

Reliability is a crucial issue among defense industry suppliers. Product failures in defense-related applications can be critical and sub-standard parts performance cannot be tolerated. MS (Military Standard) and NAS (National Aerospace Standard) fasteners are specified in defense-related uses to assure high reliability. Comprehensive and detailed requirements for MS and NAS socket screw products have been set forth and compliance with these specifications helps assure superior parts performance. Unfortunately, sub-standard fasteners represented as MS and NAS

Assuring compliance with the relevant specifications for MS and NAS parts is, of course, a concern of conscientious designers, procurers, manufacturers, end users and vendors. However, ignorance, confusion, laxity, even disregard have all played a part in the rise in the number of parts which do not meet standards. Price sensitivity, delivery pressures and government sourcing constraints have also been factors. The results have been part failures, lower safety standards, downtime, repair expenses, extra manhour costs and overruns.

How then can procurement groups and designers help assure they are sourcing parts which meet MS and NAS specifications? Specific steps such as requiring parts certification and setting up incoming quality control inspections can help.

An important first step for all concerned parties though, is full understanding of all the MS and NAS standards and associated specifications, and the problems that can result when sub-standard parts are introduced into full production schemes.

Specifications The procurement specification for both MS socket head cap screws and NAS socket head cap screws is FF-S-86. Federal Specification QQ-P-416 (cadmium plating) and ANSI B18.3 (socket cap, shoulder and set screws) also form a part of this specification. Within these documents other specifications are referenced. General topics dealt with under the specification include material, mechanical properties, dimensions, tolerances, plating, carburization/decarburization limitations, discontinuity limitations, hydrogen deembrittlement, quality assurance and testing. These requirements are detailed and explicit and, when met, provide for high reliability in fasteners.

One significant problem with parts which are represented as MS or NAS fasteners, but are not, is that suppliers fail to recognize or adhere to the secondary specifications, such as QQ-P-416 (when plating is required), or even the basic dimensional requirements of the American National Standards Institute (ANSI B18.3).

Manufacturing Stringent control of all manufacturing processes is critical to the production of fasteners that meet specifications. Doubtless, certain manufacturing practices produce better products than others. Properly forged heads and rolled threads produce the strongest, most reliable fasteners. Forging forms the metal and actually makes the heads stronger. Machined heads and cut or ground threads are less satisfactory. Machining—actually cutting the metal—weakens fasteners, inviting fatigue failure.

Design is another important element in meeting specifications. Heads must be designed with proper bearing area, proper upset and controlled fillet radius. Socket depth must conform to dimensional requirements in order to develop proper tightening characteristics.

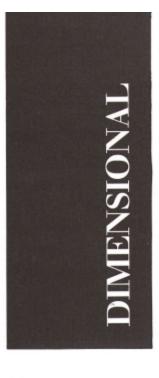
Proper selection of material, proper heat treating, control of critical plating procedures and well-equipped quality control and testing facilities are all important, too.

Failure to properly control any of these and other manufacturing processes can allow fastener products, which do not meet specifications, to get into the MS or NAS systems. These low quality fasteners can lead to premature failures and attendant problems in the field.



## Fasteners that don't meet MS & NAS Specifications THE CAUSES...THE EFFECTS

Generally, specification related problems can be classed in one of four basic areas: dimensional, mechanical/physical, plating and quality assurance. Presented here are discussions of the various problems and typical examples.





Problem Areas
Socket size causes
inadequate key engagement
Excessive socket depth, which
reduces material in the head,
may lower screw strength
Undersize threads can lead
to stripping
Undersize fillet may
promote stress failure
Poorly formed thread runout
may cause fatigue failure

All MS and NAS socket screw products must conform to the dimensional requirements of ANSI B18.3. This is the overall inch standard for socket screw products and keys. These fundamental requirements deal with body and head diameter, head height, head side height, socket width, fillet radius, wall thickness, key engagement, chamfer and basic thread length. Some products in the marketplace do not meet even these basic requirements.

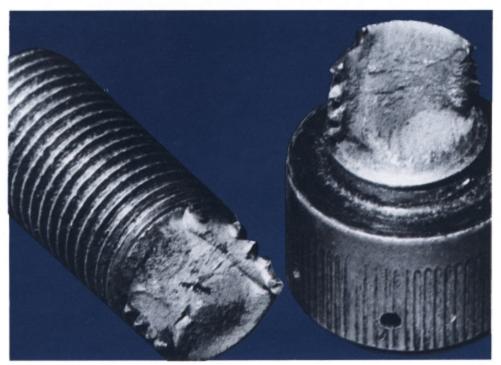
Socket width (across flats) is one problem area. When the width is excessive, poor key engagement will result and reaming may occur. If the across flat dimension is too narrow, the key may not engage at all.

(MS 24678) Excessive socket depth caused

premature fatigue failure in this part. Full screw strength was not achieved because the socket depth exceeded the maximum allowed and the wall thickness between the bottom of the socket and the head bearing surface was inadequate. When socket depth is under minimum requirements, limited key engagement can prevent maximum tightening and reduce load carrying capacity. Limited key engagement in this case can also lead to screw failure at low wrenching torques.

Undersize threads can cause thread stripping. Insufficient material in the screw blank or improper adjustment of the thread dies are two possible causes. Close control of the thread blank size and proper adjustment of dies will allow production of threads to dimensional and tolerance specification.





- 2. (MS 24678) This fastener failed prematurely because of a high stress concentration in the fillet area. An undersize fillet and machining marks were the cause. Fillets must be smooth and within the minimum/maximum dimensions of ANSI B18.3.
- 5. (MS 24678) A poorly formed thread runout (last thread) caused this fastener to fail in fatigue. When a thread runout is not properly radiused, a high stress concentration is created and premature fatigue failures can occur.



The procurement specification requires that fasteners exhibit specific strength and hardness properties. Material choice, heat treatment practices, hardenability and carburization/decarburization limitations all play a part in achieving these mechanical properties.

Of course, you have to start with the right material. Specifications call for heat-treatable alloy steel, corrosion-resisting steel or specific non-ferrous materials. Any material deviation is obviously unacceptable and could result in parts failure.

Parts are heat treated to develop the desired strength and hardness levels. Poor heat treatment practices can result in an inferior product. Furnance atmospheres must be controlled to prevent carburization and decarburization; close temperature control is required to prevent detrimental microstructural changes; and the proper quenching medium must be used to prevent cracking and ensure through-hardening.

Problem Areas
Improper material selection
lowers part quality, causes
inconsistent hardness range
Poor control of heat treating
operation lowers tensile
strength values
Carburization reduces
fatigue life, increases
likelihood of hydrogen
embrittlement
Decarburization degrades
strength and performance of
fastener

The ability of a part to be through-hardened upon quenching also depends on the hardenability of the alloy steel selected, which is a function of chemical composition. Improper alloy selection can result in undesirable hardness variations within the part.

Carburization is an increase in surface carbon content, which makes the surface harder than the core. Carburized fasteners tend to exhibit reduced fatigue performance, are less able to withstand bending stresses and are more susceptible to environmentally-assisted failure (i.e., stress corrosion cracking and hydrogen embrittlement).

If a part is to be plated, carburization can increase susceptibility of the part to hydrogen embritlement.

Decarburization is a decrease in surface carbon content, which makes the surface softer than the core. Decarburized fasteners tend to exhibit reduced fatigue performance.

Fasteners supplied per MS and NAS requirements must meet specific carburization and decarburization limits. In short, FF-S-86 requires that there be no evidence of carburization or total decarburization on the thread surface.

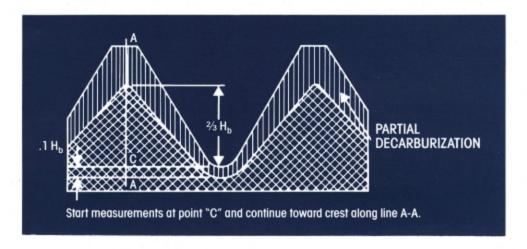
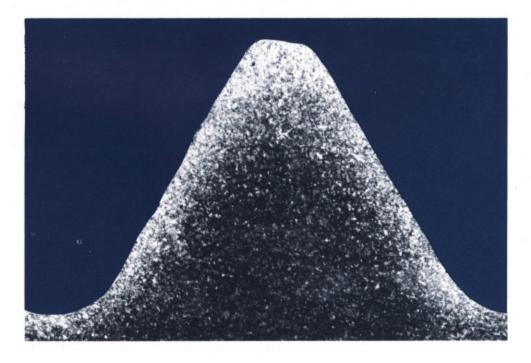


Figure 1
Definition of Partial Decarburization Limits
(Federal Specification, FF-S-86, screw, cap, socket head)





Poor plating practice is one of the major reasons fasteners fail to satisfy MS and NAS specification requirements. To avoid problems, responsible manufacturers should observe the procedures detailed in the specification: proper cleaning practices, stress relief, plating thickness requirements, hydrogen embrittlement relief, certification and rigorous quality assurance. Failure to carefully monitor any of these criteria can result in hydrogen embrittlement problems, out-of-tolerance thread dimensions, uneven plating thickness or inadequate corrosion resistance.

**Hydrogen Embrittlement** Classic hydrogen embrittlement is the phenomenon whereby the atomic hydrogen present in a metal under load: 1. Diffuses over a period of time to the points of highest stress. 2. Segregates to interfaces (i.e. boundaries). 3. Promotes discrete crack growth until the cross-sectional area of the metal is sufficiently reduced for overstress failure to ensue. Theorists still do not agree on how the hydrogen interacts with the metal to start

cracks, and many models have been developed to explain the mechanism. The result, however, is still all too familiar: delayed failure with no advance warning!

**Problem Areas** 

Cold work without stress relief, heavy chemical cleaning and improper control of plating or baking processes can cause hydrogen embrittlement and delayed fracture failures Plating of off-the-shelf parts can result in unacceptable plating thickness "Flash" plating of off-the-shelf fasteners can reduce corrosion resistance

Hydrogen embrittlement is a serious concern with fasteners supplied to MS/NAS specification because their higher tensile strengths make them more susceptible to this phenomenon. Preventive measures rely on the use of plating practices that minimize the potential for hydrogen pick-up. The various procedures outlined in the specification must be stringently controlled by the manufacturer/plater. An attendant problem in this area is related to the fact that many parts are plated by sub-contractors. Failure to recognize and communicate critical parts information to the plater can lead to serious problems.

Cold work (machining, grinding, cold forming and cold straightening) which follows heat

treating can cause residual surface tensile stresses which may promote hydrogen embrittlement. Cold worked parts must undergo a stress relief operation before plating. Stress relief is required under QQ-P-416.

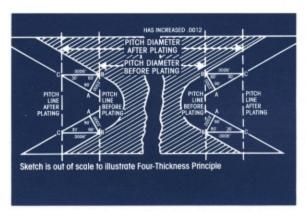
Heavy acid cleaning to remove heat treat scale and foreign matter can add large amounts of hydrogen to the parts and encourage hydrogen embrittlement. Cleaning methods must be controlled according to type and material of fastener. Aggressive acid solutions should be avoided.

Obviously, the plating procedure itself requires meticulous care to produce quality plated fasteners. Proper procedures for each strength level fastener must be followed and plating bath chemistries should be frequently monitored to assure they are maintained within process limits.

The MS/NAS specification requires alloy steel cap screws be baked to minimize the embrittlement potential that results from the plating process. Specifications call for a four hour bake at  $375 \pm 25^{\circ} F$  within four hours of plating. Some suggest that the "four hours within four hours" requirement is insufficient to achieve total deembrittlement. To help assure the problem is avoided, some users have added special requirements to their purchase orders, specifying a 23 hour bake within one hour of plating.

MS and NAS coated alloy steel screws must be furnished with certification of hydrogen embrittlement relief treatment and, when specified, must be subjected to a stress durability test. Manufacturers and sub-contracted platers often are not equipped to perform this and other important testing (such as magnetic particle inspection).

 (MS 24678) Any deviation from the exacting standards required for proper cleaning, plating, deembrittlement and testing can result in failures such as this.



Plating Thickness Plating thickness seems simple enough. However, because of the thread configuration, a screw's pitch diameter is increased by four times the plating thickness (see diagram, fig. 2). To maintain the pitch diameter within specified limits, part tolerances must be tighter to allow for the extra thickness added by plating. If off-the-shelf fasteners are supplied for plating, statistical analysis shows that, on average, 16% of the plated screws will be oversize. Only by making the fasteners properly undersize will 100% of the finished plated surface parts fall within tolerance.

Due to delivery pressures and other constraints, *off-the-shelf* fasteners are often "flash" plated to avoid the pitch diameter thickness problem. This short-cut can result in reduced corrosion resistance.

Carelessness in the plating procedure can also lead to uneven plating thickness and inadequate protection against corrosion. Poor control of the plating current can cause a too-rapid deposit of plating and an uneven build-up on the threads. The plating thickness will tend to be greater on the crests, meeting gage limits, but the deposit on the flanks and roots of threads may be too thin to provide the necessary protection. Again, it can be seen that proper control of the process is all-important in producing fasteners to specification.





## Problem Areas Flawed parts reach users because of lax quality control Breakdowns in process control can result in defective fasteners

Comprehensive quality assurance procedures are obvious prerequisites in the manufacture of MS and NAS fasteners. Specific and thorough testing is required under the procurement specification and it would be virtually impossible to maintain the high standards required with these products without such controls.

Under the specification requirements, lot sampling must be performed for defects, mechanical and metallographic properties and

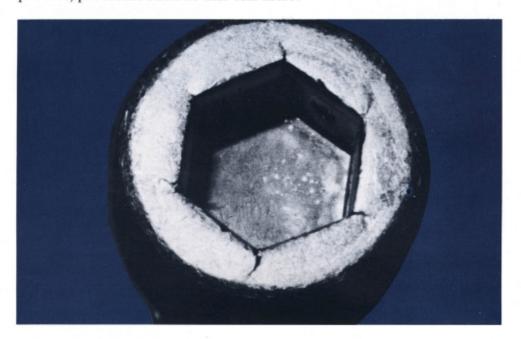
protective coatings. Specific test procedures and quality standards must be adhered to for MS and NAS fasteners. Testing must be performed by the manufacturer or an independent facility.

Surprisingly enough, even the simplest inspections often are not performed. Many parts with so-called discontinuities unacceptable under the standards find their way into the MS and NAS systems when a close final inspection by the manufacturer would certainly have screened out the defective parts.

Here are two examples of discontinuities (laps, seams, cracks and other surface defects).

 Parts from this lot failed in fatigue. Thread laps below the pitch diameter may be caused by broken, chipped or misaligned dies. The discontinuities are in an area of the screw thread that is the most critical and most highly stressed area of the fastener in dynamic applications. 2. **(MS 24678)** These forging cracks were caused by poor manufacturing practices. Their location is in an area of the head that is unacceptable under the requirements of FF-S-86 and may cause the socket to split under the stress of installation.

Process control is another important aspect of quality assurance. Without careful monitoring at every step of the manufacturing process, problems such as this can arise:



5. (MS 24678) This socket reamed at well below the recommended seating torque. To facilitate cross drilling the lockwire hole, the screw was annealed after the heat treatment procedure. However, the part was never re-heat treated. Cross drilling must always be performed either before heat treatment or in the heat treated condition.





## Conclusion

The complexity of producing fasteners to the MS/NAS specification demands absolute control of each process throughout the manufacturing system. The consequence of a breakdown in any area could be part failures and serious losses.

Proper quality assurance standards should substantially reduce the number of flawed parts. But a higher assurance of quality results from a statistical process control observed in manufacturing systems which encompass all the necessary facilities to produce fasteners "in-house"—from design to the finished part. This provides certifiable control of the quality of each lot of fasteners at every phase of manufacture. SPS Technologies has such a comprehensive "in-house" system.

## **Specifications**

FF-S-86	Federal Specification, screw, cap, socket head (Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402)
ANSI B18.3	Socket cap, shoulder and set screws (American National Standards Institute, 1430 Broadway, New York, NY 10018)
QQ-P-416	Federal Specification, plating, cadmium
	(electrodeposited) (Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402)



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