EVALUATION SUBJECT:
FOUNDATION SUPPORTWORKS
PP288 PUSH PIER SYSTEM

REPORT HOLDER:
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CSI Division: 31 00 00 - EARTHWORK
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1.0 SCOPE OF EVALUATION

1.1 Compliance to the following codes & regulations:
- 2009 International Building Code® (IBC)
- 2012 International Building Code® (IBC)
- 2015 International Building Code® (IBC)

1.2 Evaluated in accordance with:
- IBC Chapter 18

1.3 Properties assessed:
- Structural
- Geotechnical

2.0 PRODUCT USE

Foundation Supportworks, Inc. (FSI) Model PP288 push pier systems are used to support foundations of existing structures or to provide additional axial compression capacity to existing foundation systems. The systems are alternatives to driven piles described in IBC Section 1810.3.1.4

3.0 PRODUCT DESCRIPTION

3.1 Product information: FSI Model PP288 push pier systems consist of an under-footing bracket (side load), external sleeve, starter tube with friction-reduction collar, and push pier tube sections with slip-fit couplings. The under-footing bracket is secured against and below the existing footing while pier sections are hydraulically driven (pushed) through the bracket and into the soil below using the combined structural weight and any contributory soil load as drive resistance. Pier sections are added and driven until a suitable load bearing stratum is encountered. The weight of the structure is then transferred through the foundation brackets and piers, and to firm load bearing soil or bedrock.

3.2 Material information

3.2.1 Retrofit Bracket Assemblies FS288B and FS288BL: The FS288B and FS288BL bracket assemblies consist of an FS288B or FS288BL bracket, an external pipe sleeve (FS288ES48), a cap plate (FS288C), two threaded rods, and matching nuts. The assemblies are illustrated in Figure 1.

3.2.1.1 FS288B and FS288BL Brackets: The FS288B and FS288BL brackets are constructed from factory-welded, 0.250-inch-, 0.375-inch-, and 0.500-inch-thick (6.4 mm, 9.5 mm, and 12.7 mm) steel plates conforming to ASTM A36, with a minimum yield strength of 36 ksi (248 MPa) and a minimum tensile strength of 58 ksi (400 MPa). The available bracket finish is either plain steel or hot-dip galvanized in accordance with ASTM A123.

3.2.1.2 FS288ES48 External Sleeve: The external sleeve (FS288ES48) is manufactured from a 48-inch-long (1219 mm), $3^1/_2$-inch outside diameter (89 mm) and 0.216-inch (5.49 mm) nominal wall thickness pipe conforming to ASTM A500, as specified in the quality control documentation. One end of the external sleeve has a 1.00-inch long (25.4 mm) section trumpeted to a final outer diameter of 4.00 inches (101.6 mm). The sleeve finish is either plain steel or hot-dip galvanized in accordance with ASTM A123.

3.2.1.3 FS288C Cap Plate: The FS288C cap plate is manufactured from a $^1/_2$-inch-long (12.7 mm), $3^1/_2$-inch outside diameter (89 mm), 0.216-inch (5.49 mm) nominal wall thickness steel pipe that is factory-welded to a 1-inch-thick (25.4 mm), 5-inch-wide (127 mm), 9-inch-long (229 mm) steel plate. The $^1/_2$-inch-long (12.7 mm) steel pipe conforms to ASTM A53, Types E and S, Grade B, having a minimum yield strength of 35 ksi (241 MPa) and a minimum tensile strength of 60 ksi (413 MPa). The steel cap plate conforms to ASTM A572, Grade 50 (345 MPa), having a minimum yield strength of 50 ksi (345 MPa) and a minimum tensile strength of 65 ksi (448 MPa). The available cap plate assembly finish is either plain steel or hot-dip galvanized in accordance with ASTM A123.

3.2.1.4 Threaded Rod and Nuts: The cap plate is attached to the retrofit bracket with two $^3/_4$-inch-diameter by 16-inch-long (19.1 mm by 406 mm) threaded rods, and matching $^3/_4$-inch (19.1 mm) heavy hex nuts. The $^3/_4$-inch-diameter (19.1 mm) steel threaded rods conform to ASTM A193, Grade B7, having a minimum yield strength of 105 ksi (724 MPa) and a minimum tensile strength of 125 ksi (862 MPa). The matching $^3/_4$-inch-diameter (19.1 mm) steel heavy hex nuts conform to ASTM A563 Grade DH or DH3, or ASTM A194 Grade 2H. The threaded rods and nuts are zinc-coated in accordance with ASTM B633, with coating classification Fe/Zn 8.

3.2.2 Starter and Pier Tube Sections: The central steel shaft of the starter and pier tube sections are 2.875-inch outer diameter (73 mm) by 0.165-inch (4.19 mm) nominal wall thickness hollow structural section in conformance with ASTM A500 as specified in the quality control documentation. The starter tube includes a 1.00-inch-long (25.4 mm) by 3.375-inch (85.7 mm) outer diameter friction-reduction collar machined from steel conforming to ASTM A36 with a minimum yield strength of 36 ksi (248 MPa) and a minimum tensile strength of 58 ksi (400 MPa). The starter tube and pier tube shaft finishes are triple coated in-line galvanized.

3.2.3 Shaft Couplings: The shaft coupling material is factory crimped or plug-welded to one end of the tube section and consists of 2.50-inch (63.5 mm) outer diameter by 0.180-inch (4.57 mm) nominal wall thickness hollow structural section in conformance with ASTM A53 Grade B, Type E & S with a minimum yield strength of 35 ksi (241 MPa) and a minimum tensile strength of 60 ksi (413 MPa). The pier tube shaft coupling finish is plain steel.

4.0 DESIGN AND INSTALLATION

4.1 General: Structural calculations (analysis and design) and drawings, prepared by a registered design professional, shall be approved by the code official for each project, and shall be based on accepted engineering principles, as described in IBC Section 1604.4, and shall conform to IBC Section 1810. The design methods for the steel components are Allowable Strength Design (ASD), described in IBC Section 1602 and AISC 360 Section B3.4. The structural analysis shall consider all applicable internal forces due to applied loads, structural eccentricity and maximum span(s) between push pier foundations. The structural analysis, the IBC, and this report shall be used to select an appropriate push pier system.

The ASD capacities of FSI push pier system components are indicated in Table 2. The geotechnical investigation shall address the suitability of the push pier system for the specific project. The requirements for deep foundations in IBC Section 1803.5.5 shall be considered. In addition, effects on the supported foundation and structure and group effects on the pile-soil capacity shall be considered. The investigation shall provide estimates of the axial compression capacities for the push piers, and the expected total and differential settlements due to single pier or pier group, as applicable.

A written report of the geotechnical investigation shall be submitted to the code official as one of the required submittal documents, prescribed in IBC Section 107, at the time of the permit application. The geotechnical report shall comply with provisions in IBC Section 1803.6 and also include, but need not be limited to, the following information:

1. Information on groundwater table, frost depth and corrosion-related parameters, as described in Section 5.5 of this report.
2. Soil properties, including those affecting the design such as support conditions for the piers.
3. Recommendations for design criteria.
4. Any questionable soil characteristics and special design provisions, as necessary.

4.1.2 Bracket Capacity (P1): Only localized limit state of concrete bearing strength in compression has been evaluated in this evaluation report for compliance with IBC Chapter 19 and ACI 318. All other structural requirements in IBC Chapter 19 and ACI 318 applying to the concrete foundation, such as those limit states described in ACI 318 (anchorage per Appendix D, punching (two-way) shear, beam (one-way) shear, and flexural (bending) related limit states), have not been evaluated in this evaluation report. The concrete foundation shall be designed and justified to the satisfaction of the code official with due consideration to structural detailing, applicable limit states, and the direction and eccentricity of applied loads, including reactions provided by the brackets, acting on the concrete foundation.

4.1.3 Shaft Capacity (P2): The top of shafts shall be braced as prescribed in Section 1810.2.2 of the IBC. In accordance with Section 1810.2.1 of the IBC, any soil other than fluid soil shall be deemed to afford sufficient lateral support to prevent buckling of systems that are braced. When piers are standing in air, water or fluid soils, the unbraced length is defined as the length of piers that is standing in air, water or fluid soils plus an additional 5 feet (1524 mm) when embedded into firm soil or an additional 10 feet (3048 mm) when embedded into soft soil. Firm soils shall be defined as any soil with a Standard Penetration Test (SPT) blow count of five or greater. Soft soil shall be defined as any soil with a SPT blow count greater than zero and less than five. Fluid soils shall be defined as any soil with a SPT blow count of zero [weight of hammer (WOH) or weight of rods (WOR)]. The SPT blow counts shall be determined in accordance with ASTM D1586. For fully braced conditions where the pier is installed in accordance with Section 1810.2.2 of the IBC, and piers do not stand in air, water, or fluid soils, the shaft capacities shall not exceed the ASD shaft compression capacities shown in Table 2. Shaft capacities of push pier foundation systems in air, water or fluid soils, shall be determined by a registered design professional.

The elastic shortening/lengthening of the pier shaft will be controlled by the variation of applied loads from the pier lock-off load and the mechanical and geometrical properties of the $2^{7}/_{8}$-inch-diameter (73 mm) round structural tubing. The shaft elastic shortening can be determined from equation Eq.-1:

$$\Delta_{shaft} = \frac{\Delta P \times L}{A \times E} \quad \text{(Eq. 1)}$$

Where:

Δ_{shaft} = change in shaft length due to elastic shortening (inches/mm)
ΔP = change in load between the applied load and the pier lock-off load (lbf/N)
L = pier shaft length (inches/mm)
A = shaft cross-sectional area (in^2/mm^2) (taken from Table 1)
E = shaft steel modulus of elasticity (29,000,000 psi/199,900 MPa)

4.1.4 Soil Capacity (P4): For determination of allowable soil capacity in axial compression, a minimum factor of safety of 2.0 shall be applied to the final drive force. The final drive force shall not exceed the maximum drive force rating of the applicable PP288 push pier system as shown in Table 2.

4.1.5 System Capacity: The ASD allowable capacity of the FSI push pier foundation system in compression depends upon the analysis of interaction of brackets, shafts, and soils; and shall be the lowest value of P1, P2, and P4 as shown in Table 2.

4.2 Installation

4.2.1 General: The FSI push pier foundation systems shall be installed by FSI trained and certified installers. The FSI push pier foundation systems shall be installed in accordance with this section (Section 4.2), site-specific approved construction documents (engineering drawings and specifications), and the manufacturer's written installation instructions. In case of conflicts, the more restrictive governs.

4.2.2 FS288B and FS288BL Retrofit Bracket Installation:

1. An area shall be excavated approximately 3 feet (914 mm) square and to a depth approximately 9 to 13 inches (229 to 330 mm) below the bottom of footing at the push pier location. The soil shall be removed below the bottom of footing to about 9 inches (229 mm) from the footing face in the area where the bracket bearing plate will be placed. The vertical and bottom faces of the footing shall, to the extent possible, be smooth and at right angles to each other for the mounting of the support bracket. The concrete surfaces shall be free of all soil, debris and loose concrete so as to provide a full and firm contact of the retrofit bracket.

2. Notching of the footings may be needed to place the retrofit bracket directly under the wall/column. Notching shall be performed, however, only with the acceptance of the registered design professional and the approval of the code official.

3. The bracket shall be placed under the footing and raised into position with the horizontal and vertical bearing plates in full contact with the concrete surfaces. The bracket shall be temporarily held in place using wood cribbing or other mechanical means. The under-footing brackets do not require mechanical anchorage to the concrete foundation.

4. The external sleeve shall be placed over the starter tube and both the external sleeve and starter tube shall be inserted through the bracket from the top. Care shall be taken that the sleeve and starter are properly aligned and extend past both the top and bottom plates of the bracket.

5. The drive stand shall be secured to the bracket, the hydraulic drive cylinder attached to the drive stand and connected to the hydraulic operating system.

6. The drive stand shall be aligned by activating the hydraulics and extending the drive cylinder rod to make slight contact with the starter tube section. A digital level, protractor or other device shall be used to check alignment of the drive stand, sleeve, starter and bracket. The alignment shall be adjusted as necessary to allow a 3.0 ±1.0-degree installation angle. Temporary cribbing may be used between the drive stand and the foundation wall to set the correct installation angle while advancing the starter tube and external sleeve.

7. The external sleeve and starter tube shall be driven together until the trumpeted end of the sleeve is seated at the top of the bracket. Pier tubes shall then coupled and pushed through the external sleeve. When the maximum cylinder stroke has been reached, the cylinder shall be retracted, a drive tube tool shall be set in place, and the push shall be completed to the top of the bracket or external sleeve.

8. The drive pressure at the final stroke of each pier tube section shall be recorded. This process shall continue until the pre-determined drive pressure (final drive force) is achieved or the structure starts to lift. After reaching the final drive force, the pressure shall be released from the hydraulic system and the drive stand and drive cylinder shall be removed from the bracket. The drive process

shall be repeated at each of the proposed pier locations. The final drive force shall not exceed the maximum drive force rating of the push pier system as shown in Table 2.

9. A lift cylinder shall be connected to each retrofit bracket assembly to lift the structure to the desired elevation and/or transfer the designated portion of the foundation loads to the push pier system.

4.3 Special Inspection: Continuous special inspection in accordance with Section 1704.8 of the 2009 IBC or Section 1705.7 of the 2012 and 2015 IBC shall be provided for the installation of foundation piers and foundation brackets. Items to be confirmed by the special inspector include, but are not limited to, the manufacturer's certification of installers, verification of the product manufacturer, push pier bracket and component configuration and identification, inclination and position of the push piers, final drive force, push pier lock-off load, depth of the foundation piers, and compliance of the installation with the approved construction documents and this evaluation report.

In lieu of continuous special inspection, periodic special inspection as defined in IBC Section 202 is permitted, provided that all following requirements identified below, are satisfied: (1) The installers are certified by the manufacturer and the evidence of installer training and certification by the report holder are provided to the code official; (2) Structural observations in accordance with the 2009 IBC Section 1710, 2012 IBC Section 1704.5, or 2015 IBC Section 1704.6 are provided; (3) A periodic inspection schedule, as part of the statement of special inspection, prepared by a registered design professional, is submitted to and approved by the code official. As a minimum, the periodic inspection schedule shall include, but not be limited to, the following:

1. Before the start of work: Verify manufacturer, verify installer's certification by the manufacturer, and confirm push pier and bracket configuration compliance with the approved construction documents and this evaluation report.

2. Installation of the first push pier foundation system: Verify that the location, inclination, final drive force, push pier lock-off load and depth of the push piers comply with the approved construction documents and this evaluation report. Verify that installers keep an installation log.

3. First connection to the building structure: Verify that installation of brackets comply with the approved construction documents and this evaluation report.

4. End of work: Verify that the installation log complies with requirements specified in the approved construction documents. Verify that installation of all structural connections complies with approved construction documents and this evaluation report.

5.0 LIMITATIONS

FSI Model PP288 push pier foundation systems described in this report comply with, or are suitable alternatives to what is specified in, the code listed in Section 1.0 of this report, subject to the following conditions:

5.1 The FSI push pier foundation systems are manufactured, identified and installed in accordance with this report, approved construction documents (engineering drawings and specifications), and the manufacturer's published installation instructions. In case of conflicts, the more restrictive governs.

5.2 The FSI push pier foundation systems have been evaluated for support of structures assigned to Seismic Design Categories A, B, and C in accordance with IBC Section 1613. Push pier foundation systems that support structures assigned to Seismic Design Category D, E or F, or are located in Site Class E or F, are outside the scope of this report.

5.3 Installations of the push pier foundation systems are limited to regions of concrete members where analysis indicates no cracking occurs at service load levels.

5.4 The push pier brackets shall be used only to support structures that are laterally braced as defined in Section 1810.2.2 of the IBC.

5.5 The push pier foundation systems have not been evaluated for use in soil conditions that are indicative of a potential pier deterioration or corrosion situation as defined by the following: (1) soil resistivity less than 1,000 ohm-cm; (2) soil pH less than 5.5; (3) soils with high organic content; (4) soil sulfate concentrations greater than 1,000 ppm; (5) soils located in a landfill, or (6) soil containing mine waste.

5.6 Zinc-coated steel and bare steel components shall not be combined in the same system, except where the sacrificial thickness (T_s) for the zinc-coated components is taken as that given for bare steel components. All push pier foundation components shall be galvanically isolated from concrete reinforcing steel, building structural steel, or any other metal building components.

5.7 The push pier shafts shall be installed at a maximum angle of 3.0 ± 1.0-degrees from the vertical.

5.8 Special inspection is provided in accordance with

Section 4.3 of this report.

5.9 Engineering calculations and drawings, in accordance with recognized engineering principles, as described in IBC Section 1604.4, prepared by a registered design professional, are provided to, and are approved by the code official.

5.10 The adequacy of the concrete structures that are connected to the FSI brackets shall be verified by a registered design professional, in accordance with applicable code provisions, such as Chapter 15 of ACI 318 and Chapter 18 of IBC, and subject to the approval of the code official.

5.11 A geotechnical investigation report for each project site shall be provided to the code official for approval in accordance with Section 4.1.1 of this report.

5.12 When using the alternative basic load combinations prescribed in Section 1605.3.2, the allowable stress increases permitted by material chapters of the IBC (including Chapter 18) or the referenced standards are prohibited.

5.13 Evaluation of compliance with Section 1810.3.11.1 of the IBC for buildings assigned to Seismic Design Category C, and with Section 1810.3.6 of the IBC for all buildings, is outside the scope of this evaluation report. Such compliance shall be addressed by a registered design professional for each site, and the work of the design professional shall be subjected to approval of the code official.

5.14 Settlement of push piers is beyond the scope of this evaluation report, and shall be determined by a registered design professional as required in Section 1810.2.3 of the IBC.

5.15 The FSI push pier foundation system components are manufactured at the following facilities: Distefano Technology & Manufacturing Company, 3838 South 108th Street, Omaha, Nebraska 68144; Behlen Manufacturing Company, 4025 East 23rd Street, Columbus, Nebraska 68601; PowerBrace, 5153 Northeast 17th Street, Des Moines, Iowa 50313; and TSA Manufacturing, 14901 Chandler Road, Omaha, Nebraska 68138; under a quality control program with inspections by Benchmark Consulting & Inspection, L.L.C. (AA-660).

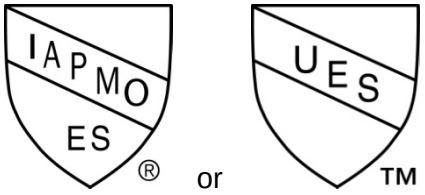
6.0 SUBSTANTIATING DATA

Data in accordance with IBC Section 1810.3.1.4.

- Test Reports for compression loading Push Pier Foundation System
- Engineering Calculations

7.0 IDENTIFICATION

The FSI push pier foundation system components described in this report are identified by labels that include the report holder's name (Foundation Supportworks, Inc.); the name and address of Distefano Technology & Manufacturing Company, Behlen Manufacturing Company, PowerBrace or TSA Manufacturing; the product name, the model number (PP288); the part number; the IAPMO UES evaluation report number (ER-289); and the third-party inspection agency (Benchmark Consulting & Inspection, L.L.C.)



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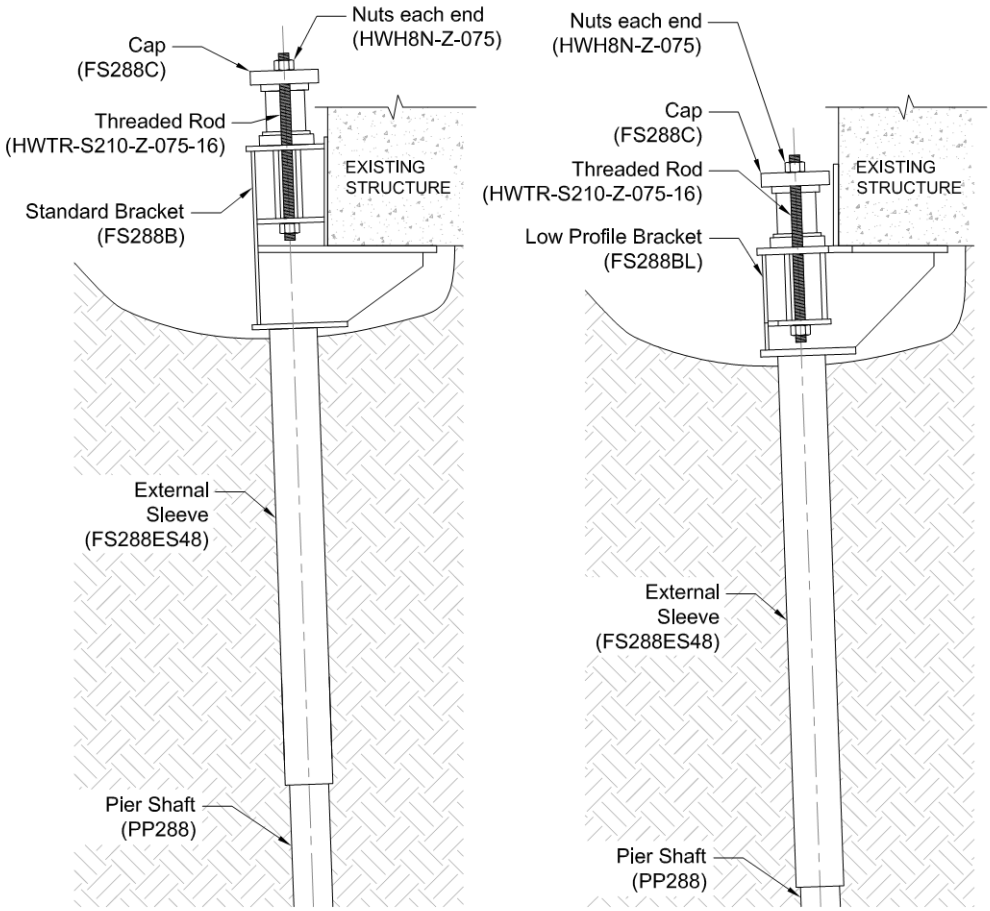

Figure 1: FS288B and FS288BL Retrofit Bracket System Components

TABLE 1 - MECHANICAL PROPERTIES OF 2.875-INCH DIAMETER PUSH PIER SHAFTS

Mechanical Properties	Un-corroded	After 50 Year Corrosion Loss
Steel Minimum Yield Strength, F_y	50 ksi	50 ksi
Steel Minimum Ultimate Strength, F_u	55 ksi	55 ksi
Modulus of Elasticity, E	29,000 ksi	29,000 ksi
Nominal Wall Thickness	0.165 in.	0.165 in.
Design Wall Thickness	0.153 in.	0.117 in.
Outside Diameter, OD	2.875 in.	2.839 in.
Inside Diameter, ID	2.569 in.	2.605 in.
Cross Sectional Area, A	1.31 in^2	1.00 in^2
Moment of Inertia, I	1.22 in^4	0.93 in^4
Radius of Gyration, r	0.96 in.	0.96 in.
Elastic Section Modulus, S	0.85 in^3	0.65 in^3
Plastic Section Modulus, Z	1.14 in^3	0.87 in^3

For SI: 1 inch = 25.4 mm, 1 ksi = 6.895 MPa, 1 lbf = 4.448 N

TABLE 2 - PP288 (WITH RETROFIT BRACKET) ASD COMPRESSION CAPACITIES

Bracket Part No.[1]	Sleeve Part No.[1]	PP288 Bracket Description	Allowable Compression Capacity (kips)			
			Bracket (P1)[2]	Shaft (P2)[3]	Soil (P4)[4]	Foundation System[5]
FS288B or FS288B-G	FS288ES48 or FS288ES48-G	Standard Bracket w/48" Sleeve	28.5	29.4	30.0	28.5
FS288BL or FS288BL-G	FS288ES48 or FS288ES48-G	Low Profile Bracket w/48" Sleeve	25.4	29.4	30.0	25.4

For SI: 1 inch = 25.4 mm, 1 kip = 1,000 lbf = 4.448 kN

[1]Part numbers with "G" suffix indicate hot-dip galvanized coating. Part numbers without a "G" suffix indicate plain steel.

[2]Bracket capacities are based on full-scale load tests and assumes a minimum concrete compressive strength (f'_c) of 2,500 psi (17.24 MPa).

[3]Shaft capacities are applicable only to foundation systems that are fully braced as described in Section 4.1.3.

[4]Soil capacities are determined by taking the final drive force during installation and dividing it by a minimum factor of safety of 2.0. Maximum drive force shall not exceed 60.0 kips.

[5]Foundation system allowable capacities are based on the lowest of P1, P2, and P4 listed in this table. Section 4.1.5 describes additional requirements.