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COMDTPUB P16700.4

9 OCTOBER 2001

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 7 01

Subj: PROCEDURES FOR HULL INSPECTION AND REPAIR ON VESSELS BUILT OF RIVETED CONSTRUCTION

Ref: (a) Navigation and Inspection Circular (NVIC) 7-68, Notes on Inspection and Repair Of Steel Hulls
(b) Navigation and Inspection Circular (NVIC) 3-68, Tensile Fasteners

1. PURPOSE. Several recent riveted vessel repair jobs have highlighted a shortage of good information generally available on rivet repairs. This circular is intended to provide marine inspectors, surveyors and vessel owner/operators with best practice guidance to use while conducting inspections on older, riveted hull, steel vessels.

2. ACTION. Officers in Charge, Marine Inspection, should help ensure widest dissemination of this information. Coast Guard inspectors and U. S. vessel owners/operators are encouraged to use the guidance found in this NVIC to assist them in conducting inspections and repairs on vessels built using riveted construction.

3. DIRECTIVES AFFECTED. None.

4. DISCUSSION. The need to inspect a riveted hull vessel is an infrequent event for most marine inspectors. However, some riveted hull vessels remain a part of the operational U.S. fleet and need to be examined and repaired. Repairs to rivets or riveted plates should follow the guidelines offered in enclosures (1) and (2). These guidelines will assist in producing

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*NON-STANDARD DISTRIBUTION: B:a G-MOC, G-MO-1, G-MSE, MSC (1) results that are acceptable to the Coast Guard. Many shipyards have very limited capability to conduct adequate rivet repairs. In addition, costs have become relatively high to repair a riveted hull vessel. This leads some vessel operators to conduct improper repairs. Improper repairs, such as, drilling plates and injecting epoxy between these plates will not be accepted.

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Encl: (1) Riveted Hull Repair and Replacement Procedures
(2) Drawings of cross section examples of rivet deterioration

Riveted Hull Repair and Replacement Procedures

1. Summary. This enclosure will provide the marine inspector and vessel operator with the basic principles of inspecting, repairing and replacing rivets and shell plating on vessels built using riveted construction. The American Bureau of Shipping (ABS) Rules for Steel Vessels should be applied when considering rivet diameter, rivet spacing and plate thickness, etc. The ABS rules concerning rivets are found in ABS publications published prior to 1969 and may not be readily available. However, vessels with riveted hulls typically have a long history of inspection and repair. This history will provide the marine inspector and vessel operator with the necessary rivet dimensions needed to conduct repairs. Material test requirements for rivet steel should comply with the standards of section 25 of the 1969 ABS rules. However, as a rule, repairs and replacement rivets should meet the same standards and dimensions as the existing rivets.

2. Pre-inspection Procedures. When a riveted vessel arrives in port for a credit drydock exam, the first order of business is to examine the underwater body. In some cases on vessels operating in salt water service, the rivets have been coated with a "mastic", or epoxy coating used to protect the rivets from further wastage and wear. This presents a possible problem because this coating can hide known and unknown problems. The inspector should ask the owner's representative the following questions about a coating that covers up rivets:

(1) When was the mastic applied,
(2) Where was the mastic applied,
(3) Were the rivets closely examined prior to the application of the mastic,
(4) Who conducted the close-up examination,
(5) Was a USCG Inspector present for the close-up examination,
(6) Was ABS present during the close-up examination, and
(7) Was this examination documented by the USCG or ABS.

Without documentary evidence under item (7), a close-up exam of the rivets is required and the coating shall be removed. The OCMI may consider alternatives, equivalents or rivet sample testing in selected areas in lieu of removing all of the coating.

3. Rivet and Joint Standards. The ABS Rules for Classification and Construction of Steel Vessels (1862-1969) section 25, contains the standards for rivets and joints. The information is provided in a series of tables. For example, table 25.1 provides the minimum breadth of plating overlap for seams, lapped butts and butt straps. The table also provides the required rivet diameter based upon plate thickness. Standard rivet sizes range from ½ inch to 1 ¼ inches in diameter. The rivet must be made of ductile steel that meets the required testing standards. By physical test, the shank must be able to sustain doubling together cold without fracture. The head must not fracture when flattened hot to 2 ½ times shank diameter.

4. Plate and Joint Preparation. Joint preparation, which precedes the actual riveting operation, is very important and will greatly effect the workmanship of joints and seams. Rivet holes will be either drilled or punched and reamed.

DRILLING

Drilling in place – using the holes in the other plate or member as a guide – gives a well-aligned, accurate hole and should be used for heavy, critically stressed joints. With equipment available today, such as magnetic locking devices, it is no longer a problem to drill directly perpendicular into a plate and thus preventing an oblong hole due to inconstant drilling angles. Drilling is the most common method of plate preparation, and must be used if plate thickness is 7/8" or greater.

PUNCHING AND REAMING

Punching involves using a pneumatic or hydraulic punch to make a hole in the plate. Punching cold works the steel around the hole (reducing the strength of the steel immediate to the hole by 10-15%) and results in microscopic cracks which might be the source of major cracking under heavy stress. Reaming to 1/8 inch larger than punched diameter will remove this metal. Reaming also removes distortion caused by the punching operation and any misalignment between punched holes. If the misalignment approaches 1/4 of the diameter of the hole, it is apparent that a 1/8" increased ream will not fair a substantial hole; further the rivet is now angled and may not perform as expected. The alternative to such a condition is an oversized hole and rivet, where allowable, or filling the hole with weldment and redrilling. Punching a long, heavy member – a gunwale angle, for example – will result in an actual lengthening of the member and subsequent mismatch of holes; drilling is best for such a situation.

BOLTING UP

The drilled or punched plate is carefully bolted in place with temporary steel bolts about 1/8" undersized. The number of bolts can vary from every other hole to one in four dependent upon plate thickness (i.e. stiffness and rivet spacing), location, and fit-up. Too many bolts may induce a "spring" when released prior to riveting, whereas too few may not bring surfaces into adequate contact. For critically stressed members, a bolt in every hole is recommended. Faying surfaces, the area where 2 plates come into contact, must be bolted and held in tight contact to prevent inclusion of metal chips and shavings lodging between the surfaces during reaming or drilling. Some technical papers favor unpainted faying surfaces for optimum frictional contact, although custom favors a thin coating of preservative. Care must be taken to ensure dirt is not introduced into the joint with the paint. Good faying surface contact should be little problem with flat plate, but considerable heating and mauling may be needed for shaped plates. Once the two plates are bolted up, the holes are then reamed to size (1/32" to 1/16" larger than nominal rivet diameter) and countersunk. This countersink must be deep enough or the finished point will be inadequate in holding strength.

LINERS, STOPWATERS, AND INSERTS

Steel liners, placed before riveting, will be necessary to fill out the aperture left between framing and strakes, and plate overlaps. The plating system (in and out, cylinder, or flush) determines whether tapered or parallel liners are needed. ABS Rules establish liner dimensional requirements.

Stopwaters (soft packing) are needed to maintain oil tightness and watertightness between compartments. They break the flow where an uncalked edge passes through a calked surface (e.g. internal shell seam and watertight bulkhead. Liquid may flow unobstructed along the seam and cross the calked structure). A line of welding sometimes serves as a stopwater in lieu of the soft packing material.

A steel insert is generally used where the lap portion of a welded butt overlaps a riveted seam. To prevent welding through the butt root opening into the underlying plate, it is common practice to slip a 16 gauge steel sheet between the surfaces.

5. Riveting Operation. Rivet installation usually consists of a 5 person operation consisting of the heater, 2 passers, the bucker and the driver. The heater heats the rivet to the proper temperature and gives the rivet to the outside passer. The outside passer takes the hot rivet and passes it though a small hole in the shell plate to the inside passer. The inside passer puts the hot rivet in the rivet hole. The bucker then braces the rivet head with a pneumatic hammer. The bucker is responsible for keeping the rivet tight to the shell plate and making sure the rivet head is not deformed during driving. The driver then uses a pneumatic hammer with a concave die to form the rivet point and fill the countersink. A competent rivet team can install a rivet approximately every 3 seconds.

6. Caulking. Caulking involves forcing an edge of the outside, overlapping plate tight against the inside plate to form a watertight seal on the lap joint. Essentially, a ledge or shoulder is made on the lower part of the edge of the outside plate. A pneumatic hammer with a special die is used to create the crease in the plate edge that forms the shoulder. This shoulder is then forced down and wedged into the faying surface using the same tool. The caulked joint is then examined to make sure that the joint is tight and that in the process of caulking, the lower plate was not cut or unduly scarred.

7. Inspecting and Testing of New Rivets. A visual examination of each new rivet should be conducted. Rivet heads should not be cracked or unduly malformed and they should be closely seated against the plate surface. Rivet points should completely fill the countersink and shapes should not be unduly eccentric. The degree of "crown" to the point will vary with customer dictates. A slight crown is normally desired for main deck and shell work because it provides some hedge against corrosion and wear-down losses. Also, if the point's diameter exceeds the countersink, the rivet will have a tendency to leak. The plate around rivet points should be examined to ensure it has not been unduly and consistently scarred during driving.

Each rivet should be tested for tightness by placing the thumb against one side of the rivet head, forefinger of the same hand on the plate, and tapping the opposite side of the head with a light sounding hammer. The vibration felt will tell whether the rivet is tight, slack but not requiring replacement, or so slack as to require a new rivet. Loose rivets, that vibrate or ring upon sounding, should be replaced. A slight vibration is not cause for removal. Hammer testing only reveals the tightness of the rivet in tension and is not to be a valid test of how completely the rivet fills the hole.

To check for leaks, water from a high pressure hose is played against the external seam and a check made on the opposite side. Rivets exhibiting seepage may be rehammered but those which are clearly leaking should be redriven. Another method of tightness checking, within tank boundaries, is the standard air test with soaping of the external joints. However, air pressure within the tank should be kept to a minimum to prevent structural damage. Once afloat major riveting should be structurally tested with a hydrostatic head.

8. Inspection of Old Rivets. Routine drydock examinations of the riveting of underwater shell joints is accomplished by checking visually for loosening and deterioration of countersunk points and caulked edges from the outside and inspections as indicated from inside the hull. Deterioration is characterized by erosion of the rivet point somewhat below the surface of the surrounding plate exposing the countersink. Deterioration is the result of wear on the rivet points. Once the point is lost, accelerated corrosion occurs.

With dry conditions, leaking and seepage may be evidence of loose rivets. However, many "good" rivets may leak when the vessel is on blocks. If the rivet is tight as determined by sounding, then it may only need coating. If corrosion has taken place so as to expose part of the countersunk plate or the rivet has "started" (a crack has opened between point and countersink), repair or replacement should be undertaken dependent upon the number and location of such defectives.

9. Replacement and Repair of Old Rivets. After the initial inspection of the hull and rivets has been completed, a decision needs to be made about which rivets, if any, need to be replaced or repaired. In making this decision, the following factors should be considered:

a. The vessel's present condition and past repairs.
b. Location on the hull.
c. The number of deteriorated rivets in any location.
d. The condition of the plate surrounding the rivets including general wastage, pitting, and the condition of the caulking edge.
e. Depth of deterioration of the rivet into the rivet hole. When a rivet head deteriorates 25%, rivet replacement should be considered.

Where **replacing** rivets is indicated, extreme care must be used in burning out the loose rivets to prevent cutting into the plate. Where this occurs, it may be necessary to move up to the next size rivet, re-reaming the old hole. In such cases minimum landing and pitch distances should be maintained, although, here again, some relaxation may be considered for scattered rivets.

Repairing or tightening-up a rivet may cause near-by rivets to become loose. The tendency is to then tighten these loose rivets. This will, in turn, loosen other rivets and a small repair job could become a major undertaking. The key is to not hammer or drive too hard on the rivet causing it to over-tighten and knowing when to stop chasing the loose or leaking rivets. It is routine that a few rivets will leak. Often rust can cause a minor leaking rivet to stop in as little as 24 hours.

There are probably well over a million rivets in a large riveted ship. It is routine that a few of these will leak. According to accepted marine practice, it is satisfactory to **repair** a few "scattered" defective rivets where no comprehensive joint deterioration by corrosion, wear, or leakage is evident. Three acceptable methods of rivet repair are bobbing, frenching and ring welding.

BOBBING

Cold working the point around the lip or edge with a riveting gun and small convex die to draw a seeping rivet tight.

FRENCHING

Veeing and wedging the lip of point metal more firmly into the countersink with a special frenching tool and then filling in the "trench" with a fine weld bead. This actually draws a rivet tight without possibly distorting and weakening the metal around the rivet as ring welding may do.

RING WELDING

Carefully welding a fine bead around a rivet point as a temporary countermeasure to leakage. Such a weld has a tendency to crack. More effective repairs should be done when possible. Due to their highly stressed locations, rivets in the way of lapped or strapped butts or in deck plating outboard of the hatches should not be repaired by ring welding.

10. Areas of Concern. Riveted butts in the way of the midbody deck and bottom plating deserve special attention since they are subjected to high longitudinal bending stresses. Where there is evidence that a butt has started to "work", common practice calls for redriving the entire butt or replacing it with a welded insert

Side shell plating seams near the neutral axis at the quarter points are subjected to peak shear stresses – particularly as a vessel pitches in a seaway – and should be carefully examined for tightness. An examination of a typical bulk carrier stress curve confirms the location of this high shear stress. For this reason there may be some design strengthening of such shell seams by additional rows of rivets.

The bows and particularly the quarters of Great Lake bulk carriers also suggest close rivet examination because this is often where repeated dock and lock wall contact and heavy ice contact occurs. Side shell plating and rivet points in the way of quarter point lapped or strapped butts may suffer a scraping and reduction of material to the point of an under-strength condition. Some self-unloaders often brush channel banks and may sustain advanced rivet and plate deterioration in the way of the lower portion of the bilge strakes.

Erosion of rivet heads may be particularly noticeable around restrictive bell-mouths of ballast piping. Since heat is a definite catalyst for corrosion, particular inspection care should be given to rivets in compartments subjected to high moisture and heat levels such as double bottoms and side tanks in the way of boilers, lower engine rooms and peak tanks. Also, rivets sustaining high vibration levels may be suspect (e.g. engine foundations and the area near the sternport and propeller).

Tankers running in the petroleum products trade may be most susceptible to corrosion in rivets located high in the tanks. Coal, salt, or sulphur cargoes also lead to accelerated wastage.

In vessels carrying cement, leaking rivets can often be detected by a cap of hardened cement around the heads.

11. Welding. Production welding in the vicinity of riveted joints must be done prior to preparing the holes for riveting as the heat may well either loosen rivets or disturb hole alignment.

Because steel used in riveted hulls may be more sensitive to brittle fracture than steel employed in newer, welded ships, welding repairs are limited to the following:

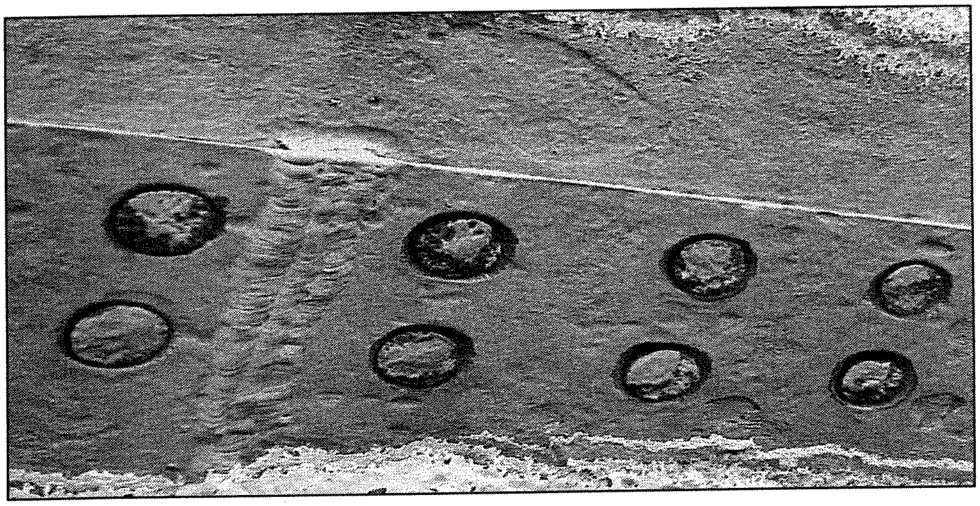
a. Flush butts between new and existing strakes of shell and deck may be welded. Such welds must have full penetration.
b. Welding repairs to misaligned or burned holes is acceptable practice only if the welding is sound.
c. Welding repair to build up deteriorated caulking edges may also be accepted if the workmanship is of high quality and the material which is added is free of substantial defect.
d. Light welding across a riveted seam to form a stopwater is acceptable.
e. Lapped butts involving the use of fillet welds **should not** be used.

12. Documentation Requirements for Coast Guard Marine Inspector. Upon completion of the examination ensure that the narrative states what you have done. If you have conducted a close-up exam of all the rivets and then allowed a mastic to be applied, ensure that you state that in your MSIS narrative and make an MISN entry attesting to the complete close-up exam.

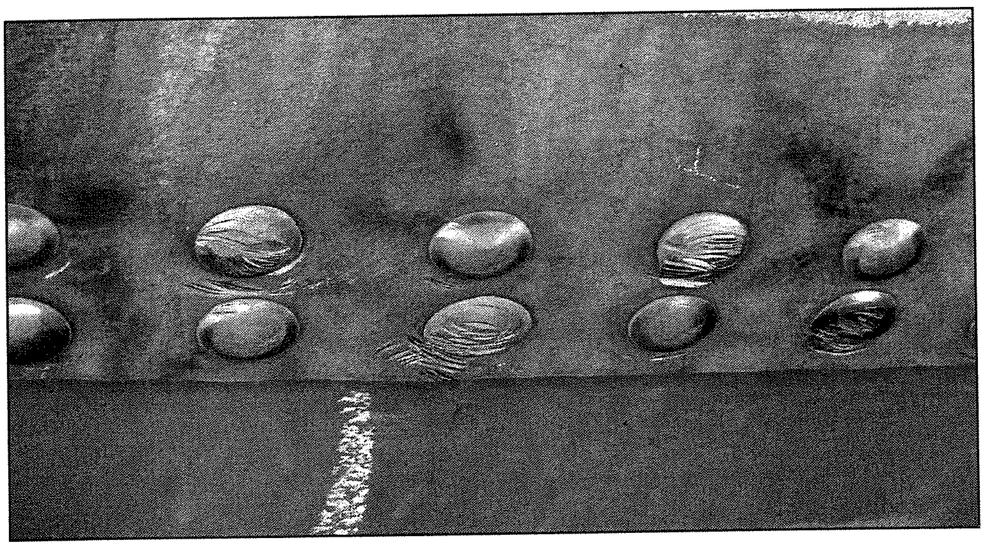
If you only had sections of the mastic removed for a close-up exam, again, ensure that narrative reflects that and state between what frames the mastic was removed. Make an entry in MISN stating between what frame numbers the mastic was removed. Make the expiration date of the MISN the end of the expected life of the vessel or at least two months beyond the next credit drydock exam.

Document completely any repairs that were made to the rivets or riveted plates in your narrative. Documentation of the above process in MSIS is required.

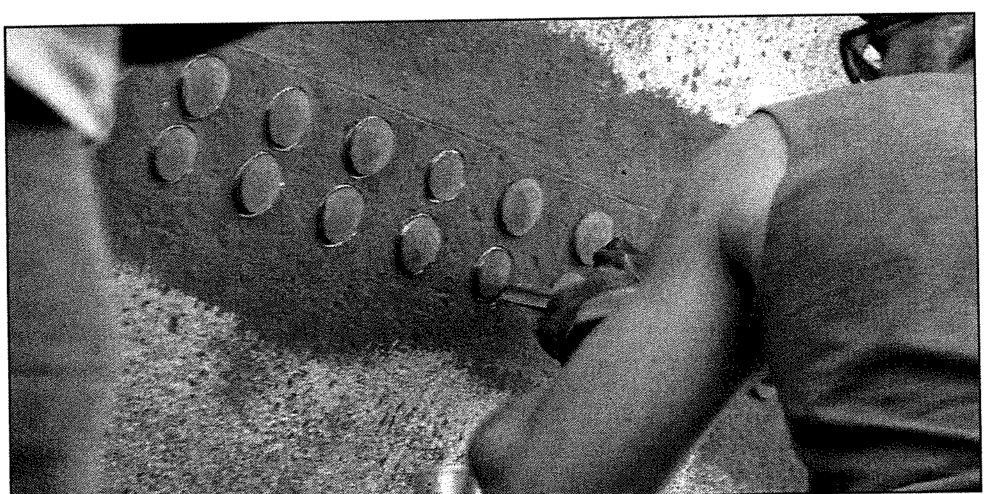
PICTURES



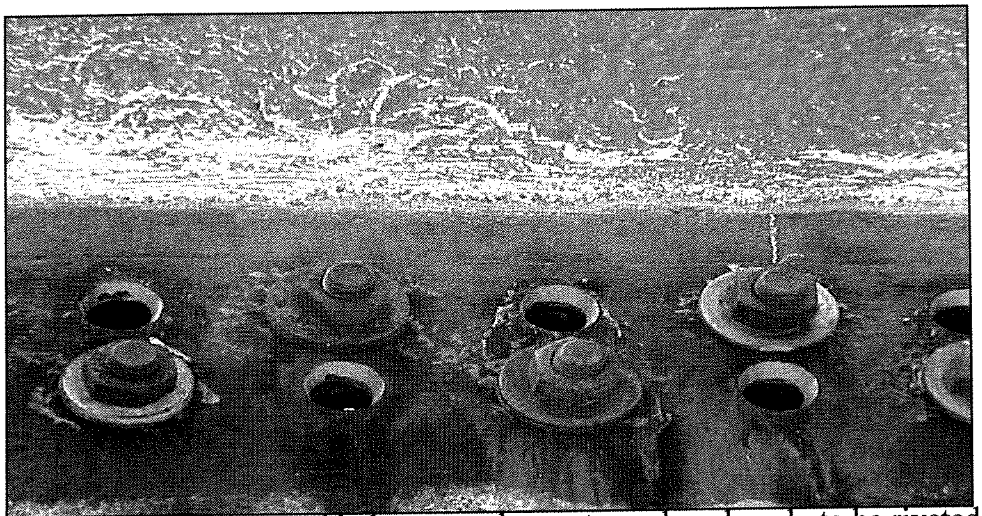
Deteriorated rivets in need of replacement.



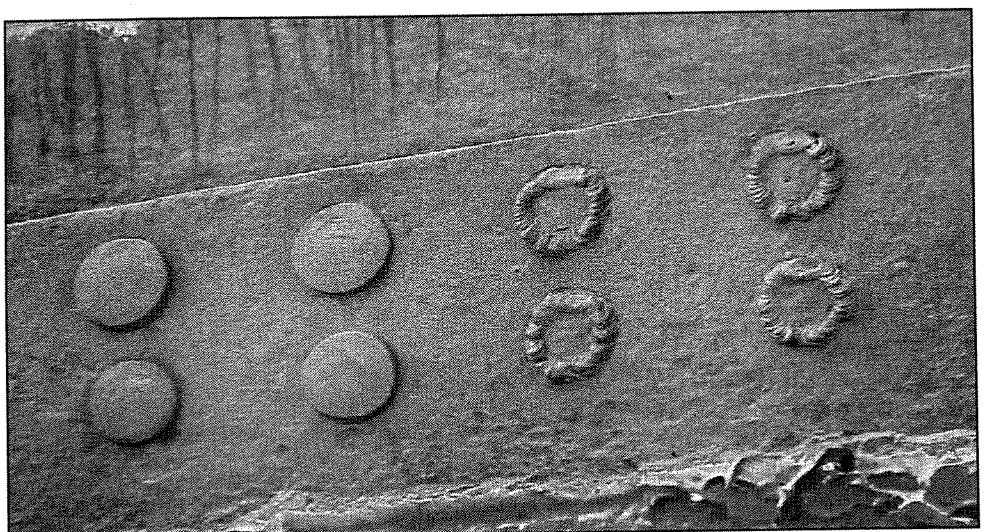
New rivets. The scarred rivets are an example of an inexperienced riveter.



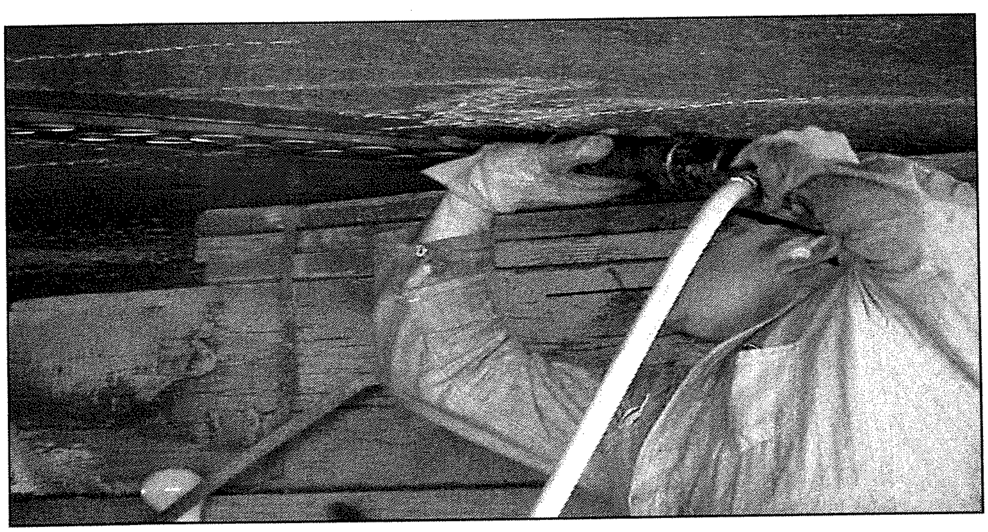
Tightening rivets using a frenching tool



Plates bolted up and holes reamed, countersunk and ready to be riveted.

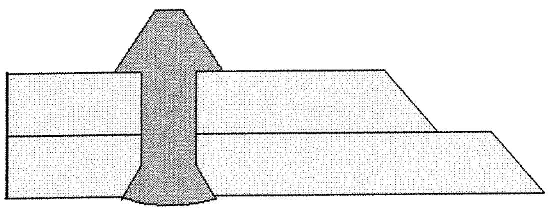


Ring welded rivet points. This is used only for temporary repairs.

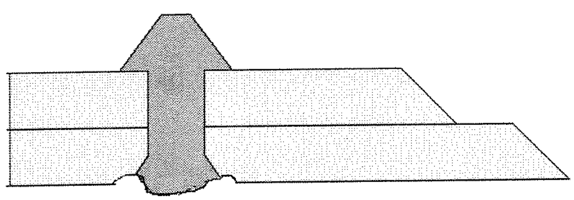


The caulker, in effect, creating a shoulder of metal forced between the faying (closely joined) surfaces.

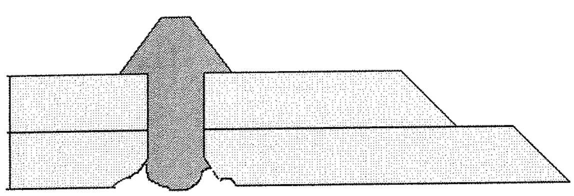
CROSS SECTION EXAMPLES OF RIVET DETERIORATION



Example A. A typical, sound rivet the point completely fills the countersink. The head is flush with the plate. If rivet has small leak, Bobbing may be an acceptable repair.



Example B. The point has begun to deteriorate and does not completely fill the countersink. Enough of the rivet remains in the countersink to hold the rivet tight, so no need to be replaced yet. The rivet may leak so a French and Weld may be an acceptable repair.



Example C. The rivet point no longer fills the countersink and is not holding the plates tight, The rivet will leak. The plates are susceptible to shearing force and the rivet may pop out resulting in joint failure. Replacement is the only acceptable repair.