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Transport of Radioactive Material Code of Practice

Design and Operation to Minimise Seizure of Fasteners

Produced by the Transport Container Standardisation Committee

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Publisher

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FOREWORD

This Code of Practice has been revised to give guidance on the prevention of seizure of mating threaded components. It applies to ISO metric screw threads to BS 3643 and Pipe threads of Whitworth form to BS EN ISO 228-1.

Other threads to Whitworth form, although obsolescent, are included in Appendix B for use on existing equipment only.

This document is an updated version of the previous issue dated June 2005. The amendments are relatively modest, being limited to improvements in guidance on the application of bolt operations, updating of supporting references and related documents to maintain the currency of the document.

1 GENERAL

1.1 Scope

This Code of Practice covers the requirements to be followed to facilitate the assembly, and prevent seizure, of mating screw threads.

1.2 Related Documents

The following documents are referred to in this Code of Practice

BRITISH STANDARDS

BS 84	Parallel screw threads of Whitworth form (obsolescent)
BS EN ISO 228-1	Pipe threads where pressure-tight joints are not made on the threads
BS 2573	Rules for the design of cranes: specification for classification, stress calculations and design criteria for structures (superseded). Note BS-EN-13001 supersedes BS 2573
BS 3580	Guide to design considerations on the strength of screw threads
BS 3643	ISO metric screw threads
	Part 1 Principles and basic data
	Part 2 Specification for selected limits of size
BS-EN-13001	Cranes General Design
	Part 1 General principles and requirements
	Part 2 Load actions
	Part 3 Limit states and proof competence of steel structure
DTD-734A	Chromium-Nickel; non-corrodible steel wire (suitable for manufacture of wire thread inserts)

AMERICAN STANDARD

ASTM A453/A453M	Standard Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels
UNS-S21800	Nitronic 60 Stainless Steel Bar and Wire, Product Data Bulletin 7/2011.

1.3 Introduction

Seizure or surface damage of threads can arise when assembling or dismantling screw threaded components. One of the most severe forms that can occur is termed 'galling', where gross damage of the thread surfaces and in some cases total seizure can occur.

The problem of thread seizure is most commonly caused by one or more of the following conditions:

(a) Use of certain materials which are prone to seizing, e.g. austenitic stainless steels, pure aluminium, copper.

(b) Insufficient clearance between the mating screw threads.

(c) Poor surface finish.

(d) Inaccurate thread form.

(e) Workshop residues on the threads.

(f) Damage or burrs to the threads.

(g) Inaccurate alignment of the mating threads – particularly when the thread diameter is large in relation to the thread pitch.

In addition, surface hardness, cleanliness, lubrication and the choice of thread can all effect the interaction between the metal surfaces that make up the mating threads. For example, the loss of lubricant due to adverse operating conditions can result in the build-up of excessively high loads or temperatures leading to excessive wear and distortion and consequential problems with component dis-assembly. Specialist advice on individual cases should be sought from appropriate component suppliers and materials experts.

The procedures given in the following sections of this Code are intended to minimise the occurrence of assembly and dismantling difficulties. It is therefore recommended that the requirements of this Code be specified where it can be identified that difficulties are likely to arise. Such cases may include situations where the mating parts are both of similar materials, or where fine threads are used on a relatively large diameter, or where temperature cycling is anticipated.

Section 2 of this Code provides technical guidance on mating components for materials in general, whereas Section 3 gives additional requirements for mating components made specifically from austenitic steel.

Section 4 provides guidance on general design considerations to minimise wear and reduce the risk of galling, whereas Section 4 provides considerations of good practice for bolting operations.

1.4 Drawing Statements

This Code of Practice recommends certain procedures which are largely dependent on the particular application. Hence, if a designer wishes to specify these procedures by quoting this Code, he must also ensure that the drawing or manufacturing instructions call for any specific dimensioning or cleaning specifications or the lubricant, if any, dictated by that application.

A typical drawing statement would be:

THREADS TO BE IN ACCORDANCE WITH TCSC 31 SECTIONS 2 AND 3

LUBRICATE THE THREAD WITH MOLYBDENUM DISULPHIDE ANTI-SCUFFING PASTE IMMEDIATELY PRIOR TO ASSEMBLY WITH MATING PART

In addition, the appropriate lubricant would be specified and if this requires modification in accordance with Section 3, or Appendix B of this Code the amended pitch, major and minor diameters would also be given.

2 TECHNICAL GUIDANCE

2.1 Materials

Wherever possible mating screwed parts should be made of dissimilar materials. However, due allowance should be made for any adverse consequences of doing so, such as the effects of thermal expansion, or any tendency to promote corrosion due to the different electrochemical potentials of the materials.

2.2 Hardness

The greater the difference between the hardness of two mating surfaces, the less likelihood of the materials being “picked-up” and transferred from one surface to another, or left as detritus in the space between the surfaces. Therefore, similar hardness materials for mating screw threads should be avoided where possible.

2.3 Surface Finish

The surface finish of the screw threads plays an important part in the prevention of seizure of fasteners – particularly where the materials used are of a type, which are prone to seizure. In general rougher surface finishes increase the wear, but these increase the ability to accommodate debris and lubricants in the surface of the material. Also, very smooth surfaces (less than about 0.2μm) lack the ability to store wear debris and lubricants within their structure. This can promote “cold welding” of the surfaces due to the larger true contact area, combined with the lack of a mechanism (lubricant), and the space, to keep them apart. A surface roughness Ra of between 0.4μm and 3μm is recommended to minimise this effect.

Rolled external threads can be recommended as having a good assured surface finish within the above recommended range together with an assured contour and pitch, and, on appropriate materials, a work-hardened surface. One method of easily achieving an equivalent good surface finish on internal threads, together with a work-hardened surface, is by the use of a cold formed thread insert.

Shot peening or grit blasting, can be beneficial processes to apply to finished threads, particularly for materials such as austenitic stainless steels which can be work hardened. Bolts that have CNC manufactured threads, as opposed to rolled threads, will frequently have a significantly smoother surface and will also benefit from shot peening. The cold worked surface that is produced by shot peening/ grit blasting makes the material more resistant to galling and also improves its fatigue resistance. In addition, the shallow indentations caused by the shot can act as lubricant reservoirs.

2.4 Surface Treatment including Plating

Where similar materials are used in an assembly, the tendency for seizure between them to occur may be reduced by treating the surface of one of the mating components to change its characteristics e.g. heat-treatment, ion implantation or plating. Care should be taken when using electroplated bolts, especially on high strength steel bolts such as grade 12.9 bolts. This is because the standard cleaning process prior to electroplating can cause hydrogen embrittlement of the bolt material itself and this has caused bolt failures at relatively low loads.

2.5 Thread Ends

Machine cut external threads on parts including bolts and studs should have a sufficient plain length, undercut to the minor diameter, at both leading and trailing ends. A radius should be specified in the corners to minimise stress raisers. Where practicable, the length of undercuts should be equal to three thread pitches. The feathered portion at each end of external threads should be removed back to the first full thread as shown in Figure 1. Where possible, internal threads should also have the feathered portion removed. In the case of nuts this should be done at both ends.

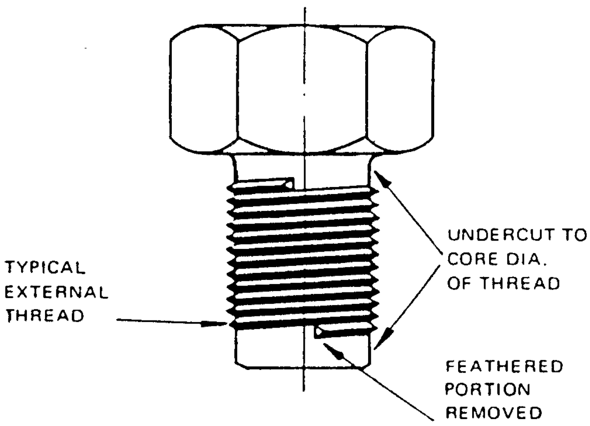

Figure 1 - Treatment of machine-cut threads

2.6 Cleaning

After manufacture, threaded components must be cleaned. It is recommended that a cleaning specification is prepared to suit the component material, and in some cases, the environment for which the component is intended.

Once a component has been cleaned, great care must be taken to ensure that it does not come into contact with contaminating materials. Clean, dry, lint-free gloves should be worn for all subsequent handling.

As soon as practicable the component should be sealed in a clean polyethylene bag to protect it from contamination. Adequate precautions must be taken to prevent mechanical damage to the packaging during storage or in transit.

2.7 Lubrication

Many lubricants contain chlorides. These may be unsuitable for particular applications where crevice or stress corrosion may be encouraged, or for particular materials such as stainless steel whose life can be significantly affected by such processes. With the exception of those applications that preclude the use of lubricants, screw threads should, in general, be adequately lubricated. Whilst most oils and greases are efficient lubricants, their propensity to pick up and retain dirt, grit and other contamination can make them less desirable than dry lubricants such as molybdenum disulphide sprays.

For stainless steel, commercial anti-scuffing compounds are available containing copper, graphite, molybdenum disulphide, PTFE, nickel etc. to suit the application. If the component is intended for operation under significant levels of nuclear radiation, care must be taken to select a compatible lubricant.

Clearly, lubricants must **not** be used which might cause damage or adversely affect the performance of the items being lubricated, or where the lubricant is incompatible with other processes, e.g. in vacuum leakage testing where off-gassing problems could occur. It should also be noted that corrosion problems may be encountered if using molybdenum disulphide lubricants on Nickel-base alloy bolts at high temperature. Any lubricant used on a package that is loaded into a chemically controlled area, such as a fuel pond, must be shown to be chemically compatible with the fuel pond chemistry.

2.8 Thread Inspection

Mis-matched threads or non-uniform threads greatly increase the likelihood of thread seizure (galling). Because of the complexities of inspecting threads dimensionally, the use of calibrated GO/NOT GO and WEAR plug and screw ring gauges are recommended for inspection.

2.9 Tightening Torque

The torque to be applied to fasteners should be addressed when considering a properly fastened joint. Too small a torque may allow separation of the joint and result in fatigue failure. In contrast, too large a torque may cause failure of the bolt or stripping of the threads, particularly if one of the bolting materials is of a much lower strength.

For a correctly fastened joint it is recommended that the bolts should be tightened in a controlled manner to a pre-determined torque to give an acceptable pre-load stress determined by the nature of the application. Typically, a pre-load stress of between 70% and 80% of the bolt material yield stress may be used, as recommended in BS 2573. The tightening torque required to develop this pre-load stress may be calculated using the following formula (taken from BS 3580):

$T = 1/5\ P_o D$ where

T = Tightening torque (Nm)

P_o = Initial tensile load in the bolt developed by tightening (N)

D = Basic major diameter i.e. nominal diameter (except for pipe threads) (m)

The above formula uses a friction coefficient of 0.2 (1/5) and for threads lubricated with a thin film of ordinary oil or grease the formula given is accurate to about ± 20%. However, friction may vary widely depending upon materials in contact, surface plating, cleanliness and lubrication conditions, which can result in a friction coefficient as low as 0.05 or up to 0.35 or higher in certain austenitic stainless steel assemblies. Therefore, in critical applications or where friction effects may vary widely, torque-tension relations should be determined experimentally or alternative methods of tightening used.

The use of impact wrenches should be avoided as these increase the likelihood of galling.

3 AUSTENITIC STAINLESS STEEL COMPONENTS

3.1 Thread Modifications

When both mating parts are to be manufactured in austenitic stainless steel, in addition to the requirements of Section 2, it is also necessary to ensure that there is a clearance between the two thread profiles. This can be achieved by following the recommendations given in this Section.

3.2 ISO metric Threads

Experience indicates that satisfactory results will be attained by specifying the coarse pitch series and a 'medium' (6H/6g) class of fit from BS 3643: ISO metric screw threads: Parts 1 and 2. A 'close' class of fit can produce a size-and-size condition, therefore a closer fit than this is not acceptable.

3.3 Pipe Threads

Screw threads to BS EN ISO 228-1 shall be made to a modified class of fit as given below.

EXTERNAL THREADS

External threads shall be made to BS EN ISO 228-1, except that the tolerances on the pitch and major diameters are to be reduced to those given in Appendix A (Table 1) of this Code. The minor diameter is to remain as shown in BS EN ISO 228-1.

INTERNAL THREADS

Internal threads shall be made to BS EN ISO 228-1, except that the minor diameter shall be as given in Appendix A (Table 2) of this Code. This shall be achieved by truncating the threads, e.g. by reaming. The major and pitch diameters are to remain as shown in BS EN ISO 228-1.

3.4 Parallel Threads of Whitworth Form

Parallel threads of Whitworth form including BSW, BSF and other selected non-standards to BS 84 are obsolescent and should not be used on new designs. However, these are included within this Code for completeness and use in the case of maintenance for existing plant and equipment. See Appendix B.

3.5 Stainless Steel Assemblies

Avoid using stainless bolts in stainless steel assemblies wherever possible e.g. ASTM A453 covers high-temperature bolting materials, with expansion coefficients comparable to austenitic stainless steels.

To avoid seizure of stainless steel mating screw threads on assembly, one possible approach is to make one part austenitic and the mating part martensitic.

Grades of stainless steels have been developed for anti-galling and wear resistance, two of which are Nitronic[1] 60 (UNS S21800) and Waukesha 88[2] (UNS N26055).

[1] Nitronic is a registered trademark of Armco, Inc.

[2] Waukesha 88 is a registered trademark of Waukesha foundry Co.

Appendix C (Tables 9 & 10) show the galling resistance of stainless steels and alloys and includes the anti-galling grades.

Where possible to reduce the possibility of galling occurring dissimilar materials should be used. Inconel, Monel and Nimonic alloys provide good resistance to galling and aluminium bronzes, particularly those containing nickel, provide excellent resistance when paired with stainless steels.

Positive experience has been reported in the use of A4-70 bolts mating with stainless rolled thread inserts, assembled clean and dry with no lubrication. These inserts have a very high hardness and tensile strength when manufactured by cold-working to DTD734A. In this instance the bolt threads were also silver plated, and no seizure problems have been experienced.

4 DESIGN CONSIDERATIONS

The following points should be taken into consideration during the design of mating parts using screw threads to minimise wear and reduce the risk of galling.

- Materials - where possible use dissimilar grades and avoid materials of similar hardness. If this is not possible then consider applying surface treatment to change the characteristics.

- Surface finish - For best resistance to wear and galling the mating thread surfaces should have a Ra value of between 0.4μm and 3μm.

- Tolerance - In applications where both items are manufactured from austenitic stainless steel, metric thread applications should use coarse pitch series and a fit no tighter than a ‘medium’ class of fit (6H/6g). For pipe threads use a modified class of fit.

- Inspection - Inspect threads for dimensional compliance, preferably by gauging.

- Manufacture - Use rolled threads where possible. Where machined external threads are used the first and last thread should be feathered back to full form.

- Torque - apply correct value of torque and avoid use of impact wrenches.

- Cleaning - clean and protect threads from damage prior to use.

- Lubrication - Lubricate threads where possible.

5 OPERATIONS

The following should be considered:

(i) The de-torque and torque should be slow, smooth and progressive. It is recommended that bolts are wound in and out by hand with electrical / pneumatic equipment only used for final torque / initial de-torque.

(ii) If bolts are removed during package operation it is useful to record the de-torque values. High de-torque values can be indicative of the onset of galling or previous over-tightening.

The bolts and receiver threads will, on a microscopic scale, plastically deform to accommodate each other and effectively become a pair. Thus it is always preferable, if bolts are refitted, to use the same bolts in the same receiver threads each time. It also follows that the risk of galling is not necessarily reduced by fitting new bolts at every operation.

APPENDIX A: Pipe Thread Sizes

Table 1 Modified External Pipe Threads (Parallel Fastening)

DESIGNATION OF THREAD *	NUMBER OF THREADS IN 25.4mm *	MAJOR DIAMETER (mm)				PITCH DIAMETER (mm)			
		BASIC*	MAX.	TOL.	MIN.	BASIC*	MAX.	TOL.	MIN.
1/16	28	7.723	7.678	0.102	7.577	7.142	7.120	0.079	7.041
1/8	28	9.728	9.677	0.104	9.573	9.147	9.121	0.081	9.040
1/4	19	13.157	13.101	0.109	12.992	12.301	12.273	0.086	12.187
3/8	19	16.662	16.601	0.112	16.490	15.806	15.773	0.089	15.685
1/2	14	20.955	20.889	0.117	20.772	19.794	19.756	0.094	19.662
5/8	14	22.911	22.840	0.122	22.718	21.749	21.709	0.099	21.610
3/4	14	26.441	26.365	0.127	26.238	25.279	25.235	0.102	25.133
7/8	14	30.201	30.117	0.130	29.987	29.039	28.992	0.107	28.885
1	11	33.249	33.160	0.135	33.025	31.770	31.717	0.112	31.605
1 1/8	11	37.897	37.805	0.137	37.668	36.418	36.363	0.114	36.248
1 1/4	11	41.910	41.816	0.140	41.676	40.431	40.373	0.114	40.259
1 1/2	11	47.803	47.704	0.145	47.559	46.324	46.264	0.119	46.144
1 3/4	11	53.746	53.642	0.147	53.495	52.267	52.202	0.124	52.078
2	11	59.614	59.505	0.152	59.352	58.135	58.067	0.127	57.940
2 1/4	11	65.710	65.596	0.157	65.438	64.231	64.158	0.132	64.026
2 1/2	11	75.184	75.065	0.163	74.902	73.705	73.627	0.137	73.490
2 3/4	11	81.534	81.410	0.165	81.244	80.055	79.974	0.140	79.835
3	11	87.884	87.754	0.170	87.584	86.405	86.319	0.145	86.175
3 1/2	11	100.330	100.193	0.175	100.018	98.851	98.763	0.150	98.613
4	11	113.030	112.888	0.180	112.707	111.551	111.458	0.155	111.303
4 1/2	11	125.730	125.585	0.183	125.402	124.251	124.155	0.157	123.998
5	11	138.430	138.283	0.183	138.100	136.951	136.855	0.157	136.698
5 1/2	11	151.130	150.980	0.185	150.795	149.651	149.553	0.160	149.393
6	11	163.830	163.678	0.188	163.490	162.351	162.250	0.163	162.088

*Extracted from Table 1 of BS EN ISO 228-1:2003

Table 2 Modified Internal Pipe Threads (Parallel Fastening)

DESIGNATION OF THREAD*	NUMBER OF THREADS IN 25.4mm*	MINOR DIAMETER (mm)			
		BASIC*	MAX.	TOL.	MIN.
1/16	28	6.561	6.843	0.152	6.690
1/8	28	8.566	8.847	0.152	8.694
¼	19	11.445	11.890	0.254	11.636
3/8	19	14.950	15.395	0.254	15.141
½	14	18.631	19.174	0.305	18.870
5/8	14	20.587	21.130	0.305	20.825
¾	14	24.117	24.661	0.305	24.356
7/8	14	27.877	28.420	0.305	28.115
1	11	30.291	30.932	0.381	30.551
1 1/8	11	34.939	35.580	0.381	35.199
1 ¼	11	38.952	39.594	0.381	39.213
1 ½	11	44.845	45.486	0.381	45.105
1 ¾	11	50.788	51.430	0.381	51.049
2	11	56.656	57.297	0.381	56.916
2 ¼	11	62.752	63.393	0.381	63.012
2 ½	11	72.226	72.868	0.381	72.487
2 ¾	11	78.576	79.218	0.381	78.837
3	11	84.926	85.568	0.381	85.187
3 ½	11	97.372	98.014	0.381	97.633
4	11	110.072	110.714	0.381	110.333
4 ½	11	122.772	123.414	0.381	123.033
5	11	135.472	136.114	0.381	135.733
5 ½	11	148.172	225.014	0.381	148.433
6	11	160.872	161.514	0.381	161.133

*Extracted from Table 1 of BS EN ISO 228-1:2003

APPENDIX B: Parallel threads of Whitworth Form

BSW, BSF and selected non-standard threads of Whitworth form are obsolescent and **should not be used in new designs.**

Standard BSW and BSF threads (Obsolescent)

Standard (but not selected) screw threads to BS 84, shall be made to a modified class of fit as given below.

EXTERNAL THREADS

External threads shall be made to BS 84, except that the tolerance on the effective and major diameter are to be reduced to those given in Table 3 for BSW threads and Table 5 for BSF threads.

INTERNAL THREADS

Internal threads shall be made to BS 84, except that the minor diameter shall be as given in Table 4 for BSW threads and Table 6 for BSF threads.

This shall be achieved by truncating the threads, e.g. by reaming. The major and effective diameters are to remain as shown in BS 84.

Selected non-standard Whitworth threads (Obsolescent)

Selected or non-standard threads of Whitworth form shall be made to BS 84 'Medium class', modified as given below.

EXTERNAL THREADS

The maximum effective diameter and the maximum major diameter shall be made smaller than their respective basic sizes by an amount 'X' for the effective diameter and by an amount 'Y' for the major diameter. Values of 'X' and 'Y' shall be obtained from Table 7.

The minimum effective diameter and the minimum major diameter shall be determined by application of the tolerances given in Table 7, to the modified maximum effective and maximum major diameters.

The requirements may be tabulated thus:

Modified max effective diameter = Basic effective diameter – 'X'

Modified min effective diameter = Modified maximum effective diameter – Tolerance

Modified max major diameter = Basic major diameter – 'Y'

Modified min major diameter = Modified max major diameter – Tolerance

The basic effective diameter is obtained by subtracting the basic depth of thread, as given in Table 7, from the basic major diameter.

Example

Bolt $1^1/_4$ in. 12 TPI Whit (Modified 'medium' class)

Basic major diameter = 1.2500 in.

Basic effective diameter = 1.2500 – 0.0534 = 1.1966

Modified max effective diameter = 1.1966 – X = 1.1966 – 0.0030 = 1.1936 in.

Modified min effective diameter. = 1.1936 – Tol = 1.1936 – 0.0049 = 1.1887 in.

Modified max major diameter = 1.2500 – Y = 1.2500 – 0.0047 = 1.2453 in.

Modified min major diameter = 1.2453 – Tol = 1.2453 – 0.0062* = 1.2391 in.

*The tolerance value of 0.0062 in. is the sum of tolerance on effective diameter and the value given in the right hand column of Table 7.

The minor diameter shall be in accordance with BS 84, Table 18 for a 'medium' class of fit.

INTERNAL THREADS

To BS 84, Table 19 for a 'normal' class of fit except that the minor diameter shall be modified as given in Sub-Clause (f).

The minor diameter shall be made larger than the basic minor diameter by an amount equal to 'Z' which shall be obtained from Table 8. The maximum minor diameter shall be determined by the application of the tolerances (given in Table 8) to the modified minimum minor diameter. That is:

Modified min minor diameter = Basic minor dia. + 'Z'

Modified max minor diameter = Modified min. minor dia. + Tolerance.

The basic minor diameter is obtained by subtracting twice the basic depth of thread from the basic major diameter. See Table 7.

Example

Nut $1^1/_4$ in. 12 TPI Whit (Modified 'normal' class)

Basic minor diameter = 1.2500 – (0.0534x2) = 1.2500 – 0.1068 = 1.1432 in.

Modified min minor diameter = 1.1432 + Z = 1.1432 + 0.0150 = 1.1582 in.

Modified max minor diameter = 1.1582 + tol = 1.1582 + 0.0097 = 1.679 in.

The major and effective diameters shall be in accordance with BS 84 Table 19 for a 'normal' class of fit.

NOTE: The modified 'medium' class fits for selected and non-standard threads of Whitworth form are based on a 'medium' class bolt and a 'normal' class nut.

Table 3 Modified Medium Class – BSW Sizes – External Threads

NOMINAL SIZE* (in)	TPI*	MAJOR DIAMETER (in)				EFFECTIVE DIAMETER (in)			
		BASIC*	MAX.	TOL.	MIN.	BASIC*	MAX.	TOL.	MIN.
$^{1}/_{8}$	40	0.1250	0.1230	0.0037	0.1193	0.1090	0.1078	0.0029	0.1049
$^{3}/_{16}$	24	0.1875	0.1852	0.0044	0.1808	0.1608	0.1596	0.0035	0.1561
$^{1}/_{4}$	20	0.2500	0.2475	0.0048	0.2427	0.2180	0.2168	0.0039	0.2129
$^{5}/_{16}$	18	0.3125	0.3097	0.0051	0.3046	0.2769	0.2756	0.0042	0.2714
$^{3}/_{8}$	16	0.3750	0.3719	0.0053	0.3666	0.3350	0.3336	0.0045	0.3291
$^{7}/_{16}$	14	0.4375	0.4342	0.0057	0.4285	0.3918	0.3903	0.0048	0.3855
$^{1}/_{2}$	12	0.5000	0.4964	0.0060	0.4904	0.4466	0.4451	0.0052	0.4399
$^{9}/_{16}$	12	0.5625	0.5589	0.0062	0.5527	0.5091	0.5075	0.0053	0.5022
$^{5}/_{8}$	11	0.6250	0.6211	0.0064	0.6147	0.5668	0.5651	0.0056	0.5595
$^{11}/_{16}$	11	0.6875	0.6836	0.0060	0.6770	0.6293	0.6276	0.0058	0.6218
$^{3}/_{4}$	10	0.7500	0.7458	0.0068	0.7390	0.6860	0.6842	0.0060	0.6782
$^{7}/_{8}$	9	0.8750	0.8706	0.0074	0.8632	0.8039	0.8018	0.0063	0.7955
1	8	1.0000	0.9953	0.0080	0.9873	0.9200	0.9176	0.0066	0.9110
$1^{1}/_{8}$	7	1.1250	1.1201	0.0083	1.1118	1.0335	1.0308	0.0067	1.0241
$1^{1}/_{4}$	7	1.2500	1.2451	0.0086	1.2365	1.1585	0.1558	0.0069	1.1489
$1^{1}/_{2}$	6	1.5000	1.4948	0.0092	1.4856	1.3933	1.3903	0.0071	1.3832
$1^{3}/_{4}$	5	1.7500	1.7445	0.0098	1.7347	1.6219	1.6185	0.0074	1.6111
2	4.5	2.0000	1.9943	0.0104	1.9839	1.8577	1.8540	0.0077	1.8463
$2^{1}/_{4}$	4	2.2500	2.2440	0.0107	2.2333	2.0899	2.0859	0.0080	2.0779
$2^{1}/_{2}$	4	2.5000	2.4940	0.0110	2.4830	2.3399	2.3359	0.0080	2.3279

*Extracted from Table 1 of BS 84:1956

Table 4 Modified Normal Class BSW Sizes – Internal

NOMINAL SIZE* (in)	TPI*	MINOR DIAMETER (in)			
		BASIC*	MAX.	TOL.	MIN.
1/8	40	0.0930	0.1020	0.0040	0.0980
3/16	24	0.1341	0.1474	0.0073	0.1401
¼	20	0.1860	0.2030	0.0100	0.1930
5/16	18	0.2413	0.2594	0.0101	0.2493
3/8	16	0.2950	0.3145	0.0105	0.3040
7/16	14	0.3461	0.3674	0.0113	0.3561
½	12	0.3932	0.4169	0.0127	0.4042
9/16	12	0.4557	0.4794	0.0127	0.4667
5/8	11	0.5086	0.5338	0.0132	0.5206
11/16	11	0.5711	0.5963	0.0132	0.5831
¾	10	0.6220	0.6490	0.0140	0.6350
7/8	9	0.7328	0.7620	0.0152	0.7468
1	8	0.8400	0.8720	0.0170	0.8550
1 1/8	7	0.9420	0.9776	0.0196	0.9580
1 1/4	7	1.0670	1.1026	0.0196	1.0830
1 1/2	6	1.2866	1.3269	0.0233	1.3036
1 3/4	5	1.4938	1.5408	0.0290	1.5118
2	4.5	1.7154	1.7688	0.0324	1.7344
2 1/4	4	1.9298	1.9868	0.0370	1.9498
2 1/2	4	2.1798	2.2368	0.0370	2.1998

*Extracted from Table 1 of BS 84: 1956

Table 5 Modified Medium Class – BSF Sizes – External Threads

NOMINAL SIZE* (in)	TPI*	MAJOR DIAMETER (in)				EFFECTIVE DIAMETER (in)			
		BASIC*	MAX.	TOL.	MIN.	BASIC*	MAX.	TOL.	MIN.
$^{3}/_{16}$	32	0.1875	0.1855	0.0042	0.1813	0.1675	0.1664	0.0033	0.1631
$^{7}/_{32}$	28	0.2188	0.2166	0.0044	0.2122	0.1959	0.1948	0.0036	0.1912
$^{1}/_{4}$	26	0.2500	0.2476	0.0044	0.2432	0.2254	0.2243	0.0037	0.2206
$^{9}/_{32}$	26	0.2812	0.2787	0.0046	0.2741	0.2566	0.2554	0.0039	0.2515
$^{5}/_{16}$	22	0.3125	0.3097	0.0046	0.3051	0.2834	0.2822	0.0041	0.2781
$^{3}/_{8}$	20	0.3750	0.3720	0.0049	0.3671	0.3430	0.3417	0.0044	0.3373
$^{7}/_{16}$	18	0.4375	0.4342	0.0052	0.4290	0.4019	0.4005	0.0047	0.3958
$^{1}/_{2}$	16	0.5000	0.4964	0.0054	0.4910	0.4600	0.4585	0.0050	0.4535
$^{9}/_{16}$	16	0.5625	0.5589	0.0056	0.5533	0.5225	0.5210	0.0052	0.5158
$^{5}/_{8}$	14	0.6250	0.6212	0.0059	0.6153	0.5793	0.5777	0.0054	0.5723
$^{11}/_{16}$	14	0.6875	0.6837	0.0062	0.6775	0.6418	0.6401	0.0056	0.6345
$^{3}/_{4}$	12	0.7500	0.7459	0.0065	0.7394	0.6966	0.6948	0.0059	0.6889
$^{7}/_{8}$	11	0.8750	0.8706	0.0071	0.8635	0.8168	0.8147	0.0062	0.8085
1	10	1.0000	0.9954	0.0077	0.9877	0.9360	0.9336	0.0066	0.9270
$1^{1}/_{8}$	9	1.1250	1.1201	0.0080	1.1121	1.0539	1.0512	0.0068	1.0444
$1^{1}/_{4}$	9	1.2500	1.2451	0.0084	1.2367	1.1789	1.1762	0.0069	1.1693
$1^{3}/_{8}$	8	1.3750	1.3698	0.0086	1.3612	1.2950	1.2920	0.0070	1.2850
$1^{1}/_{2}$	8	1.5000	1.4948	0.0088	1.4860	1.4200	1.4170	0.0071	1.4099
$1^{5}/_{8}$	8	1.6250	1.6198	0.0090	1.6108	1.5450	1.5420	0.0072	1.5348
$1^{3}/_{4}$	7	1.7500	1.7446	0.0093	1.7353	1.6585	1.6551	0.0074	1.6477
2	7	2.0000	1.9946	0.0096	1.9850	1.9085	1.9051	0.0076	1.8975
$2^{1}/_{4}$	6	2.2500	2.2443	0.0098	2.2345	2.1433	2.1396	0.0077	2.1319
$2^{1}/_{2}$	6	2.5000	2.4943	0.0100	2.4843	2.3933	2.3896	0.0078	2.3818
$2^{3}/_{4}$	6	2.7500	2.7443	0.0102	2.7341	2.6433	2.6396	0.0079	2.6317
3	5	3.0000	2.9940	0.0108	2.9832	2.8719	2.8679	0.0083	2.8596

*Extracted from Table 7 of BS 84: 1956

Table 6 Modified Normal Class – BSF Sizes Internal Threads

NOMINAL SIZE* (in)	TPI*	MINOR DIAMETER (in)			
		BASIC*	MAX.	TOL.	MIN.
$^{3}/_{16}$	32	0.1475	0.1577	0.0052	0.1525
$^{7}/_{32}$	28	0.1730	0.1841	0.0052	0.1789
¼	26	0.2008	0.2125	0.0055	0.2070
$^{9}/_{32}$	26	0.2320	0.2437	0.0055	0.2382
$^{5}/_{16}$	22	0.2543	0.2684	0.0061	0.2623
$^{3}/_{8}$	20	0.3110	0.3280	0.0080	0.3200
$^{7}/_{16}$	18	0.3663	0.3844	0.0081	0.3763
½	16	0.4200	0.4395	0.0085	0.4310
$^{9}/_{16}$	16	0.4825	0.5020	0.0085	0.4935
$^{5}/_{8}$	14	0.5336	0.5549	0.0093	0.5456
$^{11}/_{16}$	14	0.5961	0.6174	0.0093	0.6081
¾	12	0.6432	0.6669	0.0107	0.6562
$^{7}/_{8}$	11	0.7586	0.7838	0.0112	0.7726
1	10	0.8720	0.8990	0.0120	0.8870
$1^{1}/_{8}$	9	0.9828	1.0120	0.0132	0.9988
$1^{1}/_{4}$	9	1.1078	1.1370	0.0132	1.1238
$1^{3}/_{8}$	8	1.2150	1.2470	0.0150	1.2320
$1^{1}/_{2}$	8	1.3400	1.3720	0.0150	1.3570
$1^{5}/_{8}$	8	1.4650	1.4970	0.0150	1.4820
$1^{3}/_{4}$	7	1.5670	1.6026	0.0176	1.5850
2	7	1.8170	1.8526	0.0176	1.8350
$2^{1}/_{4}$	6	2.0366	2.0769	0.0213	2.0556
$2^{1}/_{2}$	6	2.2866	2.3269	0.0213	2.3056
$2^{3}/_{4}$	6	2.5366	2.5769	0.0213	2.5556
3	5	2.7438	2.7908	0.0270	2.7638

*Extracted from Table 7 of BS 84: 1956

Table 7 Modified Selected Non-Standard Threads. Whitworth Form – External

TPI	BASIC DEPTH OF THREAD (in)	x* (in)	TOLERANCE ON EFFECTIVE DIAMETER (UNIT OF TOLERANCE = 0.001 in)													y* (in)	TOL. ON MAJOR DIA. (TO BE ADDED TO TOL. ON EFFECTIVE DIA.) (in)
			BASIC MAJOR DIA. (in) {	ABOVE	1/8	1/4	1/2	3/4	1 1/4	2	3	4	6	8	11	15		
				UP TO AND INCLUDING	1/4	1/2	3/4	1 1/4	2	3	4	6	8	11	15	20		
40	0.0160	0.0010			2.7	3.0	3.1	3.4	3.8								0.0020	0.0007
36	0.0178	0.0012			2.7	3.0	3.1	3.4	3.8								0.0022	0.0007
32	0.0200	0.0014			2.8	3.1	3.2	3.5	3.8								0.0025	0.0008
28	0.0229	0.0016			2.8	3.1	3.2	3.5	3.8								0.0028	0.0008
26	0.0246	0.0018			3.1	3.3	3.6	3.8	4.2	4.5							0.0031	0.0008
24	0.0267	0.0020			3.1	3.3	3.6	3.8	4.2	4.5							0.0033	0.0008
20	0.0320	0.0022				3.4	3.7	3.9	4.3	4.6							0.0036	0.0008
18	0.0356	0.0024				3.9	4.1	4.4	4.7	5.0	5.3	5.6					0.0039	0.0010
16	0.0400	0.0026				3.9	4.1	4.4	4.7	5.0	5.3	5.6					0.0041	0.0010
14	0.0457	0.0028					4.7	4.9	5.3	5.6	5.9	6.2					0.0044	0.0013
12	0.0534	0.0030					4.7	4.9	5.3	5.6	5.9	6.2					0.0047	0.0013
11	0.0582	0.0032						5.1	5.3	5.7	6.0	6.3	6.7				0.0049	0.0015
10	0.0640	0.0034						5.1	5.3	5.7	6.0	6.3	6.7				0.0052	0.0015
8	0.0800	0.0036						5.7	6.1	6.3	6.7	7.0	7.3	7.7			0.0055	0.0016
6	0.1067	0.0038							6.9	7.1	7.4	7.7	8.1	8.5	8.9		0.0057	0.0022
4	0.1601	0.0040								8.3	8.5	8.9	9.2	9.6	10.0	10.4	0.0060	0.0030

*See Clause B2 (b)

Table 8 Modified Selected Non-Standard Threads. Whitworth Form – Internal

TPI	MINOR DIAMETER (in)	
	Z*	TOL.
40	0.005	0.0040
36	0.006	0.0040
32	0.007	0.0041
28	0.008	0.0041
26	0.009	0.0043
24	0.010	0.0043
20	0.011	0.0060
18	0.012	0.0075
16	0.013	0.0075
14	0.014	0.0097
12	0.015	0.0097
11	0.016	0.0110
10	0.017	0.0110
8	0.018	0.0140
6	0.019	0.0213
4	0.020	0.0370

*See Clause B2 (f)

APPENDIX C: Galling resistance of stainless steels and alloys

Galling is the tearing of metal surfaces which suddenly renders a component unserviceable. Galling is a major concern in the application of threaded assemblies. A 'button and block' galling test has been developed to rank stainless steels and alloys for their galling tendencies. The tables given in this appendix have been taken from the Nitronic 60 Stainless Steel Bar and Wire (UNS-S21800), Product Data Bulletin 7/2011.

Table 9 Galling resistance of stainless steels

Block material	Condition & Nominal Hardness (Brinell)	----------Button material----------									
		410	416	430	440C	303	304	316	S17400	Nitronic 32	Nitronic 60
Type 410	Hardened & stress relieved (352)	3	4	3	3	4	2	2	3	46	50+
Type 416	Hardened & stress relieved (342)	4	13	3	21	9	24	42	2	45	50+
Type 430	Annealed (159)	3	3	2	2	2	2	2	3	3	36
Type 440C	Hardened & stress relieved (560)	3	21	2	11	5	3	37	3	50+	50+
Type 303	Annealed (153)	4	9	2	5	2	2	2	3	3	50+
Type 304	Annealed (140)	2	24	2	3	2	2	2	2	30	50+
Type 316	Annealed (150)	2	42	2	37	3	2	2	2	3	38
S17400	H 950 (415)	3	2	3	3	2	2	2	2	50+	50+
Nitronic 32	Annealed (235)	46	45	8	50+	50+	30	3	50+	30	50+
Nitronic 60	Annealed (205)	50+	50+	36	50+	50+	50+	38	50+	50+	50

Values shown are unlubricated threshold galling stress (ksi) for the 'button & block' galling test. Condition and hardness apply to both the button and the blank material. Tests were terminated at 50 ksi, so values given as 50+ indicate the samples did not gall.

Table 10 Galling resistance of alloys

Metals in contact					Threshold Galling Stress ksi
Alloy	**Nominal Hardness (Brinell)**		**Alloy**	**Nominal Hardness (Brinell)**	
Silicon Bronze	(200)	vs.	Silicon Bronze	(200)	4
Silicon Bronze	(200)	vs.	Type 304	(140)	44
A286	(270)	vs.	A286	(270)	3
AISI 4337	(484)	vs.	AISI 4337	(415)	2
AISI 1034	(415)	vs.	AISI 1034	(415)	2
Waukesha 88	(141)	vs.	Type 303	(180)	50+
Waukesha 88	(141)	vs.	Type 201	(202)	50+
Waukesha 88	(141)	vs.	Type 316	(200)	50+
Waukesha 88	(141)	vs.	S17400	(405)	50+
Waukesha 88	(141)	vs.	20Cr-80Ni	(180)	50+
Type 201	(202)	vs.	Type 201	(202)	15
Type 201	(202)	vs.	Type 304	(140)	2
Type 201	(202)	vs.	S17400	(382)	2
Type 201	(202)	vs.	Nitronic 32	(231)	36
Type 301	(169)	vs.	Type 416	(342)	3
Type 301	(169)	vs.	Type 440C	(560)	3
Type 410	(322)	vs.	Type 420	(472)	3
Type 416	(342)	vs.	Type 416	(372)	13
Type 416	(372)	vs.	Type 410	(322)	4
Type 416	(342)	vs.	Type 430	(190)	3
Type 416	(342)	vs.	20Cr-80Ni	(180)	7
Type 440C	(560)	vs.	Type 440C	(604)	11
S17400	(311)	vs.	Type 304	(140)	2
S17400	(380)	vs.	Nitronic 32	(401)	13
S17400	(435)	vs.	Type 304	(140)	2
S17400	(400)	vs.	S17700	(400)	3
S17400	(435)	vs.	S17700	(435)	2

Nitronic 32	(235)	vs.	S17400	(380)	11
Nitronic 32	(401)	vs.	Nitronic 32	(401)	34
Nitronic 32	(235)	vs.	Nitronic 32	(401)	34
Nitronic 32	(235)	vs.	Type 304	(140)	7
Nitronic 32	(401)	vs.	Type 304	(140)	13
Nitronic 32	(205)	vs.	AISI 1034	(205)	2
Nitronic 50	(205)	vs.	Nitronic 50	(205)	2
Nitronic 50	(321)	vs.	Nitronic 50	(321)	2
Nitronic 50	(205)	vs.	Nitronic 32	(401)	13
Nitronic 50	(321)	vs.	Nitronic 32	(235)	8
Nitronic 50	(205)	vs.	Type 304	(140)	4
Nitronic 60	(205)	vs.	Type 301	(169)	50+
Nitronic 60	(205)	vs.	Type 420	(472)	50+
Nitronic 60	(213)	vs.	S17400	(313)	50+
Nitronic 60	(205)	vs.	S17400	(332)	50+
Nitronic 60	(205)	vs.	Nitronic 50	(205)	50+
Nitronic 60	(205)	vs.	S13800	(297)	50+
Nitronic 60	(205)	vs.	S13800	(437)	50+
Nitronic 60	(205)	vs.	AISI 4337	(448)	50+
Nitronic 60	(205)	vs.	Stellite 6B	(415)	50+
Nitronic 60	(205)	vs.	A286	(270)	49
Nitronic 60	(205)	vs.	20Cr-80Ni	(180)	36
Nitronic 60	(205)	vs.	Ti-Al-4V	(332)	50+

Values shown are unlubricated threshold galling stress (ksi) for the ‘button & block’ galling test. Values given as 50+ indicate that the samples did not gall.