U.S. Department of Transportation

United States Coast Guard

Commander
Eighth Coast Guard District
Hale Boggs Federal Bldg.

501 Magazine Street
New Orleans, LA 70130-3396
Staff Symbol: (moc)
Phone: (504) 589-6193
FAX: (504) 589-4999

16711
D8(m) Policy Ltr 10-2000
12 April 2000

From: Commander, Eighth Coast Guard District
To: Distribution

Subj: ATLANTIC AREA BEST PRACTICES: RIVET INSPECTION GUIDANCE

1. Enclosure (1) is forwarded for your information and use. It includes a forwarding letter from the Seventh Coast Guard District, and Prevention Department guidance from Marine Safety Office Tampa, including three separate enclosures on inspection and repair of riveted vessels.

2. Should you have any questions, please contact LCDR W. H. Daughdrill at (504)589-6193.

G. D. MARSH
By direction

Encl: (1) LANTAREA (Am) ltr 16010 of 15 February 2000

Dist: All Eighth District MSOs, MSU and MSDs

U.S. Department of Transportation
United States Coast Guard

Commander
United States Coast Guard
Atlantic Area

431 Crawford Street
Portsmouth, Va. 23704-5004
Staff Symbol: Am
Phone: (757)398-6372

16010

FEB 15 2000

From: Commander Atlantic Area (Am)
To: Commander, First Coast Guard District (m)
Commander, Eighth Coast Guard District (m)
Commander, Ninth Coast Guard District (m)

Subj: BEST PRACTICES SUBMISSION

Ref: (a) Atlantic Area/Maritime Defense Zone Atlantic Best Practices Program, LANTAREA/MARDEZLANTINST 16010.2

1. Enclosure (1) is forwarded for your review per reference (a).

2. The enclosure is a Best Practice from MSO Tampa that provides guidance for the inspection of vessels of riveted construction. I request that you review it for applicability within your District and I welcome any comments or opinions of this Best Practice.

3. I encourage your staffs to continue to submit policies or procedures that help us to perform our missions so that ideas can be shared throughout the Atlantic Area. My POC for the Best Practices program is LT Karen Jones, (757)398-6689.

J. T. KUCHIN
By Direction

Encl: (1) Commander, Seventh Coast District (mc-3) ltr dtd Jan 28, 2000; Rivet Inspection Guidance for Vessels of Rivet Construction

Copy: Commandant (G-MOC-2) (original)
Activities Baltimore
MSO Hampton Roads
MSO/Group Philadelphia
MSO Wilmington
Commander, Pacific Area (Pm)
Commander, Seventh Coast Guard District (mc-3) (w/o encl)

U.S. Department of Transportation
United States Coast Guard

Commander(m)
Seventh Coast Guard District

909 S.E. First Ave. RM 808
Miami, FL 33131-3050
Staff Symbol: mc-3
Phone: (305) 536-6535
FAX: (305) 536-5091

16715

JAN 28 2000

From: Commander, Seventh Coast Guard District
To: Commandant (G-MOC-2)
Via: Commander, Atlantic Area (Ami) 2/15/00

Subj: RIVET INSPECTION GUIDANCE FOR VESSELS OF RIVET CONSTRUCTION

Ref: (a) Navigation and Vessel Inspection Circular (NVIC) 7-68, "Notes on Inspection and Repair of Steel Hulls

1. Enclosure (1) is a policy implemented at Marine Safety Office Tampa to address the inspection of older vessels of riveted construction during dry-dock examinations. Feedback from the field has indicated that the guidance contained in reference (a) for rivet hull construction is limited. Enclosure (1) provides additional guidance for overseeing the inspection and repair of these vessels.

2. The enclosed policy is provided for your review and possible distribution as a "best practice" for other commands conducting dry-dock inspections on riveted hull vessels. In addition, I recommend this practice be instituted in an update of NVIC 7-68.

WILLIAM H. FELS

Encl: (1) MSO Tampa CPD Policy Memo #4-99, " Rivet Inspections" dated 26 May 99

U.S. Department
of Transportation

United States
Coast Guard

Commanding Officer
United States Coast Guard
Marine Safety Office

155 Columbia Dr.
Tampa, FL 33606
Staff Symbol:
Phone: 813-228-2193
FAX: 813-228-2399

CPD POLICY MEMO #4-99
May 26, 1999

CHIEF PREVENTION DEPARTMENT POLICY MEMO NO. 4-99

Subj: RIVET INSPECTIONS

Ref: (a) Navigation and Vessel Inspection Circular No. 7-68

1. PURPOSE: This instruction provides guidance to the marine inspectors in carrying out inspections on U.S. Flag vessels that have rivets used in their construction.

2. ACTION: All inspectors and boarding officers shall become familiar with the contents of this policy and references. Suggested changes shall be routed to the Chief, Vessel Branch (CVB) for consideration.

3. DIRECTIVES AFFECTED: None

4. DISCUSSION: Tampa currently has two major deep draft shipyards. During the drydock exams of several older vessels employing riveted construction it was found that guidance on proper repairs of rivets was lacking. The purpose of this instruction is to provide guidance to the inspector beyond ref (a) so that he/she can make the correct decisions when confronted with a rivet inspection. Enclosures 1, 2 and 3 are outstanding papers that address rivet inspections and repairs and are required reading by MSO Tampa Inspectors who will be involved in inspecting these types of vessels.

5. PROCEDURE:

a. **VESSEL ARRIVAL**: 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, the rivets have been coated with a "mastic", or epoxy coating used to protect the rivets from further wastage and wear. The problem with this coating is that it can hide a lot of problems. The inspector should ask the owner representative the following questions about this coating:

(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.

b. **DOCUMENTARY EVIDENCE**: Without documentary evidence under item (7), a close-up exam of the rivets is required and the coating shall be removed. The OCMI shall be notified.

Subj: RIVET INSPECTIONS

Any deviations to the above, such as alternatives, equivalents or testing of sample selected areas shall be made by the OCMI only.

c. **DOCUMENTATION PROCEDURES:**

(1) 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.

(2) 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.

(3) Document completely any repairs that were made to the rivets or riveted plates in your narrative. Documentation of the above process in MSIS MINS is required by this office.

6. FINAL COMMENTS: Repairs to rivets or riveted plates should meet the guidelines offered in the enclosures. Most yards do not have the capability to conduct the adequate rivet repairs. Some traveling teams are available from some yards, particularly on the Great Lakes, to conduct proper repairs. It is recommended that rivet surveys be conducted as soon as possible and owners be reminded that timely action is needed to prevent delays. Improper repairs, such as drilling plates and injecting epoxy between plates will not be accepted. If in doubt, advise the CID as soon as possible.

P. G. McLAUGHLIN
By direction

Encl: (1) Repair Techniques of Riveted Vessels (Dvorak and Brauer, Bay Shipbuilding, WI., undated)
(2) Marine Riveting on the Great Lakes (LCDR Cunningham, dtd 28SEP67)
(3) Professional Note (MSO Baltimore 1-77)

Repair Techniques of Riveted Vessels
Robert G. Dvorak and James L. Brauer*

- Robert Dvorak, Hull Superintendent and James Brauer, General Foreman/Dockmaster, Bay Shipbuilding Co., Sturgeon Bay, Wisconsin, a division of the Manitowoc Marine Group, Inc.

INTRODUCTION

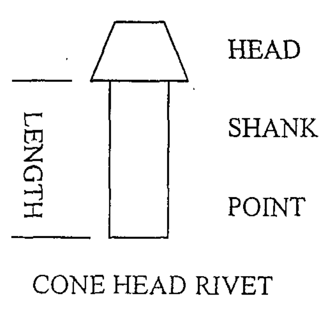
The Manitowoc Marine Group repairs vessels that normally operate in the North American Great Lakes including 1000 foot long self-unloading bulk carriers that are of all welded construction. Due to the fresh water environment, we are able to work on operating vessels of riveted construction up to 100 years old. We are currently involved in a seven year program to renew the underwater hull on a cement carrier built in 1906. We are also replacing approximately an 11 ft. wide by 300 ft. long section of port and starboard side shell plating on a ship originally built in Manitowoc in 1936, as a self-propelled oil tanker. This vessel was converted to a self-unloading cement barge in 1987 at Bay Shipbuilding and is one of the 18 vessels we have at our Bay Shipbuilding yard in Sturgeon Bay, Wisconsin for winter maintenance and repairs. In addition, the variety of vessels in our yard provides first hand observation in the technological advances our industry has made from all riveted hulls, to welding in non-critical areas mixed with riveting on bilge and shear strakes, to all welded construction.

Our riveting crews have assisted with repairs in Rhode Island, Long Beach California, and Johore Baru, Malaysia. These repairs included fixing leaking rivets, caulking leaking seams, removing old rivets and re-driving new ones. This presentation should provide you with information on what type of repairs can be done on rivets, caulking edges, and alternatives for riveted repairs.

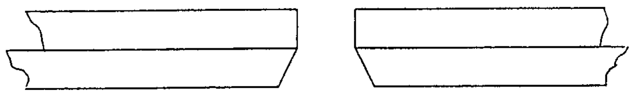
INSPECTION AND SURVEYS

A pre-docking survey or even sounding of tanks while the ship is floating can be used as an indicator for leaking rivets or seams. Are we making water? Where is it coming from? Crew reports and surveyors working for the ship owners typically handle this.

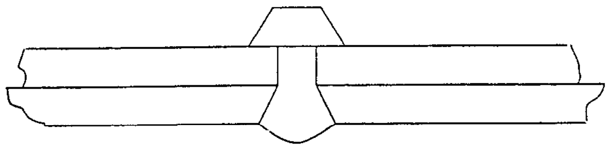
When the vessel is dry-docked for a hull survey, the inspection may reveal a variety of repair needs. The point and head of the rivet are examined for deterioration. The vessel may have deteriorated rivet points that are weeping, leaking or loose. Sprung caulking edges on the riveted lap of hull plates caused by minor groundings may be present. The internal survey will also give an indication of the condition of the rivet heads. This is valuable when rivet points on the exterior of the vessel are hard to see because of paint or rust. To test a loose rivet, a finger is placed on one side of the rivet head while tapping on the opposite side of the head with a small hammer. A loose rivet will move or vibrate.



CONE HEAD RIVET



COUNTERSUNK PLATES



DRIVEN RIVET

The key areas on the rivet that deteriorate affecting the strength of the joint are the head and the countersunk point. If the head area is reduced in size greater than 20 to 25% of it's original size, replacement is required for active ships. Sometimes scale or wastage must be removed to see the actual size of the rivet head. The rivet point acts like a wedge to hold the outside and inside lap tightly together. When this point deteriorates so that part of the point is gone and areas of the plate countersink are visible, rivet failure is possible. Rivet points also lose the ability to be tightened when they deteriorate because of the loss of this wedge portion of countersunk rivet.

Although it can be advantageous to inspect for leaky rivets as soon as the hull is dry, the type of deterioration or loose rivets that require attention will still be noticeable for days after. Inspection will show wastage on the point of the rivet where it fills the countersink of the plate, or a continual dripping or seepage around the perimeter of the point is evidence of loose rivets. If corrosion has taken place so as to expose part of the countersunk plate or the rivet has developed a crack between point and countersink, repair or replacement should be undertaken. Rivet points can also be damaged as the hull scrapes along a dock wall or other hard objects. A more severe situation may require the complete renewal of a damaged plate and associated rivets. A paper written in 1967 by Lieutenant Commander D. C. Cunningham entitled "Marine Riveting On the Great Lakes" is commonly referenced when repairing riveted vessels.

Cunningham states that "riveted butts in the way of the midbody deck and bottom plating deserve special attention due to the high longitudinal bending stress. Where there is evidence that a butt has started to "work" common practice calls for re-driving the entire butt or replacing it with a welded insert. cutting back to good metal at least a couple of feet on either side of the butt."

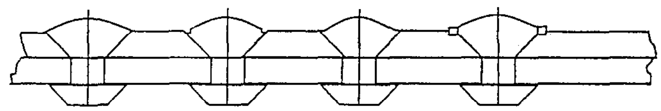
REPAIR OF OLD RIVETS

First, we will address typical repairs made when the existing plate is satisfactory and only the rivets require attention. The rivet will either be repaired in place or removed and redriven. In the case of hull rivets, most repairs in place should be done from the outside of the ship in order to correct the source of the problem. Cunningham describes three methods of rivet repair: 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 firmly into the countersink with a special frenching tool and then filling in the trench with a small weld bead. This actually draws the rivet tight. (On the Great Lakes, we refer to this as frenching and welding.)

"Ring Welding" - carefully welding a fine bead around a rivet point as temporary counter measure to leakage. Such a weld has a tendency to crack.



NORMAL FRENCHED FRENCHED AND BOBBED FRENCHED AND RING WELDED

The Manitowoc Marine Group would add frenching and bobbing to ring welding. This method uses the veeing of the edge of the rivet point perimeter tightened by the bobbing tool. When rivet conditions permit, this method can eliminate "hot work" on repairs to fuel bunkers and single skin tankers.

Care and foresight must be used in any repairs to rivets in place. A typical riveted seam has two rows of rivets spaced 4 to 5 inches apart and when you tighten one, the neighboring rivet can be loosened slightly. This procedure could go on forever as you tighten one and loosen the next one, etc. The key is not pounding too hard on the rivet and knowing when to stop chasing the weepers.

In his paper, LCDR Cunningham reminds us that "It is routine that a few of these will leak". Often rust can cause a weeping rivet to stop leaking in as little as 24 hours.

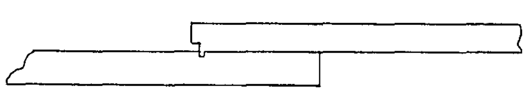
RIVET REPLACEMENT

In the case where loose rivets cannot be tighten by the previously mentioned methods, judgment comes into play on how extensive the problem is. Frenching and welding of the rivet points and welding of a caulking seam may be satisfactory in instances where the repair location on the vessel is not critical and number of rivets to be repaired is minimal. In other cases it may be necessary to remove and replace the rivet. Care must be used in burning out the old rivet to prevent damage to the existing plate and it's countersink. The rivet hole and countersink is then cleaned up by reaming to proper size and a light turn with the countersink. The new rivet is then driven, and neighboring rivets and caulking edges addressed with bobbing/frenching/re-caulking/etc.

CAULKING PLATE EDGES

On the riveted plate connection, water can penetrate the vessel two ways; through the loose rivet or from the caulking edge. The exposed edge of the outside plate is called the caulking edge. Caulking on steel vessels involves forcing an edge of the outside plate tight against the inside plate sealing the lap joint. This is accomplished with an air powered chipping hammer and a caulking tool that wedges the inboard part of the caulking edge toward the inside plate.

CAULKING FIRST CUT



CAULKING SECOND CUT

The first pass with the tool cuts a wedge shaped groove about 1/8" to ¼" wide. The high side of the wedge shape is against the inside plate. On the second pass, the tool is turned 180¡ and used to force the wedge shape down flat and tight against the inside plate. The finished caulking edge has a slight step on it's inboard edge towards the inside plate.

Repairs to caulking edges of riveted plates are also done from the outside of the plate. If a gap greater than 1/16" exists between the two plates, the edge can be heated and brought tight by means of a flattening hammer. This double headed hammer has a round end to be hit with a sledge hammer and a square end that rests against the plate. After the plate is heated enough to allow it's edge to be hammered back in place, one person holds the flattening hammer against the plate and another hits the round end with a sledge hammer. Finally the edge is recaulked and neighboring rivets are bobbed or frenched. Caulking seams are welded in some instances depending on the seam location. The same situation holds true when repairing rivets in place. If you weld a caulked seam, you will have an effect on the neighboring rivets and they may required the bobbing/frenching treatment. Also, the seam will require caulking an additional 12" to 24" beyond the welded end. On smaller vessels, like tug boats, it can be more cost effective to weld the seam all around the ship and weld all the rivets. Continuous welding can be more efficient than doing a section and chasing the leak all around the ship. From a cosmetic point of view, welding seams and rivets may not be as desirable as the caulking, frenching and bobbing method. The later method does not alter the appearance of the vessel as much as welding does. However, for underwater areas on inactive vessels, frenching and welding will only be seen when the vessel is dry-docked. As always the decision rests with the ship owner on unclassed vessels. On vessels classed to haul cargoes, welding of caulking edges of riveted seams has not been allowed, except for small areas at transitions between riveting and welding. Typically this would be outside of the two-thirds mid-length of the vessel.

PLATE REPLACEMENT

Replacing a shell plate on a riveted vessel occurs when the plate is damaged, or when it's condition has deteriorated to the point that renewal is required. The cost of replacing a plate that is riveted is at least 5 times more expensive and more time consuming than one that is completely welded. For this reason ship owners are always trying to minimize riveting. As an example, a basic task list is shown for replacing a welded plate versus a riveted plate with welded frames. An average plate is ¾" by 96" by 288".

OPERATION SEQUENCE FOR PLATE REPLACEMENT

All Welded PlateRiveted Plate

1. Remove damaged plate1. Remove damaged plate (if plate is inside lap, you need a skilled burner capable of saving the countersink on the outside plate)
2. Layout new plate and burn2. Layout new plate including rivet holes, burn
3. Hang plate, regulate, tack weld frames 3. Punch new rivet holes
4. Weld frames, seams and butts 4. Countersink rivet holes
5. Test5. Hang plate, regulate, tack weld frames
6. Bolt up half of rivet holes
7. Ream rivet holes 1/16" over size of rivet diameter
8. Countersink holes
9. Change bolts to other half of rivet holes
10. Ream and countersink other rivet holes
11. Drive half the rivets
12. Remove bolts between new rivets
13. Drive other half of rivets
14. Caulk seams
15. Test

On certain ships under 600 feet in length, riveted bottom plating can be replaced with lapped plates with welded frames and seams. A few rivets are driven where the rivet seams meet the welded seams. The bilge strake of plate remains riveted and new rivets are driven at this connection. Riveted passenger and car ferries have replaced riveted shell plate with lapped welded plate. In most of the shell plate replacement on riveted vessels over 600 feet in length, plate connections riveted and welded are replaced in kind. That is bilge and shear strakes are riveted; strakes in between are welded. Most frame connections are welded.

RIVETING OPERATION

Riveting operations (Items 11 & 13) usually require 5 people to install the rivets; Driver, Heater, Bucker or Holder On, and 2 Passers. The heater handles logistics of the rivets, the different lengths and types required. If the rivet is too short, it will not fill the countersink or the point will be too flat. If the rivet is too long, the rivet will be so large that the driver has to remove excess stock from the rivet point during forming. This adds to his work and slows the process. When driving 300 to 600 rivets a day on piece work, seconds saved for each rivet add up. A kerosene fired forge is used to heat the rivets to a light yellow color. Rivets should be driven in the upper range of 1000-1950oF (Cunningham, 1967). The heater paces the crew by tossing hot rivets to be caught in a funnel by the outside passer at a pace that is comfortable to the driver. 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 engages the head of the rivet with a pneumatic hammer similar to the one the driver uses but with a die shaped to conform to the head of the rivet. The bucker is responsible for keeping the rivet tight to the shell plate and making sure the rivet head is not deformed during driving. He should also sound the rivets to check for any loose ones before the crew moves to a new location. When the bucker has the hot rivet in the rivet hole, the driver forms the rivet to fill the countersink and finishes the point of the rivet. To do this, he uses a 100 PSI pneumatic hammer with slightly concave die. Ideally the driver leaves a small sliver of stock to be removed as he does his final forming of the rivet point. This insures that the rivet hole and countersink are filled and leaves a slight convex point on the rivet. When all rivets are driven, the edges of the new plate are caulked. The pace is set so that when the driver finishes a rivet a fresh one is in the next rivet hole about 3 seconds later.

TESTING REPAIRS

Testing of riveted work can be done with water or air test. Water is the preferred method. First the inside of the plate is visually inspected for appearance of rivets, and weld size and quality. Then a water hose is used to spray the inside of the plate while the outside is inspected for leaks. Air testing would involve the tank being pressurized with air to 2 PSI. A water leg or similar safety device must be used to prevent over pressurizing of the tank. Testing soap is applied on rivets and caulking edges. Bubbles will develop where there are leaks. Repairs can be made and retested until the vessel is watertight.

If time allows, a pre-test with water will help to seal any small weepers before the final test for water tightness. Any weeping rivets or leaks in the caulking seams can be repaired by additional caulking or bobbing of the rivet point. Inspectors should be aware that small weepers will seal up. Internal rivets on watertight connections between tanks can be sealed by the same methods used outside the shell plate. Bounding angles that connect the frames and keelsons to watertight bulkheads can be tightened by caulking. On riveted ships showing signs of deterioration, good paint systems and other methods to prevent electrolysis, such as cathodic protection, and checking for grounds in electrical systems have proven to arrest the situation.

CONCLUSIONS

Rivets can be welded in certain locations on classed vessels under the following conditions:

- Frame rivets where less than 10 percent of the countersink is exposed.
- Seam rivets not in the two-thirds mid length of the vessel
- Scattered seam rivets if allowed by surveyor

Rivets may be tightened by:

- Bobbing
- Frenching

Frenching and bobbing
Frenching and welding
Ring welding (least desirable)

Seams can be repaired by:

Recaulking

Welding and re-caulking 12" to 24" beyond end of weld On vessels in a static condition, repairs rather than replacements should be able to be made on a larger scale. However, riveted plates and seams can be removed and replaced with welded plates and seams. What you choose to do with your ship is up to you. We are capable of providing the services you require to accomplish your rivet repairs. To paraphrase a famous San Franciscan, Paladin. "Have riveting gun. Will travel" Acknowledgments The authors wish to acknowledge the assistance provided by Nancy Anschutz and Eugene Ehlers, Bay Shipbuilding Co., and Christine Randall, Head Curator, Door County Maritime Museum, Sturgeon Bay, Wisconsin.

References

Thearle, Samuel J. P., The Modern Practice of Shipbuilding in Iron and Steel, William Collins, Sons, & Company, Ltd., 1886 Haliday, George V. Swanson, W. E., Ship Repair and Alteration, Cornell Maritime Press, 1942 "Specifications for Riveting", Part 1 - Steel Construction for Vessels of the U.

S. Navy, U. S. Government Printing Office, October 1940

"Marine Riveting on the Great Lakes", D. C. Cunningham, LCDR, USCG, September,

1967

Return to the Preservation Conference Schedule page.
Return to the National Maritime Museum Association home page.

Version 1.00, 7 July 1997

28 September 1967

MARINE RIVETING ON THE GREAT LAKES

D. C. Cunningham, LCDR, USCG

INDEX

This paper has as its purpose the presentation of a range of practical information on marine riveting. At present, in spite of hundreds of books, articles, and papers published on different phases of riveting (most of them prior to 1945), to my knowledge there does not exist today a good up-to-date and comprehensive volume on the subject. This paper does not presuppose to represent such an effort. It is rather a collection of information accumulated over the past few months from shipyard personnel, inspectors, marine engineers, and surveyors, balanced against extensive library research.

After a brief history of riveting, rivets themselves, joints, procedures, inspections, repair, and testing will be discussed. The text has been oriented towards existing practice on the Great Lakes. Although there are riveted marine boilers in use, hull riveting only is primarily covered. Boiler riveting is taken up extensively in Marine Engineering Regulations (Subchapter F).

INTRODUCTION

The story of riveting as the traditional marine fastener spans more than a century. Since the launching of iron-hulled transatlantic steamers in the 1840's, these hot driven metal pins have proved an effective method of joining together the plates and shapes making up a ship's structure.

In today's new vessels, riveting has been generally replaced by all welded construction --- with the possible exception of riveted longitudinal seams designed as crack arrestors. But here on the Great Lakes, riveted ships ---a few dating back to the 1800's --- continue to predominate.

It seems certain that marine riveting is destined eventually to be completely replaced by welding or sophisticated mechanical fasteners. Of comparable note, in the 1950's civil engineering was plagued with a critical shortage of qualified riveters. As a result, there began a transition to mechanical fasteners in the fabrication of large metal structures such as cranes, antennas, bridges and buildings. Now little, if any, heavy riveting is done in such construction.

Today, in the marine field, qualified riveters are becoming increasingly scarce. When a big riveting job arrives at a Great Lakes shipyard --- for example, severe grounding or collision damage --- it may be difficult to muster sufficient qualified riveting gangs for a full scale repair effort. (It might be noted that a good riveting gang can only drive 400-500 rivets per day). Then, with the riveting done, they have to shift to other work. The situation is aggravated by the long apprenticeship leading to a first class riveter; about a year is needed to develop a top man. Further, riveting costs are high and may run as much as $5 per rivet.

The state of the art is becoming such that there may be an overall decline in riveting quality, necessitating much closer checks by supervisory and inspection personnel. A point may even be reached where riveters should be required to officially demonstrate their qualifications, much the same as now required for marine welding.

HISTORY

Although the art of riveting dates concurrently back to man's earliest use of ductile metals, hot riveting, as we generally know it, is traceable back to riveted steam boilers, steam engines, and bridges, all of which preceded iron hull ships. In those earliest days, the art of riveting was most non-scientific; it represented a small feature of a myriad of rapidly expanding mechanical inventiveness. Metal plate and structure were riveted together without a great deal of structural analysis. A number of disastrous boiler explosions soon proved the dangers of such an approach and the need for more precise engineering investigations and practice.

Since 1880 there has been extensive research into riveted joints, literally amounting to expenditures of millions of dollars. Many lively controversies were generated --- punched vs. drilled holes, value and amount of countersink, merits of clamp strength, and the spread of load over various rivets, to mention but a few.

The basically manual and indeterminate nature of the riveted joint has made it most difficult to accurately analyze. To understand it thoroughly involves metallurgy, mathematical analysis, shear, tensile, and compressive loading, fatigue, corrosion, and frictional resistance. And, for all the many careful investigations under laboratory conditions, riveting remains a most practical art, with quality directly proportional to the skill of the individual riveter.

RIVET MATERIAL

Let's start with the rivet itself. The material is flanged-quality steel, which is somewhat more ductile than ordinary mild steel. American Bureau of Shipping Classification Rules establish material parameters which are checked at plant locations by ABS surveyors and by Coast Guard Inspectors. By physical test, the shank must be able to sustain doubling together cold without fracture. If between ¾"-1 ¼" diameter, it may be bent around a 1 ¼" diameter in lieu of flat. The head must not fracture when flattened hot to 2 ½ times shank diameter.

RIVET DIMENSIONS

ABS Rules further state that panhead, buttonhead, or conehead types may be used for watertight work and proportions for each are given. Standard sizes will vary from ½" to 1 ¼" diameters in 1/8" increments. The manufacturer will supply various lengths. On the Lakes the practice seems to be the use of coneheads. There may be a very slight swelling in the portion of the shank near the head to promote oil and watertightness. If the shank swelling were excessive it would prevent the head from properly seating by acting as a collar during driving operations. Rivet points will be discussed later.

Discussion of the ABS Tables which establish the design parameters for riveted joints follows. These tables date back to data derived many years ago and reflect practical rather than theoretical experience.

ABS TABLES

TABLE A --- The minimum breadth of plating overlap for seams, lapped butts, and butt straps. Rivet diameter vs. plate thickness is also given. The footnote is most significant and states the "landing" (distance from rivet hole center to plate edge) must be at least 1 ½ times rivet diameter. Thus the common shipyard rule of 1 1/2D + 1/8D (calking) for landing. A second footnote sets the distance between centers of adjacent rivet rows (not pitch, which is the distance between individual rivets in their respective rows) at:

2 1/2D for seams
3D for straps
3 1/2D for end laps

The "Spacing in Inches" table is simply a multiplication table between rivet diameters and inches.

This breadth of overlap, coupled with distance between rows, minimum landing, the number of rows, and the various tables for pitch, determines rivet placement within each type riveted joint.

TABLE B --- Number of rows (single through quadruple) and maxi-pitch for plating. end connections (lap and single strapped butts). Rivet D vs. plate thickness is repeated and countersink angle vs. thickness given.

TABLE C --- Number of rows and maximum pitch for plating seams.

TABLE D --- Butt strap thickness dependent upon plate thickness.

TABLE E --- Pitch of rivets in bars (rolled shapes).

TABLE F --- Due to the more "searching" quality of oil (it will pass through smaller cracks than water) closer pitch is required in some structures.

TABLE G --- End connections of important structural stiffeners (girders, webs, and stringers) are more closely riveted for increased strength at end location of increased stress.

TABLES H thru L --- Tables relating to smaller supporting members and attachments.

HOW RIVETED JOINTS FAIL

In theory, riveted joints are "balanced" designs in which – like the Deacon's one horse shay – all modes of failure occur simultaneously under destructive loading. This is also basically true in practice although the concept is tempered by practical considerations of construction. Usual riveted joint failures are listed below:

(1) rivet shear --- the rivets are "chopped" without substantial elongation as the plates slide along their faying surfaces.
(2) rivet tensile failure --- the rivets are stretched until failure. (note: this can create quite a missile hazard, as in the case of vessel collisions).
(3) plate cracking --- tensile failure by the plate failing across a line of decreased cross-sectional area in the way of the rivet holes.
(4) plate crushing --- the rivet crushes out a path to the plate edge. The plate may fail by shear (a section is pushed out) or tensile failure (the plate is ripped).
(5) pulled through plate --- the rivet head or point is directly pulled through the plate.

Modes of failure indicate generally the factors which are important in the balanced design of a riveted joint --- rivet dimensions (diameter, countersink, head and point size); plate thickness and overlap; type, location and nature of joint; watertight or oiltight requirements; rivet pitch and row spacing (back pitch or gage); structural end stiffening.

It's not difficult to visualize the balance which should be struck between these factors. With insufficient landing, a rivet may push out (crush) or tear the ligament between the holes and the plate edge. Rivet total cross sectional areas (by number and diameter) must relate to plate thickness to prevent untimely failure of the rivet in shear/tension or the plate in tension (crack through rivet holes) or crush. Minimum point and head size is necessary to prevent them from being pulled through the plate.

Generally the ABS Rules are explicitly followed in the joint design; however, in the very practical efforts of the ship construction and repair, there will be some occasional deviation. It is the consensus that these rules may be stretched for the scattered rivet (e.g., and oversized rivet with a landing of less than 1 1/2D in a repair job or failure to meet dimensions around intricate structure) with common sense and experience the necessary gauges.

RIVETING PRACTICE – PLATE AND JOINT PREPARATION

Joint preparation which precedes the actual riveting operation cannot be over stressed in importance. This at least equals the importance of riveting itself for fabrication of an adequate joint.

DRILLING

Rivet holes will be either drilled (if the member is 7/8" or over in thickness) or punched and reamed. 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 problem to drill directly perpendicular into a plate and thus prevent an oblong hole by inconstant drilling angle. However, it is slower and more expensive than punching and reaming.

PUNCHING AND REAMING

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" larger than punched diameter will remove this metal. Reaming also removes distortion caused by the punching operation and the misalignment between punched holes such as is almost certain to exist. However, if the misalignment approaches 1/4D 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.

The latter is generally held to be poor practice unless the plates are separated to prevent being welded together. It should not be accepted unless reasonable welding can be accomplished and perhaps even proved by non-destructive testing.

Not only the amount of hole misalignment but also the percentage of poor holes should be considered when weighing the net effect on joint strength.

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.

In two ply work punching should be from the faying surface outward and any extrusion or burr fully removed.

Particular care is necessary in 3 or 4 ply work to attain good alignment.

BOLTING UP

The punched plate is carefully bolted in place with forged steel temporary or "service" 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 indicated.

Faying surfaces must be bolted and held in tight contact to prevent inclusion of metal chips and shavings 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.

Other fit-up detail – a drift pin may be used to shift plates into proper alignment but should not be used to drive its own hole. Plate edges to be calked should be planed.

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. Joggled frames or plating would avoid the undesirable extra liner weight but are quite expensive to fabricate. ABS Rules establish liner dimensional requirements.

Stopwaters (soft packing) are needed to maintain oil tightness and watertightness between compartments and generally are the responsibility of the fabrication personnel. 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 third type of 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. The plate is left in place and the edge carefully called for watertightness. Copper sheeting should not be used as it tends to dilute and weaken the butt weld metal.

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 recountersunk. This countersink must be deep enough or the finished point will be inadequate in holding strength. Procedures vary on the reaming/bolting/riveting sequence. However, it is essential that "trash" not be allowed between faying surfaces and that bolts should keep these surfaces tight until rivets take over.

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.

This completes the very important preparation which precedes riveting. The faying surfaces must be bolted up sufficiently tight to exclude a test blade and holes should be reasonably true. <u>The force of driving or contraction of the rivet upon cooling should not be expected to close excessive clearances.</u>

THE RIVETING OPERATION

The three man riveting gang is now ready to go to work. Their roles will be discussed one by one.

THE RIVETER

The riveter is in charge and responsible for working the unformed shank down to a proper balanced point. It is significant that he must judge fit-up, countersink, and hole alignment prior to driving the rivet. If these are poor, he should require correction.

After the bucker-upper pushes the rivet through from inside the hull, the riveter ensures it is at proper diameter, length, and temperature and that, prior to working, the slag has been knocked clear. If all is not correct, he raps a couple times with his air hammer and the rivet is pulled back and rejected.

Another is pushed through and the riveter works the hot shank up into the hole with his slightly concave die in direct axial drive of his air hammer. Then with a degree of pivotal motion he works the cooling metal into the countersink forming the rivet point. He should either continue gun pressure on the rivet past the point of plastic flow and until it has cooled to blackness or should return to it shortly for brief redriving.

This sustained working of the point is essential to fully developed clamp and fatigue strength.

Some riveters will work the excess metal off to one side with their die and quickly remove it with a chipping hammer prior to finishing the point. With a rivet of exact length this is not necessary.

Some of the most difficult shell riveting is on the underside of the hull. Here, particularly, the riveter position is the key. When working in such a vertical position a riveter may rest his "holding" hand on his knee, braced on a ladder rung and use his leg muscles for the needed leverage. It has been said that a good riveter gets into the correct position and makes it look easy. Awkward position is tantamount to inferior riveting.

THE BUCKER-UPPER

The holder-on (bucker-upper) holds the head of the rivet with a riveting gun, air jack, or dolly bar while the riveter form the point. By necessity, his most efficient route around the ship's internals generally dictates local riveting sequence. He will be assisted by a passer who will initially hold the hot rivet in position.

THE HEATER

The heater is the third man in the team. He keeps a variety of lengths of rivet up to the proper temperature in his coke, electric, gas or oil fired heater. Rivets should be driven in the upper end of the range 1000-1950F. (Note: Rivets less than 3/8" diameter may be driven cold). The maximum temperature is described as light yellow. Heating into the white heat range above this temperature will result in extensive rivet fractures while driving due to loss of ductility. Bend tests of such overheated rivets, upon cooling, disclose definite brittleness. Excessive "soaking" in the furnace is also detrimental and results in coarsening of the grain and excessive surface oxidation. Direct flame impingement on the rivet should be avoided since it may either melt the rivet or slag or present problems outlined above. Once his rivets are to temperature, the heater selects the proper length and passes it to the bucker-upper (either manually or thru an enclosed pnuematic carrier tube of some type). Length will vary with location and the heater must make an experienced judgement to supply the correct one. If too long the rivet may cool before heading is completed, the point may be too large, etc. If too short, the point will be too small and the plate may be scarred in the operation. As an example, for a 1" diameter conehead – countersunk point rivet joining two ¾" plates tightly bolted, the correct length would be 2 11/16".

CALKING

Good calking is necessary to ensure oil and watertightness of a riveted joint. In effect, a shoulder of metal is forced between the faying surfaces by a special pneumatic calking tool. This shoulder should be deep rather than high or the faying surfaces will be unduly sprung apart, destroying clamp strength. Particular care must be exercised to ensure the underlying plate is not badly scored.

STRENGTH AND WORKING OF THE RIVET JOINT

Now that we have a completed riveted joint, just where is its strength? Thermal contraction of the hot rivet on cooling develops an elastic tension which has come to be known as frictional resistance or clamp force. This force between the two faying surfaces must be overcome before the rivet is placed in shear or bearing.

Although clamp force is somewhat variable by its very nature, it seems generally accepted that it is of the magnitude of about 10,000 to 18,000 psi and that such a force will carry the load under working conditions if joint preparation and actual riveting have been good.

However, design of riveted joints in the U.S. is based not on this clamp strength, but rather upon the rivets being brought into bearing against the plate. If the rivet completely filled the hole, the rivet would be in bearing upon the installation but tests have shown this not to be the case. As the rivet contracts on cooling minor clearances do result between plate and rivet. It is important that these clearances be kept as small as possible in a hot riveted joint by minimum initial clearance of the unpointed rivet, good hole alignment, and good riveting procedure.

When the joint is first stressed, it behaves elastically until clamp force is overcome and the joint slips an amount dependent on rivet clearances. After slip starts, some degree of individual rivet and plate deformation rapidly takes place until the rivets are collectively brought into bearing and shear. Basic riveted joint design assumes an even distribution of stress between rivets. This state is approached as the joint is loaded. Once slip has occurred and the joint goes into bearing it is believed that the joint will leak either through loosening of the rivets or breaching of the calked edges.

Then the rivets and plate perform elastically until permanent deformation and ultimate failure. Whether a significant amount of clamp strength continues during these latter stages is almost impossible to assess; but it does appear dubious. In most cases the joint fails by the plate cracking across the rivet holes or by shearing of the rivets.

INSPECTION OF NEW RIVETS

After driving, there are four tests a riveted joint should pass:

Visual Examination – 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 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.

Since they are subjected to high longitudinal bending stresses, riveted butts in the way of the midbody deck and bottom plating deserve special attention.

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, cutting back to good metal but at least a couple feet on either side of the butt.

Side shell plating seems 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 row of rivets, etc.

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 occurs. And Lake boats are renowned for the number of docks and locks they make during an operating season.

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 understrength condition. Some self-unloaders often brush channel banks and may sustain advanced rivet and plate deterioration in the way of the lower portion of bilge strakes. Extensive corrosion or erosion of calked edges may result in joint leakage and require recalking. 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. Naturally rivets sustaining high vibration levels may be suspect (e.g. engine foundations and the area of sternport and propeller).

It is interesting to note that in salt water, or fresh water polluted with chemical wastes, rivet points generally corrode more rapidly than the neighboring plate.

Rivets in tankers running in the light petroleum products trade may be most susceptible to corrosion where coming into contact with such a cargo. As in the case of structural deterioration, rivets high in the tanks are often the hardest hit. Coal, salt, or sulphur cargoes also lead to accelerated wastage.

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

REPAIRS TO DEFECTIVE RIVETS AND RIVETED JOINTS

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 –

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.

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.

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 seal or ring welding.

Deteriorated heads may be built up by careful welding if the rivet is otherwise sound and corroded metal first removed.

U.S. Navy rules require the repair or replacement of rivets when head thickness has been reduced by 25% for 40.8 lb plate and smaller and by 20% in plate over this weight. These rules also prohibit welded repairs which result in fusion between plates in the joint.

Where redriving 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 case minimum landing and pitch distances should be maintained, although, here again, some relaxation may be considered for scattered rivets.

Welding repairs to misaligned or burned holes is acceptable practice only if as discussed previously, the welding is sound. Welding repair to deteriorated calking edges may also be accepted if the workmanship is of high quality and the material which is added is free of substantial defect.

MISCELLANEOUS REMARKS ABOUT MARINE RIVETING

FATIGUE FAILURES IN BOTTOM SHELL RIVETED BUTTS

One type of failure of riveted joint which has been most noteworthy over the years on Great Lakes bulk carriers has been the fatigue failure of bottom shell plating in the way of lapped and strapped butts. In some cases the failure has finally resulted in complete fracture while in others it has weakened the plate to the point where, upon bend test, it failed at some point less than a right angle (as little as a 10 degree bend for some pre-1948 steel). In brief, all the fatigue prerequisites were present – application of a large number of loading cycles; repeated stress, all below the point of non-elastic strain; and a local stress concentration.

This last factor is most significant. Calking and recalking into the underlying plate provides the discontinuity (stress concentration point/notch/stress raiser) which may ultimately lead to fatigue failure of bottom shell lapped or strapped butts. Corrosion or erosion may increase the severity of such calking trenches.

As general information, fatigue cracks propagate slowly and intermittently; there is no deformation accompanying the fracture. (By comparison, brittle fracture proceeds very rapidly and ductile fracture is accompanied by considerable deformation. There are also differences in grain appearances, etc.).

It may be very difficult to see this calking trench while the vessel is on drydock unless sandblasting is used to remove mud, growth and corrosion. An actual line of working or failure can best be seen from the inside of the vessel although an actual crack would probably be forced closed by keel block support.

It has been determined under test that clamp strength of a joint (related to joint continuity or stiffness) has a pronounced effect on fatigue strength. Here, again, is emphasized the importance of good joint/preparation and contact and thorough working of the rivet in the development of maximum frictional strength.

STATUS OF REPLACEMENT MECHANICAL FASTENERS

HUK fasteners, high tensile steel bolts (smooth shank), and high tensile steel bearing bolts (knurled shank) are available today as replacements for marine rivets but are not presently acceptable for all locations and applications on Coast Guard inspected vessels.

All these fasteners develop a clamp strength several times that of a rivet and generally depend on it for their design strength. Thus good joint preparation as previously discussed continues to be most important. For example, the manufacturer of one bearing bolt gives 1/16" as the maximum allowable hole misalignment to prevent undue bending stresses on the bolt.

Since its formation in the 1950's, the Research Council on Bolted and Riveted Structural Joints has initiated comprehensive investigations into the use of more sophisticated mechanical fasteners in non-vessel structural applications. Although there appears to be some questions on their use in certain highly stressed vessel joints (in some cases constructed of notch-sensitive pre-1948 steel), if professional standards and manufacturers instructions are followed these fasteners should perform satisfactorily in new construction designed for their use.

Their use in repair work, however, (i.e. as rivet substitutes) is very questionable. each proposal should be weighed individually, considering number, location, details of plate condition, etc. It's questionable to combine different fasteners in one important joint. (e.g. smooth shanked bolts with rivets – since one is designed for service in bearing and the other in clamp strength. There would probably be excessive clearances around the bolt – particularly with a little misalignment – and if the joint went into bearing, the bolt would not assume its share of the load in conjunction with the rivets).

ARE RIVETED SHIPS MORE FLEXIBLE THAN WELDED SHIPS?

This question is most interesting on the Lakes because of the L/D hull ratio of the long, shallow bulk carriers; and it gets into the basics of a riveted joint. In other words, is there some minute slippage in riveted joints?

Under appropriate sea conditions these long Laker hulls noticeably twist and work. Each vessel has its own characteristic motion.

In researching this particular item, it was found that careful studies were conducted after World War II and hull deflections between riveted and welded ships of similar design were compared. There was no significant difference in their flexibilities. This conflicted with the prevailing opinion of many operating personnel. Today, on the Lakes, there are personnel who hold that riveted ships are more limber. However it is most doubtful that any slip occurs in riveted joints unless the hulls are highly stressed; with such slip, rivet leakage would most likely be evidenced.

It is worth noting that stress raisers are significant on a riveted ship just as on a welded one. There are examples of complete structural failures of riveted hulls by cracks initiated at discontinuities. By comparison with welded hull failures, cracks in riveted hulls often stopped before total girder failure took place.

<u>Primary References</u>

(1) "Marine Engineers Handbook" – Labberton and Marks (McGraw – Hill) 1945
(2) "Merchant Marine Officers Handbook" – Turpin and Mac Ewen (Cornell Maritime Press) 1965
(3) "A Guide To Sound Ship Structures" – A. D'Arcangelo (Cornell Mar. Press) 1964
(4) "Riveted Joints" – A.E.R. DeJonge (ASME) 1945
(5) "Bibliography on Bolted and Riveted Structural Joints" – J. Fisher and L. Beedle (Lehigh University Inst. of Research) 1964
(6) "Supplement to Bibliography on Bolted and Riveted Structural Joints" (same as 5, above)
(7) "Handbook of Ship Calculations, Construction and Operation" – C. Hughes (McGraw – Hill) 1942
(8) "The Design and Construction of Ships" – J. ?iles (J.B. Lippincott Co., Philadelphia, Pa.) 1908
(9) "Principles of Naval Architecture" – H. Rossell and L. Chapman (SNAME) 1942
(10) "Structural Design of Warships" – W. Hovgaard (U.S. Naval Institute) 1940
(11) ABS Classification Rules – 1967
(12) "Manual of Ship Construction" – G. Manning
(13) "Design and Construction of Steel Merchant Ships" – D. Arnott (SNAME) 1955
(14) Navigation and Vessel Inspection Circular 4-60 – Notes on Inspection and Repair of Steel Hulls
(15)"Strength of Materials" – F. Singer 1951
(16) "Merchant Ship Construction" – H. Pursey 1950
(17) "Modern Shipfitters Handbook" – W. Swanson 1941
(18) U.S. Navy, Bureau of Ships Manual
(19) ASME Boiler Construction Code
(20) "Riveting and Arc Welding" – H. Rossell (Simmons – Boardman Publishing Co.) 1934
(21) "Practical Ship Production" – A. Carmichael (McGraw-Hill) 1941
(22) "Modern Ships – Elements of their Design, Construction and Operation" – J. LaDage (Cornell Maritime) 1965
(23)"Fatigue of Welded Steel Structures" – W. Munse (Welding Research Council) 1964
(24) "Mechanical Design and Systems Handbook" – H. Rothbart, Ed. (McGraw-Hill) 1964

Articles or Papers

(1) "Clamp Force – The Silent Partner in Riveted Joint Dependablility" – G. Maney (Fasteners, Vol. 1946)
(2) "The Real Strength of Rivets" – J. Diemer (Fasteners-1962)
(3) "The Effect of Bearing Pressure on the Static Strength of Riveted Connections" – W. Hunse V. of Ill. Bulletin No. 454
(4) "The Effect of Rivet Bearing on the Fatigue Strength of Riveted Joints" – V. of Ill., SRS No. 170
(5) "High Strength Structural Bolts vs. Rivets" – E. Chesson – "Building Research" 1964
(6) "Transactions" of SNAME - various articles
(7) "Mechanical Fasteners for Marine Applications" and related papers and manufacturers instructions. – R. Hansen, Lamson and Sessions Co. 1967
(8) "Transactions" of ASCE – articles in Volumes 99 (1934) and 109 (1944) discuss riveted joints
(9) "Testing loose rivets" – Powers – V. 61, pg. 386
(10) "Riveted as Welded Ship Structure" E.M. Mac Cutcheon – The Welding Journal February 1949
(11) "Observations on Hull and Structural Maintenance" – an article by Paul J. Ranahan & Leslie D. Weston

PROFESSIONAL NOTES (K. B. SCHUMACHER)
BAL. 1-77
20 December 1977

Subj: Riveted Hull Repairs

Ref: (a) NVC 7-68 Inspection and repair of

1. GENERAL

Most, if not all, vessels being built today are completely welded and their hulls do not contain rivets. There are, however, many existing inspected vessels that are either completely riveted or have riveted strakes which were installed as crack arrestors. The referenced NVC gives guidelines for the inspection and repair of rivets. These guidelines have not always been followed in our zone or around the Coast Guard. The purpose of this note is to reaffirm the guidelines in reference (a) and to provide information to you, the inspectors, which I hope will help you to do top quality inspections.

2. BACKGROUND

Recent drydock inspections in the Baltimore zone have revealed a substantial problem in the condition and repair of riveted hulls. The conditions are:

a. Deteriorated rivets. The deterioration is characterized by erosion of the rivet point somewhat below the surface of the surrounding plate exposing the countersink. (See figure 1). This deterioration is common on the bottom of tank vessels, especially those operating on the Gulf Coast, and on freight vessels along the top of the bilge strake. The deterioration is the result of wear on the rivet points by the bottom and by docks; once the point is lost accelerated corrosion results. Though deteriorated, the rivets inspected were tight in the hull.

b. Unauthorized rivet repairs. NVC 7-68 authorizes repair of deteriorated rivets by ring welding as a temporary measure in scattered locations. A permissible permanent repair is to remove the corroded metal from the point, build up the point by welding and caulk. The vessels we have inspected have had large numbers of adjacent ring welded and pad welded rivets. In some cases the deteriorated rivets have merely been covered by an epoxy compound. These unauthorized repair methods have become common practice, with shipyard and classification society personnel and owners representatives advocating them and objecting to application of the NVC standard. But, as the NVC states, rivets which do not fill their holes do not effectively carry their share of the load. Ring welding or merely covering with epoxy does not remedy this situation.

c. Unauthorized welding of riveted plates. Because steel in riveted hulls may be more sensitive to brittle fracture than steel in newer ships, welding repairs are limited to:

(1) Shell and deck seams involving existing plating thicker thatn ½" should ordinarily not be welded.

(2) Flush butts between new and existing strakes of shell and deck may be welded. Such welds must have full penetration.

(3) Lapped butts involving the use of fillet welds should not be used. Welded lapped seams may be used where plating is ½" or less in thickness.

(4) For greater thicknesses, replacement should be as original or the design changed, requiring plan approval, so that butt welds can be employed. A typical method of doing this with in-and-out plating is shown in the sketch on page 33 of reference (a).

If welding is proposed on lapped seams in tanks used for carrying oil, caution must be taken to insure that the area including the lapped area is free from oil. In some vessels fiber caulking material was used between laps and this may also present a problem to welding. Caulking edges are essentially at a lapped butt or seam where the outer plates' edge has been caulked or pushed into and married with the metal of the inner plate with a pneumatic tool for an effective watertight seal. As this edge erodes/corrodes in service, it may be re-caulked or cut back and caulked. The ability to do this is limited by the plate edge to rivet hole distance. In some instances where this distance has been reduced to a minimum an insufficient amount of plate remains for rivet holding (ligament) to allow further cutting and re-caulking. Often the result has been an unauthorized repair by welding. As noted above, the NVC does not allow any welding of lapped riveted butt strakes or lapped seams where plate thickness exceeds ½". Welding of riveted seams becomes more important where the riveted strake is a required crack arrestor – a plate strake installed to prevent the catastrophic propagation of hull cracks. Welding of these strakes (i.e. fillet welding on lapped seam) entirely defeats the purpose of the crack arrestor. The ABS Rules deleted reference to riveted construction requirements after 1969; pre-1969 rules are still applicable and are available in the Inspection Division office. This particular problem, if in question, should be addressed to the Chief Inspection Division. If necessary, ABS – New York through HQ (MMT) will be consulted to determine if the design function of a strake of plating was that of a crack arrestor. Individual surveyors may not be aware of this function. In one instance, on a 1930+ vintage dredge, we have found extensive wear on lap butts on the flat bottom. This had progressed to the point where almost the entire plate thickness of the rivet hole countersink was worn away. It represented 30-45% or more plate thickness loss in way of the lapped butt. The only adequate repair here, as where the caulking edge is lost, is plate and rivet renewal or a modified design requiring plan approval. Here, though a substantial part of the rivet was lost and its holding/load bearing capability reduced, the rivets were found to be still tight in the hull.

3. ADDITIONAL INFORMATION

Questions have arisen concerning how to sound rivets and how to ensure tightness between bulkheads.

a. Rivets sounding is properly done only from the inside of the hull at the rivet head, by hammer tapping the rivet head with a finger on the opposite side of the head at the plate and rivet head. Loose rivets, which vibrate or ring upon sounding, should be replaced. A slight vibratory movement is not cause for renewal.

b. Waterstops serve to stop the movement of liquids between the faying surfaces of riveted lapped strakes. They usually consist of welding across the riveted seam between rivets or the insertion of impregnated canvas between the faying surfaces. Waterstops are located at bulkheads. When riveted repairs are undertaken, care should be taken to maintain the integrity of or to renew the waterstops.

4. ACTION

The inspector must evaluate the vessel's present condition and past repairs in reference to the NVC. There are several judgement factors which must be considered; these include:

a. Location on the hull; rivets in the amidships section are in a critical location.

b. The number of deteriorated rivets in any location.

c. The number and locations of generally deteriorated rivets areas.

d. The condition of 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.

Consideration of these factors will determine the necessity of removing and repairing old, unsatisfactory repairs. There are no published guidelines in this area and knowledge about riveted construction has become minimal. Individual surveyors may wrongly feel constrained by past rivet repairs and even bound to accept new repairs of the same nature.

Ins summary, an uncontrolled rivet repair practice has developed in the industry, and the USCG has not enforced the NVC requirements. The result is that some hulls have been so extensively repaired by incorrect methods as to create serious hull strength questions. The marine inspector is in a position to correct this problem and to educate others in the marine industry. All riveted hull areas should be carefully evaluated and, should any question result, the Chief of the Inspection Division should be consulted.

NOTE ON RIVET DETERIORATION

CICCALONE 11/90

The attached diagram has been prepared to show three typical cases of the condition of rivets that may exist in lapped seams of older vessels.

Rivet A – Rivet A typifies a sound rivet. Even 30+ year old vessels will still have rivets where the heads which include the crowned reinforcement above the adjacent plate surface are still visible. In most cases, the reinforcement disappears and the rivet head lies flush with the plate. This is quite normal and sometimes considered optimal.

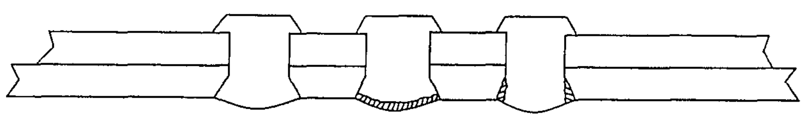
Rivet B – Rivet B is typical of many of the rivets in the COASTAL MANATEE. The center of the rivet has experienced some deterioration. Additionally, there is a small portion of the countersink visible where the head has wasted away. However, as the diagram indicates, there is a significant amount of rivet material left in the shoulders of the countersink that continues to hold the rivet fast and not adversely affect the clamping force of the joint. Inspectors should not be concerned with this condition unless the rivet has "started". The term "started" refers to the condition when the rivet has worked sufficiently to create a crack between itself and the countersink of the plate. This normally results in a leak which is readily visible once the hull dries. This is not a serious condition unless there are large numbers of adjacent rivets which are leaking. Any repairs should be accomplished by accepted cold-working methods that will reseal the heads. Building up or "pointing" rivet heads should be discouraged today because most welders do not have the experience to do it. Addition of too much heat or ringing the rivet head will cause it to loosen to the point where it is useless.

Rivet C – Rivet C typifies a bad rivet that should be replaced. The head has eroded so far that there is virtually no material left in the shoulder and in effect, has caused the rivet to resemble a straight pin. Any type of shearing force will easily cause this rivet to tear or pop, resulting in joint failure. Application of heavy preservative hull coatings makes this condition hard to spot as it becomes difficult to determine the erosion in the countersink. A good white blast of the hull will expose these rivets.

Footnote: Contrary to popular belief there is still riveting expertise available to effect rivet renewals. There are at least three crews in the Great Lakes major vessel drydocking yards who are available to travel. Additionally, at least one of the companies serving the Port of Portland (OR) Ship Repair Facility at Swan Island also has a riveting crew.

TYPICAL RIVET DETERIORATION

INTERNAL SIDE



A B C

EXTERNAL SIDE

PLATES	- 1"
RIVETS	- 1"
COUNTER SINK	- 39 DEGREES
PITCH	- 4.5 RIVET D