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3.

maximum operating temperature

The highest equipment temperature for which the equipment is designed to be operated.

minimum design temperature

The lowest specified temperature for which the primary load carrying component is intended.

minimum operating temperature

The lowest temperature of the equipment at which it can be used/operated.

operating temperature range

The temperature range between minimum and maximum operating temperatures at which the equipment can be used/operated.

NOTE: this may differ from ambient / environmental temperatures, manufacturer will provide procedures for warming and cooling equipment

RSC hoisting rated load

Rated load for the top drive/rotary swivel/power swivel RSC when supporting **API 8C rated** hoisting equipment (see 4.3.8.3 and Figure 12, panel c).

4.2 Design Conditions

The following design conditions apply.

- a) The design load and the safe working load shall be as defined in Section 3.

NOTE: The owner/user of the equipment is responsible for determination of the safe working load for any hoisting operation.

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- b) Unless changed by supplementary requirement SR 2 (see A.3), the minimum design temperature for primary load carrying components shall be $-20\text{ }^{\circ}\text{C}$ ($-4\text{ }^{\circ}\text{F}$).

NOTE: The operator of the equipment is responsible for determination of the safe working load for any hoisting operation;

NOTE: The operating temperature range shall be specified by the manufacturer. This range may not be the same for all parts of the equipment, where differences exist, they may be specified separately or the most restrictive range shall be used.

WARNING: Use of equipment covered by this specification at rated loads at temperatures below the design and test temperature can result in bodily injury, death, equipment failure, or a combination thereof (see A.3).

4.3.8.3 Rotary Shouldered Connections Supporting API 8C Rated Hoisting Equipment

~~API RSC hoisting rated load shall be calculated as in Equation (3) through Equation (12); see Figure 12, panel c.~~

API RSC hoisting rated load shall be:

- Calculated as in Equation (3) through Equation (12); see Figure 12, panel c; or
- Established by performing an alternative design validation test in accordance with 5.4

NOTE See Figure 1 for locations of tensile areas.

$$\text{Tensile rated load (for pin) in SI units, kN} = (YS_{\min}) (A_p) / (SF_D \times 1000) \quad (3)$$

$$\text{Tensile rated load (for box) in SI units, kN} = (YS_{\min}) (A_{bt}) / (SF_D \times 1000) \quad (4)$$

or

$$\text{Tensile rated load (for pin) in USC units, short tons} = (YS_{\min}) (A_p) / (SF_D \times 2) \quad (5)$$

$$\text{Tensile rated load (for box) in USC units, short tons} = (YS_{\min}) (A_{bt}) / (SF_D \times 2) \quad (6)$$

where

$YS_{\min}$ is the specified minimum yield strength, MPa (ksi);

SF_D is the design safety factor (see 4.8);

A_p is the pin cross-sectional area as defined by:

$$A_p = \frac{\pi}{4} [(C - B)^2 - ID^2] \text{ mm}^2 (\text{in.}^2), \text{ without stress-relief groove (see API 7-2);} \quad (7)$$

or

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$$A_p = \frac{\pi}{4} [D_{SRG}^2 - ID^2] \text{ mm}^2 (\text{in.}^2), \text{ with stress-relief groove (see API 7-2);} \quad (8)$$

where

A_{bt} is the box cross-sectional area as defined by:

$$A_{bt} = \frac{\pi}{4} [OD^2 - D_{CB}^2] \text{ mm}^2 (\text{in.}^2), \text{ without stress-relief groove, with or without boreback stress-relief contour (see API 7-2);} \quad (9)$$

or

$$A_{bt} = \frac{\pi}{4} [OD^2 - D_{BG}^2] \text{ mm}^2 (\text{in.}^2), \text{ with stress-relief groove (see API 7-2);} \quad (10)$$

where

C is the pitch diameter of thread at gauge point, mm (in.), (see API 7-2);

ID is the inside diameter of the pin, mm (in.);

D_{SRG} is the diameter of the pin stress-relief groove, mm (in.), (see API 7-2);

OD is the outside diameter of the box, mm (in.);

D_{CB} is the diameter of the cylinder of the box boreback stress-relief contour, mm (in.), (see API 7-2);

D_{BG} is the diameter of the box stress-relief groove, mm (in.), (see API 7-2);

$$B = 2 \left(\frac{H}{2} - f_r \right) + T \times (3.175) \text{ in metric (SI) units, mm;} \quad (11)$$

or

$$B = 2 \left(\frac{H}{2} - f_r \right) + T \times \left(\frac{1}{8} \right) \times \left(\frac{1}{12} \right) \text{ in U.S. customary (USC) units, in.;} \quad (12)$$

where

H is the thread height not truncated, mm (in.), (see API 7-2);

f_r is the root truncation, mm (in.), (see API 7-2);

T is the taper, mm/mm (in./ft), (see API 7-2).

~~Alternatively, the tensile rated load of the API RSC may be established by performing an alternative design validation test in accordance with 5.4.~~

4.5 Contact Surface Radii

Contact radii/envelope limits for hoisting tools shown in Figure 8, Figure 9, and Figure 10 shall conform to the limits in Table 9. Equipment with rated loads lower than those in Table 9 are excluded from this requirement.

NOTE: Envelope limits apply to ratings 1251 Short Tons and higher.

4.6.3 Hoisting equipment that contains pressure shall have a pressure rated load.

5.2.3.1 The stress values computed from the strain gauge measurement system readings shall not exceed the values obtained from design calculations (based on the design validation test load) by more than the uncertainty

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of the testing apparatus specified in 5.5. Failure to meet this requirement or premature failure of any test unit shall be cause for a complete reassessment of the design followed by additional testing of an identical number of test units as originally required, including a test unit of the same size and rating as the one that failed.

5.4 Alternative Design Validation Test Procedure and Rating

~~A single bore size in the bore size range of a given elevator frame may be qualified by testing that single bore size. All bore sizes in the bore size range of the given elevator frame may be qualified by testing the bore size that will result in the highest stress.~~

8.4.7.1 General

Accessible surfaces of each finished component shall be inspected in accordance with 8.4.7 after completion of all final heat treatment and final machining operations.

If the equipment is subjected to a load test, the qualifying NDE shall be performed after the load test. For materials susceptible to delayed cracking, as identified by the manufacturer, NDE shall be done no earlier than 24 hours after the load test. The equipment shall be disassembled for this inspection. Conductive surface coatings shall be removed prior to examination. Nonconductive surface coating shall be removed prior to examination unless it has been demonstrated that the smallest relevant indications as defined in 8.4.7.3 can be detected through the maximum applied thickness of the coating.

Table 9a—Hoisting Tool Contact-surface Radii / Envelope Limits – Part 1*

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Load rating [Short Tons]	travelling block and hook bail envelope limits					hook and swivel bail envelope limits			
	A1 max	A2 min	B1 min	B2 max		E1 min	E2 max	F1 max	F2 min
25 to 40	2.750	2.750	3.250	3.000		2.000	1.500	3.000	3.000
41 to 65	2.750	2.750	3.250	3.000		2.000	1.750	3.500	3.500
66 to 100	2.750	2.750	3.250	3.000		2.250	2.000	4.000	4.000
101 to 150	2.750	2.750	3.250	3.000		2.500	2.250	4.500	4.500
151 to 250	4.000	4.000	3.250	3.000		2.750	2.500	4.500	4.500
251 to 350	4.000	4.000	3.250	3.000		3.000	2.750	4.500	4.500
351 to 500	4.000	4.000	3.500	3.250		3.500	3.250	4.500	4.500
501 to 650	4.000	4.000	3.500	3.250		3.500	3.250	4.500	4.500
651 to 750	6.000	6.000	3.500	3.250		4.250	4.000	4.500	4.500
751 to 1250	6.000	6.000	6.250	6.000		5.250	5.000	5.000	5.000
1251 to 1750	6.500	6.500	8.000	7.750		not specified			

Table 9b—Hoisting Tool Contact-~~surface~~ Radii / Envelope Limits – Part 2*

Load rating [Short Tons]	elevator link upper eye and hook link ear envelope limits						
	C1 max	C2 min	D1 min	D2 max	V min	X min	U max
25 to 100	2.500	2.500	1.500	1.125	5.000	6.250	2.000
101 to 150	2.500	2.500	1.500	1.125	4.500	13.000	3.850
151 to 250	4.000	4.000	1.750	1.375	7.750	10.000	5.500
251 to 350	4.000	4.000	1.750	1.375	9.000	11.500	5.500
351 to 500	4.000	4.750	2.250	1.875	9.250	11.700	6.500
501 to 750	4.000	5.000	2.500	2.500	10.000	14.000	8.625
751 to 1250	4.500	5.000	3.000	2.750	12.400	16.500	8.700
1251 to 1750	6.250	6.250	3.000	2.850	12.400	16.800	11.000
Load rating [Short Tons]	elevator link lower eye and elevator link ear envelope limits						
	G1 max	G2 min	H1 min	H2 max	W min	Y min	Z max
25 to 100	1.000	1.000	2.000	2.000	5.000	6.250	2.000
101 to 150	0.938	1.500	2.000	2.000	3.800	5.000	1.950
151 to 250	1.219	1.875	2.750	2.750	5.250	7.500	2.700
251 to 350	1.469	1.875	2.750	2.750	5.375	7.750	2.938
351 to 500	1.875	2.000	3.250	3.250	6.400	9.500	3.750
501 to 750	2.250	2.375	5.000	5.000	10.000	14.000	8.625
751 to 1250	2.750	2.875	6.250	6.250	12.400	16.500	8.700
1251 to 1750	2.850	3.000	6.250	6.250	12.400	16.800	11.000

Figure 8—Traveling Block and Hook Bail Contact-~~Surface~~ Radii

Figure 9—Hook and Swivel Bail Contact~~Surface~~ Radii

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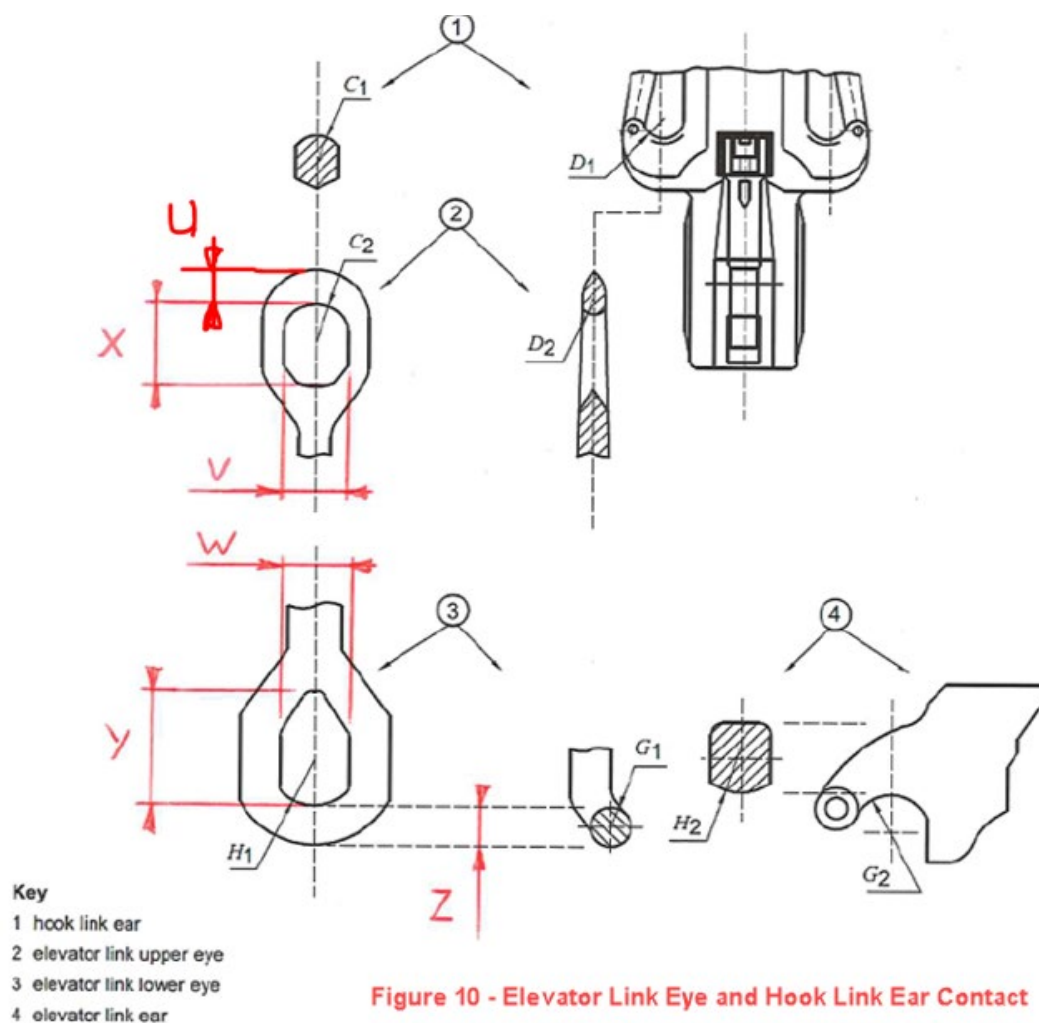


Figure 10 - Elevator Link Eye and Hook Link Ear Contact

~~Figure 10—Elevator Link Eye and Hook Link Ear Contact-Surface Radii~~

9.7 Elevator Links

Elevator links shall conform to the dimensions in Table 9 and Figure 10.

Elevator links shall be designed and manufactured in pairs. Links up to and including 4.25 m (14 ft) in length (as measured between the contact surfaces) shall match within 4 mm ($1/8$ in.). Links over 4.25 m (14 ft) in length shall match within 7 mm ($1/4$ in.).

Elevator link interfaces with the elevator link ears shall not exceed the radii/envelope limits described in Table 9 and Figure 10.

9.8 Elevators

9.8.1 Dimensions

Drill-pipe elevators for use with taper-shoulder tool joints and square-shoulder tool joints shall have bore dimensions as specified in Table 10.

Casing elevators and tubing elevators shall be suitable for use with casing and tubing manufactured in accordance with ISO 11960 or API 5CT. Casing elevators and tubing elevators shall have bore dimensions as specified in Table 11 and Table 12 (see Figure 11).

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Elevator interfaces with the elevator links having a rating of 1251 Short Tons and higher shall not exceed the envelope limits described in Table 9 and Figure 10.

Requirements of Sections 4 through 8 and Sections 10 and 11 apply for sucker-rod elevators.

Drill-Collar elevators shall interface with elevator grooves in drill collars manufactured as per API 7-1.

NOTE The allowable tolerance on the outside diameter immediately behind the tubing upset may cause problems with slip-type elevators.

9.8.3 Elevators and Spiders Testing

9.8.3.1 Design validation testing of slip-type elevators and slip-type spiders shall be carried out with the slips/ inserts in place. Proof load testing may be carried out without the slips/inserts installed, using a tapered mandrel designed to simulate the actual loading conditions.

9.8.3.2 Alternative design validation testing of a single bore size in the bore size range of a given elevator frame may be qualified by testing that single bore size. All bore sizes in the bore size range of the given elevator frame may be qualified by testing the bore size that will result in the highest stress.

9.8.3.23 The slips' activating mechanism(s) shall be functionally tested on each production unit, demonstrating full conformance with design requirements.

9.8.3.34 Inserts shall be exempt from mechanical testing and traceability requirements.

9.8.3.45 Primary load-carrying components of elevators (except for elevator slips) shall meet the impact testing requirements of 8.4.4. Elevator slips shall be made from materials possessing a minimum impact toughness (average of three tests) of 33 J (25 ft-lb) with no individual value less than 26 J (19 ft-lb) at a maximum test temperature of -20°C (-4°F).

9.8.3.56 The manufacturer of the equipment shall provide, in the documentation delivered with the equipment (see 11.3c), frequency of inspection and acceptance criteria for NDE of slip-type elevator setting rings.

9.8.3.67 Proof load testing, as described in 8.6, shall apply. Additionally, the following shall apply.

- a) Hinge pins or latch pins manufactured from wrought material are exempt from proof load testing requirements.
- b) Replacement hinge pins and latch pins shall meet or exceed the original manufacturer's specifications;

9.9.2 Rotary Swivel Prototype Pressure Testing

~~An assembled prototype of the rotary swivel shall be hydrostatically pressure tested. As an alternative, individual pressure-containing components of the swivel can be tested separately if the holding fixtures simulate the load condition applicable to the component in the assembled swivel.~~

The rotary swivel shall:

- a. Be hydrostatically pressure tested as an assembled prototype, or
- b. Have the individual pressure-containing components of the swivel tested separately if the holding fixtures simulate the load condition applicable to the component in the assembled swivel

The hydrostatic pressure test shall consist of the following four steps:

- a) primary pressure-holding period;
- b) reduction of the pressure to zero;
- c) thorough drying of all external surfaces of the components;

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d) secondary pressure-holding period.

The test pressure shall be at least twice the working pressure for working pressures up to and including 34.5 MPa (5,000 psi). For working pressures above 34.5 MPa (5,000 psi), the test pressure shall be at least 1.5 times the working pressure, but not less than 69 MPa (10,000 psi). The pressure-holding periods shall be no less than 3 min, the timing of which shall not start until the test pressure has been reached and the equipment and pressure-monitoring device have been isolated from the pressure source. During this period, no visible leakage shall be allowed. Throughout the test, the pressure shall not drop below the specified test pressure, nor shall it change by more than 2.5 % of the test pressure or 3.45 MPa (500 psi), whichever is less.

Washpipes containing mechanical seals (designed to have a controlled leak) are exempt from the 'no visible leakage shall be allowed' requirement as described above. The leakage rate shall not exceed the seal manufacturer's limits.

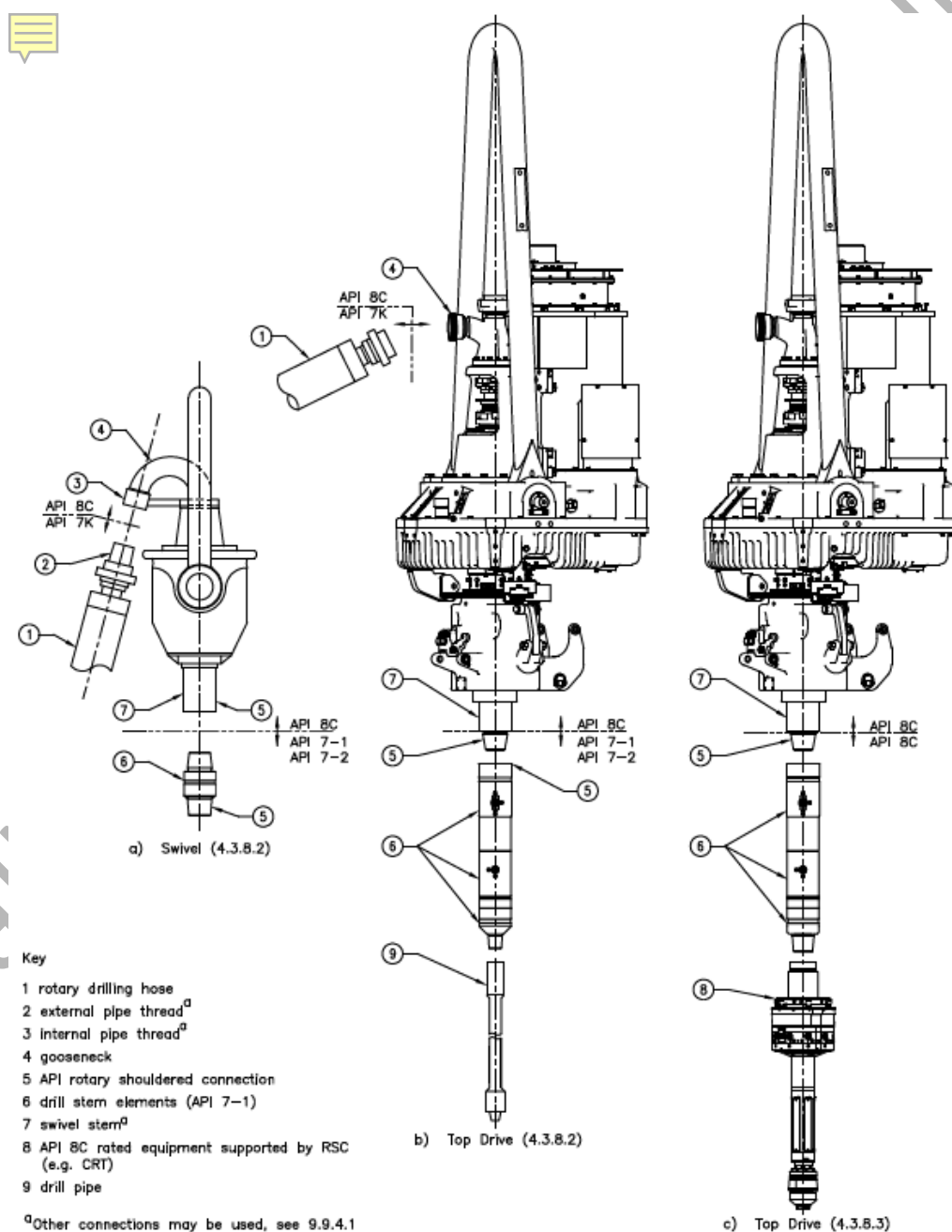


Figure 12—Rotary Swivel and Top Drive Connections

9.13 Drill-string Motion Compensators

~~Traveling drill string motion compensators' contact surface radii shall be in conformance with the dimensions given in Table 9 and Figure 8~~

9.13.1 General

The purpose of a Drill-string Motion Compensator is to reduce the Weight-On-Bit (WOB) variation during drilling operations performed from a floating, heaving drillship or semi-submersible. Other operations may be utilized such as pin or lock to bottom operation, landing the BOP, etc. This is accomplished by compensating for the heaving movement of the vessel using a hydro-pneumatic spring type design. Other types of compensation may be used however this section is applicable to the hydro-pneumatic type design. Drill-string Motion Compensators can be suspended from the traveling block, traveling vertically in the derrick or be mounted to the top of the derrick

This specification shall apply to mechanical, hydraulic, and pneumatic components of Drill-string Motion Compensators.

NOTE 1 Drill-String Motion Compensator PID control systems and algorithms are outside the scope of this section.

NOTE 2 Heave compensating drawworks, cylinder hoisting, and deadline type compensators are not within the scope of this section.

9.13.2 Design

9.13.2.1 Design Safety Factor

9.13.2.1.1 Drill-string Motion Compensators suspended from the traveling block

Design safety factors for components in the load path shall be determined as specified in 4.7 and Table 1.

9.13.2.1.2 Drill-string Motion Compensators mounted to the top of the derrick

Design safety factors are dependent on the function and location of the components comprising the Drill-string Motion Compensator. The following bullet points shall be used to determine these design safety factors.

— Steel structures shall be designed in accordance with API 4F.— Design safety factors for wire rope sheaves in the load path shall be determined as specified in 4.7 and Table 1.

— Crown shafts, including fastline and deadline sheave support shafts, shall be designed using an allowable stress method with a minimum allowed bending moment using Equation (1)

$$M_b = 0.60 F_y S$$

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Where

M_b is the maximum bending moment, Nm (in-lbs)

F_y is the specified minimum yield strength, Pa (psi)

S is the elastic section modulus, mm³ (in³)

9.13.2.2 Load Ratings

Three primary types of loads shall be associated with a Drill-string Motion Compensator. The load rating shall be taken at the crown block for top mounted compensators and at the becket for inline compensators.

- Compensating Load (CL)
- Non-compensating Load (NCL)
- Hydraulically Locked Load (HLL).

NOTE 1 CL, NCL, and HLL are further described in Section 9.13.2.2.1 through 9.13.2.2.3

NOTE 2 Load ratings of Drill-string Motion Compensators shall be determined in compliance with the requirements of 5.4 and 9.13.2.2.1 through 9.13.2.2.3.

9.13.2.2.1 Compensating Load (CL).

Drill-string Motion Compensators shall be rated by the maximum Compensating Load (MCL) that can be applied when the compensator is at the 50% stroke position.

The CL shall be defined as the weight that can be supported by the Drill-String Motion Compensator while compensating for the movement of the drilling vessel (see Figure 1).

NOTE: The CL does not include allowance for the weight of the drill string and any additional tools such as Top Drives or other attachments suspended from the Drill-String Compensator.

9.13.2.2.2 Mechanically locked Load (MLL).

The MLL shall be defined as the load supported by the Drill-string Motion Compensator structure when the load is not supported hydraulically or pneumatically. The Drill-string Motion Compensator shall not provide motion compensation in this configuration. NCL can be achieved by either mechanically locking the cylinders out of the load path or by geometric design of the structure.

NOTE The MLL capacity is typically higher than the LL capacity.

9.13.2.2.3 Hydraulically Locked Load (HLL).

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Drill-string Motion Compensators that are provided with the ability to hydraulically lock the cylinders at any stroke position shall report in the documentation the maximum **HLL** that can be applied when the cylinders are hydraulically locked.

NOTE 1 The capability to hydraulically lock the cylinders is not a requirement of this specification.

9.13.2.3 Rated Compensator Stroke

The full range of stroke, including stroke that is used for end cushioning, that can be accommodated by the Drill-string Motion Compensator cylinder(s) shall determine the rated stroke.

NOTE: Compensator cylinder stroke may not equal compensator stroke by design.

9.13.2.4 Pneumatic Operating Medium

The gas used in the Drill-string Motion Compensator system shall be either air or nitrogen. The Drill-string Motion Compensator manufacturer shall specify the gas to be used.

The gas quality requirements shall be specified by the manufacturer.

9.13.2.5 Hydraulic Fluids

Hydraulic fluid shall:

- a. be specified by the drill-string motion compensator manufacturer as suitable for the compensator; or,
- b. Otherwise approved by the manufacturer.

NOTE important considerations are:

- Viscosity (with temperature relation),
- pH value,
- corrosion properties
- lubricity value,
- ignition characteristics
- operating temperature range,
- foaming characteristics,
- color so as to permit ready detection of leaks,
- material compatibility,
- cleanliness

Warning – Mineral based hydraulic fluids shall not be used when air is used as the compressible gas. High gas pressures may allow auto-ignition to occur.

9.13.2.6 Compensating Load and Pressure vs Stroke

9.13.2.6.1 Performance Curves

The manufacturer shall provide plots of CL vs stroke for the full stroke range of the Drill-string Motion Compensator. At a minimum, curves shall be provided that correspond to 50%, 75%, and 100% of CL as shown in Figure 1.

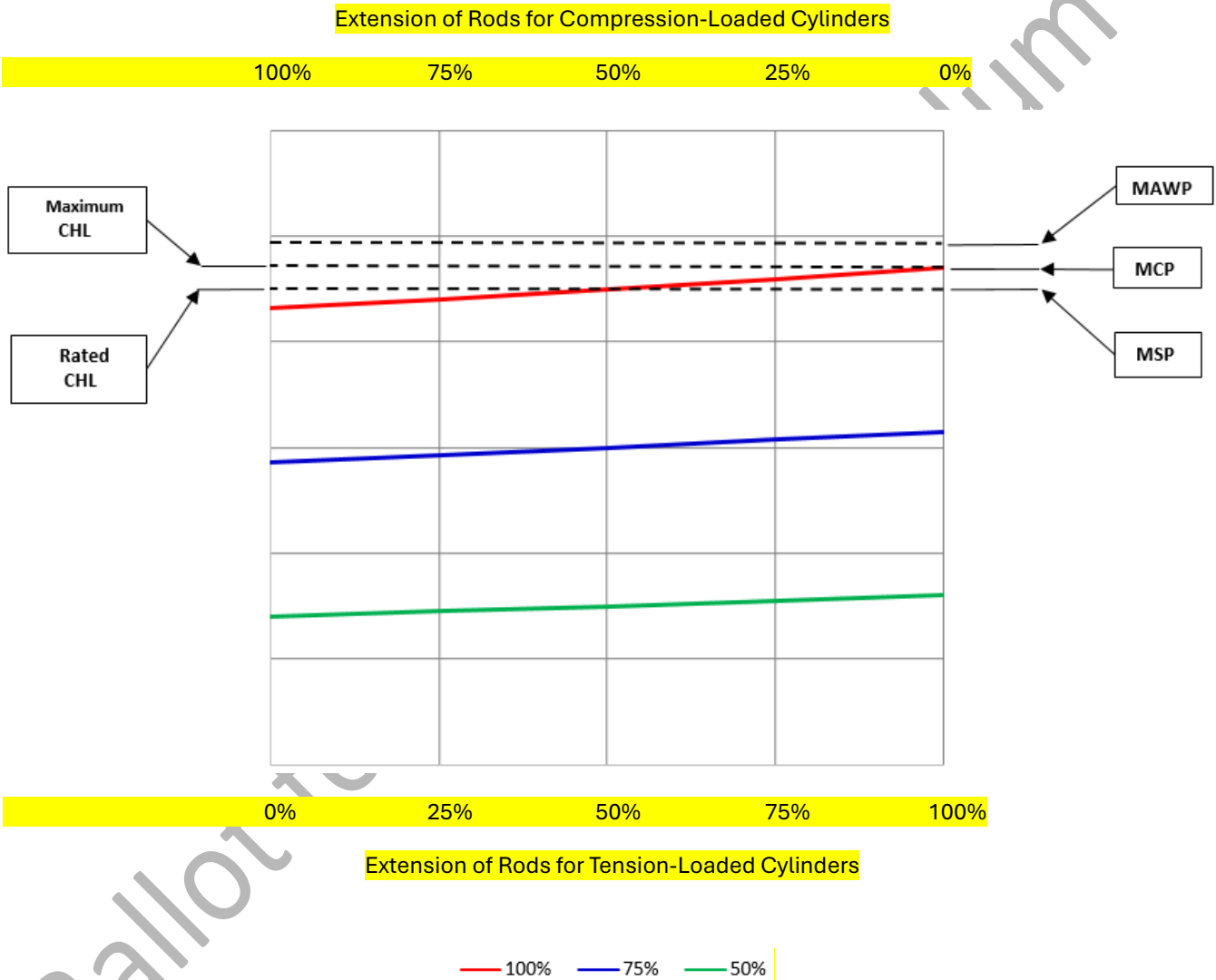


Figure 1

NOTE Figure 1 shows an example plot. Annex D shows example calculations.

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The calculations shall include compression and expansion characteristics of real gas using one of the real gas methods defined below:

- 1) NIST (National Institute of Standards and Technology) data,
- 2) Benedict-Webb-Rubin equation of state (EOS),
- 3) Van der Waals EOS,
- 4) Polytropic constant table per Annex E,
- 5) An alternate polytropic constant if justified and documented through testing.

Adiabatic behavior shall be assumed for Methods 1) through 3). Since Method 5 is time dependent, the minimum applicable duration shall be stated.

9.13.2.6.2 Allowable Compensating Load Variation due to Gas Volume Change

NOTE The CL variation with stroke, exclusive of mechanical friction and hydraulic inefficiencies, is directly related to the total working air pressure vessel volume connected to the Drill-string Motion Compensator. Fewer APV's provide larger CL variation as the vessel heaves.

9.13.2.7 Pressure

The Drill-string Motion Compensator system safety relief valve's set pressure shall not exceed the maximum allowable working pressure (MAWP) of the system.

The maximum compression pressure (MCP) shall be limited to no more than 93 % of the MAWP to accommodate for safety relief valve tolerances.

The maximum supply pressure (MSP) shall be less than or equal to the MCP minus the potential increase in pressure that can be caused by real gas compression due to changes in cylinder stroke (see Figure 1). Given the actual Drill-string Compensator cylinder stroke position, the Drill-string Motion Compensator pressure shall be limited so that the maximum pressure achieved at the cylinder stroke extents shall not exceed MCP.

NOTE: Pressure settings above MSP are allowed depending on the actual stroke of the cylinders provided that the 100% performance curve is not exceeded.

9.13.3 Design Standards

9.13.3.1 Pressure Vessels

Pressure vessels shall be designed, fabricated, and tested in accordance with ASME BPVC, section VIII, Division 1 or Division 2; ISO 11120; or other nationally or internationally recognized standard. A corrosion allowance shall be included in the design pressure wall thickness. The increase in thickness shall be selected either to achieve the desired life of the vessel or by agreement between the manufacturer and the purchaser. The corrosion allowance shall be documented in the data book. Each vessel shall be equipped with a shut-off valve, condensate drain valve, and pressure-relief device.

9.13.3.2 Cylinders

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Cylinders shall be designed, fabricated, and tested to conform to the requirements of ASME BPVC, Section VIII, Division 1 or Division 2, or other nationally or internationally recognized standards. Any associated non-pressure boundary components such as solid rods, rams, or like elements shall be designed in accordance with AISC or other nationally or internationally recognized standard.

9.13.3.3 Bolting

Bolting for Drill-string Motion Compensator cylinders and pressure vessels shall conform to the requirements of ASME BPVC Sec VII, Division 1 or Division 2, or other nationally or internationally recognized standard.

Bolting for piping shall conform to the requirements of ASME B31.3 or other nationally or internationally recognized standard.

Bolting used for mounting equipment and accessories to the Drill-String Motion Compensator shall meet industry standard or OEM requirements.

9.13.3.4 Piping

Piping shall be designed in accordance with ASME B31.3 or other nationally or internationally recognized standard.

For interconnect piping that is outside the Drill-string Motion Compensator manufacture's scope of supply, the manufacturer shall provide recommended pipe size and maximum equivalent length to minimize hydraulic and pneumatic inefficiencies during operation.

9.13.3.5 Wire Rope

Wire rope used in Drill-string Motion Compensator assemblies, exclusive of the drilling wire, shall conform to API 9A or other recognized wire rope standard. The rope shall be sized to have a minimum design safety factor of 3.0 on breaking strength. The design safety factor shall be determined by dividing the wire rope breaking strength by the maximum load that can be applied.

9.13.3.6 Sheaves

Sheave diameters shall be determined in accordance with recommendations given in API 9B. The sheave diameter factor shall meet or exceed "Condition B." Otherwise, the sheaves shall conform to API 8C section 9.2.

9.13.3.7 Electrical Wiring

Electrical equipment and wiring shall conform to API 500, API 505, or other national or international recognized standard such as NFPA 70, *National Electrical Code*, Class I, Division 2 or IEC 61892.

9.13.3.8 Drill-string Compensator Mounting

The manufacturer shall provide the mounting and installation information to purchaser, including design load, orientation, alignment, allowable fleet angle if wire rope is utilized, and minimum clearances.

Traveling type Drill-string Motion Compensators shall be capable of being maintained over the well centerline throughout its travel

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9.13.4 Operational Controls

The Drill-string Motion Compensator system shall, at a minimum, include equipment to control and monitor the following

- Hook load
- Stroke position
- System pressure
- Locked/unlocked condition
- APV storage pressure.

9.13.5 Temperature Considerations

The manufacturer shall state the appropriate service temperature range of the Drill-string Motion Compensator system.

NOTE Cited design codes may not address extreme low-temperature service.

9.13.6 Rod Materials and Coatings

Cylinder rods shall be made from a corrosion-resistant material or have a corrosion-resistant coating.

NOTE 1 Typically, rod material or coatings are selected to provide suitable corrosion resistance, hardness, wear, seal compatibility, and durability.

NOTE 2 Advance corrosion-resistant coatings are now widely available in addition to the traditional industrial hard chrome over steel. These may include laser clad alloys, high-velocity oxygenated fuel (HVOF) compounds, or ceramics. When advanced corrosion-resistant coatings are used, careful selection of appropriate seal and bearing materials are required to ensure adequate wear and life results.

NOTE 3 Ceramic-coated rods may be subject to corrosion in the underlying base material if using a water-glycol hydraulic fluid. In the presence of some materials and design configurations, some fluids may act as an electrolyte and thus produce an electrical potential across the rod.

9.13.7 Energy Control Provisions

A Drill-string Motion Compensator stores a large amount of potential energy in the form of a compressed gas. The Drill-string Motion Compensator shall include energy control provisions that will arrest, reduce, or eliminate the energy in a controlled manner in the event the compensator experiences a sudden loss of hook load. The Drill-string motion compensator energy control provision shall include design features that prevent structural damage to the Drill-String motion compensator during the dissipation of energy.

Note 1: Examples of design features include but are not limited to, orifice plates, cylinder cushions, speed limiting valves and/or servo controlled valves.

Note 2: This is normally accomplished by controlling the acceleration of the cylinder rods to a velocity that will not overcome the cylinder integrity.

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9.13.7.1 Loss of Gas Pressure Due to Hose Rupture

A device that automatically closes in response to a sudden loss of gas pressure due to a hose rupture shall be installed at each end of the hose to maintain support of the drill string.

Note: The Drill-string Motion Compensator can experience a sudden loss of pressure due to a rupture or failure of a high pressure hose. Support of the drill string and stored gas pressure and air pressure vessels can suddenly be lost in this kind of event.

9.13.7.2 Loss of Control System

The Drill-string Motion compensator system shall be designed to continue in its last commanded state without an increase or decrease in motion compensation tension levels either compensating or remaining locked until the control system has been restored.

9.13.7.3 Emergency Disconnects

The energy control provisions included shall allow for the drill string to lift up in a controlled manner with the full available stroke of the drill-string compensator. A loss of electrical power to the drill string compensator system shall not prevent the completion of this operation.

9.13.8 Marking

The marking requirements of this section shall supersede the marking requirements in section 10. The manufacturer shall attach a nameplate to each Drill-string Compensator. The nameplate shall include the following information.

- Name of manufacturer
- Unique serial number
- Max Compensating Load
- Max Non-Compensating Load
- Hydraulically locked load
- Maximum allowable working pressure
- Compensating stroke
- API 8C

9.13.9 Materials

9.13.9.1 General

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The material requirements of section 9.13.9 shall be used for primary load carrying components and are not intended to overrule material requirements of Drill-string Motion Compensator components covered by other API specifications or other design codes when specified in section 9.13.

NOTE: Other design code examples are ASME BPVC, Sec VIII, Div I, ASME B31.3 or other national or internationally recognized design codes.

9.13.9.2 Materials Selection

Material selection for primary-load-carrying components and pressure-containing components shall include the following evaluations in the design review documentation.

- type of loading
- temperature range
- fatigue (if a factor in the design)
- environmental conditions
- Strength requirements,

Material selection for nonmetallic materials shall include the following evaluations in the design review documentation

- type of loading,
- temperature range
- explosive decompression resistance (if appropriate)
- environmental conditions
- strength and ductility requirements.

9.13.9.3 Written Specifications

All materials (including nonmetallic) shall conform to a written specification. The written specification shall be a nationally or internationally recognized standard, or the manufacturer's document.

Specifications for metallic components used for primary-load-carrying components or pressure-containing components shall at a minimum contain requirements for the following.

- Material chemical composition limits and tolerances;
- forming practices – forgings, etc.;
- heat treatment procedures when required, including cycle time and temperature with tolerances, heat-treating equipment, and cooling media;
- nondestructive examination (NDE) requirements;

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- mechanical property requirements including yield strength, tensile strength, elongation, reduction of area, hardness range, and if required, impact toughness properties.

Specifications for nonmetallic components used in primary-load-carrying components or pressure-containing components shall define the following:

- material type;
- service temperature range;
- tensile strength, elongation, and elastic modulus;
- acceptable hardness range – shore, in accordance with ASTM D2240;
- density, compression set, and fluid compatibility;
- fiber reinforcement – type, composition, and properties.

9.13.9.4. Impact Testing

Inline Drill-string motion compensator primary load path materials shall follow the requirements of section 6.3. Top mounted Drill-string motion compensators shall follow the requirements of this section.

Impact testing shall be conducted when the minimum design temperature is 0° C (32° F) or lower.

Charpy V-notch impact tests shall be conducted in accordance with ASTM A370, ASTM E23, or equivalent industry standard using full-size specimens if the component size permits. When full size specimens are not practical, subsize specimens shall be tested and meet the criteria per method defined by ASTM A370.

Impact testing shall be conducted at temperatures of -20° C (-4° F) or lower, and no higher than minimum design temperature. Specimens tested with orientation transverse to the major grain flow shall exhibit 20 J (15 ft-lb) minimum average value and 14 J (10 ft-lb) for a minimum of a set of three specimens. Specimens tested with orientation parallel to major grain flow shall exhibit 27 J (20 ft-lb) minimum average value and 20 J (15 ft-lb) for a single minimum of a set of three specimens.

9.13.9.5 Hardness

Material shall meet the hardness requirements specified in the nationally or internationally recognized standard, or the manufacturer's document.

9.13.10 Quality Control

Drill-string Motion Compensators are composed of various components that are designed and manufactured to comply with specific codes, rules, and regulations as required by Section 9.13. The components listed below identifies the corresponding quality control requirements as applicable.

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- Pressure vessels shall comply with the quality control requirements of ASME BPVC, Section VIII, Division 1 or Division 2 or other recognized standard to which the pressure vessel was designed and manufactured.
- Cylinders shall comply with the quality control requirements of ASME BPVC, Section VIII, Division 1 or Division 2 or other recognized standard to which the cylinders are designed and manufactured.
- Piping shall comply with the quality control requirements of ASME B31.3 or the quality requirements of an alternative recognized piping code as specified by the equipment manufacturer.
- Wire rope shall comply with the quality control requirements of API 9A or an alternative recognized code as specified by the equipment manufacturer.
- Sheave and sheave shafts shall comply with the quality control requirements of API 8C Section 9.
- Crown block structures designed for top of derrick mounted Drill-string Compensators shall comply with the quality control requirements of API 4F.

10 Marking

10.1 Product Marking

Each ~~item~~ product of hoisting equipment shall be marked with “API Spec 8C” or “API 8C”, license number (if applicable), the manufacturer’s name or mark, date of manufacture (MM/YYYY), the relevant PSL number and the rating specified in 10.2. Additional markings shall be applied in accordance with Section 9 and 10.4. Equipment for which supplementary requirements apply shall be marked with the relevant “SR” numbers.

10.2 Rating Marking

Each ~~item~~ product of hoisting equipment shall be marked with rated load/pressure rating unless otherwise specified in the individual equipment requirements.

EXAMPLE A PSL 1 traveling block with a rated load of 8000 kN (899 short tons), manufactured by the XYZ Company is marked as follows: **XYZ CO 899 ton API Spec 8C PSL 1**

11.3 Documentation to Be Delivered with the Equipment

c) operations/maintenance manuals, which shall include, but not be limited to:

4) Operating procedures and temperature limits;

A.3 SR 2 Low-Temperature Test

The maximum impact test temperature for materials used in primary load-carrying components with a required minimum operating design temperature below -20°C (-4°F) shall be specified by the purchase.

Annex D

(informative)

Example Calculations for Drill-string Motion Compensator

D.1 General

The following (Table C.1) is a spreadsheet based calculation that displays the input data and the calculated Drill-string Motion Compensator performance as a function of compensator stroke. In this example, real gas characteristics are imported from the National Institute of Standards and Technology (NIST) as listed in 9.12.2.5.1. Other forms of calculations are acceptable as long as similar data and results are depicted.

Table D.1 – Drill-string Motion Compensator Calculations

API 8C Summary Data:			Calculation Method	
Maximum Supply Pressure (MSP)	3,000	Psig	Method	Real Gas, Isentropic-NIST
Maximum Compression Pressure (MCP)	3,869	Psig	Gas	Air
Maximum Allowable Working Pressure (MAWP)	4,150	Psig	Temperature	80 °F
Maximum Compensating Hook Load (Max CHL)	619	Kips	Base Entropy	1.2482 BTU/lbm-R
Rated Compensating Hook Load (Rated CHL)	600	Kips		

Drill-String Motion Compensator Rating Calculation			
Maximum Supply Pressure (MSP)	3,000	psig	This is the maximum pressure that can be applied to the system
PRV Tolerance Factor	93	%	This is the PRV tolerance factor to allow for inaccuracies with
Net Volume (BE)	386,737	In3	Includes APV, pipe, and HP accumulator air volume
Net Volume (RE)	23,991	In3	Includes LP accumulator and rod side annulus volume, less min oil volume
Area BE	355	In2	This is the area of the blind end of the compensator cylinder
Area RE	75	In2	This is the annulus area of the rod end of the compensator cylinder
HP Accumulator Diameter	22.83	In	
HP Accumulator volume	58.827	In3	
HP Accumulator Min Oil Volume	62,247	In3	This is equal to compensator cylinder total volume
Compensator Cylinder ID	19.5	In	
Rod OD	11	In	
Stroke	300	In	This is the compensator cylinder total stroke
Number of line parts	0		This is the number of line falls/mechanical advantage
Min LP Accumulator Oil Volume	0	In3	This is the LP accumulators minimum oil volume
Min LP Accumulator pressure	7.55	Psig	This is the LP accumulator's minimum pressure
LP Accumulator volume	12.816	In3	This is the LP accumulator's total volume
APV Volume	366,142	In3	APV volume per compensator cylinder
Air Line Volume	15,015	In3	Pipeline volume to compensator from APVs
Hose Line Volume	13,154	In3	This is the hose volume from the valve manifold to the compensator

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Dead Weight

22,753 Lb

Total dead load on compensator

Polytropic Gas Exponent (n)

1.4

Polytropic constant for use with gas compressor calculation for low pressure

Table D.1—Drill-string Motion Compensator Calculations (Continued)

STROKE POSITION (in)	VESSEL HEAVE (ft)	DSC PRESS (psig)	TOTAL DEAD WT (lb)	CSL (lb)	EFFECTIVE POLYTROPIC CONSTANT	T (°F)	LOAD VARIATION (%)
0	-12.5	2,927.68	11,468.83	573,827.40	1.945	74.2	5.3
10	-11.7	2,937.71	11,468.83	575,870.57	1.945	75.6	4.9
20	-10.8	2,947.79	11,468.83	577,925.33	1.946	76.9	4.6
30	-10.0	2,957.92	11,468.83	579,991.79	1.946	78.3	4.2
40	-9.2	2,968.12	11,468.83	582,070.03	1.947	79.7	3.9
50	-8.3	2,978.37	11,468.83	584,160.14	1.947	81.1	3.6
60	-7.5	2,988.69	11,468.83	586,262.20	1.948	82.4	3.2
70	-6.7	2,999.06	11,468.83	588,376.31	1.948	83.8	2.9
80	-5.8	3,009.49	11,468.83	590,502.56	1.949	85.2	2.5
90	-5.0	3,019.98	11,468.83	592,641.03	1.949	86.5	2.2
100	-4.2	3,030.53	11,468.83	594,791.83	1.950	87.9	1.8
110	-3.3	3,041.14	11,468.83	596,955.05	1.950	89.3	1.4
120	-2.5	3,051.82	11,468.83	599,130.78	1.951	90.6	1.1
130	-1.7	3,062.55	11,468.83	601,319.11	1.951	92.0	0.7
140	-0.8	3,073.35	11,468.83	603,520.14	1.952	93.4	0.4
150	0.0	3,084.21	11,468.83	605,733.98	1.952	94.8	0
160	0.8	3,095.14	11,468.83	607,960.71	1.952	96.1	0.4
170	1.7	3,106.12	11,468.83	610,200.44	1.953	97.5	0.7
180	2.5	3,117.18	11,468.83	612,453.27	1.953	98.9	1.1
190	3.3	3,128.29	11,468.83	614,719.29	1.954	100.2	1.5
200	4.2	3,139.48	11,468.83	616,998.61	1.954	101.6	1.9
210	5.0	3,150.72	11,468.83	619,291.34	1.955	103.0	2.2
220	5.8	3,162.04	11,468.83	621,597.57	1.955	104.3	2.6
230	6.7	3,173.42	11,468.83	623,917.42	1.956	105.7	3.0
240	7.5	3,184.87	11,468.83	626,250.98	1.956	107.1	3.4
250	8.3	3,196.38	11,468.83	628,598.36	1.957	108.5	3.8
260	9.2	3,207.97	11,468.83	630,959.68	1.957	109.8	4.2
270	10.0	3,219.62	11,468.83	633,335.04	1.958	111.2	4.6
280	10.8	3,231.34	11,468.83	635,724.55	1.958	112.6	5.0
290	11.7	3,243.14	11,468.83	638,128.32	1.959	113.9	5.3
300	12.5	3,255.00	11,468.83	640,546.47	N.A.	115.3	5.7

D.2 Performance Plot

Figure C.1 is produced from the calculated data shown in C.1 for the 100% rated compensated hook load. Separate plots may be made for the 50% and 75% curves or all curves may be shown on a single plot. See 9.13.2.5.1 for detailed compensator performance curve requirements.

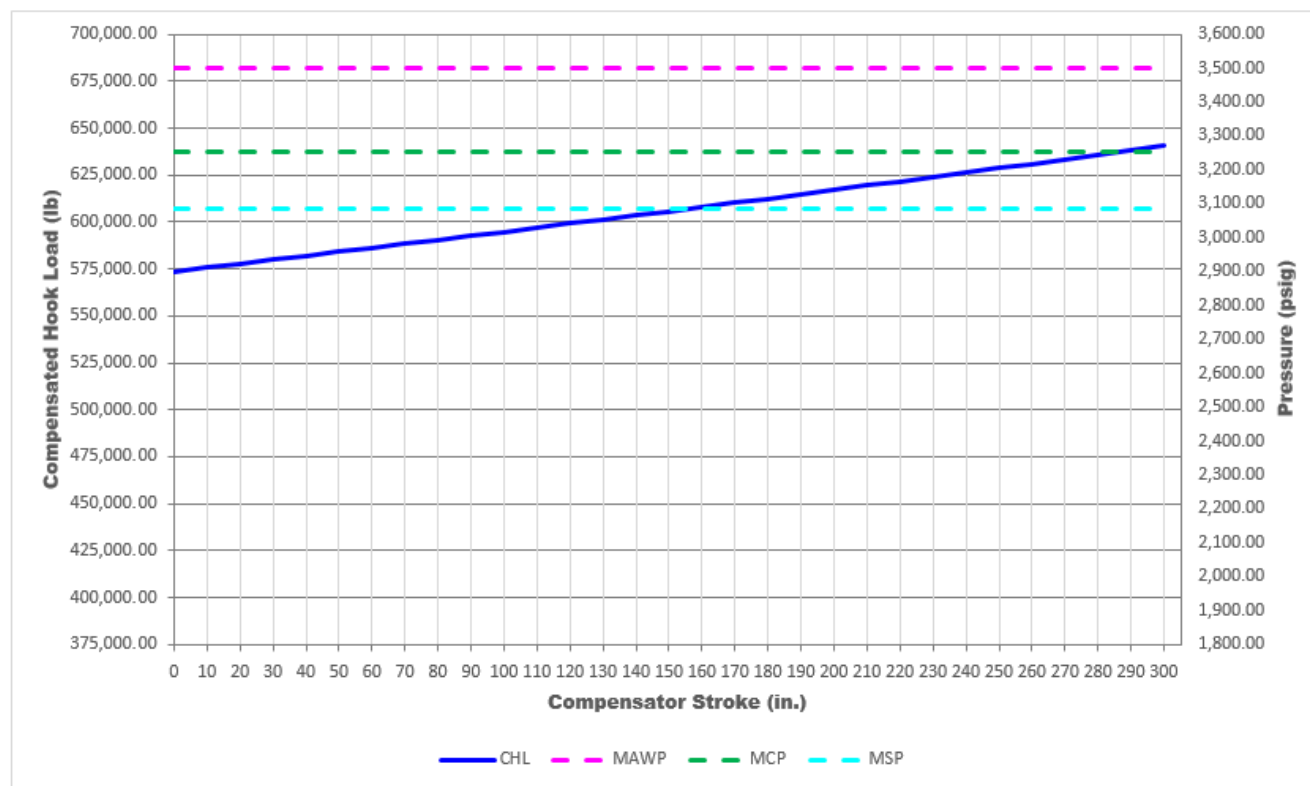


Figure D.1 – Compensated Hook Load and Pressure vs Stroke

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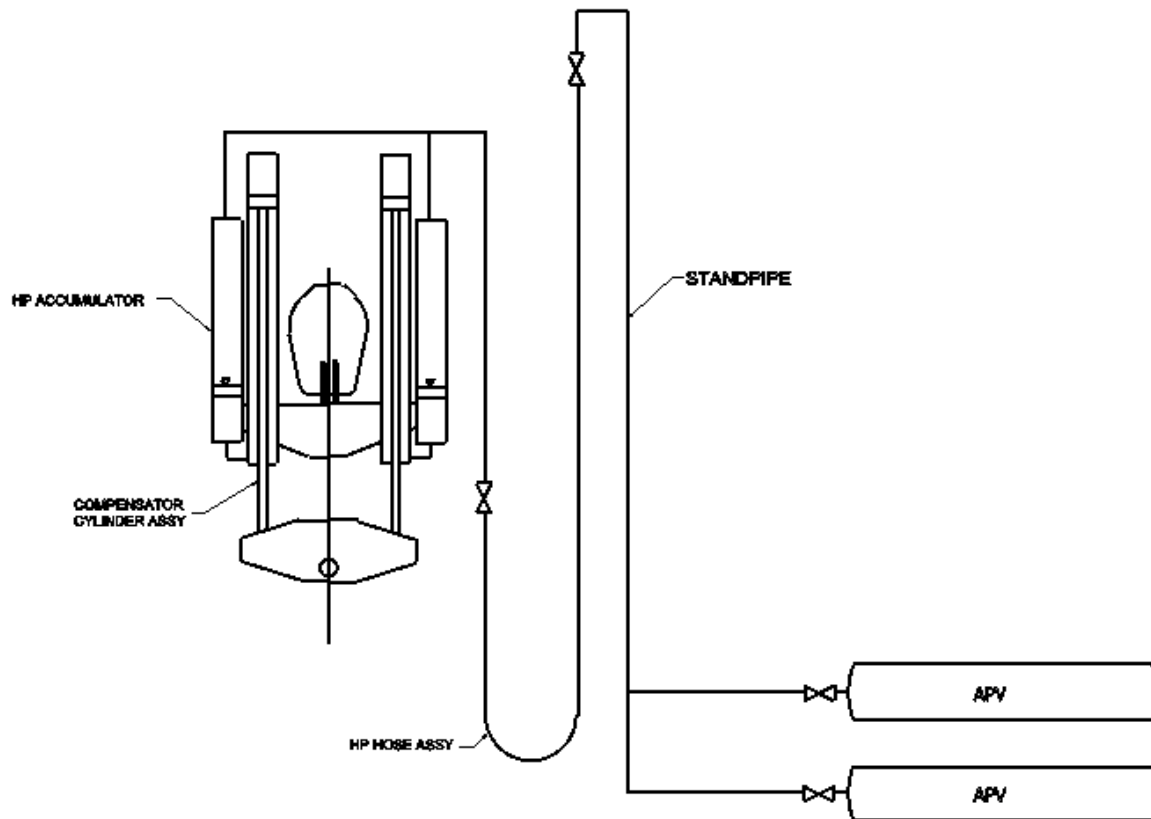


Figure D.2 Typical Drill-string Motion Compensator System

Annex E (informative)

Effective Polytropic Constants for Isentropic Compression and Expansion of Air and Nitrogen

Tables D.1 through D.12 are polytropic constants that can be used for Drill-string Motion Compensator performance curves as an alternative to the NIST, Benedict–Webb–Rubin EOS, van der Waals EOS, or actual test data as described in 9.13.2.5.1.

NOTE Use Tables D.1 through D.6 for compressed air or Tables D.7 through D.12 for compressed nitrogen.

Table E.1—Polytropic Constant Table—Air Compressed to 85 % of Initial Volume

Isentropic Compression of Air to 85 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	–40	–4	40	80	120	–40	–4	40	80	120
500	640	639	639	638	638	1.4772	1.4720	1.4663	1.4617	1.4573
1000	1302	1296	1292	1289	1286	1.6009	1.5763	1.5549	1.5401	1.5279
1500	2009	1988	1972	1961	1954	1.7831	1.7190	1.6684	1.6363	1.6119
2000	2784	2728	2687	2662	2645	2.0226	1.8985	1.8053	1.7491	1.7079
2500	3642	3527	3444	3396	3362	2.3039	2.1071	1.9616	1.8757	1.8142
3000	4588	4390	4248	4166	4110	2.6039	2.3331	2.1312	2.0125	1.9284
3500	5617	5317	5099	4975	4888	2.9014	2.5646	2.3078	2.1557	2.0479
4000	6719	6305	5998	5821	5698	3.1825	2.7922	2.4858	2.3015	2.1703
4500	7882	7348	6942	6705	6539	3.4400	3.0094	2.6606	2.4469	2.2934
5000	9093	8438	7928	7624	7411	3.6718	3.2126	2.8293	2.5896	2.4154

Table E.2—Polytropic Constant Table—Air Compressed to 90 % of Initial Volume

Isentropic Compression of Air to 90 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	–40	–4	40	80	120	–40	–4	40	80	120
500	586	586	586	586	585	1.4739	1.4690	1.4638	1.4594	1.4553
1000	1185	1182	1180	1178	1177	1.5916	1.5686	1.5485	1.5346	1.5232
1500	1810	1798	1789	1783	1779	1.7648	1.7045	1.6569	1.6267	1.6036
2000	2471	2440	2418	2404	2394	1.9928	1.8756	1.7876	1.7345	1.6956
2500	3177	3114	3069	3043	3024	2.2617	2.0748	1.9369	1.8555	1.7973
3000	3929	3823	3746	3702	3671	2.5503	2.2914	2.0992	1.9865	1.9066

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3500	4726	4566	4449	4381	4334	2.8391	2.5146	2.2688	2.1238	2.0211
4000	5559	5341	5177	5081	5015	3.1148	2.7353	2.4403	2.2639	2.1386
4500	6425	6144	5929	5801	5712	3.3701	2.9475	2.6096	2.4042	2.2571
5000	7315	6972	6702	6540	6426	3.6022	3.1477	2.7738	2.5422	2.3748

Ballot for 6th Ed Addendum 1

Table E.3—Polytropic Constant Table—Air Compressed to 95 % of Initial Volume

Isentropic Compression of Air to 95 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	540	540	540	540	540	1.4708	1.4663	1.4615	1.4574	1.4535
1000	1086	1085	1084	1083	1082	1.5832	1.5616	1.5428	1.5296	1.5188
1500	1642	1637	1633	1631	1629	1.7484	1.6916	1.6466	1.6180	1.5961
2000	2214	2201	2192	2186	2182	1.9659	1.8550	1.7717	1.7214	1.6844
2500	2804	2778	2759	2749	2741	2.2233	2.0456	1.9146	1.8374	1.7820
3000	3413	3369	3338	3319	3306	2.5011	2.2536	2.0703	1.9630	1.8869
3500	4039	3974	3927	3899	3879	2.7812	2.4687	2.2333	2.0948	1.9969
4000	4680	4592	4526	4486	4459	3.0509	2.6826	2.3988	2.2298	2.1099
4500	5334	5221	5134	5082	5046	3.3031	2.8897	2.5627	2.3651	2.2240
5000	5997	5860	5752	5686	5639	3.5346	3.0863	2.7224	2.4988	2.3377

Table E.4—Polytropic Constant Table—Air Expanded to 105 % of Initial Volume

Isentropic Expansion of Air to 105 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	464	465	465	465	465	1.4655	1.4617	1.4574	1.4538	1.4503
1000	925	926	927	927	928	1.5688	1.5496	1.5328	1.5210	1.5113
1500	1378	1382	1384	1386	1387	1.7202	1.6692	1.6288	1.6030	1.5831
2000	1820	1829	1836	1840	1843	1.9196	1.8195	1.7442	1.6986	1.6651
2500	2249	2267	2280	2288	2294	2.1566	1.9951	1.8761	1.8059	1.7555
3000	2665	2695	2717	2730	2739	2.4145	2.1875	2.0201	1.9222	1.8528
3500	3070	3113	3147	3166	3180	2.6774	2.3879	2.1714	2.0445	1.9549
4000	3465	3524	3569	3597	3616	2.9342	2.5888	2.3257	2.1700	2.0599
4500	3852	3926	3986	4021	4047	3.1781	2.7852	2.4796	2.2965	2.1663
5000	4232	4323	4396	4441	4474	3.4058	2.9738	2.6305	2.4220	2.2727

Table E.5—Polytropic Constant Table—Air Expanded to 110 % of Initial Volume

Isentropic Expansion of Air to 110 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	433	433	433	433	434	1.4632	1.4596	1.4557	1.4523	1.4489
1000	860	861	862	863	864	1.5625	1.5444	1.5285	1.5173	1.5080
1500	1272	1278	1283	1286	1289	1.7079	1.6595	1.6210	1.5964	1.5775
2000	1666	1682	1693	1700	1706	1.8995	1.8041	1.7323	1.6887	1.6566
2500	2038	2069	2092	2105	2115	2.1274	1.9730	1.8594	1.7922	1.7440
3000	2389	2439	2477	2500	2516	2.3762	2.1585	1.9982	1.9044	1.8379
3500	2720	2794	2850	2884	2908	2.6310	2.3522	2.1443	2.0225	1.9365
4000	3036	3135	3212	3258	3291	2.8810	2.5470	2.2935	2.1438	2.0380
4500	3339	3463	3562	3623	3667	3.1201	2.7381	2.4427	2.2662	2.1410
5000	3631	3781	3903	3979	4034	3.3449	2.9225	2.5894	2.3879	2.2440

Table E.6—Polytropic Constant Table—Air Expanded to 115 % of Initial Volume

Isentropic Expansion of Air to 115 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	405	405	405	406	406	1.4610	1.4578	1.4540	1.4508	1.4476
1000	802	804	805	807	808	1.5567	1.5396	1.5245	1.5138	1.5049
1500	1180	1188	1194	1198	1201	1.6967	1.6506	1.6139	1.5904	1.5723
2000	1534	1554	1569	1578	1585	1.8811	1.7899	1.7213	1.6796	1.6489
2500	1860	1899	1929	1946	1959	2.1006	1.9528	1.8440	1.7796	1.7334
3000	2159	2223	2272	2301	2322	2.3409	2.1319	1.9780	1.8880	1.8242
3500	2433	2527	2599	2642	2673	2.5877	2.3192	2.1193	2.0022	1.9196
4000	2688	2813	2911	2971	3013	2.8311	2.5081	2.2638	2.1197	2.0179
4500	2927	3083	3210	3287	3343	3.0651	2.6941	2.4085	2.2383	2.1176
5000	3153	3341	3496	3593	3664	3.2864	2.8742	2.5512	2.3564	2.2175

Table E.7—Polytropic Constant Table—Nitrogen Compressed to 85 % of Initial Volume

Isentropic Compression of Nitrogen to 85 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	640	640	639	638	638	1.4823	1.4765	1.4706	1.4660	1.4617
1000	1304	1298	1294	1290	1288	1.6121	1.5864	1.5642	1.5489	1.5365
1500	2014	1993	1976	1966	1958	1.7968	1.7329	1.6817	1.6491	1.6241
2000	2788	2734	2694	2669	2651	2.0319	1.9126	1.8208	1.7646	1.7231
2500	3640	3533	3453	3405	3372	2.3012	2.1170	1.9767	1.8923	1.8311
3000	4573	4391	4256	4177	4121	2.5840	2.3348	2.1435	2.0285	1.9458
3500	5582	5310	5106	4986	4901	2.8625	2.5556	2.3151	2.1694	2.0645
4000	6657	6284	5999	5831	5712	3.1253	2.7712	2.4865	2.3116	2.1851
4500	7788	7308	6935	6711	6552	3.3665	2.9763	2.6538	2.4523	2.3053
5000	8964	8377	7908	7624	7421	3.5841	3.1679	2.8145	2.5896	2.4238

Table E.8—Polytropic Constant Table—Nitrogen Compressed to 90 % of Initial Volume

Isentropic Compression of Nitrogen to 90 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	587	586	586	586	586	1.4787	1.4734	1.4679	1.4635	1.4595
1000	1187	1184	1181	1179	1178	1.6024	1.5784	1.5574	1.5430	1.5313
1500	1812	1801	1791	1786	1781	1.7782	1.7181	1.6698	1.6390	1.6154
2000	2473	2444	2421	2408	2398	2.0022	1.8895	1.8027	1.7495	1.7102
2500	3176	3118	3074	3048	3030	2.2599	2.0848	1.9518	1.8717	1.8137
3000	3922	3824	3751	3708	3677	2.5321	2.2939	2.1116	2.0022	1.9236
3500	4707	4562	4453	4388	4342	2.8026	2.5068	2.2765	2.1375	2.0376
4000	5528	5330	5178	5087	5023	3.0603	2.7161	2.4420	2.2744	2.1535
4500	6377	6124	5925	5805	5720	3.2993	2.9168	2.6043	2.4104	2.2694
5000	7249	6941	6693	6541	6432	3.5172	3.1057	2.7610	2.5435	2.3840

Table E.9—Polytropic Constant Table—Nitrogen Compressed to 95 % of Initial Volume

Isentropic Compression of Nitrogen to 95 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	540	540	540	540	540	1.4754	1.4705	1.4654	1.4612	1.4575
1000	1086	1085	1084	1083	1083	1.5936	1.5711	1.5514	1.5378	1.5267
1500	1643	1638	1635	1632	1630	1.7615	1.7047	1.6591	1.6299	1.6075
2000	2215	2203	2193	2188	2183	1.9755	1.8686	1.7864	1.7359	1.6986
2500	2804	2780	2762	2751	2743	2.2224	2.0558	1.9293	1.8531	1.7980
3000	3410	3370	3340	3322	3309	2.4846	2.2566	2.0826	1.9784	1.9035
3500	4032	3973	3928	3901	3882	2.7469	2.4621	2.2414	2.1085	2.0132
4000	4668	4588	4526	4489	4462	2.9989	2.6652	2.4012	2.2405	2.1248
4500	5315	5214	5133	5084	5049	3.2349	2.8610	2.5586	2.3720	2.2367
5000	5971	5848	5748	5686	5642	3.4520	3.0467	2.7112	2.5011	2.3475

Table E.10—Polytropic Constant Table—Nitrogen Expanded to 105 % of Initial Volume

Isentropic Expansion of Nitrogen to 105 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	-40	-4	40	80	120	-40	-4	40	80	120
500	464	464	465	465	465	1.4698	1.4655	1.4610	1.4573	1.4540
1000	925	926	927	927	928	1.5786	1.5585	1.5408	1.5286	1.5186
1500	1377	1381	1383	1385	1387	1.7327	1.6817	1.6405	1.6141	1.5938
2000	1819	1828	1834	1839	1842	1.9293	1.8327	1.7582	1.7123	1.6784
2500	2249	2266	2278	2286	2292	2.1571	2.0053	1.8902	1.8209	1.7707
3000	2667	2694	2715	2728	2737	2.4009	2.1915	2.0324	1.9371	1.8687
3500	3074	3114	3145	3164	3178	2.6472	2.3832	2.1800	2.0580	1.9706
4000	3473	3526	3569	3595	3614	2.8869	2.5742	2.3294	2.1811	2.0746
4500	3863	3931	3986	4020	4045	3.1147	2.7601	2.4773	2.3042	2.1792
5000	4248	4330	4398	4440	4471	3.3278	2.9383	2.6218	2.4257	2.2832

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Table E.11—Polytropic Constant Table—Nitrogen Expanded to 110 % of Initial Volume

Isentropic Expansion of Nitrogen to 110 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	−40	−4	40	80	120	−40	−4	40	80	120
500	433	433	433	433	433	1.4674	1.4634	1.4591	1.4556	1.4524
1000	859	860	862	863	864	1.5720	1.5530	1.5362	1.5246	1.5150
1500	1271	1277	1282	1285	1287	1.7202	1.6716	1.6324	1.6072	1.5878
2000	1665	1680	1691	1698	1704	1.9093	1.8170	1.7459	1.7021	1.6696
2500	2038	2067	2089	2102	2112	2.1285	1.9833	1.8732	1.8069	1.7587
3000	2392	2438	2474	2496	2512	2.3639	2.1630	2.0104	1.9191	1.8535
3500	2728	2795	2848	2880	2903	2.6026	2.3484	2.1531	2.0359	1.9520
4000	3049	3139	3210	3255	3287	2.8361	2.5336	2.2976	2.1550	2.0526
4500	3358	3471	3563	3620	3662	3.0592	2.7146	2.4412	2.2743	2.1539
5000	3657	3793	3906	3978	4030	3.2692	2.8888	2.5818	2.3922	2.2547

Table E.12—Polytropic Constant Table—Nitrogen Expanded to 115 % of Initial Volume

Isentropic Expansion of Nitrogen to 115 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	−40	−4	40	80	120	−40	−4	40	80	120
500	405	405	405	405	406	1.4651	1.4614	1.4574	1.4541	1.4510
1000	801	803	804	806	807	1.5660	1.5480	1.5320	1.5209	1.5118
1500	1178	1186	1192	1196	1199	1.7088	1.6625	1.6250	1.6009	1.5823
2000	1532	1551	1566	1576	1583	1.8909	1.8027	1.7346	1.6926	1.6615
2500	1860	1897	1925	1942	1955	2.1023	1.9632	1.8576	1.7940	1.7478
3000	2162	2222	2268	2296	2317	2.3297	2.1367	1.9902	1.9025	1.8395
3500	2442	2528	2596	2637	2667	2.5611	2.3161	2.1282	2.0156	1.9348
4000	2704	2818	2909	2966	3007	2.7884	2.4959	2.2683	2.1309	2.0323
4500	2951	3093	3210	3283	3337	3.0067	2.6720	2.4077	2.2466	2.1305
5000	3186	3356	3499	3590	3658	3.2132	2.8422	2.5445	2.3612	2.2284

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