into the well to the specified depth applies to obtaining data for the plumbness tolerance as well as the alternate-alignment tolerance. Although other methods of checking plumbness and alignment are available, such as gyroscopic or laser methods, most of these are offered through specialist service companies. Variation in results between test methods can occur, and any potential user considering these methods should review the repeatability of the testing method with the service provider.

SECTION D.2: APPARATUS REQUIRED FOR PLUMBNESS AND ALIGNMENT TESTS

Sec. D.2.1 Plummet

The plummet shall consist of a rigid spindle with round plates at both ends. The outer diameter of the end plates shall be 0.5 in. (13 mm) smaller than the inside diameter of that part of the casing or hole being tested. The distance between end plates shall be approximately 1.25 times the diameter of that part of the casing or hole being tested. The plummet shall be heavy enough to keep the plumb line taut. The plumb line is attached to the plummet at the exact center of the top end plate and shall be of uniform diameter.

Sec. D.2.2 Apex

The apex shall be stationary with a recommended minimum height of 10 ft (3.05 m) above the casing or hole (Figure D.2).

Sec. D.2.3 Pulley

The pulley shall be suitable for running the plumb line and plummet being used.

SECTION D.3: PROCEDURE FOR TEST MEASUREMENTS

Plumbness and alignment are determined by lowering the plummet a maximum of 10 ft (3.05 m) at a time and measuring the horizontal deflection of the plumb line from the center of the top of the casing or

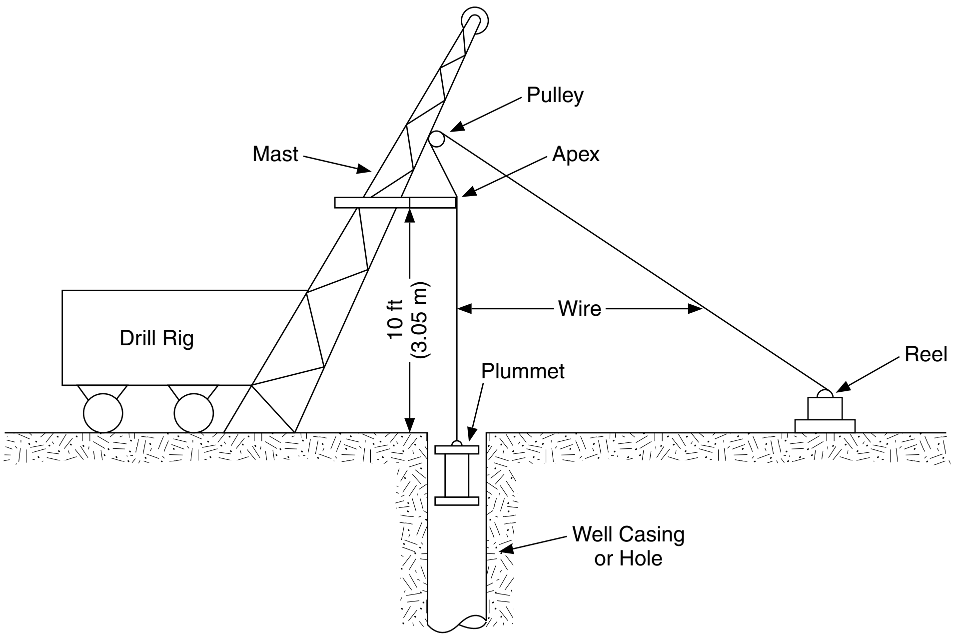


Figure D.2 Suspension of the plummet using drill rig

hole at each interval. If during the field measurements there is reason to suspect that the plummet is approaching the maximum allowable deviation, it may be prudent to take more frequent measurements. The horizontal deflection shall be measured in two planes, 90° from each other.

SECTION D.4: DETERMINATION OF DRIFT (HORIZONTAL DEVIATION)

The drift (horizontal deviation) of the casing or hole at each recorded depth shall be calculated by using the following formula:

$$\text{Drift} = \frac{\text{Deflection}\ (\text{Height} + \text{Depth})}{\text{Height}} \qquad \text{(Eq D.1)}$$

Where:

Drift = calculated horizontal deviation of casing or hole from the vertical, in. (mm)

Deflection = measured horizontal deflection of the plumb line from center of the top of casing or hole, in. (mm)

Height = height of apex above the top of casing or hole, ft (m)

Depth = depth of plummet below the top of casing or hole, ft (m)

The calculated drift of the casing or hole at the depth intervals recorded in Figure D.3 should be plotted as shown in Figure D.4.

Details of Plumbness and Alignment Test Well No. 1 Date: 3-21-15 *Size of Hole or Casing = 19¼ in., ID; Size of Plummet = 18¾ in., OD;* *Height of Apex Above Top of Well = 10.0 ft*								
Depth of Plummet Below Top of Well	Horizontal Deflection of Plumb Line—ft				Calculated Drift of Well—ft			
ft	North	South	East	West	North	South	East	West
10	0.010		0	0.0000	0.020		0	0.0000
20	0.010			0.010	0.030			0.030
30	0.010			0.015	0.040			0.060
40	0.010			0.015	0.050			0.075
50	0.010			0.015	0.060			0.090
60	0.005			0.015	0.035			0.105
70	0.005			0.015	0.040			0.120
80	0.005			0.020	0.045			0.180
90	0.005			0.020	0.050			0.200
100	0.005			0.020	0.055			0.220
110	0.005			0.010	0.060			0.120
120	0.005			0.010	0.065			0.130
130	0	0		0.005	0	0		0.070
140		0.005	0	0		0.075	0	0
150		0.010	0	0		0.160	0	0
160		0.010		0.005		0.170		0.085
170		0.010		0.005		0.180		0.090
180		0.010		0.010		0.190		0.190
190		0.010		0.010		0.200		0.200
200		0.010		0.010		0.210		0.210

ID: inside diameter; OD: outside diameter

Figure D.3 Plumbness and alignment test data sheet

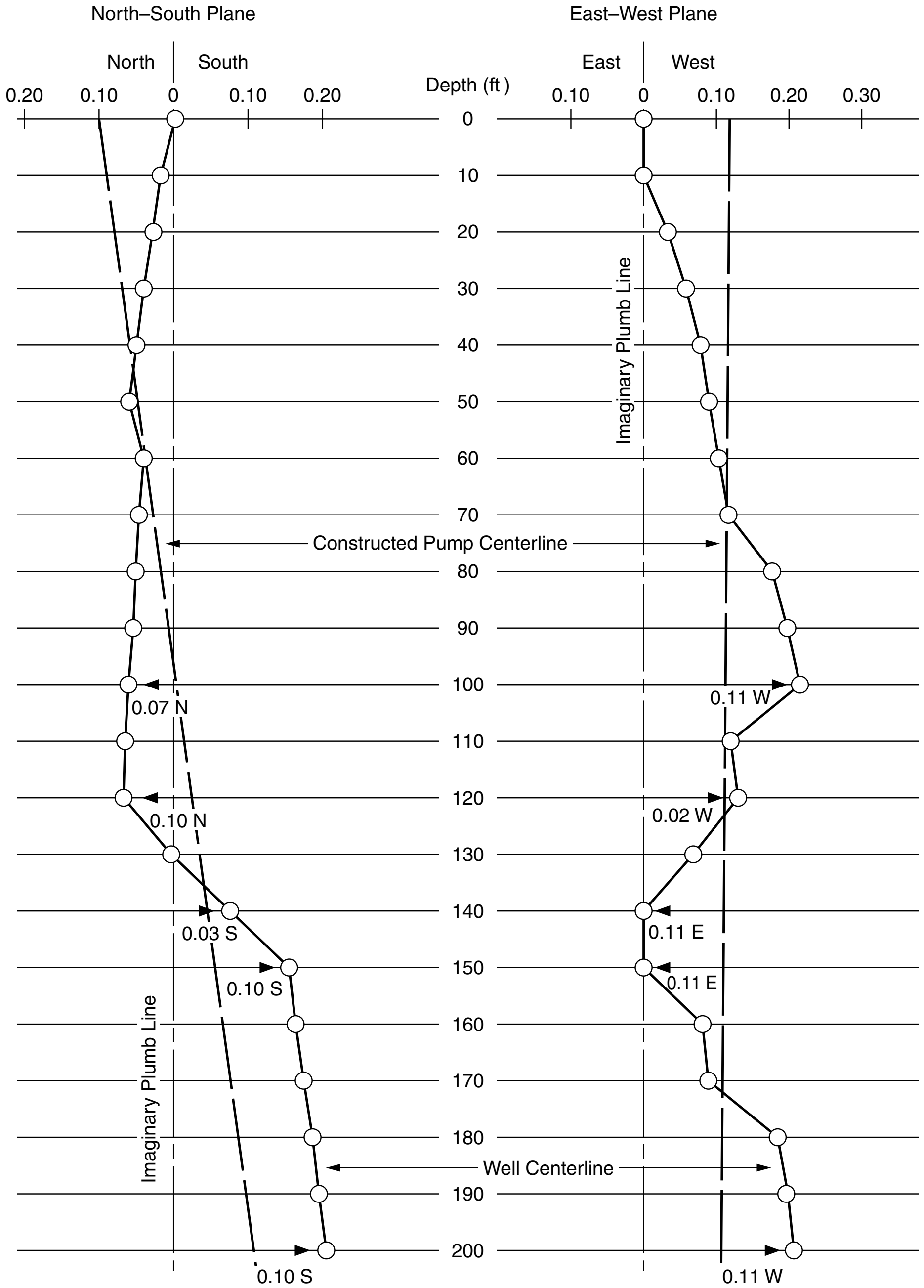
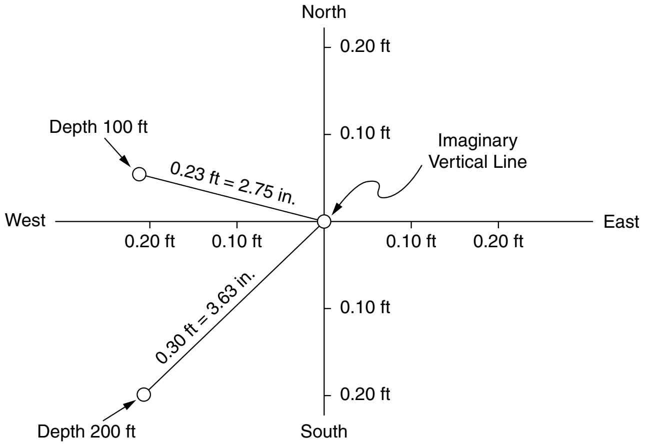


Figure D.4 Longitudinal projections of well and constructed pump centerlines on north–south and east–west vertical planes

Drift Is Greatest at Depths 100 ft and 200 ft

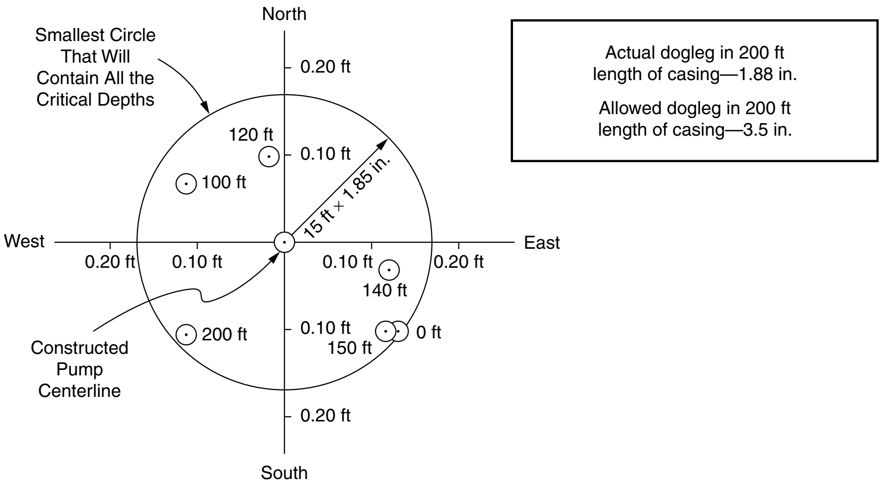
Depth ft	Actual Drift in.	Allowed Drift* in.
100	2.75	12.83
200	3.63	25.66

*For 19.250-in. ID casing.



NOTE: This well meets the specifications for plumbness.

Figure D.5 Graphic representation of requirements of plumbness in Sec. 4.7.9



Vertical alignment specification for 19.250-in. ID casing and 12.25-in. OD pump:

Maximum allowable horizontal distance between the actual well centerline and a straight line representing the pump centerline, this line being constructed so as to minimize the horizontal distance between the two centerlines, shall not exceed 3.5 in. (one-half the difference between the ID of that part of the well being tested—19.250 in.—and the desired maximum OD of the pump—12.25 in.: 19.250 – 12.25 = 7.0, one-half of 7.0 equals 3.5).

Misalignment Radius = 1.88 in.

This figure is the maximum horizontal distance between well centerline and a straight line representing the pump centerline, this line being constructed so as to minimize the horizontal distance between the two centerlines. This figure can be considered a measurement of the maximum dogleg of the well.

Misalignment Diameter = 3.75 in.

This figure is the difference between well ID and the largest pump OD that can be inserted into the well without bending. This figure can be considered a measurement of the loss in effective diameter of the well.

NOTE: This well meets the specifications for alignment.

Figure D.6 Graphic representation of requirements for alignment in Sec. 4.7.9

SECTION D.5: ITEMS TO BE PROVIDED BY CONSTRUCTOR

The following items are to be provided to the purchaser by the constructor as part of the testing procedure for well plumbness and alignment.

1. Test sheet—written statement covering details of the plumbness and alignment test data (see Figure D.3).
2. Well diagram—longitudinal projections of actual well centerline and proposed pump centerline (see Figure D.4).
3. Plumbness graph—calculated drift of the well-casing centerline from vertical (see Figure D.5).
4. Alignment graph—horizontal deviations of actual well-casing centerline from proposed pump centerline (see Figure D.6).
5. Diagram—a diagram showing the effective well diameter and the determination of the largest pump that can be inserted into the well without bending (see Figure D.7).

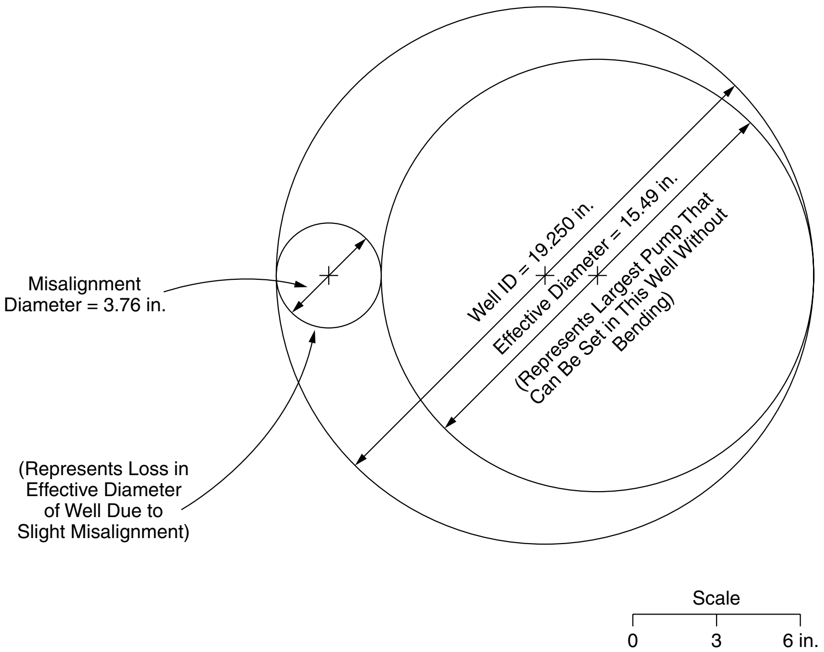


Figure D.7 Relationship between misalignment diameter from Figure D.6, effective diameter of the well, and inside diameter of the well

SECTION D.6: PLOTTING AND INTERPRETATION OF TEST RESULTS

The calculated drift of the well at the recorded depth intervals shall be plotted on cross-section format in two planes, 90° from each other, as shown in Figure D.4. First, plot the calculated horizontal deviations in one plane, called the *north–south plane*, and then in the other plane 90° from the first, called the *east–west plane*. The lines obtained by connecting the plotted points represent the actual well centerline in each plane.

Straight lines representing the pump centerline shall be constructed on the same cross-section format in the north–south and east–west planes again, as shown in Figure D.4. Working first with the north–south plane, construct a straight line representing the pump centerline from top to bottom of the section of casing or hole that was tested. Make any adjustments necessary so that the horizontal distance from this line to any plotted point on the well centerline is a minimum. This line is the optimum position for the pump in the north–south plane. Repeat this procedure for the east–west plane. The resulting graph is a longitudinal projection of well and constructed pump centerlines.

A graph of horizontal deviations of well centerline from pump centerline shall be drawn as shown in Figure D.6. Construct a set of perpendicular axes, labeling the endpoints to indicate direction. The intersection of these axes, referred to as the *origin*, represents the optimum position of the proposed pump centerline in a horizontal plane, at any depth, as previously positioned in Figure D.4.

Transfer the horizontal distances between the proposed pump centerline and the well centerline from Figure D.4 onto Figure D.6, and label each transferred point according to depth. Be sure to transfer each point to its proper quadrant on Figure D.6. To save time, only the critical depths may be considered (depths where the greatest horizontal distances between the two centerlines are involved).

When completed, Figure D.6 shows the relationship between the actual well centerline and the proposed pump centerline at critical depths for this particular proposed pump-centerline location. In other words, Figure D.6 can be considered a view directly down the proposed pump centerline as positioned in Figure D.4, showing the varying locations of the well center with depths.

Finally, using the origin as center, draw the smallest circle that will contain all the plotted points. The diameter of this circle is equal to the difference between the well inside diameter and the largest pump outside diameter that can be inserted into the well without bending (see Figure D.7) when the pump is positioned as in Figure D.4.

One-half the diameter of this circle is equal to the maximum horizontal distance between the well centerline and a straight line representing the pump centerline, this line being constructed to minimize the horizontal distance between the two centerlines. Figure D.6 will identify which depths are most critical for pump clearance.

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APPENDIX E

Well Development and Testing

This appendix is for information only and is not a part of ANSI/AWWA A100.

SECTION E.1: WELL DEVELOPMENT PROCEDURE

A variety of methods can be applied for preliminary development of wells, including such commonly used techniques as bailing, surging, flushing, pumping, jetting, and airlifting. Following the use of one or more of these preliminary methods, a well pump shall be used for final development and for testing development.

Sec. E.1.1 Test-Pump Capacity

The pump and prime mover shall have a capacity in excess of the anticipated lift and final production capacity of the well. The pump shall be set to a depth in excess of the anticipated pumping level.

Sec. E.1.2 Variable Discharge Rates

The development equipment and method used shall permit variable pumping discharge rates.

Sec. E.1.3 Discharge Piping

The discharge piping provided shall be of sufficient diameter and length to conduct water to a point designated by the purchaser, and shall include orifices, meters, or other devices that will accurately measure the discharge rate. The discharge piping shall also include a valve or other appropriate device for controlling or regulating the discharge rate.

SECTION E.2: MEASUREMENT OF OPERATING PARAMETERS DURING DEVELOPMENT

Sec. E.2.1 Discharge Rate

The device used to measure the pump discharge rate shall have a minimum accuracy of 95 percent.