U.S. Department of Homeland Security

United States Coast Guard

Commandant
United States Coast Guard

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NAVIGATION AND VESSEL INSPECTION CIRCULAR (NVIC) NO. 7-68 CHANGE 1

Subj: NOTES ON INSPECTION AND REPAIR OF STEEL HULLS

1. PURPOSE. This Circular provides comprehensive guidance to Coast Guard Officers in Charge, Marine Inspection (OCMIs), Recognized Organizations (ROs), repair facilities, and vessel owners and operators regarding acceptable practices for structural repairs to steel hulls on U.S. flag vessels.

2. ACTION. This NVIC applies to all owners and operators of U.S. flag vessels subject to inspection pursuant to 46 USC 3301 that undergo periodic repairs, maintenance, or modifications.

3. AUTHORIZED RELEASE. Internet release is authorized.

4. PUBLICATIONS AFFECTED. NVIC 07-68 is hereby canceled. All references to NVIC 07-68 in other Coast Guard policies should use this version, NVIC 7-68 CH-1. Where this circular conflicts with COMDTINST 16000.71, this circular takes precedence. This Circular does not impose new regulatory requirements. It identifies generally quality standards for use in drafting repair plans as required by existing structural-integrity regulations in 46 Code of Federal Regulations (CFR) under the applicable vessel subchapter.

5. DISCLAIMER. This guidance is not a substitute for applicable legal requirements, nor is it itself a regulation. It is not intended, nor does it impose legally binding requirements on any party. It represents the Coast Guard's current thinking on this topic and is issued for guidance purposes to outline methods of best practice for compliance with applicable law. An alternative approach may be taken if the approach satisfies the requirements of the applicable statutes and regulations.

6. MAJOR CHANGES. This NVIC provides updated guidance for vessel owners and operators regarding ship repair procedures including additional guidance on pitting and corrosion repair in Section 5 while also incorporating the International Association of Classification Societies (IACS) Recommendation #47 Part B (Ship Repair and Maintenance), as an acceptable standard for ship repair.

7. BACKGROUND: Steel-hull construction and repair methods have changed significantly since original publication of these notes in 1968. Modern vessels employ optimized scantling, higher-strength steels, and structural arrangements requiring improved control of alignment, weld quality, distortion, and coating restoration. Modern steels are engineered for enhanced weldability, strength, and corrosion resistance, which has improved the quality and durability of welded vessels. The introduction of advanced technology and welding techniques have increased consistency and quality control, while the use of advanced inspection methods, including ultrasonic testing and radiography, ensures weld integrity and safety.

8. DISCUSSION: This change updates legacy standards by recognizing the IACS Recommendation #47 Part B as an acceptable repair-quality standard and supplements this NVIC with current industry best practices, including detailed requirements for fit-up, alignment, welding, inspection, surface preparation and procedures for evaluating and repairing pitting corrosion. It provides an option for industry to utilize IACS Recommendation #47 Part B in conjunction with or in place of this guidance depending on the nature of the vessel's repair and the repair organization's capability.

9. APPEALS. Persons aggrieved by a decision of the Coast Guard that a vessel did not meet regulatory standards may appeal in accordance with the procedures contained in 46 CFR § 1.03. The Coast Guard will notify the appellant of its decisions.

10. ENVIRONMENTAL ASPECT AND IMPACT CONSIDERATIONS. The Office of Environmental Management, Commandant (CG-SHORE-V) reviewed this Commandant Instruction, and the general policies contained within, and determined that this policy falls under the Department of Homeland Security (DHS) categorical exclusion A3. This Commandant Instruction will not result in any substantial change to existing environmental conditions or violation of any applicable federal, state, or local laws relating to the protection of the environment. It is the responsibility of the action proponent to evaluate all future specific actions resulting from this policy for compliance with the National Environmental Policy Act (NEPA), other applicable environmental requirements, and the U.S. Coast Guard Environmental Planning Policy, COMDTINST 5090.1 (series).

11. DISTRIBUTION. No paper distribution will be made of this change. An electronic version will be located on the following Commandant (CG-DCO) web site https://www.dco.uscg.mil/Our-Organization/NVIC/.

12. RECORDS MANAGEMENT CONSIDERATIONS. Records created as a result of this publication, regardless of format or media, must be managed in accordance with Records & Information Management Program Roles and Responsibilities, COMDTINST 5212.12 (series).

13. FORMS. None.

14. REPORTS. None.

15. SECTION 508. This publication is created to adhere to accessibility guidelines and standards as promulgated by the U.S. Access Board with consideration of Information and Communications Technology (ICT) requirements. The customer experience (CX), plain language, and service delivery improvements were considered. If modifications are needed for this artifact, please communicate with the Section 508 Program Management Office (PMO) at Section.508@uscg.mil. Concerns or complaints for non-compliance of policy or artifacts may be directed to the Section 508 PMO, the Civil Rights Directorate for the Coast Guard, or to the U.S. Department of Homeland Security at accessibility@hq.dhs.gov.

16. QUESTIONS. All requests for changes or questions regarding this circular should be directed to Commandant (CG-CVC) staff at CGCVC@uscg.mil.

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Enclosures: (1) Notes on Inspection and Repair of Steel Hulls

Notes on Inspection and Repair of Steel Hulls

1. PURPOSE

A. This guidance applies to all U.S. flag inspected steel vessels, both classed and non-classed. The review of proposed repairs during inspections, drydock examinations, internal structural examinations, and special surveys are intended to outline the expected level of thoroughness for each inspection; ultimately, however, this determination rests with the inspector. This NVIC covers primarily permanent repairs of steel hulls. If the permanent repair needs to be postponed, the owner should propose the temporary measures to be implemented, the expected date of full repairs, and in the case of classed vessels, the condition of class to be imposed (if applicable) for the inspector's consideration.

B. The purpose of these NVIC guidelines is twofold: to consolidate technical information regarding the inspection and repair of steel vessels, and to ensure a uniform approach to hull repair requirements among marine inspection offices. It is important to note that these guidelines are not exhaustive and are not intended to replace the use of sound judgment. The OCMI should remain flexible when determining the best course of action and utilize the Coast Guard technical offices of the Marine Safety Center, Traveling Marine Inspections (CG-5P-TI) or the Office of Design and Engineering Standards (CG-ENG) when necessary. When industry presents a reasonable plan for steel repair, the OCMI should use these guidelines as a framework for their response, ensuring it is timely, informed, and collaborative.

2. REFERENCES

1. Marine Safety Manual (MSM) Volume II, Material Inspection, COMDTINST M16000 (series)Inland Tank Barge Inspection and Repair Guidelines, March 28, 1994, provide guidelines specific to inland barge repairs.

2. IACS Recommendation No. 47, Part B – Shipbuilding and Repair Quality Standard for Existing Ships

3. Applicable Class Society rules and survey guidance (ABS, DNV, LR, ClassNK, etc.) for allowable thickness diminution, net scantlings, and hull survey/repair requirements

4. Relevant Ship Structure Committee (SSC) studies (e.g., SSC-394 Strength Assessment of Pitted Plate Panels)

5. Passenger Vessel Association (PVA) Pitted Plate Assessment Tool Excel Workbook

3. GENERAL

A. The performance of an adequate inspection requires a knowledge of where to look and what to look for. With respect to hull structure, the inspector is looking for deterioration

which may affect the strength or integrity of the hull to an extent which would make it unseaworthy. The major categories of these deficiencies are as follows:

i. Wastage General or Local: Wastage refers to diminution in thickness due to corrosion. This may be general (uniform over a large area of the hull) or local (pitting or grooving) corrosion.

ii. Hull Defects: Defects include fractures, buckling or other deformation, cracking or tearing, weakening or failure of welds. Defects occur mostly at locations where stress concentration is high. Weld defects, flaws, and poorly designed joints may lead to fractures. When fractures occur at joints subject to lower but repetitive (cyclic) stresses (usually due to wave action) they are classified as fatigue fractures (fatigue cracks). Deformation is generally caused by overloading of structure. In cases where non-linear deformation occurs in response to compressive or shear stresses in slender members, the deformation is classified as buckling.

iii. Hull Damage: Hull damage may be caused by 1) navigation in extreme weather conditions, 2) loading and unloading operations, 3) water ballast exchange at sea, 4) wear and tear, 5) contact (with quayside, ice, lightering service, alliding with underwater objects, etc.). Damage caused by accidents like collisions, allisions, groundings, fire/explosions, etc. are classed as marine casualties and should be addressed in accordance with 46 United States Code (U.S.C.) Chapters 61, 46, Code of Federal Regulations (CFR), Part 4, and the Marine Casualty Reporting Procedures Guide with Associated Standard Interpretations, NVIC 1-15. It is not covered in this NVIC.

B. While it is logical to expect more wastage on the older vessels and on vessels which have seen rough service, inspection of the newer vessels is also required, because some of these deteriorations can occur even after relatively short service. These notes detail, in Section 5, some of the points which have been the source of trouble in the past and to which special attention should be given in carrying out a hull examination.

C. When during such an inspection, one or more of these deteriorations are encountered, the inspector must first evaluate if seaworthiness is compromised or not. This calls for considerable discretion because the line of demarcation between what is seaworthy and what is not, is approximate and subject to some range of interpretation. The following factors must be weighed in making this determination:

i. The extent and degree of deterioration.

ii. Whether the deterioration is currently active or has been arrested in whole or in part by protective action.

iii. The period of time involved before the next scheduled inspection of the area in question. Certain areas are accessible to inspection at every drydocking whereas other areas are only exposed during the surveys required by the classification

societies. A progressing condition which may be acceptable in one area may not be acceptable in another without repair or, at least, without a pending requirement for further inspection at a prescribed future date.

iv. Whether the repair work contemplated is necessary to restore seaworthiness or is a maintenance measure to ensure prolonged utilization of the vessel. In the first case, repair is required. In the second case, the details of the condition should be reconsidered at a future inspection and, possibly, called to the attention of the owner so that they may exercise their own good judgement.

v. Reference (A) discusses structural failures and casualty procedures to be followed in reporting and documenting Class 1, 2 and 3 structural failures and their definitions.

D. Once a decision has been reached by the inspector that repair is necessary, the specific requirement detailing the nature and extent of the work should be developed. The general rule is to "renew as original", i.e., to replace the defective structure so as to restore its original design and condition. However, in cases where the necessity for repair apparently stems from an unsatisfactory structural feature, this feature should be corrected in making the repairs. As an example, following unsatisfactory service experience, square hatch corners have been required to be modified by provision of radiused insert plates. Where such a need for design modification exists, plans covering the change should normally be prepared and approved before the work is undertaken, insofar as practicable.

E. In some instances, the owner may desire to reduce the structural work corresponding to renewal in kind by provision of supplementary structural reinforcement. When one considers the complicated and costly nature of repairs involving extensive renewals, it is evident that consideration should be given to such alternate means of repair proposed by the owner, or by the shipyard on their behalf if they are generally in line with the procedures and methods set forth in Section 6 of these notes.

F. If the vessel is classed, and/or is assigned a load line, the nature and extent of the repairs as determined by the classification society surveyor is to be given full consideration. However, if there is a difference of opinion as to what should be required, the inspector cannot discharge their responsibility by deferring to anyone else's judgement. In such cases, they should refer the matter to their superior officer for assistance and/or decision before the final requirements are written. A working liaison between the OCMI and the local representative of the classification society will generally serve to iron out such difficulties. The repair measures set forth in Section 6 of these notes are to be considered as best practices rather than specific "rules" to be rigidly enforced in all cases. They should be employed as guides taking into account the interests of the ship owner while, at the same time, fulfilling the Coast Guard's statutory responsibility with respect to seaworthiness and safety of life.

4. DOCUMENTATION AND FOLLOW-UP

A. During inspections, drydock examinations, internal structural examinations, and special surveys, Marine Inspectors should document all findings into the Marine Information for Safety and Law Enforcement (MISLE) Database. All MISLE entries shall follow the guidance in CVC-PR-009 (series) MISLE Vessel Inspection and Examination Activity Entry and Review. Documentation should include location (frame numbers, longitudinal positions, tank or compartment), representative photographs of damaged and pitted areas before and after repair, and UT readings showing the mean remaining thickness and the minimum remaining thickness of the steel plate, plus average pit depths.

B. Record the chosen repair method (e.g. coating/pit filler, weld build-up, crop and renew) and any conditions or limitations. A Special Note should also be added to the vessel's MISLE profile to monitor any identified areas of concern such as wastage, pitting repaired with coating/filler, hull defects or stress, at every dry dock.

C. For classed vessels, ensure repair plans are aligned with Class Society recommendations and that the attending surveyor approves.

Note: For marginal cases or novel repairs, consider requesting an engineering evaluation from the owner's naval architect, Class Society technical office, or Coast Guard technical offices of the Marine Safety Center or CG-ENG. A Special Note should also be included in the vessel's MISLE profile for any approved novel repairs to be checked at every dry dock.

5. NOTES ON INSPECTION

A. DETERIORATION

Deterioration of the metal structure is probably the most common, single defect in steel vessels. It can be due to a number of different causes or combinations thereof including age, inadequate maintenance, working of the hull structure, chemical or erosive action of the cargoes carried, electrolysis, local wear, some improper feature of design, etc. In some cases, such as deep pitting and external grooving, deterioration is easy to detect. In other cases, such as the general erosion of age or incipient joint or member failure, it is impossible to ascertain the deterioration without actually gauging or very careful examination. In any case, judgement is required to evaluate and determine if and to what extent repair is necessary.

B. GAUGING

i. The only practical way of determining the degree of deterioration is to measure the thickness of the member in question and compare it with the original thickness. This comparison is usually expressed in terms of percentage of wastage from the

original scantling.

ii. There are two approaches to gauging. In the first, gauging is used to provide a quantitative basis for evaluating a questionable local condition. Even though this involves only limited gauging, it should not be undertaken unless there is sufficient cause. Deep pitting over an area, holes, fractures, excessively thin edges on structural shapes, bands or belts of corrosion across bottom plating which may indicate heavy working, are all justifiable bases for requiring gauging in the affected area. However, care must be exercised not to extend gauging to have it become a "fishing expedition." The ship owner should be forewarned that requirements based on a local survey of this kind may have to be extended when the plate edges in way of the renewals are examined by the inspector.

iii. Belt gauging goes far beyond the investigating of a local condition as described in the previous paragraph. It involves taking readings around several complete transverse sections of the hull including deck, sides and bottom. It is intended to furnish information which may be used to assess the average wastage of the hull envelope and its consequent effect on the longitudinal strength of the vessel. Belt gauging is a major undertaking, costly to the ship in both time and money. It should be required only for good and sufficient cause, as for example in the following cases:

a. A vessel coming under Coast Guard certification for the first time.

b. A vessel changing service to a more exposed route.

c. A vessel undergoing a major conversion.

d. A vessel which has had a structural failure which could be attributable to age or general deterioration.

e. A vessel in which there is serious question concerning seaworthiness.

iv. In addition to the above, it should be noted to review reference (C) which may contain requirements for thickness measurements and structural examinations as part of the vessel’s classification survey program. Thickness gauging may be required at Periodical, Intermediate, Special, Damage, or other surveys when deemed necessary by the attending Surveyor based on the vessel’s age, condition, service history, corrosion protection, and examination findings. The extent and location of thickness measurements shall be in accordance with the applicable ABS MVR and Survey Instructions in effect at the time of survey. Thickness measurement reports are to be submitted to ABS for review and evaluation. Survey intervals and gauging requirements are subject to change through rule revisions; therefore, the latest edition of the applicable ABS MVR should be consulted to determine current requirements. Where possible, to minimize expense to the owner, the inspector should witness such periodic surveys and make use of the results obtained.

v. Belt gauging may clearly indicate that extensive replacements are required. In this event, a requirement to renew as original with the associated plan approval may or may not be appropriate. Frequently in lieu of renewals, strapping or partial renewal to heavier scantlings may serve to restore the required strength. This should not be resolved locally. The record of the gaugings and the proposal for repair should be submitted for approval to the OCMI and if necessary, the appropriate Coast Guard technical office (e.g. Marine Safety Center, Traveling Inspectors, etc.). It is especially important in such cases that the inspector validates the gaugings and clearly indicate they consider them to be representative of the general condition of the ship. The technical staff can evaluate the readings which are provided; but only the inspector, who has seen the vessel, can state that the readings are representative.

vi. For belt gauging to be of value in determining the average condition of the vessel, the location of the belts on the vessel and the points to be gauged within the belts should be selected by the inspector. Experience is required to make sound judgements in this regard. The following are some of the important factors which must be considered:

a. The belts should be located in sections of the hull wherein the seaworthiness is most in question. For example, in a light products tanker, a belt gauged in way of the machinery space or a cofferdam would probably not be representative of the condition prevailing in the cargo tanks. Similarly, in a dry cargo vessel, a belt across the double bottom in way of a saltwater tank would be more meaningful than a belt in way of a fuel oil tank.

b. The locations of the individual readings within the belts should be chosen with a view towards determining the average remaining plate thickness not towards finding the unique spots of minimum thickness. However, the worst single spots should be sought out first to determine whether more extensive gauging is justified. In many instances, it may be necessary to obtain more than one reading to determine the average remaining plate thickness. In such cases, the inspector, based on their personal observation, should record only one figure which they feel to be truly representative of the plate concerned.

c. Inconsistencies should be explained in the record of gaugings whenever possible. For example, a previously installed local renewal in the belt is not representative of the general condition of that strake. The reason for the anomalous reading should be noted or, preferably, the belt should be shifted to provide a reading which is representative of the strake. Similarly, if a reading is so low that renewal in the area will be required for local strength, the extent of the renewal should be indicated. Credit towards longitudinal strength could be given to extensive renewal of the strake, but not to a localized replacement.

d. In the case of longitudinally framed vessels, the belt gaugings should include readings on all deck, side and bottom longitudinals and on the

plating of the longitudinal bulkheads. Readings on internals should be taken on both the webs and the flanges and should be identified. These gaugings may be taken with a caliper.

vii. Ultrasonic Testing (UT) for the measurement of plate thickness may be used in lieu of drilling and gauging when authorized by the local OCMI. When this method is used to comply with a specific requirement for gauging, the inspector should approve the choice of locations and witness the readings. Also, the Marine Inspector should confirm the UT equipment is calibrated prior to beginning testing. Test pieces may be used to check the calibration of the instrument; however, care must be taken that the relative ease of taking accurate readings on a prepared test piece does not result in unwarranted confidence in the accuracy of readings taken on the vessel. Surface preparation to receive the probe, operator technique and competency, and condition of the "opposite" side are among the many variables which can affect readings. Therefore, comparing the ultrasonic readings with exposed structural edges or specialized field-removed scrap samples is preferable to complete reliance on test pieces for instrument calibration with the UT technician.

viii. After the gaugings have been recorded, comparison with the original scantlings can be made only by referring to the vessel's construction plans. The "Shell Expansion" is the most useful plan for this purpose; however, the "Midship Section" is also useful. To facilitate evaluation of results, a "Percentage of Wastage" nomograph is in Section 9 of these notes.

C. CORROSION

Corrosion may affect structural integrity, not just appearance. Decision-makers must consider both local loss of thickness and overall panel/structural strength. Service experience of the classification society, which forms the basis for their rules on the construction of ships, indicates that for most portions of a vessel, without other weakening factors, a local thickness deterioration of up to about 25% may be accepted before replacement is necessary. This is based in part on the condition usually found aboard ship that all structural members do not deteriorate uniformly. This means, in the application of this percentage, considerable judgement is called for depending upon the location and extent of wasted material. Localized wastage of some portions of plates or structural members in excess of 25 percent may be accepted in many cases, if the condition of the adjacent material is sufficiently good to maintain an adequate margin of strength.

D. PITTING CORROSION

i. Pitting corrosion is a localized form of corrosion that creates small, random holes or cavities in a metal's surface. The Marine Inspector should evaluate pitting on structural plating, by visual examination. Focus on common pitting areas including: bottom plating

and tank tops, bilges and low points with ponding, areas around sounding pipes, air pipes, drains, and overboard discharges, and deck areas exposed to cargo spills or areas with standing water. They should determine whether the corrosion is active, or if the plate is coated and stable. They should also distinguish between coating breakdown with light surface rust or very shallow pits and localized deep pits or clusters that may threaten structural integrity. If corrosion is active, the root cause must be corrected as part of the holistic repair strategy. If the corrosion is a past event and coating is intact, it may be documented and monitored over time.

Red Flag Indicators – Immediate Attention:

a. Deep pitting at or below the net allowable plate thickness in bottom shell, bilge, or strength deck.

b. Pitting accompanied by leakage, cracks, or buckling.

c. Wide areas of heavy pitting under failed coatings in ballast or cargo tanks,

d. Multiple layers of old doublers over heavily pitted original plating.

Note: These conditions should be treated as priority structural issues and normally resolved with crop and renew and, where appropriate, further evaluation by Class Society or Coast Guard technical offices of the Marine Safety Center, Traveling Marine Inspections or CG-ENG.

ii. Reference (B) typically considers the following pitting intensities as light (< 5% of area), moderate (5–15%), or heavy (> 15%). class rules may use different pit density intensity diagrams for categories. For the purposes of this Circular, light pitting intensities can be considered isolated pitting. Guidance on repairs of isolated pitting can be found in section 6.A. Coast Guard inspectors should evaluate moderate or heavy pitting in accordance with reference (B) which recommends using a standard sample area of 300 mm × 300 mm (12" X 12") when deciding the percentage of scattered pitting. All visible pits within this area should be measured and documented. The combined pit footprint within the sample is determined by summing the measured pit opening areas (i.e., the total area represented by the combined widths/openings of all pits in the sample). The average pit depth for the sample is determined by averaging the measured depths of the pits within that same area.

iii. To estimate section loss attributable to pitting, an equivalent average wastage for the sample is calculated by applying the area fraction of pitting to the average pit depth:

a. Area fraction pitted = (Total pit opening area in sq. inches within sample) ÷ (144sq. inches)

b. Equivalent average metal loss = (Area fraction pitted %) × (Average pit depth)

iv. The resulting equivalent average metal loss across the sample area is then compared to an allowable wastage criterion. Reference (B) allows up to 25% corrosion for the sample. The equivalent average metal loss should be converted to a percentage of the original plate thickness:

Calculated wastage = (equivalent average metal loss) ÷ (original thickness) × 100

ix. Recommended actions based on wastage are:

a. If the calculated wastage is less than 25%, the plate condition is considered acceptable for continued service with repair as appropriate (e.g., coating restoration/mitigation and monitoring).

b. If the calculated wastage meets or exceeds 25%, the plate is considered to have exceeded allowable wastage and renewal (or an approved repair restoring full structural capacity) is required, consistent with applicable marine safety and structural standards and the vessel's classification/plan requirements.

c. Pitting not meeting criteria for plate renewal should be repaired using the guidance in Section 6.A

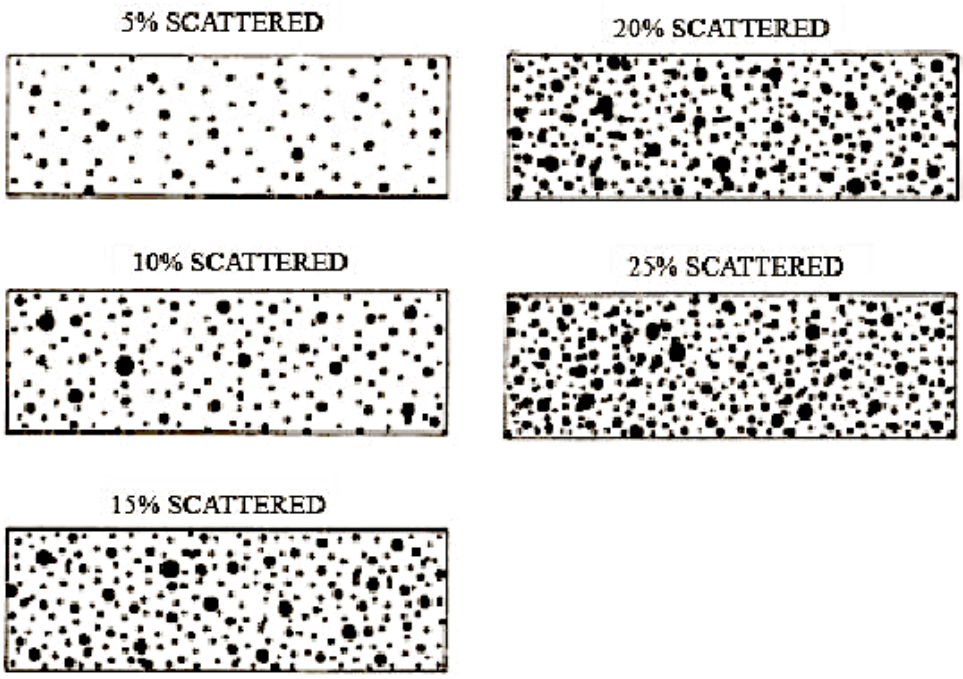


Figure 1: Pitting Intensity *(Source: ABS MVR)*

E. OVERSIZE OR UNDERSIZE SCANTLINGS

There are some vessels in existence which were built to scantlings differing from those required by the current American Bureau of Shipping Rules. In evaluating the necessity for replacing deteriorated structure in such vessels, allowance needs to be made for the fact that the vessel was

built to scantlings differing from the current requirements. Where the original scantlings are known to be in excess of requirements, a corresponding increased corrosion allowance is acceptable. Conversely, where original scantlings are below requirements, the maximum acceptable deterioration is reduced. As an example, for a vessel that is built light, or under scantlings, a 15% wastage threshold between acceptable wear and substantial corrosion, is used in determining if the affected area requires to be renewed. These limits are generally set by either class rules (under which the vessel was built to). Also, individual members may sometimes be made oversize to compensate for some other feature of the overall design. In such a case, an extra corrosion allowance would not be justified. Because of these ramifications, it may not be practical for inspectors to determine whether a vessel's original scantlings are under or over requirements. When it is believed that the original scantlings may have been light, the matter should be referred to the OCMI and if necessary, the appropriate Coast Guard technical office (e.g. Marine Safety Center, CG-ENG, Traveling Inspectors, etc.) before a full corrosion allowance is permitted. On the other hand, if the owner requests an increased corrosion allowance because of oversized scantlings, they should offer suitable verification. Proper notation on the original plans of the vessel or documentary evidence from the classification society would be acceptable for this purpose.

F. SPECIAL COATINGS

Recent advances in protective coating technology have given promise that corrosion in ship steel may be virtually eliminated. Based on this, ships constructed since 1965 have had the option of building the scantlings which are, in general, 10% below the scantlings tabulated in the Class Society Rules found in reference (C), acceptable special coatings have been applied. In all such cases, the approved hull structural plans clearly indicate such reduction by showing, for each plate and structural shape, both the required tabular scantling and the permitted reduced scantling. For example, a structural shape would be indicated on the plan as follows:

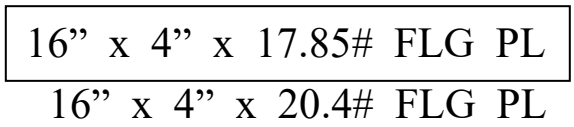


Figure 2: Scantling on hull structural plans

i. Normally, painting of the hull structure has not been the subject of Coast Guard requirements. However, in the case of vessels which have been allowed to have reduced scantlings on the basis of special coatings, it is a valid concern of the Coast Guard inspector to ensure that such coatings are maintained. If corrosion has occurred, evaluation of the degree should be referred to the required tabular scantling and not to the as-built scantling.

ii. Filling or coating-only repairs over pitting are limited. Further guidance can be found in Section 6 (A).

G. HIGH STRENGTH STEELS

i. The use of high strength steels in some recently built ships introduces new problems which must be carefully considered when evaluating structural renewals or repairs. These steels offer significant advantages in saved weight, and their use permits thinner sections to be used in highly stressed areas which would otherwise require excessively thick sections of conventional ship steel. However, the thinner plating and sections of high strength steel are not as forgiving of poor design as the heavier sections of mild steel. Special attention must be paid to the possibility of buckling and detailing in the design and careful fabrication becomes a must. Also, special procedures are required for welding. These are discussed in Section 7.

ii. Structural renewals in areas where high strength steels have been used must be made with the same high strength steel. In some cases, an equivalent grade may be substituted. Also, repairs to high-strength steels must be made in accordance with the specified procedures. A problem arises because high strength steels are not visually distinguishable from ordinary ship steel. Further, both ABS and the Coast Guard have requested that vessels utilizing high strength steels in their construction shall retain on board structural drawings identifying the special steel, indicating where it is used and specifying, in detail, the required welding and fabrication procedures.

iii. In any larger vessel built since 1964, renewal or repair in way of the main hull girder should not be undertaken without first examining the vessel's approved structural plans to confirm if high strength steels were used. If so, every care must be exercised to use the correct steel for renewals and to adhere to the specified procedures for both renewals and repairs. It is worth noting that there is no such thing as a "minor" repair where high strength steels are involved.

H. ALTERNATIVES

In some instances, owners may desire to install supplemental structural reinforcement rather than replace deteriorated material. This may be feasible, but since it constitutes a modification of design, plans detailing the proposed changes should be approved before the work is carried out.

I. DECK PLATING

Deck plating comprises a highly stressed portion of the hull girder and is of critical importance to the longitudinal strength of the vessel. Accelerated corrosion may be expected in the deck because it is subject to mechanical abuse from deck cargo, hatch beams and repeated scaling. Also, it is always exposed and frequently awash. Because of this, the deck plating, especially in the midship's half length, should be carefully examined for cracks, leaks, or signs of excessive wear. The corners of hatch or other deck openings, the corners of deck erections, pads, or other items producing discontinuities or hard spots should be examined for evidence of cracking. Whenever practicable, the detail concerned should be eased and made less abrupt when repairs

are made. In the case of riveted construction, special attention should be paid to the riveting of butts. Discovery of working or loose riveted butts calls for prompt corrective action. This may be evidence of cracking at the rivet holes not yet sufficiently extensive to extend beyond the rivet head. Cracking of the plate will, in general, call for replacement of that portion of the plating. Buckling of deck plating is uncommon; however, the use of thinner high strength plating increases the likelihood. Any such buckling can seriously impair the strength of the vessel and calls for corrective action.

J. DECK LONGITUDINALS

In tank vessels the corrosive deterioration of deck longitudinals may be much more rapid than that of deck plating. These longitudinals are necessary to support the deck plating so that it can carry local hydrostatic loading, to provide panel stiffness to the deck plating so that, as a part of the hull girder, it can carry compressive loading without buckling, and to directly contribute to the hull girder stiffness and strength. Because the relative importance of these factors may be different when dealing with different designs, it is very difficult to establish any generally applicable wastage limits. However, for the usual proportions of longitudinals to plating and usual spans, deterioration of some deck longitudinals up to a maximum of about 49% or about 0.18" wastage, whichever is the lesser, may be accepted provided the average deterioration is not more than about 30% or about 0.14" wastage, whichever is the lesser. For a single voyage, maximum deterioration of some longitudinals as high as about 50% or about 0.22" wastage has been accepted. The above applies to longitudinals fabricated from structural shapes such as inverted angles or T bars. In the case of flat bar longitudinals, the strength of the combined deck plate and longitudinal is critical in compression. Consequently, not more than about a 20% corrosion allowance should be permitted. Additionally, flat bar longitudinals should be faired or replaced if they are distorted or buckled to any degree. In the case of river tank barges not carrying any deck cargo, general deterioration of deck longitudinals up to about 40% may be accepted. Since the obvious necessity for maintaining oil tightness does not apply to the rake ends, they tend to be neglected. This should not be permitted since the rake ends provide the major buoyancy of the vessel and are, therefore, vital to seaworthiness.

K. KEEL PLATING

In recognition of local strength factors and also the additional corrosion to which keel plates are subject as a result of being unavailable for painting when sitting on keel blocks in drydock, keel plating is normally of greater thickness than the balance of the bottom plating. Taking account of the fact that a large part of this extra thickness may be regarded as an additional corrosion allowance, it is generally satisfactory to defer the replacement of keel plating until the wastage is somewhat more than would otherwise be considered acceptable. In determining the amount of such extension, consideration should be given to the condition of adjacent "A" strake(s). If the adjacent plating is in good condition and does not require replacement, the keel plating may be accepted provided the effective remaining thickness is not less than approximately 75% of the original thickness of the adjacent strakes and provided it is not buckled or otherwise damaged. If the adjacent plating is wasted so as to, itself, require replacement, it is generally wise to replace

the keel plating even though it may be wasted no more than about 25% of its thickness.

L. BOTTOM PLATING, INNER BOTTOM PLATING AND BOTTOM INTERNALS

i. The bottom plating complements the deck plating as the lower flange of the hull girder. As well as sustaining a major portion of the hull bending moment, the bottom plating is subject to increased stress due to water pressure. Its strength may be reduced either by general or localized corrosion and by buckling. In view of the prime importance of this plating, the maximum average reduction in thickness to be permitted in about the midships half-length is about 20%. If the wastage exceeds this amount the plating should be renewed. Alternate measures or means of reinforcement can be considered but since they would constitute a major change in the design of the vessel, plans for this should be submitted for approval to the OCMI and if necessary, the appropriate Coast Guard technical office (e.g. Marine Safety Center). If, after consideration of the bottom shell plating with regard to the main longitudinal strength, there should remain local areas or plates requiring attention, these may be dealt with on the basis of a maximum average wastage of about 25% from original, provided the plates and supporting structure are otherwise in satisfactory condition. Welded butts which exhibit excessive wastage (grooving) as compared to the balance of the plate should be rewelded after excavation to sound metal.

ii. Joggled lapped seams and butts are particularly prone to excessive local deterioration because of the flexing which may take place at such joints and because they provide a pocket in which corrosion may develop. Accordingly, when inspecting plating containing joggled lapped joints, it is important to check the condition of the joint itself and particularly the plating thickness in way of the joggle. Renewals should be in accordance with Section 6 of these notes.

iii. Unfair or set-in plating is common forward. A fair degree of deformation of the hull plates in the forward portion of a vessel ordinarily may be accepted without resulting in serious impairment of structural strength. However, for transversely framed ships, severe buckling or set-in condition of bottom plating within approximately the amidships half-length can seriously impair strength. In general, the greater the athwartship extent of buckling the greater the impairment in hull strength. Any appreciable buckle of sufficient athwartship extent to cross a center vertical keel or inner bottom girders is serious. Such a buckle should be corrected by replacement of plating and the buckled portions of girders. If there is no evidence to indicate the buckle was caused by grounding or other excessive local loading, or is associated with excessive wastage, it may be an indication of need for providing additional stiffening. In such instances, the OCMI and if necessary, the appropriate Coast Guard technical office (e.g. Marine Safety Center, Traveling Inspectors, etc.) should be advised of the circumstances and proposed corrective measures. Buckles of shorter athwartship extent may also require correction, depending upon the depth or height of buckles, the number of buckles, and their relative locations. For instance, several bottom buckles within the same frame space are more serious than

the same number of the same size buckles distributed in a random manner. Localized transverse bands of accelerated corrosion or grooving may be found in association with buckles. These are indicative of localized excessive stress which experience indicates may lead to cracking. Consequently, plating replacement may be called for even though the deterioration may be less than 25%. In such cases it is usually sufficient to replace less than a full plate.

iv. In the case of riveted construction, bands of stress corrosion may be observed, mostly immediately adjacent to the riveted lapped butts, even where the plating surface is generally quite fair. Experience has shown that cracking develops in these areas. Since such cracks are in primary hull girder material, their occurrence must be regarded as a very serious matter. Where zones of serious corrosion are noted, appropriate preventive action in the form of plating replacement should be taken before any actual cracking develops. In making such replacements, as in the case of welded construction, renewal of less than a complete plate is acceptable if the condition of the balance of the plate is satisfactory. The butts of such renewal inserts should be flush welded; care being taken to ensure 100% penetration. Originally riveted seams should be riveted, with sufficient existing riveting adjacent to welds released and re-driven to ensure 100% sound riveting.

v. Tank tops are considered in the computation of scantlings for load line assignment both by ABS and the Coast Guard and must be maintained in reasonable condition consistent with their inclusion in the section modulus. Apart from the function of the tank top and the double bottom internals in contributing directly to the section modulus, there are two other structural functions which are equally important. First, without support by the bottom transverses and longitudinals, the bottom plating has insufficient rigidity to carry compressive loading and tends to buckle when the vessel is subjected to a hogging bending moment. Secondly, the entire bottom structure has the function of resisting water pressure when the vessel is in ballast and of bearing the weight of cargo when loaded. It must be maintained in efficient condition to safely perform these functions.

vi. A moderate amount of buckling of tank tops is acceptable provided buckling is confined to the plating between transverse and longitudinal girders. Fairness of transverses and girders may be checked by sighting or use of a taut line along the frame and girder lines. If floors or girders are found to be appreciably deformed or cracked, they should be repaired or replaced. In doing such work, obvious defects such as sharp cornered or raggedly cut lightening holes or other cut-outs should be made fair. Buckling of floors or girders not associated with grounding or other external damage may be an indication of structural weakness and need for structural modification or reinforcement, in addition to repair. In riveted construction, loosening and failure of the riveting within the double bottom may be observed. It is apparent that once the fastenings begin to fail, the stress levels and corrosion rates in adjoining structure increase rapidly. The practical solution to this problem is the early detection of the failing fastenings and the timely and adequate replacement of these fastenings in order that the existing material in the vessel can be made to perform to its capacity.

M. SIDE PLATING

In the side plating the strake "between wind and water" is an area which is highly susceptible to corrosion. The maximum general wastage is to be expected in this area. Also, serious localized corrosion may often be encountered in way of overboard discharges and scupper openings. The latter may usually be repaired by the use of insert plates rather than by plate renewals. Suitably attached wastage doublers may be used on sound plating as a means of protection.

N. LONGITUDINAL AND TRANSVERSE BULKHEADS

Cargo hold bulkheads are usually not troubled by excessive corrosion except along the lower boundaries and in way of bilge wells. Such corrosion is a local condition and should be repaired by the use of insert plates or well-attached lapped plates if sufficient material remains for proper installation. In the case of the longitudinal and transverse bulkheads in a tankship, especially where light products have been carried, corrosion is to be expected. Wastage up to about 35% may be accepted provided there is no evidence of deformation when subjected to a hydrostatic test. The top strake of bulkhead plating in a tankship is usually made heavier in anticipation of the increased corrosion to be expected in this area which is usually wet but not submerged. Therefore, when referred to the original scantling, an increased allowance for deterioration may be permitted. Applying a 35% wastage to the original scantling of the next to topmost strake will serve to establish the minimum thickness acceptable in the topmost strake.

O. FRAMES, BEAMS AND STIFFENERS

Generally, the flanges and portions of the webs next to the flanges are more highly stressed, more subject to mechanical damage, and corrode faster than the balance of the member. If excessive wastage has occurred but is limited to the flange and outer portion of the web, cropping of the defective section rather than complete renewal may be permitted. Details on this are included in Section 6. The use of short lengths of flat bar welded in way of deteriorated material is not an acceptable repair. Full-length flat bar doublers may be satisfactory in some cases but this represents a change in design so the installation should be made in accordance with an approved plan. Notwithstanding the above, flat bar doublers are never acceptable on internals within the tanks of a tankship because of the danger of gas entrapment. Often times, projecting frames or beams are deformed due to hook pulls, damage by cargo, etc. Such conditions, if they are scattered and not serious to the extent that the members are torn or broken loose from their fastenings, may be permitted to remain until there is other work required in the area. However, this principle would not apply to structural columns.

6. NOTES ON REPAIRS

A. PITTING

i. Coating or paint only (no weld repair) for pitting not requiring plate renewal should be

repaired using the guidance of this Section. Inspectors may use the guidance in reference (B) to determine necessary pit repair. Pitting depths of <33% (1/3 of original thickness) generally do not require weld repair.

a. Coating-only or filler-only repairs of pitting may be accepted where:
    i. Pitting intensity is scattered ≤ 5% within the reference (B) standard sample size of a 300mm x 300mm (12”x12”) square and are considered shallow (e.g. ≤ 1/3 original thickness).

    ii. Plate is otherwise free from heavy wastage and meets all thickness requirements with no associated deformation or cracking.

    Note: Vessels that experience little change in draft, like small passenger vessels should be considered by the Marine Inspector for the possibility of coating or filler repairs of pits greater than 1/3 of the original thickness as long as there is a remaining thickness of no less than 6mm (1/4”).

b. In these cases, the Marine Inspector may accept proper surface preparation and use of an appropriate epoxy pit filler or coating system to restore a smooth, protective surface. When selecting a coating system and/or filler, it is recommended that the Marine Inspector coordinate with the Class Society and/or the repair party to ensure best practices are followed.

c. When a coating or filler is used, it should be noted as a special note in MISLE to be monitored at subsequent dry docks. If the coating remains intact, there are no further needs for repairs. If the coating is not intact, determine the root cause and remediate as per the Pitting Guidance Flow Chart found in Section 10 of this NVIC.

ii. Pitting repair using weld build-up (clad welding) may be accepted for pitting areas when all the following apply:

a. The minimum remaining thickness is no less than 6 mm (1/4”), based on reference (B).

b. The pit depth is greater than coating-only repair criteria

c. The pitting density is isolated or light and plate renewal is not necessary

d. There is no severe distortion or active leakage

iii. To prepare the area, clean the area to bright metal, removing coating, corrosion products, and loose material, grind or gouge out sharp notches, cracks, and severe local stress risers. The Marine Inspector should re-inspect the remaining plate thickness after pits

have been cleaned to ensure enough good steel remains for weld build up.

Note: The 6mm minimum (in reference B) is adequate for plate thickness greater than 12 mm. For vessels with lighter scantlings, such as small passenger vessels (SPVs), use of welding filler material may be considered for pitting repairs with less than 6 mm of remaining thickness. Because a certified welder is typically not required for SPVs, the inspector must use their best judgement and available guidance to determine if the repairs are allowable when remaining plate thickness is less than 6 mm. Items to consider include weld procedures and welder skill, size and number of pits with less than 6mm remaining thickness, condition of metal around that area and the location of the pits.

iv. The welding process is normally performed using a low hydrogen rod of suitable filler material compatible with the base metal. On steel hulls, this would be an E6000 or E7000 series rod. Sufficient weld material should be deposited to slightly exceed the plate thickness, then ground flush to the surrounding plate surface to avoid hard spots or local stress concentrations and ensure smooth transitions (see figure 3). Use qualified welding procedures and welders if applicable. For non-classed vessels, the Marine Inspector may accept pit repairs performed using welding procedures qualified in accordance with the American Welding Society Structural Welding Code (AWS D1.1) or an equivalent recognized standard.; Weld metal should be deposited in multiple passes, starting and ending outside the pit as shown in figure 3, while maintaining recommended preheat and interpass temperatures.

Note: For unclassed vessels (such as a K or T boat built to ABS rules) the OCMI may accept AWS B2.1. If not built to ABS rules, then the OCMI should encourage welder qualification/certification to AWS B2.1, as an equivalent level of safety.

Note: Filler metal repairs are not addressed in AWS B2.1. For the purpose of determining suitability of a Weld Procedure Specification (WPS) and Welder Performance Qualification (WPQ), clad metal repairs may be interpreted as a partial-penetration groove weld repair. In other words, a welder that is qualified to perform an otherwise equivalent groove weld is qualified to conduct clad repairs.

Note: OCMI's are encouraged to engage with the CG-5P-TI, Traveling Inspectors for any technical assistance in regard to pitting and corrosion repair.

v. Perform a visual examination and at least spot check using a Non-destruction Examination (NDE) method (e.g., Magnetic Particle Inspection (MPI), Liquid Penetrant Testing) of a representative portion of the welded area; additional UT may be used to confirm minimum remaining thickness and check for defects. Improper preparation or weld build-up may be cause to require plate renewal.

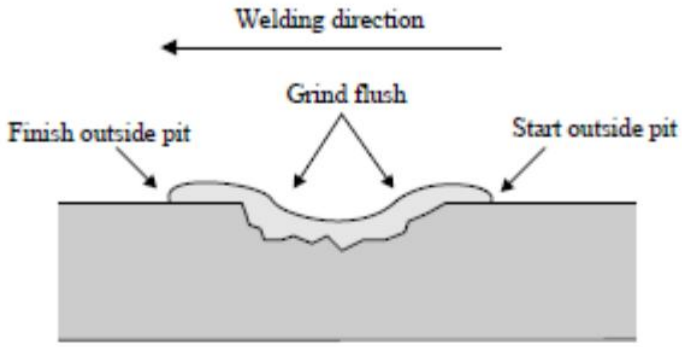


Figure 3: Welding of pits *(Source: IACS Recommendation #47, Part B)*

B. FRACTURES

i. Fractures in hull plates, etc., usually start in localized, highly stressed areas. In the preliminary inspection, the first thing to be determined is whether the fracture started in a notch or sharp angle (stress raiser), and if it did, to eliminate this feature.

ii. When major fractures occur and where considerable material is to be removed and new plates, frames, etc., are to be inserted, the repair may involve appreciably more restraint and less favorable welding conditions than for new construction. The type of repair to be made and welding procedure to be used should be carefully evaluated.

iii. Cracks in the deck or in the bottom within about the amidships half-length and which originate in structural discontinuities will frequently require the fitting of a suitable repair insert to minimize weld restraint in the local area of stress concentration. Cracks which have opened too far or are too irregular to permit satisfactory weld preparation, or which are located so that access is insufficient for producing sound, full penetration welds, also call for the fitting of inserts. Evidence of deterioration or poor quality of the fractured plate are additional reasons for plate replacement.

iv. Reference (B) is prescriptive regarding allowable plate specifications, including thickness criteria, weld preparation, weld size, and material limits, building upon this NVIC's guidance on crack-drilling and placement.

v. As previously noted, localized bands of accelerated corrosion should ordinarily be taken as evidence of such deterioration and the affected portion of plating replaced. Where none of the foregoing conditions exist, the crack may be repaired by welding without replacement of plating.

vi. In repairing cracks which do not involve steel replacement, the following procedure should be followed:

    a. Locate the ends of the crack, and approximately two plate thicknesses beyond the

end, drill a hole to prevent its extension. The use of dye penetrant or other non-destructive testing (NDT) method is desirable to locate the ends of the crack or to ensure the crack does not extend beyond the holes. The diameter of the drilled hole should be about the same as the plate thickness. Then, “V” out the crack by chipping or gouging to an accepted edge preparation for welding plates of the thickness involved.

b. Gas free, remove ceiling, etc., as necessary to provide full access to both sides of the crack. Thorough inspection of both sides of the crack should always be carried out.

c. After “V-ing” out, if a crack has a root opening too wide for closing with the first bead, do not draw the edge of the plate together by means of a steamboat ratchet or other means prior to welding. Instead, build up the groove with light beads until a groove of usual proportions is obtained or use a backing strip. Backing strips should be removed followed by back side gouging and welding.

d. Where the crack in the plating crosses stiffeners, framing or girders, the welds connecting these members to the plating should be released. This should be done by burning through the weld for a distance of at least 6 inches on each side of the crack before commencing welding on the crack. In way of gunwale or hatch side assemblies, it may be desirable to increase the length of release.

e. If the crack extends into the framing member, it should be suitably prepared and welded. If the resulting butt is welded after the plating or poor accessibility exists, the butt in the frame should be smoothly scalloped out adjacent to the plating.

f. Special care should be taken in the repair of surface cracks. Care should be taken so that the defect is completely removed by grinding or other suitable means. In that such a procedure may easily mask cracks by the "peening" effect, the use of an NDT method such as magnetic particle may be useful in detecting any remaining subsurface defect.

C. REPLACEMENT OF AND WORK ON SHELL AND DECK PLATING

i. The following precautions apply to repairs or alterations on both riveted and welded hulls:

a. The sheer strake, insofar as practicable, should be kept clear of welded fittings. Where there is no alternative but to make attachments in this region, the attachment should be suitably faired with curved brackets, as applicable, and at least 150°F. Preheat should be maintained during welding. However, the use of preheat may ordinarily be omitted if low hydrogen electrodes are used. The upper edge of the sheer strake should be fair and smooth, i.e., free of notches, nicks, and cuts, weld craters, and any irregular edge burning.

b. Insofar as practicable the stringer plate should also be kept free of welded attachments.

c. Where heavy deck fittings, such as chocks, bitts and cleats, are to be welded to the strength deck, pre-heat of at least 150°F. should be employed during welding or low hydrogen electrodes should be used. Such heavy fittings should only be installed in accordance with approved plans. Ends of deck fittings should be kept well clear of deck butts and seams. When several fittings are installed on deck, positioning them in a direct line athwartships should be avoided. Also, if they are required to be in a longitudinal line, there should be sufficient interval between each to avoid creating areas of high stress concentration in the plating between the fittings.

d. Replacement of plates having joggled lapped seams and/or butts should be made, whenever possible, with flush seams and butts (see figure 4).

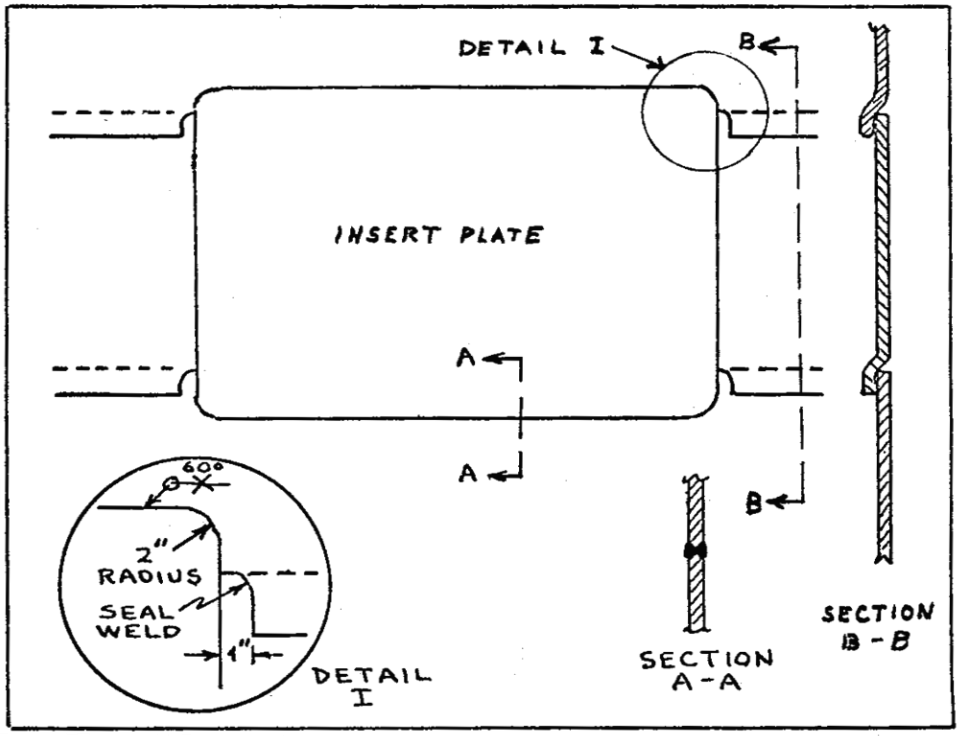


Figure 4: Lap seam insert plates

D. INSERT PLATES.

i. In welded construction, repairs involving less than a full plate should generally be made by means of an insert plate (see figure 5) installed in accordance with the following principles:

a. While less than complete plates may be replaced, the lines of cut and new welding

should, as far as practicable, lie in existing lines of welding. Inserts should ordinarily cover at least one frame space.

b. The existing plate should be cut back to good material (no less than 3/4 thickness of plate being inserted). The existing plate edge and the internals in way of the cutout should always be examined before the insert is installed.

c. The ship fitting and plate edge preparation should be such that welding grooves of proper proportions are provided so that acceptable welds can be made.

d. The weld metal of intermediate passes on butts and seams of restrained insert plates may be peened. The finish pass should not be peened but may advantageously be made using low hydrogen electrodes.

e. To minimize locked-in stresses when installing an insert plate, it is necessary to ease the restraint imposed by the surrounding structure. First, holes should be drilled as shown below to reduce the likelihood of cracks occurring at the ends of the slots. The adjacent plating should then be slotted as shown below. Butts 1 and 2 can be welded first so that the slots can serve to distribute the shrinkage somewhat rather than concentrating it at the immediate boundaries of the insert plate. Rounding the corners of the insert plate, not in way of existing seams or butts, is an acceptable alternative.

f. In certain cases, a welded lapped patch plate may be used in lieu of an insert plate for the permanent repair of small, damaged areas which lie wholly within an individual panel of plate (see figure 6). However, except for temporary repairs, their use should not be permitted in the strength deck, bottom or shell plating. Patch plates are also inadvisable in areas of high corrosion. In making the installation, the old plate should be cut away to a sufficient thickness of sound metal so that the existing metal at the edge of the patch is at least as good as if an insert were used. If the opening required to achieve this exceeds that appropriate to the use of a patch plate, an insert plate should be used. Patch plates should be a continuous fillet welded on both sides. To reduce heavy stress concentrations in the vicinity of patch plates, such plates and the holes which they cover should have their corners rounded to a radius at least equal to 1/8 (one eighth) of their transverse dimension or 3” three inches whichever is the greater.

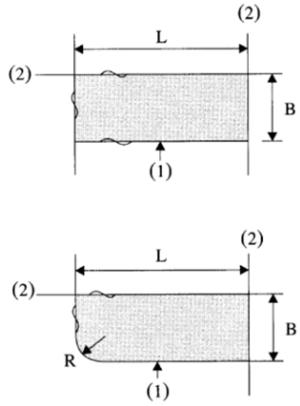
Detail	Remedial standard	Remedial limit
Remedial by insert plate 	L = 300 mm minimum B = 300 mm minimum R = 5t mm 100mm minimum (1) seam with insert piece is to be welded first (2) original seam is to be released and welded over for a minimum of 100 mm.	L = 200 mm minimum B = 200 mm minimum R = 5t mm 100mm minimum (1) seam with insert piece is to be welded first (2) original seam is to be released and welded over for a minimum of 100 mm.

Figure 5: Insert plates *(Source: IACS Recommendation #47 Part B)*

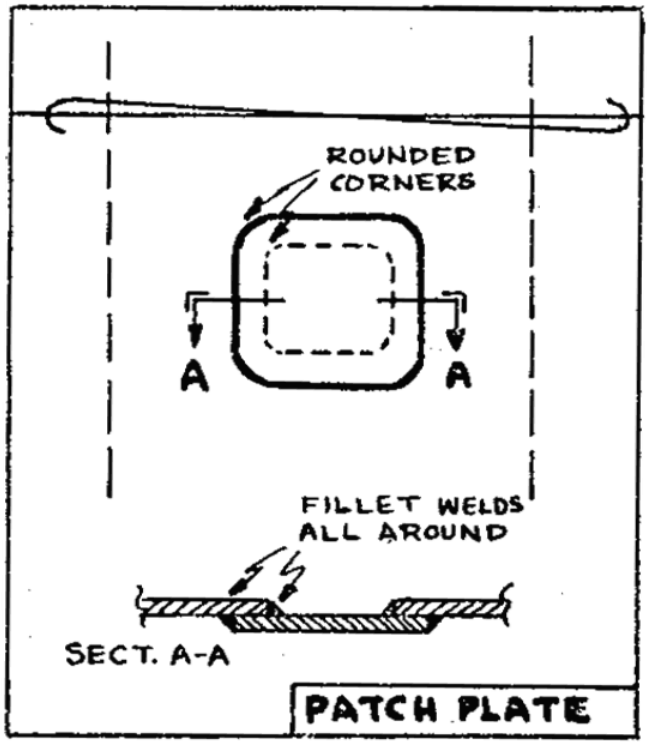


Figure 6: Insert patch plates

E. WELDED DOUBLER PLATES

i. For the purposes of this policy, a “doubler plate” or “doubler” means a steel plate, compatible with a vessel’s existing steel plate, which is lap welded to a damaged part of that vessel’s structure intended to regain its original local strength and/or to restore watertight integrity. The doubler plate should possess physical characteristics equal to or

greater to those of the original (parent) plate.

ii. A welded doubler plate is not, in general, considered suitable as a permanent repair measure for the main hull girder. Its use does not ensure continuity of strength which is achieved by the installation of an insert plate in the same location. Also, when a doubler is attached to deficient plating, its very presence creates a discontinuity which may induce rather than prevent a structural failure. Additionally, where doublers have been used, they tend to proliferate as randomly placed patches which often serve only to cover up the deficiencies which would otherwise indicate the true condition of the hull.

iii. Doublers may properly be used to provide local reinforcement at hatch corners, overboard discharges, sea chests, mast or kingpost foundations, etc. They may also be used in accordance with approved plans, in the form of strapping fitted to increase the hull girder strength and stiffness. Where used, the plating to which they are attached should be in good condition to ensure efficient attachment, by fillet welding along the edges. Plug welding, in the body of the doubler, can be used. The corners of the doubler should be tapered and well rounded.

iv. Doublers may be accepted in non-strength areas where their purpose is essentially to restore watertight integrity and local strength. Such areas include:

a. Deck plating well inboard between cargo hatches

b. House tops and superstructure decks except the first deck above the main deck in vessels with long superstructures

c. Forecastle decks and poop decks limited to approximately the forward or after one-tenth length of the vessel

d. Platform decks

vi. Even in these locations, doublers should not be permitted where special local strength is required. For example, the plating forming the house top of a small deck house is not involved in basic hull strength. Repair by doubler would be perfectly acceptable if the deck house served as a boatswain's locker or the plenum of a ventilation system. However, if the house top plating tied together the framing intended to fix the position of a mast or kingpost, a doubler patch would not be permissible. Another example in the same category is the superstructure deck plating in way of a lifeboat installation.

vii. When a doubler is deemed appropriate and is installed over a crack, the ends of the crack should be drill-stopped and, if possible, the crack should be beveled into a “V” and welded. Once the doubler is installed, monitoring for crack propagation becomes difficult, and improper welding could lead to severe structural failure, as a crack could grow without notice.

viii. On vessels without double bottoms operating on protected waters or in other similar

circumstances on such vessels, doublers may be accepted for repairs in way of engine or boiler rooms where it would be necessary to remove heavy equipment, etc. to provide access for plating replacement. However, in such cases, care should be taken that existing plating has enough thickness for efficient attachment. Doublers on tank vessels in way of cargo or fuel tanks pose a serious problem. The interface between a doubler and the plate beneath can constitute a gas pocket which is hazardous and completely inaccessible to gas-freeing procedures. Doublers should not be permitted in such locations except as detailed on approved plans.

ix. Plan approval is usually not necessary for installations made in accordance with paragraphs iii and iv above. However, a record of each installation, including its size and location, should be maintained in the vessel's MISLE profile.

x. New doubler plates, after evaluation by the OCMI or Class Society, may be authorized for temporary repairs in limited circumstances. This evaluation may be limited to the effectiveness of the doubler at restoring watertight integrity and a visual inspection (or monitoring), if possible, to assess the doubler fit up and condition. Doubler plates used for temporary repairs should be removed as soon as possible, but no later than at the next drydock, unless the OCMI or Class Society (if applicable) requires otherwise.

F. CROPPING AND RENEWING

i. Reference (B) provides comprehensive technical specifications on consumables, welding requirements, and NDT, offering significantly more in-depth guidance on general metal clearance and alignment instructions. Reference (B) contains thorough specifications equivalent to plate renewal, plate dimensions, edge preparation, and stress relief.

ii. Crop and renew should not be the default action when uncertainty exists. However, when there is deep pitting, widespread corrosion, sharp or deep insets, deformation or cracking, replacement of the affected plating or member is the preferred repair. In the case of structural members such as frames, beams, stiffeners, etc., it is a practical repair measure to crop out the distorted or wasted section of the member, the outer flange for example, and replace with new material. Where this method is used, the following conditions should prevail:

a. There should be sufficient material in the remaining portion of the member to permit sound attachment of the new metal.

b. The new portion should be in good alignment with the adjoining old portion. Care should be exercised in this regard in way of flanges.

c. There should be sufficient clearance to permit the making of good welds. If this is not the case, the member should be renewed.

d. If the attachment of the member to the adjoining plating is by riveting, the joint

will have to be checked for tightness and corrected as necessary after completion of welding.

7. WELDING

A. GENERAL

ABS MVR under Part 2 (Rule Requirements for Materials and Welding) contains the requirements and instructions to produce acceptable hull welds and the qualification of welders (see reference C). These rules are not repeated here because they are available to and should be used by inspectors engaged in construction or repair work. Some points which require special attention are discussed in the following paragraphs.

B. WELDERS

Guidance and regulations on welder qualifications are found in 46 CFR under Subchapter F (Marine Engineering), with Part 57 (Welding and Brazing) serving as the central regulatory cite. 46 CFR formally adopts Section IX of the ASME Boiler and Pressure Vessel Code as its baseline standard for qualifying welders, welding procedures, and brazers, subject to specific Coast Guard modifications and strict limitations.

In view of the importance of obtaining sound welds in repair work, 46 CFR § 57.02-3 allows for reciprocity, meaning the Coast Guard will officially accept welder credentials witnessed and certified by recognized external authorities, such as the American Bureau of Shipping (ABS) or the Naval Ships Systems Command (U.S. Navy Department). Additionally, the USCG officially recognizes welders as qualified if their test was witnessed and certified by The American Welding Society (AWS) or The American Society of Mechanical Engineers (ASME). If a welder holds a valid qualification signed off by an ABS Surveyor or AWS Certified Welding Inspector (CWI) that matches the vessel's repair procedure, the Coast Guard generally accepts them as a "qualified welder" for that job.

These qualification requirements are legally triggered by other parts of the CFR depending on the system being fabricated. For instance, 46 CFR Subchapter F, Part 54 (Pressure Vessels) and 46 CFR Part 56 (Piping systems and appurtenances) explicitly state that no production welding can begin until both the welding procedures and the individual welders have been formally qualified under Part 57. Under these rules, contractors are often required to coordinate with the local OCMI to witness the physical qualification tests before high-pressure work is approved. Cases of this nature should be referred to the OCMI and, if necessary, the appropriate Coast Guard technical office (e.g. Marine Safety Center, Traveling Inspectors, etc.) for resolution.

C. STEEL

i. Steel plate and shapes which are to be welded should meet the applicable requirements for structural steel for hulls as set forth under Part 2 (Rule Requirements for Materials

and Welding) in the ABS MVR. Half rounds, rounds and bulb bars are frequently produced from Bessemer steel which is not permitted by American Bureau of Shipping Rules due to the likelihood that such steel may be very notch sensitive at ordinary operating temperatures.

ii. All ship steel, including the above items, must be made by the open hearth, basic oxygen, electric furnace or such other processes as may be specifically approved. The ends of half-rounds and bulbs should be kept clear of existing structural discontinuities. Half-round installations which disturb the smooth, unnotched edge of the sheer strake should be avoided. High strength steels require very special handling during fabrication. Great care must be exercised in adhering to the procedures recommended by the steel manufacturer, in the care and use of the correct welding electrodes, and in the proper identification of the steel. The usual shipyard practices suitable for working with conventional ship steel are not adequate when it comes to high strength steel. Among the more important reasons for this are the following:

   a. Steels look the same, but when used in the design of a ship, much greater loads are imposed on the special steels; loads which probably could not be sustained if conventional steel was substituted by mistake.

   b. Welding electrodes which are satisfactory for conventional steel would not provide strength, in way of the welded connection, equivalent to the strength of the plates joined. In most cases, low hydrogen electrodes are recommended for welding high strength steels to avoid under bead cracking.

   c. In some high strength steels, for example, the quenched and tempered steels, a heat input during welding which would be acceptable for conventional steel, would drastically reduce the toughness of the special steel in the heat affected zone.

   d. Also, in some of these steels, the installation of temporary clips or even arc strikes on the plate can have a serious, detrimental effect.

iii. In view of the above, renewal or repairs involving high strength steels should not be undertaken without recourse to plans and procedures which have been approved for the specific installation.

D. FILLER METAL

i. Electrodes should be suited to the steel to be welded. Except when special steels are involved or specific electrodes are indicated on approved plans, the welding electrodes should be among those listed in the current American Bureau of Shipping “Type approval database” in reference (C).

ii. Electrodes should be kept dry while in storage. Where low hydrogen electrodes are used, it is especially important that they be dehydrated before use. Otherwise, moisture picked

up from the atmosphere alone without any direct wetting may result in very faulty welds.

E. EDGE PREPARATION

i. The preparation of the edge of the base metal before welding depends upon the thickness of the plate and the design of the joint. The requirements are specified in Section 6, part 5 “weld design and dimensions” of the ABS MVR. The following are some points which require special attention:

a. Rough or irregular preparation of the edge should not be accepted.

b. The dimensions of the root opening should be within the specified tolerances. Excessive root face, insufficient root gap, or insufficient bevel angle will result in poor penetration. Too wide a root gap will result in difficulty in making a satisfactory root pass unless one face of the joint is first built up by welding or a backing strip is used. These deficiencies are readily apparent if the fit-up is examined before the welding is commenced and all are correctable.

c. The surface to be welded should be clean and dry. This includes both the base metal and previous beads of welding. A clean surface is one free of dirt, slag, oil, rust, scale, or paint.

F. WELDING SEQUENCE

i. In most repair work locked-in welding stresses cannot be avoided. However, they can be minimized if some attention is given to working in accordance with a planned welding sequence. In general, this must be left to a welding engineer. But, when major repairs are undertaken, the inspector should ascertain that a welding sequence has been prepared and they should check to see that it is followed on the job. Some of the fundamental considerations in this regard are as follows:

a. It is poor practice to weld across an open butt (see figure 7).

b. Where extensive work is required on both sides of the vessel, it is better practice to have the welding progress simultaneously on both sides rather than to complete one side before starting the other.

c. In general, the order of welding should be such as to allow the maximum freedom for contraction of the weldment. For example, it would be poor procedure to fix both shorter edges of a plate before welding the longer edges.

d. Temperature is an important factor in welding. Where welding is done at temperatures below freezing, pre-heating and/or sheltering should be provided to reduce the rate of chilling. More caution in this regard is necessary when welding on thick plating than on thinner plating.

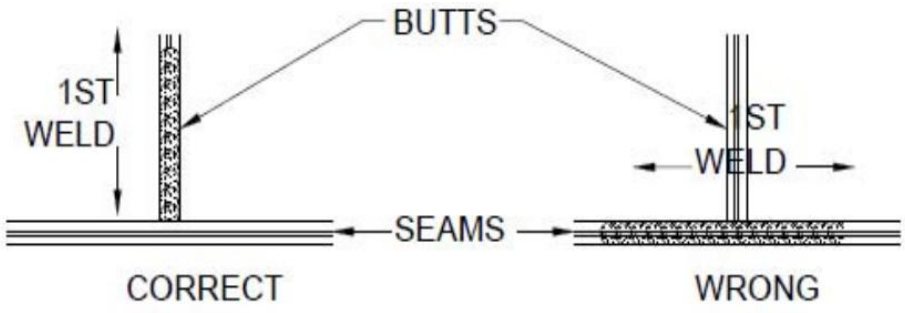


Figure 7: Different approaches to applying first weld

ii. For ordinary thicknesses and temperatures not far below freezing, work within a ship or on a ship's bottom within a graving dock may usually be considered as sufficiently sheltered.

G. PROCEDURE

i. Besides proper ship fitting and edge preparation, there should be careful alignment of the structure. Local eccentricity in butts of intercostal longitudinal beams, girders, and bulkheads attached to strength deck and shell is conducive to service cracking. The webs of such members should be carefully aligned on both sides of the interrupting (transverse) structure before welding, and changes of girder depth and flanges occurring at the interrupting section should be provided with transition fairing.

ii. Tack welds which are used to position the weldment in the fit-up should be chipped out before making the final weld. Frequently, they have been overstressed and may contain sub-surface cracks. The welding machines employed should be adequate for the job, in good condition and operated at the correct setting for the work at hand. Butt welds, except in very thin plates, call for back-chipping with a round-nosed tool or by means of flame-gouging to ensure complete penetration. The use of a backing strip, flux back-up, etc., are satisfactory alternative.

iii. Underwater welding repairs should be completed in accordance with the standards found in the American Welding Society's "Specifications for Underwater Welding." Additionally, reference (A) and (B) provide detailed criteria for this specialized repair method.

iv. Weld build-up (clad welding), when properly executed, is a recognized repair method and may be used to restore local thickness in pitted areas. Marine inspectors should refer to reference (B), the pitting tool in reference (E) and Class Society rules for additional pitting guidance. If there are concerns or uncertainty about whether weld-build up (clad welding) should be used to repair pitting, it is strongly recommended to consult with the Traveling Marine Inspectors (CG5P-TI) as each scenario for clad welding is different and may require a technical expert's determination.

v. Back-Chipping and Back-Stripping. (See figures 8 and 9).

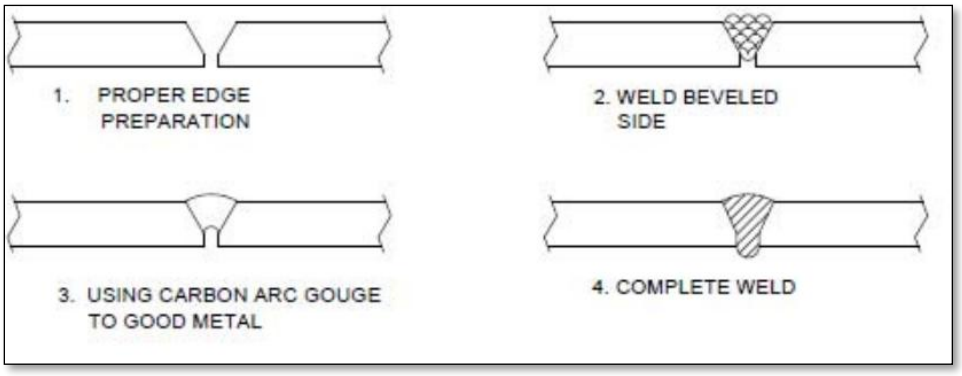


Figure 8: Back-chipping

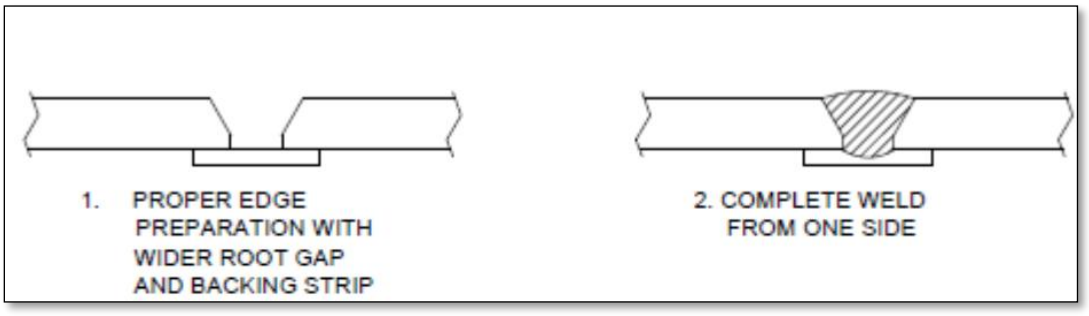


Figure 9: Back-stripping

H. WELDING DEFECTS

i. Attention is called to weld deficiencies which can occur if correct procedures are not followed. These weld deficiencies can and do lend to cracking of the main hull girder of the vessel and are about the most effective crack initiators known. The destructive potential of the deficiencies often lies dormant for protracted periods while awaiting the necessary conditions of temperature and/or service stress magnitude to trigger a crack which instantaneously propagates into a serious hull failure. Such failures can occur under moderate stresses, arising from sea action or from cargo distribution alone, on a cold winter day.

a. Sub-surface weld defects in butts and seams which include inter pass weld bead cracks, slag inclusion, incomplete penetration and lack of fusion must be avoided.

b. Slugged welds involve laying welding rods, cable, bolts or other extraneous material in a welding groove and then welding over it. Such a procedure obviously creates a serious cavity in the heart of the weld which is not detectable from surface appearance. Supervisors and workmen who have been well informed as to the critical nature of such a condition are the best protection against slugged welds. Welders turning out very high footage should have their welding subjected to radiographic examination as a precaution against "slugging."

c. Caulking of leaky welds, cracked welds or peening in no way reduces the crack initiating properties of a defective weld nor does it reduce the liability of an existing crack to propagate further. Such an operation only serves to "conceal" and thereby "build" into the vessel a potential source of serious structural failure. Accordingly, all peening or caulking of leaky or cracked ship welds should be prohibited. Leaky or cracked welds should be chipped out and re-welded.

d. Welding into or around square corners, that can occur in the installation of insert and doubler plates, should not be permitted for attachments to shell, strength decks or tank tops. Such square corners should be rounded to a 3" minimum radius. Corners of openings should be rounded to the largest practicable radius, generally not less than 1/8 the transverse dimension but not ordinarily more than 24 inches. Cuts should be made either by guided burning or should be ground to a fair smooth contour. An exception to this is the welding of an entire plate section. Generally, the corners are not rounded but the seams in the adjacent plates are released as shown in the following sketch (see figure 10) to minimize locked-in stresses and then rewelded in suitable sequence. Holes drilled as shown prior to releasing the adjacent plate will minimize the likelihood of cracks occurring at the ends of the slots.

e. Undercut butt and seam welds of shell, inner bottom and strength deck, or undercut fillet welds attaching structural members thereto, should be avoided. This is particularly important for fillet welds near or at the end of discontinuous longitudinal members, such as bilge keels, tanker longitudinals, deck clips, or foundation members. Undercutting in these locations has contributed to complete hull girder fractures.

f. Arc-strikes and light beads of welding should be avoided on the surface of strength deck, shell or tank-top plating, due to quench effect with possible subsequent crack stimulation. Arc-strikes produce hard, brittle metal locally, containing microscopic cracks. It is recommended that such areas be chipped out and re-welded using a pre-heat of at least 150° F.

g. Very often pads or lugs are welded to plates for the purpose of jacking the plates into alignment and afterwards are knocked loose with a sledge. Any projections resulting from knocking off the lugs should be chipped off and ground fair if necessary. If there are any cavities these should be welded flush.

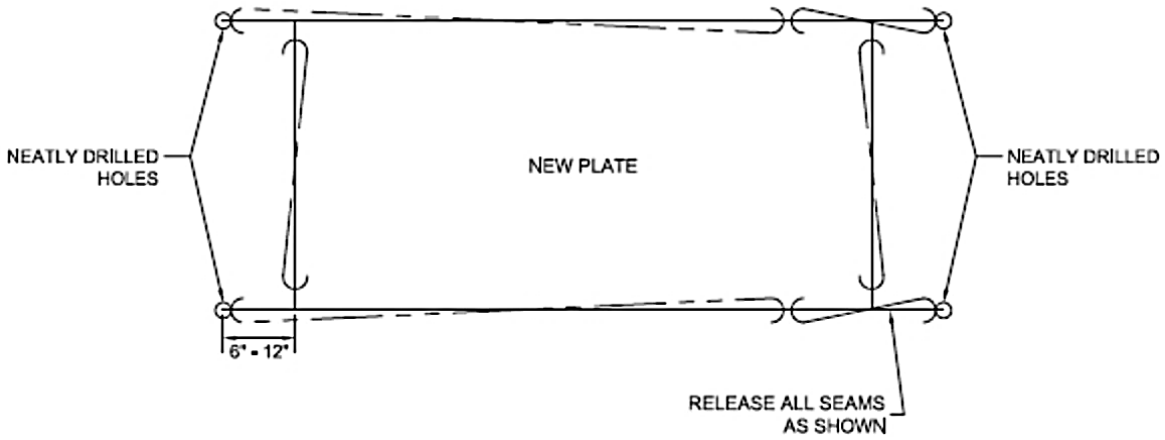


Figure 10: Weld procedure for insert plate

iii. Slugging, included slag, or submerged cracks cannot be determined by the surface appearance of welds. These defects, however, can seriously reduce the strength of a welded joint and can provide the starting point for serious fractures. In the ABS MVR under Part 2 (Rule Requirements for Materials and Welding) details are provided for radiographic or equivalent inspection of hull joints at important locations. Since any joints in the hull, including the upper decks within approximately at least the middle half-length may be regarded as important, this rule is considered to provide a basis for requiring random spot checking of hull welding by means of radiographic or ultrasonic techniques. Such spot checking should be accomplished to the extent determined necessary by experience in checking welding in the yard concerned. Yards should keep a record of the work performed by each welder. Any welder found to be deliberately slugging welds should be disqualified and may be subject to criminal prosecution.

iv. OCMI Authority under 46 USC 3306–3313 and associated regulations in 46 CFR 2.01-10 and 33 CFR 1.01-20, OCMIs may require additional inspection, NDE, testing, or repairs when necessary to ensure the safe operating condition of an inspected vessel. Types of NDE testing include but are not limited to, radiographic testing, ultrasonic testing, magnetic particle testing, dye or liquid penetrant testing and visual inspection. When welds are checked by an NDE method, such as radiography, the question often arises as to the proper standard to apply for a rejection or acceptance criterion. Slugged welds, of course, give a gross defect indication and there is no question as to the non-suitability of such a weld. Other welding defects such as slag inclusions, porosity and subsurface cracks require some judgement as to what constitutes an unacceptable weld. There is no simple answer. In some cases, such as a main strength highly stressed joint, a very rigid standard would be proper. In other cases, an evaluation of the design and the type of stress applied might indicate a large margin of safety exists and the acceptance criteria can safely be set lower. The following information sources offer guidance:

    a. IACS Recommendation #47 Part B outlines comprehensive NDT procedures, weld inspections, and other repair criteria, incorporating up-to-date testing methods.

b. IACS Unified Requirements (UR) W33 Non-destructive testing of ship hull steel welds – Rev.1 Corr1 Aug 2021.

c. SSC-245 "Guide for Interpretation of NDT of Welds in Ship Hull Structures" prepared by the Ship Structures Committee.

d. IIW Pamphlet "Radiographs of Welds."

e. American Bureau of Shipping (ABS), Guide for nondestructive Inspection of Hull Welds 2002 Guide for the Radiographic Inspection of Welds ABS Circular No. 40, Magnetic Particle Inspection.

8. RIVETING

A. GENERAL

i. Riveted vessels were historically common before welding became the industry standard in the 1930s-1940s. While no longer used in new ship construction, many older vessel designs still in operation may have riveting. Since riveted vessels are out of the ordinary, OCMIs are encouraged to contact the Coast Guard Traveling Inspectors (CG-5P-TI) for all technical questions relating to riveting.

ii. The renewal of deck and shell plating is best accomplished from an overall structural viewpoint by replacement in kind. Replacements avoid hard spots or points of high stress concentration in an otherwise less restrained hull structure. However, riveting is becoming increasingly difficult and costly. Hence, it becomes necessary to make welded repairs to riveted ships. Extensive experience and tests indicate that the steel in the existing riveted ships may be more sensitive to brittle fracture initiation and propagation, when welded, than is shipbuilding steel presently being supplied under American Bureau of Shipping requirements for Classes B or C hull steel. Because of this, the use of welding in the repair or alteration of existing riveted hulls should be limited as follows (see figure 11):

a. Shell and deck seams involving existing plating thicker than 1/2" should ordinarily not be welded.

b. As previously noted, flush butts between new and existing strakes of shell and deck may be welded. Such welds must have full penetration.

c. Lapped butts involving the use of fillet welds should not be used. Welded lapped seams may be used where plating is 1/2" or less in thickness.

d. For greater thicknesses, replacement should be as original or the design changed so that butt welds can be employed. A typical method of doing this with in-and-

out plating is shown in the sketch below. For joggled plates, see Section 5, letter K of these notes.

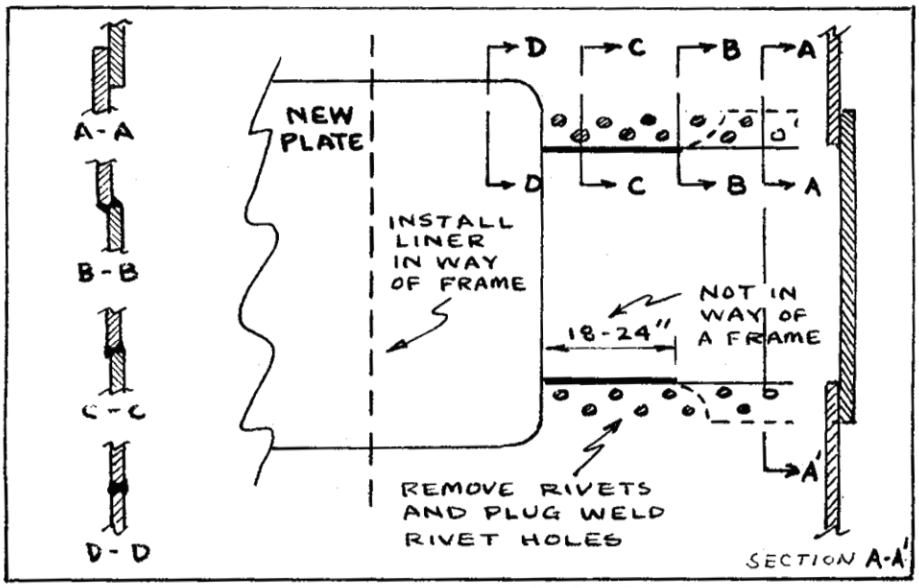


Figure 11: Riveting repair

B. HOLE PREPARATION

Where riveting is necessary and the rivet holes are punched, the holes should be reamed to remove the excessively cold-worked material which can be a source of crack initiation (see figure 12). The holes need to be reamed between 1/16" and 1/4" depending on the thickness of plate and the diameter of the hole. In most cases a ream of 1/8" will be suitable.

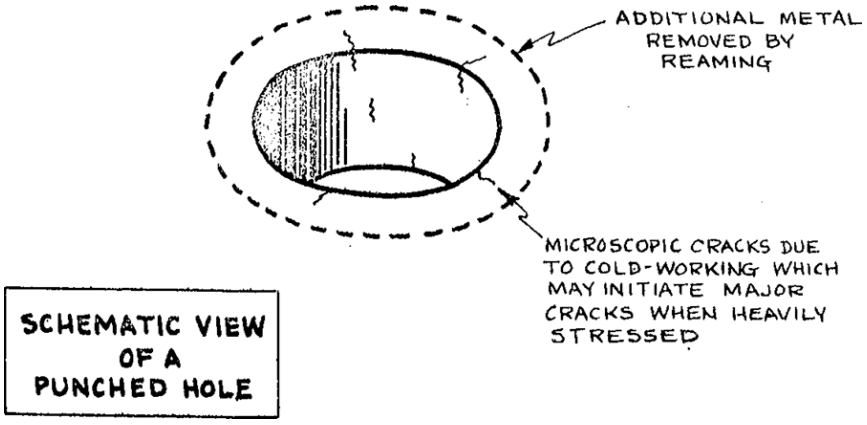


Figure 12: Riveting hole preparation

C. DETERIORATED OR MISSING RIVETS

i. The replacement of deteriorated or missing rivets, which were marginal in size in original construction, with undersize bolts is unsatisfactory. However, upon approval by the OCMI, bolts may be used for emergency purposes if oversized and closely fitted into

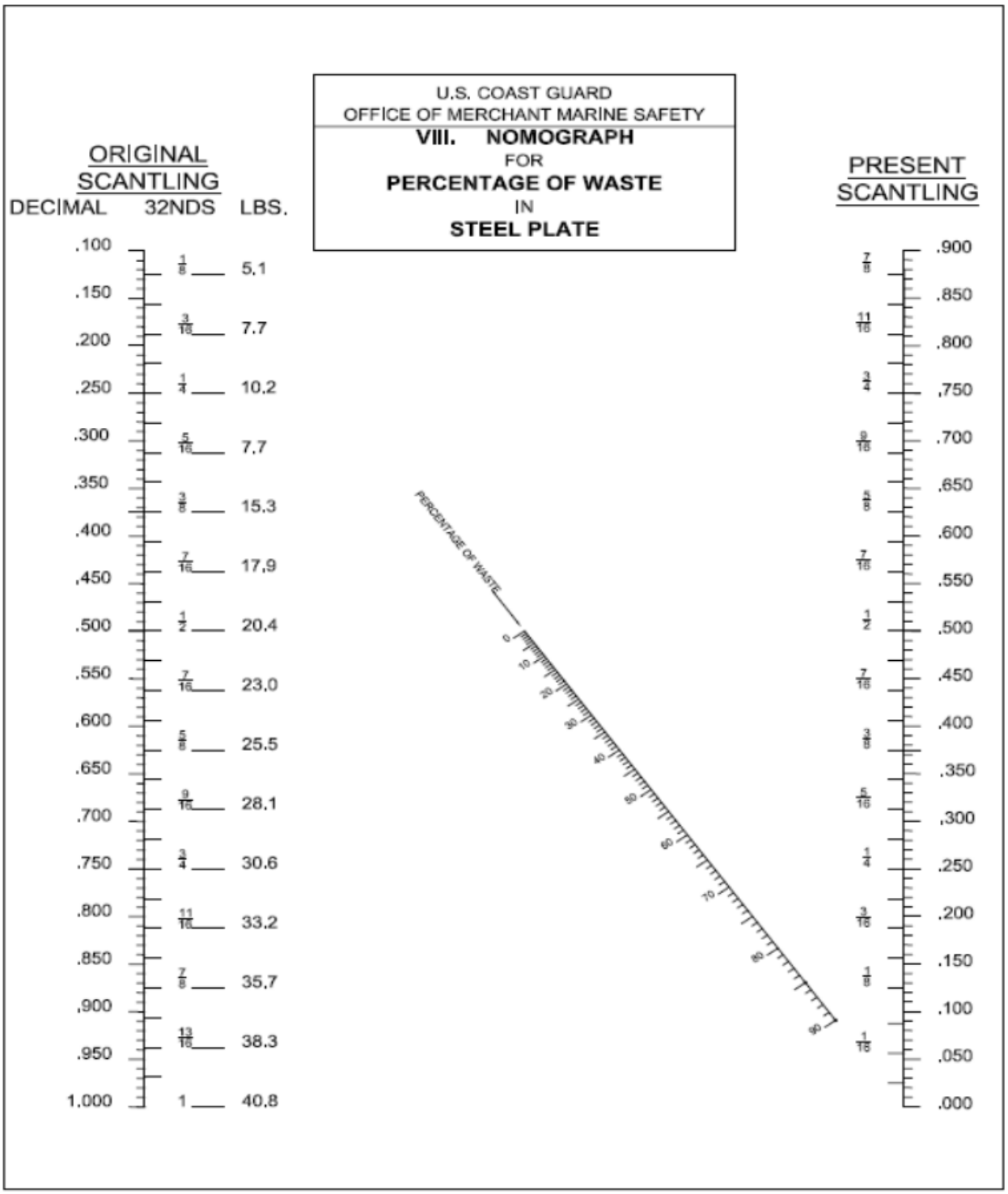
oversized, reamed holes. Often the ringing of rivets by means of welding is proposed as a repair measure for leaking or otherwise defective rivets. Rivets which do not completely fill and are not firm and tight in their holes fail to effectively carry their share of the load, and ringing with welding does not improve this situation. Accordingly, any ringing of rivets by welding must be regarded as a temporary measure acceptable only where not more than a few scattered frame or seam rivets are involved. Ringing of rivets by welding should not be permitted in way of lapped or strapped butts, or for any riveting of deck plating outboard of the hatches.

ii. The use of welding in building up the deteriorated points of otherwise sound rivets is permissible, provided the corroded metal can be and is removed prior to the time that the building up is done.

D. LOCK PINS

Certain types of lock pins have been accepted as a substitute for hull structural rivets. Unless lock pins are specified on an approved plan, they should not be used in repair applications without consulting the OCMI and if necessary, the Coast Guard Traveling Inspectors (CG-5P-TI). See NVIC 3-68 for further information on this subject.

9. NOMOGRAPH FOR PERCENTAGE OF WASTE IN STEEL PLATE



10. PITTING GUIDANCE FLOW CHART