used for this purpose.

In other applications, stage collars may be used to increase the length of the second-stage cement column by isolating the weak or loss circulation zones below the tool.

NOTE API Standard 65–2 contains information on factors that affect cement success.

4.7 Off-bottom Cementing above Open Hole Completions

In this application a stage collar is installed above an annular packer to place cement above the uncemented completion without pumping cement below the stage collar (Figure 3), leaving the annulus below the packer uncemented.



Key

- | | |
|--------------------------|----------------------|
| 1 Stage cementing collar | 4 Cemented annulus |
| 2 Annular packer | 5 Uncemented annulus |
| 3 Open hole completion | |

Figure 3—Example of Off-bottom Cementing above an Uncemented Completion

4.8 Placing Specialty Fluids in the Top Section of the Annular Space

Stage collars may be used to allow for the placement or recovery of fluids above the stage collar. The process allows the user to circulate these fluids from a known point in the well, above the TOC. This process may be performed to allow recovery of drilling fluids, placement of corrosion protection fluids, introduction of freeze suppression fluids, or any other material to address specific well conditions. In these cases, the stage collar is opened following the primary cement job. Once the tool is opened, a fluid circulation is initiated to ensure that the annular fluid is conditioned and clean, and no cement will remain above the tool. Depending on the application, the first-stage of cement may be allowed to set prior to continuing displacement operations.

4.9 Contingency Cementing

Stage collars are sometimes installed as a contingency measure in case TOC objectives are not met. If primary cement job objectives are met, a second-stage cement is not required, and the stage collar is then permanently closed using a cancellation device or other method. This operation will vary by tool design.

5 Operating Types of Stage Cementing Collars

5.1 General

Currently there are two operating types of stage cementing collars: workstring operated and non-workstring operated tools.

For both non-workstring and workstring operated tools, some applications may require special features or performance specifications.

5.2 Non-workstring Operated Tools

Non-workstring operated tools are also referred as stage collars. These tools are operated using hydraulic pressure with or without an operating plug and do not require a workstring to function the tool. When using plugs, these are launched from the top of the host string (surface or sub-surface launched). Stage collars may require the plugs, landing seats and any remaining cement to be drilled out.

Other non-workstring operated stage cementing collars include those functioned electronically or other means. These are not covered in this document.

5.3 Workstring Operated Tools

Workstring operated tools are also referred to as port collars. These tools are functioned mechanically using an opening and closing device on a workstring.

5.4 Special Features or Performance Tools

5.4.1 Integral Packer Cementing Collar

An integral packer cementing collar consists of a stage cementing collar that includes an integrated annular packing element that can be energized through inflation or compression. Chemical swelling element is outside the scope of this document. The operational sequence of setting the packer is typically integrated into the operation of the cementer and not operated independently. The packer element is usually used to support and/or protect the second-stage cement column and isolate the annulus below the tool.

The main benefits of integral packer cementing collars are:

- The setting of the packer elements is included in the operation of the stage cementing collar, thereby eliminating concerns of controlling multiple pressure events.
- Enabling actuating the packer independently from landing the first-stage plug.
- For hydraulic tools, the actuation of the packer is integrated with the operation of the stage cementing collar.

Traditionally, the inflatable packers will be used for setting in cased and open-hole applications, while the compression set packers are used in cased-hole applications. Selection of the appropriate packer should be based on the well construction needs.

5.4.2 Sub-surface Plug Launch

Where the use of stage cementing collars is needed in sub-surface or subsea applications, sub-surface launch plug sets are required. The plug set will make up to the liner or casing running tool assembly. Drill-pipe darts or balls, or both, are sequentially dropped or pumped down the workstring to release the plugs.

5.4.3 Drilling with Casing Compatibility

The main differences in two-stage cementing in drilling with casing applications are the potential loads or conditions and both to which the stage collars may be subjected. These conditions include:

- compression,
- tension,
- torsion, and

- bending.

Torque and drag calculations should be performed to determine the maximum values of loading throughout the drilling and cementing process. These loads can then be assessed through Finite Element Analysis (FEA), or equivalent analysis, to determine probabilities of failure.

Other considerations include:

- fatigue life;
- circulation rates, times and fluids;
- fluid compositions, including loss circulation material (LCM); and
- retrieval of drilling assembly.

With a stage collar in the casing string being used for drilling or if the casing will be rotated to get past an obstruction, as with any drillstring component the drilling parameters should be managed within the limitations of the stage collar with respect to burst, collapse, vibration, stick-slip, and torque. The risk of inadvertently opening a hydraulic stage collar due to pack-offs or other events that increase differential pressure should be considered.

The following information should be provided to the manufacturer for a comprehensive analysis:

- well schematics;
- casing specifications;
- survey;
- fluid properties;
- expected weight on bit, rate of penetration, rotational speed, torque on bit;
- position of the stage collar in the string (distance from bit);
- description of operations;
- cementing plan and cementing objectives;
- type of drilling with casing system (retrievable, integral); and
- expected drilling time.

5.4.4 Contingency Cementing Operation

In these applications, second-stage cement may not be required. Most stage cementing collars will still require to be shifted to the permanent close position. A cancellation device and procedure should be supplied by the manufacturer.

5.4.5 Combined Loading

As stage cementing collars are made up into the casing string, they are subject to the same loads as the casing and some operators may require consideration of combined loads in the design of the product. These loads may include tension, compression, torque, bending, internal pressure, external pressure. In addition, these loads are applied in downhole conditions which may include temperatures and environments such as sour service which could affect the material properties of the tool (both metallic and non-metallic components).

NOTE Sour service is defined as exposure to oilfield environments that contain sufficient H_2S to cause cracking of materials by the environments. NACE MR0175/ISO 15156 contains information about materials suitable for sour service.

5.4.6 Fluid Compatibility

During well construction and completion operations, many types of fluids are used. Fluids that will be in the well while running casing, circulating, cementing, and displacing the operating plugs should be reviewed for compatibility with plugs, seals and packers. Additionally, the compatibility of the well fluids with each other should be reviewed. Reactive interfaces of the different fluids can create operational difficulties during cementing and stage cementing operations.

NOTE API Technical Report 10TR6 describes a standard test method for elastomer property and the effect of liquids.

5.4.7 Operating Pressures

Tool operating pressures should be confirmed to be compatible with the intended casing running and cementing operating procedure for each well. Consideration should be given to all other tools installed in the casing string, as well as casing specifications.

Depending on tool design, tool operating pressures should include:

- maximum internal pressure during running in hole;
- maximum external pressure during running in hole;
- hydraulic opening pressure;
- mechanical opening pressure;
- fluids displacement pressure;
- closing pressure;
- cancellation pressure;
- surge and swab pressure;
- casing pressure test;
- maximum internal pressure in closed position;
- maximum external pressure in closed position; and
- high pressure stimulation, when applicable.

In addition to nominal values for the above pressures, the user should understand and consider the manufacturer's tolerances on nominal opening, closing, and cancellation pressures.

In some applications, the standard operating pressures and specifications may not be suitable. Examples of these applications include:

- hydraulic fracturing;
- tool operating pressures higher than casing pressure ratings;
- limited pump capabilities;

- synchronization with other specialty downhole tools (casing floatation devices, toe sleeves, burst disk subs, etc.);
- high burst and collapse casing;
- high ECDs; and
- surge pressure.

For these applications, customer requirements shall be clearly communicated to and confirmed by the manufacturer, including any field-service limitations or special requirements (i.e. ability to adjust pressures in the field).

5.4.8 High Pressure Stimulation

Before using cementing stage collars in a casing string that will be used for hydraulic fracturing, a complete engineering assessment should be performed. This may include pressure, temperature, axial load, and erosion effects.

5.5 Purchasing Guidelines

When selecting or specifying stage cementing collars, it is important that the following information be considered as applicable:

- a) casing specifications: size, weight, grade, connection,
- b) workstring specifications,
- c) minimum downhole restriction through which the stage collar will pass, including blow out preventer (BOP) and supplemental casing hangers,
- d) maximum outside diameter (OD),
- e) well profile, including maximum hole inclination at or above the tool and maximum anticipated dogleg severity (DLS),
- f) tool setting depth,
- g) tool length and weight,
- h) maximum drillout inside diameter (ID),
- i) seat(s) diameter,
- j) operation type (refer to Section 5),
- k) differential pressure ratings before and after tool functioning,
- l) tension and compression ratings,
- m) operating temperature range,
- n) torque,
- o) number and size of ports and total port flow-by area,
- p) nominal operating pressures, forces and tolerances,

- q) type of seal (elastomeric, metal-to-metal, other),
- r) fluid compatibility,
- s) drillout requirements,
- t) operating plug requirements,
- u) factory acceptance testing,
- v) quality requirements, and
- w) manufacturing and transportation times.

6 Manufacturing and Quality Considerations

6.1 Quality Management System Guidelines

Stage cementing collars should be developed and manufactured under a quality management system (QMS). Certification by an external body of the QMS to an established industry standard is recommended.

NOTE API Specification Q1 provides sector-specific guidance on QMS.

The manufacturing facility's QMS should include, at minimum, the following topics:

- a) procurement and supplier qualification,
- b) inspection and testing,
- c) personnel qualification,
- d) measurement and testing equipment calibration,
- e) non-conformance control, and
- f) documentation control.

6.2 Design Verification

Each new product model should go through a design verification analysis to confirm that the design meets the requirements specified in the technical specification. If the environment or application, or both, changes for a product model, the design verification process should be repeated to verify conformance to the new requirements. The design verification analysis should be reviewed and verified by a qualified individual(s) other than the individual(s) who did the original analysis.

Where verification and industry experience exist, design verification and validation documentation may be completed and approved by a qualified person to meet the functional and technical specifications and acceptance criteria. This may include a detailed field history of successful performance of the same design, and in an environment similar to that of the functional specifications. In this case, the validation methodology should be reviewed and approved by a qualified individual(s) other than the individual(s) who did the original analysis.