American Gas Association

Engineering Technical Note

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THREADED FASTENERS TORQUING

This Technical Note, prepared by a task group of the A.G.A. Operating Section's Compressor Committee, is for reference purposes only and is not intended to be a substitute, in any area, for published standards or specifications.

Proper selection, installation and maintenance of threaded fasteners used to secure gas compressors and engines are critical to maintaining continuous, safe operation of that equipment.

This Technical Note reflects the experience of industry engineers as good practice in the installation, tightening, lubrication, inspection, and preventive maintenance of threaded fasteners.

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developed by the

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INTRODUCTION

This Technical Note for installation and maintenance of threaded fasteners was prepared by a task group under the sponsorship of the Compressor Committee of the American Gas Association.

SCOPE

This Technical Note provides procedures for selecting and using threated fasteners in natural gas pipeline service.

It is not intended to substitute for any standard or specification, but has been prepared to provide a reference for selection of tools and proper torquing methods.

A Glossary of Terms is included at the back of this Technical Note.

INSTALLATION AND MAINTENANCE OF BOLTS, STUDS AND NUTS

Proper maintenance of threaded fasteners (bolts and studs) is extremely important. Any abuse may cause costly breakdowns and unsafe operating conditions. Proper maintenance depends on using correct fastener material, on periodic inspection, and on correct tightening of the fasteners. The following guidelines have been developed to cover installation and maintenance of fasteners.

All threaded fasteners included in the gas containment bolting of gas compressors (i.e., head bolting, suction and discharge flange bolting, valve cap studs, and unloader bottle studs), compressor unit power train bolting, and flywheel bolts are considered to be in critical service.

All threaded fasteners have tightening specifications based on specific prestress levels selected to prevent the fasteners from cycling and failing due to fatigue. To achieve these prestress levels, critical bolting should be tightened only to proper torque values, as specified by the engine and compressor manufacturers.

Any critical fastener material not matching manufacturer's material specifications should be replaced as soon as possible. Fasteners without identification markings should not be used in critical applications. Critical fasteners should be ordered from the compressor manufacturer or designed to meet the manufacturer's specifications, including proper material grade with corresponding code marking.

Nuts, bolts, and threads must be clean and free of burrs before assembly. Mating surfaces must also be clean and properly aligned. Small burrs on the flat, bottom surface of the nut and in the threads will absorb an unusual amount of torque, which leaves the fastener with a low prestress level. Particular care must be used during assembly of heavy parts not to damage the threads. Nuts which can be turned by hand on the threads are considered to be in proper condition for final tightening.

Unusually high prestress levels can be expected by not "sequence tightening" multiple fasteners. Tightness on each stud or bolt should be increased in small increments following a progressive crisscross patern (sequence tightening) until the final torque value is attained at all points. If one side is tightened before the other, it is possible to greatly overstress the fasteners and deform gaskets. Gradual crisscross tightening is the proper method.

New or well-annealed gaskets should be used to insure a good seal without excessive tightening. Bolted assemblies should not be tightened under pressure. Never "tighten down" a leaking gasket in an assembly that is properly torqued. The assembly should be taken apart and inspected for the cause of the leak and a new gasket installed on reassembly.

Stud bolts should be inserted and removed with care. Care must also be taken to insure that the stud bolt nut is installed properly against the lock washer, if specified. The removal of stud bolts with pipe wrenches is not recommended. Proper stud bolt removal and installation procedures should be utilized.

The integrity of all critical fasteners should be verified periodically. Non-Destructive Evaluation (NDE) techniques may be used for this inspection. Other bolting should be inspected during overhauls. Studs, bolts, and nuts (together with the assembly washers and gaskets) that have been overtorqued should be replaced. New or spare fasteners should be inspected before use in critical applications.

TIGHTENING METHODS

There are several acceptable methods of tightening the nuts on compressor bolts and studs, but a torque wrench is the most widely used. A properly calibrated torque wrench is essential to obtain satisfactory results. It is recommended that torque wrenches be recalibrated after extensive use, or at least once each calendar year. Calibration services are available from torque wrench manufacturers.

Selecting the proper size and range of torque wrench is important in obtaining accurate results. There are several considerations involved in selecting a torque wrench for a particular application. A good rule of thumb is to select a torque wrench having adequate capacity so that the working range is within the mid two-quarters of the scale. For example, if a 600-inch pound capacity torque wrench is selected, any application within 150 to 450-inch pounds is in the best working range.

Signaling-type torque wrenches incorporate a mechanism that warns the operator the moment a preset torque is reached. The Sensory Signaling Mechanism, part of every S-model torque wrench, functions independently of the measuring element. The Sensory Mechanism first sounds a distinct click, then imparts a strong definite impulse to the hand the instant the preset desired torque is applied. The results can then be read by sight. Therefore, through three senses - sound, feel, and sight - or through any one of the sensory impulses, the operator is made aware that the required torque has been reached and the "pull" on the torque wrench may be released.

Geared-head wrenches (torque multipliers) will not produce full mechanical advantage from the reduction gears. There are mechanical and frictional losses in the tool head. The tool manufacturer's instructions should be observed to determine the exact torque loss percentage for a particular torque multiplier device. The required input torque must then be increased by that amount.

Because the use of manual torque wrenches is generally limited to torques under 800 ft. lbs., use of hydraulic torquing systems has increased. Hydraulic systems are accurate and precise if maintained properly, and are well adapted for use in confined spaces.

Two methods used in hydraulic systems are nut tightening and stud tensioning. In the first, hydraulic force is applied to the nut through a ratchet drive until the torque set on the control module is achieved. In the second method, the stud is stretched hydraulically to the desired elongation as the nut is tightened to the flange surface. Both the torquing and tensioning systems advertise accurate repeatability over long periods of use and can be equally useful during disassembly.

Impact wrenches should not be used to tighten fasteners in critical applications. They may only be used to loosen nuts.

LUBRICATION OF FASTENERS

Fasteners used in engines and compressors must be tightened to the design preload to insure safe and efficient operation of the equipment. Torque values are given for clean threads, free of nicks or burrs, and for clean nut faces and flange surfaces where they contact each other.

Torque wrenches can produce unpredictable fastener preload variations, depending on the degree of lubrication or nonlubrication and the condition of seating surfaces and threads.

The use of molybdenum disulfide lubricants and similar products having extremely high antifriction properties can result in fastener overload when specified torques are applied. Manufacturer's recommendation should always be followed in selection and use of fastener lubricants, particularly in critical fastener applications. No lubricant should be used unless specified by the engine-compressor manufacturer.

A plate attached to each compressor unit, indicating the proper torque values and lubricants for critical fasteners, provides an easy and correct reference.

PREVENTIVE MAINTENANCE

Failures and potential sources of failure have been discovered in many critical fasteners on engine-driven compressors. These include compressor and power-end connecting rod bolts, compressor valve cap studs, compressor head studs, compressor rods, counterweight and flywheel bolts.

Many companies have included Non-Destructive Evaluation (NDE) programs in their torquing procedures. These programs include use of liquid penetrant, magnetic particle, Eddy current, ultrasonic and radiographic testing. Some companies inspect and record the integrity of critical bolting on a regular basis (such as at the end of each season or every 8000 operating hours.)

NDE programs using ultrasonic flaw-detection equipment have developed various methods for identifying fatigue cracks. Some use studs with known cracks for reference standards. Some cut a calibrated notch in each type of stud or bolt with different threads which is to be inspected. The notches are cut in critical stress areas at the base of the nut and the first exposed thread on a bolt or stud. This allows the technician to calibrate his instrument so that the results of the test are more reliable.

For best ultrasonic test results, stud ends should be flat and parallel. While this is not always possible, it is necessary that exposed ends of valve cover, unloader and compressor and power cylinder head studs be completely free of paint and smooth for ultrasonic inspection.

GLOSSARY OF TERMS

This section lists the explanations or definitions of some of the most frequently used terms that apply to fasteners:

I. Forces that Act on Fasteners

Bend:
Force that tends to change the center line from anything other than a straight line.

Elongation:
The increase in length, expressed as a percent of the original length, of a piece of steel that has been stretched past its yield point. Elongation and Reduction of Area are encountered in compressor fasteners that have been used improperly.

Reduction of Area:
The loss of cross-sectional area, expressed as a percent of original area, that occurs when steel has been stretched past its yield point.

Rockwell Hardness Test:
A method of determining the hardness of metal by measuring the depth of penetration a point or penetrator makes into the metal after a precisely controlled blow has been struck on the penetrator. For heat-treated steel, a cone-shaped diamond point is used, and the Rockwell Hardness value is expressed as G-scale. For soft metals, a one-sixteenth inch diameter steel ball is used as a penetrator.

Shear:
Force exerted perpendicular to the center line or axis of the bolt that tends to cut the bolt into two or more pieces.

Shear Strength:
The amount of stress, expressed in pounds per square inch (PSI), required to shear the bolt into two pieces. This is referred to as single shear strength and generally has a value of about 65 percent of the tensile strength. Double shear, where shearing forces are applied at two points along the shank of the bolt, would cut the bolt into three pieces. Double shear strength is generally about 175 percent of the tensile strength.

Stress Area:
The cross-sectional area of metal that would be exposed if a piece of threaded end of the fastener were cut off perpendicular to the center line. The threaded portion of a fastener is not as strong as the full size shank because of the spiral notch that forms the threads. Threads are not considered in measurement of the fastener area. The diameter that is used to compute the stress area is the root diameter of the threaded section.

Tensile Strength:
The stress, usually expressed in pounds per square inch (PSI), required to cause failure in tension (stretch). The tensile strength, in pounds, of a given bolt is obtained by multiplying the PSI tensile strength by the stress area. (see Stress Area)

Tension: (Prestress)
Force that is applied along the center line of a bolt that stretches it.

Torque:
The amount of twisting force, expressed in inch-pounds or foot-pounds, applied to the nut, when a nut is used, or applied to the head of a cap screw (threaded into a tapped hole.) Twelve inch pounds or one foot pound of torque would be created by exerting a one pound pull on a point of a wrench handle exactly 12 inches from the center line of a bolt.

Torsion:
The twisting force that is applied to the shank of a bolt or to the threads of a bolt or stud, when the fastener is being tightened.

Yield Strength:
The stress, usually expressed in PSI, that is necessary to stretch the fastener to the point where, after the load is removed, the fastener will not return to its previous length. Generally, when steel is stretched over two tenths of one percent (.2%) of its original length, a permanent set will occur. Yield strength is also called Yield Point.

II. Fastener Characteristics

Fillet:
The small radius or curve between the side of the shank and the washer face, under the head, of a bolt. This fillet reduces the concentration of stresses a sharp corner would create where the head and the shank of the bolt meet.

Major Diameter:
The diametrical distance across the crest or top of the threads on a bolt. This would be the same as the inside diameter of a tube that would slip snugly over the threads.

Minor Diameter:
The diametrical distance across the base or root of the threads of a bolt. If the threads were carefully removed on a lathe, the remaining diameter would be the Minor Diameter.

Pitch:
The number of threads in one inch of the threaded length of a fastener expressed as threads per inch (TPI). The thread pitch is the distance that a nut would advance on a bolt when turned one full turn.

Point:
The chamfer of the threaded end of a bolt that permits easier starting of the nut.

Root:
The deepest point of the V-notch that forms the groove of a thread.

Thread Length:
Thread length is the length of the threaded part of the fastener. Thread length shall be in accordance with manufacturer's specifications so that prestress-stretch ratio will not be changed.

UNC:
Unified National Coarse Thread series previously known as USS.

UNF:
Unified National Fine Thread series previously known as SAE.

III. Other Terms

Critical Service:
Bolts subjected to cyclic loading shock and sudden changes in load on an engine driven compressor are considered to be in critical service.

Sequence Tightening:
Increasing the tightness on each stud or bolt in small increments following a prescribed criss-cross pattern.

Torque Multiplier:
A device utilizing a gear train which multiplies the output from a torque wrench. Part of the input torque will be lost because of diminishing mechanical efficiency of the multiplier as torque input is increased.