

## Nail Head Pull-Through

**Preface:** The National Design Specification® for Wood Construction (NDS®) is published by the American Wood Council. This specification is developed from data derived for laboratory testing and experience regarding matters of wood design and construction of wood structures for the purpose of a national standard of practice.

**Background:** The 2018 NDS included for the first time information on nail head pull-through. In addition to the NDS, updates to the Wood Frame Construction Manual for One- and Two-Family Dwellings (WFCM) reference pull-through as a component of uplift in roof sheathing for wind loads.

### Terminology:

**Main Member**- in a nailed connection, the main member is normally the component that holds the point of the nail.

**Side Member**- in a nailed connection, the side member is normally the component that is attached or held to the main member.

**G** - Specific Gravity of the wood (side member)

**D<sub>H</sub>** - Diameter of the nail head (inches)

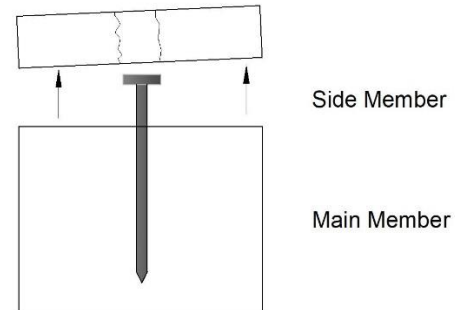
**P<sub>H</sub>** - Perimeter of nail head (inches)

**t<sub>ns</sub>** - net thickness of the side member (inches) For nails where the head is driven flush with the side member surface, it is the thickness of the side member.

**W<sub>H</sub>** - Pull-Through value (pounds)

**W**- Nail withdrawal (pounds)

**Pull-Through** - When the uplift forces on the side member of a connection exceed the capacity of that member to remain in place, the nail head will pull through separating the connection. The nail will remain driven into the main member.



**Information in the NDS:** The NDS references for nail head pull-through are based on round head nails in a range of 0.234 to 0.500 inches in diameter. These diameters represent the range associated with referenced nails in ASTM F1667 Standard Specification for Driven Fasteners: Nails, Spikes and Staples. These diameters are typically associated with hand driven nails and are normally considered as common, box or cooler nails.

There are two NDS equations that have been developed to calculate pull-through values for round head nails.

$$\text{Eq. 1 } W_H = 690 \pi D_H G^2 t_{ns} \quad t_{ns} \leq 2.5D_H$$

This equation uses the net side material thickness in the calculation for pull-through.

$$\text{Eq. 2 } W_H = 1725 \pi D_H^2 G^2 \quad t_{ns} > 2.5D_H$$

This equation does not use the thickness of the side member when calculating pull-through. Testing has shown that when the side member thickness exceeds 2½ times the diameter of the head, a limit is reached where no further increase in thickness will change the calculated values.

Pull-through values from the NDS are available in Table 1 on the next page and are based on the specific gravity of plywood and Oriented Strand Board (OSB).

**Table 1-Head Pull-Through Values,  $W_H$  (pounds) from the NDS Table 12.2F**

Side Member Specific Gravity	Head Diameter (in.)	Net Side Member Thickness (in.)											
		5/16	3/8	7/16	15/32	1/2	19/32	5/8	23/32	3/4	1	1 1/8	1 1/2
0.42	0.234	28	34	39	42	45	52	52	52	52	52	52	52
	0.250	30	36	42	45	48	57	60	60	60	60	60	60
	0.266	32	38	44	48	51	60	64	68	68	68	68	68
	0.281	34	40	47	50	54	64	67	75	75	75	75	75
	0.297	35	43	50	53	57	67	71	82	84	84	84	84
	0.312	37	45	52	56	60	71	75	86	89	93	93	93
	0.344	41	49	58	62	66	78	82	95	99	113	113	113
	0.375	45	54	63	67	72	85	90	103	108	134	134	134
	0.406	49	58	68	73	78	92	98	112	116	155	158	158
	0.438	52	63	73	79	84	99	105	120	126	167	183	183
	0.469	56	67	78	84	99	106	112	129	135	179	202	210
0.500	60	72	84	90	96	114	119	137	143	191	215	239	
0.50	0.234	40	48	55	59	63	74	74	74	74	74	74	74
	0.250	42	51	59	64	68	80	85	85	85	85	85	85
	0.266	45	54	63	68	72	86	90	96	96	96	96	96
	0.281	48	57	67	71	76	90	95	107	107	107	107	107
	0.297	50	60	70	75	80	96	101	116	120	120	120	120
	0.312	53	63	74	79	85	100	106	122	127	132	132	132
	0.344	58	70	82	87	93	111	117	134	140	160	160	160
	0.375	64	76	89	95	102	121	127	146	152	191	191	191
	0.406	69	83	96	103	110	131	138	158	165	220	223	223
	0.438	74	89	104	111	119	141	148	171	178	237	260	260
	0.469	79	95	111	119	127	151	159	183	191	254	286	298
0.500	85	102	119	127	135	161	169	195	203	271	305	339	

**Collated Nails Used in Power Tools:** Collated nails that are driven by power tools (nailers), are allowed by ASTM F1667 to have head shapes and dimensions that are suitable for use in the tool. These heads are typically round, offset round or clipped (D-head). Other styles are available on a limited basis.



ISANTA provides in ICC-ES evaluation report ESR-1539 alternative products to what are listed in the codes. These alternatives include nail sizes, head configurations and dimensions associated with power tool use.

Although the NDS specifically addresses round head nails, the NDS commentary, addresses the pull-through calculation for other head configurations. This calculation is based on head perimeter and is represented by the following equation. (Eq. 3).

$$\text{Eq. 3 } W_H = 690 P_H G^2 t_{ns} \quad t_{ns} \leq 0.8 P_H$$

*Due to limited testing, an equation was not developed for thicker side members in the AWC commentary for offset round and clipped heads. Based on the rationale for a round head nail, an argument for thicker side members could be inferred as:*

$$W_H = 550 P_H^2 G^2 \quad t_{ns} > 0.8 P_H$$

ISANTA has multiple members each producing power tool driven products which are alternatives to the code prescribed nails. Table 2 provides a range of pull-through values for the member produced nails.

Because 5/16" sheathing is not referenced in ESR-1539, it has been excluded from this table for consistency purposes.

Thicker sheathing are addressed in the footnotes of the ESR-1539 for the various shear tables and are thus reference in this document.

**Table 2 - Range of Nail Head Pull-Through Values (pounds) for ISANTA Member  
POWER TOOL DRIVEN NAILS Listed in ESR-1539<sup>1,2</sup>**

Side Member Specific Gravity	Nail Diameter (in.)	Head Style	3/8	7/16	15/32	1/2	19/32	5/8	23/32	3/4	1	1 <sup>1</sup> / <sub>8</sub>	1 <sup>1</sup> / <sub>2</sub>
0.42	0.113	Round	38-41	44-47	48-51	51-54	60-64	63-68	67-77	67-77	67-77	67-77	67-77
		Offset	35-38	41-44	44-48	47-51	55-60	57-64	57-68	57-68	57-68	57-68	57-68
		Clipped	36-38	42-45	45-48	48-51	57-61	60-64	60-69	60-69	60-69	60-69	60-69
	0.120	Round	37-41	43-47	46-51	49-54	58-64	61-68	63-77	63-77	63-77	63-77	63-77
		Offset	35-38	41-44	44-48	47-51	55-60	57-64	57-68	57-68	57-68	57-68	57-68
		Clipped	36-38	42-45	45-48	48-51	58-61	61-64	62-69	62-69	62-69	62-69	62-69
	0.131	Round	38-42	45-49	48-53	51-56	61-67	64-70	69-81	69-82	69-82	69-82	69-82
		Offset	36-39	42-46	45-49	48-53	57-62	60-66	60-72	60-72	60-72	60-72	60-72
		Clipped	36-40	42-46	45-49	48-53	58-63	61-66	62-73	62-73	62-73	62-73	62-73
	0.135	Round	38-45	45-53	48-56	51-60	61-72	64-75	69-87	69-90	69-95	69-95	69-95
		Offset	37	43	46	49	59	62	64	64	64	64	64
		Clipped	37 - 39	43 - 45	46 - 48	49 - 51	59 - 61	62 - 64	64 - 69	64 - 69	64 - 69	64 - 69	64 - 69
	0.148	Round	40-47	47-55	50-59	54-63	64-74	67-78	75-90	75-94	75-102	75-102	75-102
		Offset	41	48	51	54	65	68	78	78	78	78	78
		Clipped	44	51	54	58	69	73	83	87	88	88	88
0.162	Round	41-47	47-54	51-58	54-62	64-74	68-78	77-89	77-93	77-101	77-101	77-101	
0.180	Round	52	61	66	70	101	105	128	128	128	128	128	
0.197	Round	52	61	66	70	101	105	128	128	128	128	128	
0.5	0.113	Round	54-58	63-67	67-72	72-77	85-91	90-96	96-109	96-109	96-109	96-109	96-109
		Offset	50-54	58-63	62-68	66-72	79-86	81-90	81-96	81-96	81-96	81-96	81-96
		Clipped	51-54	59-64	64-68	68-73	81-86	85-91	85-97	85-97	85-97	85-97	85-97
	0.120	Round	52-58	61-67	65-72	69-77	82-91	87-96	89-109	89-109	89-109	89-109	89-109
		Offset	50-54	58-63	62-68	66-72	79-86	81-90	81-96	81-96	81-96	81-96	81-96
		Clipped	52-55	60-64	64-69	69-73	82-87	86-91	87-99	87-99	87-99	87-99	87-99
	0.131	Round	54-60	64-69	68-74	73-79	86-94	91-99	97-114	97-116	97-116	97-116	97-116
		Offset	51-56	59-65	64-70	68-75	80-88	85-93	85-102	85-102	85-102	85-102	85-102
		Clipped	52-55	60-64	64-69	69-73	82-87	86-91	87-99	87-99	87-99	87-99	87-99
	0.135	Round	57-66	66-78	71-83	76-89	90-105	95-111	106-127	106-133	106-145	106-145	106-145
		Offset	52	61	66	70	83	87	90	90	90	90	90
		Clipped	52-56	60-65	64-70	69-75	82-89	86-93	87-103	87-103	87-103	87-103	87-103
	0.148	Round	57-66	66-78	71-83	76-89	90-105	95-111	106-127	106-133	106-145	106-145	106-145
		Offset	58	68	72	77	92	97	110	110	110	110	110
		Clipped	62	72	77	82	98	103	118	123	125	125	125
0.162	Round	58-66	67-77	72-83	77-88	91-105	96-110	109-127	109-132	109-143	109-143	109-143	
0.180	Round	74	87	93	99	143	149	181	181	181	181	181	
0.197	Round	74	87	93	99	143	149	181	181	181	181	181	

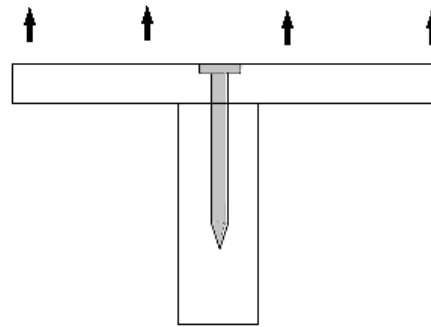
<sup>1</sup>Based on nominal head dimensions      <sup>2</sup>5/16 thick sheathing is not referenced in ESR-1539 and is not shown in this table.

## Uses for Nail Head Pull-Through Data

In the 2018 WFCM Table 3.10 Roof Sheathing Attachment Requirements for Wind Loads was significantly updated to include information regarding uplift load per nail in roofing. In years past, uplift was only a function of nail withdrawal from the main member in the connection and did not consider head pull-through.

With the changes in Table 3.10, the uplift is based on the minimum capacity of either withdrawal or fastener head pull-through. Adjustment factors referenced in the NDS must be taken into consideration when calculations are made.

## Fastener Uplift Design Examples

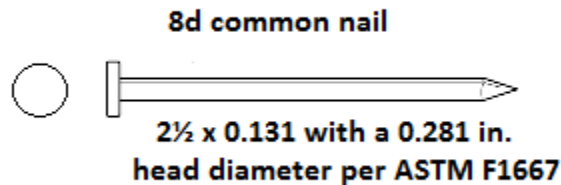


### Example 1

Main Member  
2 x 4 Spruce Pine Fir (SPF)  
Specific Gravity = 0.42

Side Member  
7/16" Plywood (not Structural I)  
Specific Gravity = 0.42

Nails  
2½ x 0.131 8d Common Nail  
(hand driven)



Checking Fastener Withdrawal

W = 21 pounds per inch for a smooth shank nail driven into Spruce Pine Fir with an assigned specific gravity of 0.42 - per Table 12.2C NDS or Table 4 ESR-1539

Length of penetration =  $2\frac{1}{2} - \frac{7}{16} = 2\frac{1}{16}$

Withdrawal =  $21 \times 2\frac{1}{16} = \mathbf{43 \text{ pounds}}$

Checking Nail Pull Through

$t_{ns} = .4375$

$2.5D_H = 0.703$   $2.5D_H$  greater than  $t_{ns}$ , so EQ 1 is used  $W_H = 690 \pi D_H G^2 t_{ns}$

$690 \times \pi \times .281 \times 0.42^2 \times .4375$

or the value taken from Table 1

$W_H = \mathbf{47 \text{ pounds}}$

Side Member Specific Gravity	Head Diameter (in.)	Net Side Member Thickness (in.)												
		$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{15}{32}$	$\frac{1}{2}$	$\frac{19}{32}$	$\frac{5}{8}$	$\frac{23}{32}$	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{2}$	
0.42	0.234	28	34	39	42	45	52	52	52	52	52	52	52	
	0.250	30	36	42	45	48	57	60	60	60	60	60	60	
	0.266	32	38	44	48	51	60	64	68	68	68	68	68	
	<b>0.281</b>	34	40	<b>47</b>	50	54	64	67	75	75	75	75	75	
	0.297	35	43	50	53	57	67	71	82	84	84	84	84	
	0.312	37	45	52	56	60	71	75	86	89	93	93	93	
	0.344	41	49	58	62	66	78	82	95	99	113	113	113	
	0.375	45	54	63	67	72	85	90	103	108	134	134	134	
	0.406	49	58	68	73	78	92	98	112	116	155	158	158	
	0.438	52	63	73	79	84	99	105	120	126	167	183	183	
	0.469	56	67	78	84	99	106	112	129	135	179	202	210	
0.500	60	72	84	90	96	114	119	137	143	191	215	239		

Excerpt from Table 1

In this example, the nail withdrawal value is less than the head pull-through values and thus controls the design capacity. NDS Table 11.3.1 contains the adjustment factors for the connections, is based on end use conditions and must be evaluated.

**Example 2:** Consider the same size nail, with the same main member and side member conditions, but using

- Round head power tool driven nails
- Offset Round power tool driven nails
- D-Head power tool driven nails

Withdrawal: The same as example 1, **43 pounds**

Pull-Through taken from Table 2, the pull-through values range from 43-49 pounds for nails supplied by ISANTA members.

Side Member Specification	Nail Diameter (in.)	Head Style	3/8	7/16	15/32	1/2	19/32	5/8	3/4	23/32	3/4	1	1 1/8	1 1/2
0.42	0.113	Round	38-41	44-47	48-51	51-54	60-64	63-68	67-77	67-77	67-77	67-77	67-77	67-77
		Offset	35-38	41-44	44-48	47-51	55-60	57-64	57-68	57-68	57-68	57-68	57-68	57-68
		Clipped	36-38	42-45	45-48	48-51	57-61	60-64	60-69	60-69	60-69	60-69	60-69	60-69
	0.120	Round	37-41	43-47	46-51	49-54	58-64	61-68	63-77	63-77	63-77	63-77	63-77	63-77
		Offset	35-38	41-44	44-48	47-51	55-60	57-64	57-68	57-68	57-68	57-68	57-68	57-68
		Clipped	36-38	42-45	45-48	48-51	58-61	61-64	62-69	62-69	62-69	62-69	62-69	62-69
	0.131	Round	38-42	45-49	48-53	51-56	61-67	64-70	69-82	69-81	69-82	69-82	69-82	69-82
		Offset	36-39	42-46	45-49	48-53	57-62	60-66	60-72	60-72	60-72	60-72	60-72	60-72
		Clipped	36-40	42-46	45-49	48-53	58-63	61-66	62-73	62-73	62-73	62-73	62-73	62-73
	0.135	Round	38-45	45-53	48-56	51-60	61-72	64-75	69-90	69-87	69-90	69-95	69-95	69-95
		Offset	37	43	46	49	59	62	64	64	64	64	64	64
		Clipped	37 - 39	43 - 45	46 - 48	49 - 51	59 - 61	62 - 64	64 - 69	64 - 69	64 - 69	64 - 69	64 - 69	64 - 69
	0.148	Round	40-47	47-55	50-59	54-63	64-74	67-78	75-94	75-90	75-94	75-102	75-102	75-102
		Offset	41	48	51	54	65	68	78	78	78	78	78	78
		Clipped	44	51	54	58	69	73	87	83	87	88	88	88
	0.162	Round	41-47	47-54	51-58	54-62	64-74	68-78	77-93	77-89	77-93	77-101	77-101	77-101
	0.180	Round	52	61	66	70	101	105	83	128	128	128	128	128
	0.197	Round	52	61	66	70	101	105	83	128	128	128	128	128

Excerpt from Table 2

In this example,

- Withdrawal value = 43 pounds
- Pull through for round head nails is between 45-49 pounds
- Pull through for offset round head nails is between 42-46 pounds
- Pull through for D-head nails is between 43-45 pounds

The controlling factor is tied between withdrawals and pull through for offset round and/or D-Heads nails. As in example 1, NDS Table 11.3.1 must be consulted for the appropriate adjustment factors for the connection end use applications.

NOTE: Table 2 applies ONLY to ISANTA members. Other manufacturers of power tool driven nails are **not** included and should not be assumed to be within the range of values shown in Table 2. . Reference applies only to those products listed in Appendix B of ESR-1539. [http://www.icc-es.org/reports/pdf\\_files/ESR-1539.pdf](http://www.icc-es.org/reports/pdf_files/ESR-1539.pdf)

## Referenced Documents:

*National Design Specification® for Wood Construction*  
2018 Edition.

*Wood Frame Construction Manual for One- and Two- Family Dwellings 2018 Edition*  
Published by the  
American Wood Council  
222 Catoclin Circle, SE, Suite 201  
Leesburg, VA 20175

*ICC-ES Evaluation Report ESR-1539*  
Published by ICC Evaluation Service (ICC-ES)  
3060 Saturn Street, Suite 100  
Brea, CA 92821

*ASTM F1667 Standard Specification for Driven Fasteners:  
Nails, Spikes and Staples*  
Published by ASTM International  
100 Barr Harbor Drive  
West Conshohocken, PA 19428

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