Ball Studs and Ball Stud Socket Assemblies—SAE J491b

SAE Recommended Practice
Last revised February 1977

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LAND SEA AIR SPACE

PREPRINT

BALL STUDS AND BALL STUD SOCKET ASSEMBLIES—SAE J491b

SAE Recommended Practice

Report of Parts and Fittings Division approved August 1922 and revised by Parts and Fittings Committee January 1951 and last revised by Ball Stud and Tie Rod Socket Committee February 1977.

General Specification

Purpose—This SAE Recommended Practice has been established for the purpose of providing design criteria and suggested dimensional proportions which may be used for ball studs and ball stud socket assemblies as used on steering systems or control mechanisms of passenger vehicles, trucks, and off-road equipment.

The recommended practice does not cover all applications. It is intended to provide assistance in obtaining functional satisfaction and interchangeability.

The inclusion of dimensional data in this report is not intended to imply that all the products described are stock production sizes. Consumers are requested to consult with manufacturers concerning stock production parts.

Terminology

Master Gage—A taper gage that serves as a standard or base, designed to specific dimensions within blueprint specifications.

Blueing—A nondrying light paste with a pigment or die (such as "prussian blue") that colors a contacting surface. Blueing must be distributed evenly with minimum thickness on the taper surface of the master gage.

Blueing in a Master Gage—Blueing as applied to a master gage and gage forced onto a taper by hand pressure with a slight twisting motion followed by a rocking motion of the stud in the gage. (The gage should not rock.) Gage is removed for visual check of contact surface of taper.

Ball Studs

Selection of Size—Tensile and compressive forces and functional load requirements of the tie rod must be considered in selecting the proper ball stud size.

The proper ball stud size for a specific application can be reasonably well estimated by considering the stud as a cantilever beam supported at the junction with the mating boss, and loaded radially through the ball end by a force, or forces, the magnitude and direction of which have been previously determined. The type of loading, ball stud and bearing material, heat treatment, and safety factor requirements will influence the size of unit chosen for a specific application.

Design requirements which cannot be satisfied by the tabulated dimensions may be safely fulfilled by deviating wherever necessary provided due consideration is given to the functional stresses.

Materials—Plain carbon and alloy steels are widely used for ball stud fabrication. The principal requirements for either type of steel are: case hardenability to provide a wear resistant skin, good machinability or formability, and good quenching and drawing properties to provide a tough core without surface cracks or brittleness under impact loading. Some of the more popular standard materials used for ball studs lie in the same category as SAE 1019, 4615, 8115, 8615, 8620, and 8640 steels.

Processing—Processing of ball studs is usually dictated by the size, volume of production, and equipment available. Ball studs used on passenger car and light truck steering systems are usually cold formed. Larger ball studs of relatively low production volume such as used on heavy duty trucks and off-road equipment are often fabricated as machined parts. Hot upset forging methods have also been used. The forming or machining is followed by total or selective case hardening. Depending on the application and method of fabrication, it may be desirable to control the surface roughness.

Attachment—The ball stud locking taper is usually used in conjunction with screw thread and nut attachment to allow for repair or replacement. The taper (usually 1.5 in. taper per foot) is designed to attach into mating parts made of steel; however, by proper design the ball studs can be adapted to mate with other materials for which different tapers may be desirable.

The nut selection should be determined by design requirements.

The specified nut torque or seating force may draw the stud locking taper into the mating arm significantly depending on several variables such as amount of taper, size of taper, material, heat treat, surface, and operating conditions. When using a slotted nut, the nut should be tightened to specification and then tightened further if necessary to align a slot with the cotter hole.

The amount of stud taper draw-in should be determined experimentally for each specific application.

The boss thickness and hole gage diameter at the nut face of the boss must be so related to the stud gage diameter as to provide sufficient unexposed threads to allow for draw-in at specified nut torque (reference Fig. 5). To obtain the full stud cantilever strength, the face of the mounting boss should correspond nominally with the large end of the stud taper.

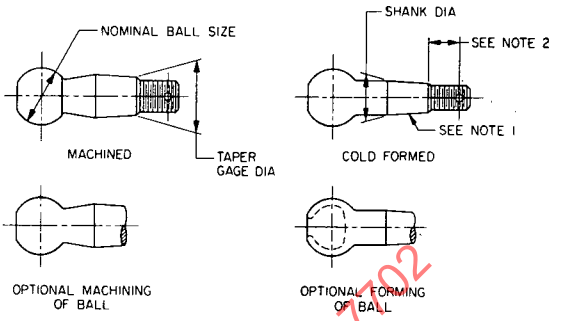
In addition to the screw thread and nut attachment method, permanent attachment means may be used such as riveting (upsetting), welding, spinning, or staking. These methods may be used in conjunction with a locking taper or an interference press fit, in which case the stud is usually a straight shank end with a shoulder for locating purposes.

The permanently attached studs are used in conjunction with tubular ("horizontal type") sockets which can be assembled onto the stud. The screw thread and nut tapered studs are usually preassembled into ball stud sockets, but can also be used with horizontal type sockets.

Sockets

Selection of Size—The socket size is generally dependent upon the ball stud size necessary for a specific application; however, the tensile and compressive forces and functional load requirements of the tie rod must also be considered in selecting the proper socket size.

Materials—Tie rod sockets are often made of SAE 1030, 1038, 1040, 1041, and 1541 steels; however, a number of standard and special steels may be used to provide the desired mechanical properties for each application. Tubular



NOTES:

1. TAPER 1.5 IN./FT ON DIAMETER UNLESS OTHER SPECIFIED. MUST SHOW 60% MINIMUM AREA OF CONTACT WHEN BLUED IN A MASTER GAGE (SEE GENERAL SPECIFICATIONS).
2. COTTER PIN HOLE DIAMETER SHOULD CONFORM TO SAE J485. THE HOLE LOCATION IS DETERMINED BY THE ATTACHMENT EYE AND NUT SIZE. THE HOLE SHOULD BE LOCATED TO PROVIDE A MINIMUM OF 50% ENGAGEMENT OF THE COTTER PIN WITH NUT SLOT AFTER ALLOWING FOR DRAW-IN AT SPECIFIED NUT TORQUE.

   COTTER PIN HOLE MAY BE OMITTED AND OTHER THAN SLOTTED NUT USED WHEN APPLICATION PERMITS.

FIG. 1—"FULL BALL" BALL STUDS

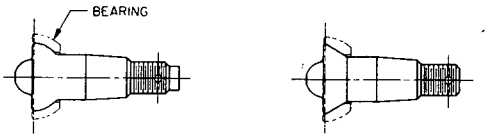


FIG. 2—"HALF BALL" BALL STUDS FOR SEPARATE SPHERICAL BEARINGS

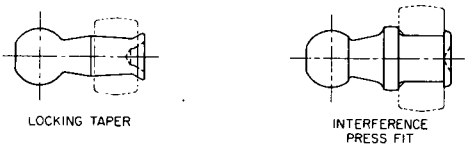


FIG. 3—PERMANENTLY ATTACHED STUDS—RIVETED, WELDED, SPUN, OR STAKED

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

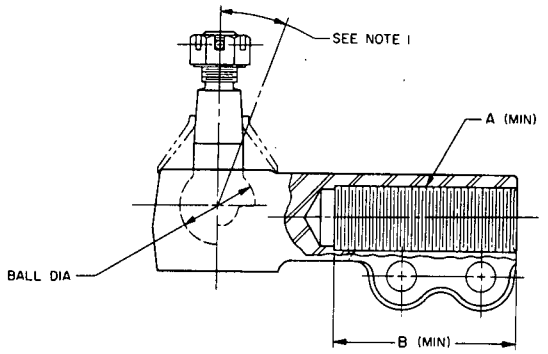


FIG. 4—TYPICAL BALL STUD SOCKET ASSEMBLY WITH INTERNAL THREADED STEM

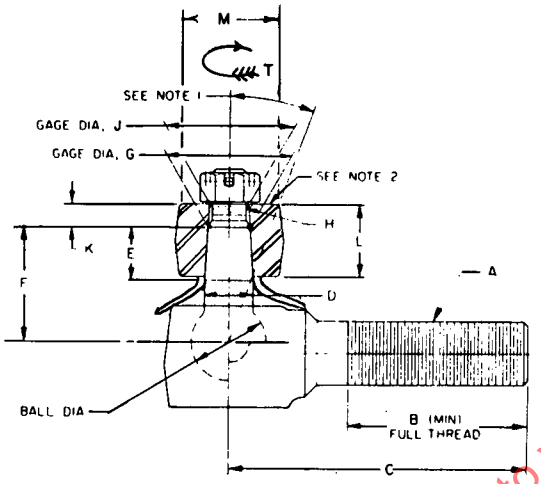


FIG. 5—TYPICAL BALL STUD SOCKET ASSEMBLY WITH EXTERNAL THREADED STEM

NOTES:

1. 0 - ANGULAR TRAVEL DETERMINED AS REQUIRED FOR SPECIFIC APPLICATION.
2. NUT SURFACE ON BOSS MUST BE SUFFICIENTLY SQUARE WITH TAPERED HOLE TO PREVENT EXCESSIVE STRESS ON STUD THREADED END.

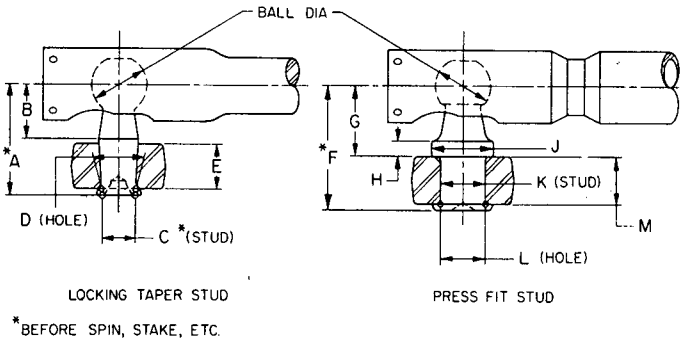


FIG. 6—TYPICAL TUBULAR ("HORIZONTAL TYPE") SOCKET ASSEMBLY FOR RIVETED, SPUN, STAKED, WELDED, OR THREADED TAPER STUD ATTACHMENT. (FOR THREADED TAPER STUDS, USE TABLE 1 DIMENSIONS)

("horizontal type") sockets may also be made from seamless or welded tubing, frequently in SAE 1010, 1020, and 1025 steels.

Processing and Attachment—Tie rod sockets are usually machined forgings with external threaded stems for attaching to mating components. In heavy duty or off-road applications, the socket is often forged with integral clamp ears and threaded with internal threads for attaching to mating components. Sockets may also be forged into both ends of an integral link. In applications of sockets with threaded stems for attachment to tubular intermediates or turnbuckles, a right-hand thread is usually paired with a left-hand thread to provide fast assembly and adjustment.

Threads—Unified Class 2A of the size indicated in Table 1. Ends of threaded features should be chamfered from approximately 0.02 in. below the minor diameter, the length of chamfer to be ½ to 1½ threads.

In applications of sockets with threaded stems, the length of engagement of stem threads with the attaching rod or sleeve depends on design and may vary, but should be approximately 2½ times the thread diameter. Under extremes of adjustment, where the application permits, engagement may be as low as 1½ times the thread diameter.

Lubrication—Lubrication fittings, if required, may be placed at any convenient location on the periphery or face of the socket provided the location does not create forging processing, assembly, or functional complications.

TABLE 1A—BALL STUD SOCKET ASSEMBLY DIMENSIONS[a] (DIMENSIONS IN UNITED STATES CUSTOMARY UNITS)

Nominal Ball Dia	Socket Thread		Socket Length	Ball Stud					Attachment Arm				Stud Nut
	Size A	Length B	C	Shank Dia D	Taper Length E	Gage Dia Location F	Gage Dia G	Thread Size H	Gage Dia J	Draw-In Clearance K[b]	Thickness L	Boss Dia M[c]	Tightening Torque T[d]
in	in	in	in	in	in	in	in	in	in	in	in	in	in
5/8	1/2-20	1.74	2.62	0.469	0.41	1.06	0.418	3/8-24	0.402	0.128	0.50	1.25	15-30
3/4	9/16-18	1.94	2.94	0.547	0.45	1.20	0.490	7/16-20	0.473	0.136	0.56	1.38	30-45
7/8	11/16-18	2.06	3.12	0.625	0.52	1.36	0.560	1/2-20	0.543	0.136	0.62	1.50	35-55
1	11/16-18	2.21	3.38	0.703	0.72	1.62	0.613	9/16-18	0.590	0.184	0.88	1.75	55-80
1 1/8	7/8-18	2.75	3.88	0.781	0.84	1.88	0.675	5/8-18	0.652	0.184	1.00	1.88	80-110
1 1/4	1-16	3.19	4.25	0.875	0.94	2.03	0.758	5/8-18	0.731	0.216	1.12	2.00	80-110
1 1/2	1 1/8-12	3.75	4.88	1.031	1.12	2.44	0.890	3/4-16	0.863	0.216	1.31	2.25	100-140
1 3/4	1 1/4-12		5.75	1.250	1.28	2.81	1.074	7/8-14	1.043	0.248	1.50	2.75	120-170
2				1.350	1.50	3.22	1.166	1-12	1.131	0.280	1.75	3.00	140-220
2 1/4				1.510	1.78	3.72	1.285	1 1/8-12	1.250	0.280	2.00	3.25	180-270
2 1/2				1.700	2.06	4.34	1.441	1 1/4-12	1.406	0.280	2.25	3.50	230-320

[a]These dimensions may be varied as required for specific applications. See General Specifications.

[b]Before tightening nut.

[c]The boss diameter or "hoop size" was determined by using the recommended nut tightening torque to determine "hoop size" at recommended thickness "L" with the stress level below the yield strength of medium carbon steel forgings.

[d]Ranges of tightening torque for 1.5 in/ft taper in medium carbon or alloy steel forgings. For other materials or tapers, these torque values must be adjusted. The torque values recommended are empirical values determined by combined experience of SAE Ball Stud and Tie Rod Socket Committee members.

ϕTABLE 1B—BALL STUD SOCKET ASSEMBLY DIMENSIONS[a] (DIMENSIONS IN SI UNITS)

Nominal Ball Dia[e]	Socket Thread		Socket Length	Ball Stud					Attachment Arm				Stud Nut
	Size A[e]	Length B	C	Shank Dia D	Taper Length E	Gage Dia Location F	Gage Dia G	Thread Size H[e]	Gage Dia J	Draw-In Clearance K[b]	Thickness L	Boss Dia M[c]	Tightening Torque T[d]
in	in	mm	mm	mm	mm	mm	mm	in	mm	mm	mm	mm	N·m
5/8	1/2-20	44.2	66.6	11.91	10.4	26.9	10.62	3/8-24	10.21	3.3	12.7	31.8	20-40
3/4	9/16-18	49.3	74.7	13.89	11.4	30.5	12.45	7/16-20	12.01	3.5	14.2	35.0	40-60
7/8	11/16-18	52.3	79.3	15.87	13.2	34.5	14.22	1/2-20	13.79	3.5	15.8	38.1	50-75
1	11/16-18	56.1	85.9	17.86	18.3	41.2	15.57	9/16-18	14.99	4.7	22.4	44.5	75-110
1 1/8	7/8-18	69.9	98.6	19.84	21.3	47.8	17.15	5/8-18	16.56	4.7	25.4	47.7	110-150
1 1/4	1-16	81.0	108.0	22.23	23.9	51.6	19.25	5/8-18	18.57	5.5	28.5	50.8	110-150
1 1/2	1 1/8-12	95.3	124.0	26.19	28.5	62.0	22.61	3/4-16	21.92	5.5	33.3	57.2	140-190
1 3/4	1 1/4-12		146.1	31.75	32.5	71.4	27.28	7/8-14	26.49	6.3	38.1	69.9	160-230
2				34.29	38.1	81.8	29.62	1-12	28.73	7.1	44.5	76.2	190-300
2 1/4				38.35	45.2	94.5	32.64	1 1/8-12	31.75	7.1	50.8	82.6	240-370
2 1/2				43.18	52.3	110.2	36.60	1 1/4-12	35.71	7.1	57.2	88.9	310-430

[a]These dimensions may be varied as required for specific applications. See General Specifications.

[b]Before tightening nut.

ϕ [c]The boss diameter or "hoop size" was determined by using the recommended nut tightening torque to determine "hoop size" at recommended thickness "L" with the stress level below the yield strength of medium carbon steel forgings.

ϕ [d]Ranges of tightening torque for one unit per eight units of length taper in medium carbon steel forgings. For other materials or tapers, these torque values must be adjusted. The torque values recommended are empirical values determined by combined experience of SAE Ball Stud and Tie Rod Socket Committee members.

[e]No direct SI conversion for nominal sizes that are not measurements.