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NAVY WELD DEFECT TOLERANCE STUDY

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Date: March 21, 1981

# Report Documentation Page

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by

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# NAVY WELD DEFECT TOLERANCE STUDY

(Contract No. 3-36233, Task S-26)

## SYNOPSIS

The study deals with a statistical analysis of quality control data collected from six major U. S. shipyards involved in naval ship construction. This examination is confined to non-combatants built out of mild steel only. The purpose of the study was to assess the significance of weld discontinuities with a view towards optimizing weld acceptance standards so *as* to minimize unnecessary weld repair.

CONTENTS


| | | |
|---|---|---|
| | SYNOPSIS | a |
| 1. | INTRODUCTION | 1 |
| II. | PROCEDURE | 2 |
| III . | DISCUSSION | 2 |
| | (a) Visual Inspection | 5 |
| | (b) Radiography | 5 |
| | (c) Ultrasonic Testing | 6 |
| IV. | CONCLUSION | 11 |
| V. | ACKNOWLEDGEMENT | 12 |
| VI. | RECOMMENDATION | 14 |

REFERENCES

TABLE 1, UT or RT Inspection Requirements for Surface Ships

TABLE II, Accumulated Q C Data Obtained From Six Major U. S. Shipyards

APPENDIX 1

Questionnaire for Naval Weld Defect Tolerance Project

## I. INTRODUCTION

This study deals with a statistical analysis of quality control data and general information compiled on U. S. Naval ships of the type which are built of mild steel materials exclusively. Combatants using high strength steels were not included in this survey. It follows that the conclusions derived may not be construed *to* apply to steels other than mild steel.

Task S-26 represents Part II of the "Weld Defect Tolerance Study" program. The first report published in 1980 was a comprehensive examination on the significance of weld discontinuities in commercial ship's hulls (l). Its main conclusions were that

- Not all defects are detrimental,
- Existing weld acceptance standards are overly conservative,
- Fracture mechanics represents a progress in engineering critical assessment of defects,
- Porosity and slag are the two least harmful discontinuities,
- Most of the weld repair activity involves removal of slag and porosity,
- Weld repair should not be construed to be an ipso facto improvement in weld quality,
- Predominant in-service failure mode of commercial ships is fatigue caused mostly by poor design details, misalignments and poor fit-up,
- Quality Control Systems Loop (QCSL) is important to increase quality and productivity and to establish cause-and-effect relationships.

The response to the original "Weld Defect Tolerance Study" by the u. s. Shipbuilding industry was such as to prompt the initiation of a similar study on naval ships of the type mentioned above. More U. S. shipyards participated in the second survey. Six major yards that are involved in Navy

work supplied quality control information; which is the basis of this Part II report.

An ultimate goal of the entire Weld Defect Tolerance Study is to set the ground work for, and to point directions towards optimizing weld acceptance standards, decreasing welding costs and improving weldment quality. Such standards should reflect a correct perception of the contemporary understanding of previous experimental lessons and the current welding engineering knowledge. The two are inseparable, because one builds on the other.

## II. PROCEDURE

Much like the original study, a "Questionnaire for Naval Weld Defect Tolerance Project" was sent to the six participating yards to fill out. A copy of the blank questionnaire is shown in Appendix I. The supplied data as well as the relevant Navy specifications constituted the statistical base of this report. In addition, a correlation of results between commercial and naval ships was made. Questions for which data and information were either not available or were incomplete in scope were excluded from the analysis.

## III. DISCUSSION

Nature is not perfect. It logically follows that neither construction materials nor engineered structures are free of imperfections. The same is true about weld repair[1]. Given that situation, our engineering task must therefore be directed towards understanding the real significance of a weld defect when we are called upon to make a judgement on it. Obviously, the only time weld acceptance standards of any type are needed, is when a defect has been clearly identified and its structural significance has been questioned by an engineering criterion. Welders must constantly be encouraged to make as sound ("perfect") a weld as possible, totally independent of the rationale

behind a particular weld acceptance standard, which may be utilized in the engineering assessment of his weld. When fracture mechanics-based standards speak of a relaxation of present workmanship-type standards, it does not mean that welders may now lay a sloppy weld bead!!!

As Dr. Dawes (4) said, "as far as the general public is concerned, no structure should contain defects". In fact, all engineering materials and structures contain defects at some scale of examination! In an era of increasing public pressure for "perfect" products, engineers will be forced to collect data. Furthermore, increasingly-more sophisticated engineering tools such as fracture mechanics will be required to prove the significance of defects to resolve product liabilities in litigation cases effectively. QCSL is a natural compliment to and a bridge between the more traditional quality control method and the fracture mechanics approach.

The soundness of engineering judgement is normally measured by accurate data. Theory usually begins with a hypothesis and becomes factual when proven valid by performance data. Statistical data gathering is not easy (l). The amount of data available in the U. S. shipbuilding industry is rather scant in a statistical sense. It is, however, possible in a number of areas, to make certain obsenations. These observations can be quite accurate even though the family of data is small, provided the data is correct and consistent.

A cause-and-effect relationship is relatively easy to arrive at when that relationship is approached by a correlative study. That is, a correlation between inspection results and their field performance checked at convenient intervals over a period of time in service. It would be an extremely useful exercise, for instance, *to* test in a field environment, slag inclusions or porosity, which are deemed "marginal" by welding inspectors. To be conservative, these discontinuities might first be left in "non-critical" welds of a ship.

In subsequent tests, a more critical area having the same type, size and amount of discontinuity ought to be tested in oceanic services. Then, the two performance results ought to be compared.

The statistical data are normally reflective of what happens during construction and/or in service. The data supplied for us was incomplete in a sense that making a correlation with in-service performance was not possible. The only thing we have in this respect to report is that a few respondents to the questionnaire stated no knowledge of ship performance failure arising from weld defects exclusively.

It might be useful to point out that collection of data seines the interest of all segments of the industry equally well. Therefore, owners ought to participate in information gathering as well. Today's information may be and often is, tomorrow's answer. The "Quality Control Systems Loop" (QCSL) is for this reason beneficial to all the participants. Owner/operators can benefit from better maintenance economics, while designers can have better understanding of how to improve joint details if feedback is obtained from the field and is constantly analyzed.

Naval ships undergo more extensive Q C inspection than their commercial counterparts. For example, commercial ships are subjected to volumetric inspection less than 5%-10%, while inspection of the seine type in naval snips may exceed 25%, particularly in the mid 3/5 of the ship's hull. (See Table 1). (2, 3)

Methods of nondestructive inspection include:

1. Visual
2. Radiography
3. Ultrasonic
4. Magnetic particle

5. Dye penetrant

6. Eddy current

Visual inspection is 95%-100% of all welds.

The accumulated data is presented in Table II. The following observations can be made from this information.

(a) Visual Inspection

For all intents and purposes, all the welds in a ship's hull receive a 100% visual inspection. The total amount of defects found by visual means is reported to range from 2-25% giving an average value of 7%. Although not all the participating yards provided information about the total amount of weld repair as a consequence of visual inspection, the information supplied was most interesting. The total amount of weld repair ranged from 3-25% giving an average value of 72 for the six shipyards. Curiously, this would suggest that what is being seen, in terms of defects, is just about always repaired. According to one shipyard, 70% of all the weld repair activity comes from visual inspection. This would mean that, (1) most of the repaired defects are surface defects and,(2) the probability is about 3:1 for repairing the majority of the defects in ship construction as a result of visual detection. This obsenation would also underscore the importance of the Quality Control Systems Loop.

Characteristic defects found by visual inspection include porosity, undercut, slag and other surface irregularities.

(b) Radiography

Usually the mid 3/5 of the hull assembly involving most typically intersections of welds are subjected to RT inspection. The total radiographic test amounts to about 25%. The quantity of weld dicontinuities

seen in radiographic films is reported to range from 1-20% in the six yards, with an average of 9% per ship. Of this amount, an average of 7.3% is repaired. This would mean that about 81% of the discontinuities detected by RT is in fact weld repaired.

Discontinuities detected by the radiographic technique consist of slag inclusions, porosity mostly, and LOF/LOF, cracks and others to a much lesser extent. Such a prognosis is not unique to shipbuilding welds. Dr. Kasen (5) reported 8:1 preponderance of blunt flaws as opposed to crack-like defects in Alaskan pipeline. The orientation dependence of discontinuities by radiography is strong. This means a high probability for crack-like dicontinuities to go undetected by x-ray. These two-dimensional or planar defects have, in turn, the highest probability of initiating a weldment failure under an appropriate loading condition.

(c) Ultrasonic Testing

Nearly the same observations may be made about UT as was said of RT. On the average, the total amount of defects found by UT is 8.5%. It turns out that an equal amount is weld repaired, mostly LOF/LOP, then slag, and to a lesser extent porosity and others. One of the implications in all of this is that welds with lack of fusion and lack of penetration do get weld repaired, if and when detected.

The cumulative total amount of all weld discontinuities found by visual, RT and UT methods results in an average value of 8%. A similar average percentage point (8%) is obtained for the cumulative total amount of weld repair reported by the six U. S. shipyards who participated in this quality control survey.

Ranking of defects by welding processes used in six major U. S. yards as of 1980 is as follows:

| | | |
|---|---|---|
| SMAW | 1. | Slag |
| | 2. | Porosity |
| | 3. | LOF/LOP |
| | 4. | Undercut |
| | 5. | Others |
| SAW | 1. | LOF/LOP |
| | 2. | Slag |
| | 3. | Porosity |
| | 4. | Others |
| FCAW | 1. | Slag |
| | 2. | Porosity |
| | 3. | LOF/LOP |
| | 4. | Others |
| | 1. | Porosity |
| (solid wire) | 2. | LOF/LOP |
| | 3. | Others |
| MIG | 1. | Porosity |
| (innershield) | 2. | Slag |
| | 3. | LOF/LOP |
| | 4. | Others |

Classification of weld defects in accordance with nondestructive testing methodologies and manual welding versus automatic ("wire welding") processes shows the following picture:

| NDT | MANUAL | | | AUTOMATIC | | |
|---|---|---|---|---|---|---|
| RT | 1. | Slag | 45% | 1. | LOF/LOP | 35% |
| | 2. | Porosity | 28% | 2. | Slag | 27% |
| | 3. | LOF/LOP | 20% | 3. | Porosity | 18% |
| | 4. | Others | balance | 4. | Others | balance |
| LT | 1. | LOF/LOP | 46% | 1. | LOF/LOP | 53% |
| | 9. | Slag | 31% | 2. | Slag | 26% |
| | 3. | Porosity | 18% | 3. | Porosity | 16% |
| | 4. | Others | balance | 4. | Others | balance |

Grouping the weld discontinuities on the basis of shop versus shipway using only visual inspection results has revealed the ensuing information:

| NDT | SHOP | | | SHIPWAY | | |
|---|---|---|---|---|---|---|
| Visual | 1. | Porosity | 19% | 1. | Undercut | 18% |
| | 2. | Undercut | 16% | 2. | Porosity | 17% |
| | 3. | Slag | 13% | 3. | Slag | 13% |
| | 4. | LOF/LOP | 8% | 4. | LOF/LOP | 6% |
| | 5. | Others | balance | 5. | Others | balance |

On the question of how much weld repair U. S. shipyard welding and quality control experts would consider unnecessary, the estimates were 60%, 50%, 40%, 25%, 15% and 0%. Interestingly enough, the yard with the opinion of zero percent superfluousness in weld repair has reported the lowest . percentage of defect occurrence overall. This is suggestive of an excellent, quality shipyard performance. In point of fact, this shipyard reported only 5% weld repair as a result of 100% visual inspection and of 25% RT inspection.

On the average, one-third (~32%) of all weld repairs per ship was considered unnecessary. Reasons for this opinion were given as:

- "porosity and slag should not be repaired when small and hurried and when loss of cross-section is less than 10%",
- "undercut should not be repaired when corrected by contour grinding or when 'minor'",
- "LOF/LOP should not be repaired when located in low stress areas",
- "'cosmetics' should not be repaired".

The accuracy of present NDT methods used in U. S. shipyards is deemed satisfactory for workmanship-type weld acceptance standards, but it is not reliable enough for fracture mechanics-based standards.

This survey has shown that the most troublesome locations on a ship, which are likely to require weld repair are:

inserts
intersections of butts and seams
corners
thick to thin joints
bi-metallics
around "rat" holes
poor access areas
intakes, hull appendages (struts, sea chests, emitters)

On the question of "are you aware of cracks in ships caused exclusively by a weld defect", the dominant answer was a "NO". The overriding concensus with respect to the predominant cause of in-service failures pointed to "poor design", and to fatigue as-being the dominant failure mode. Brittle fracture has been viewed as a "possibility".

With the exception of one yard, all the others were of the opinion that there was no discernible benefit to the more extensive volumetric inspection performed on these types of naval ships than similar inspections carried out on commercial ships, but to a considerably lesser extent.

Perhaps the best way to illustrate the U. S. shipbuilding industry's feeling about "what is your opinion about the 'Quality Control Systems Loop' approach to weld defect tolerance" is to quote the answers of the six shipyards.

1. "Such a closed loop is essential to improving quality and productivity. While there appears to be a general feeling in industry that present acceptance criteria are not based on fitness-for-use; it will be essential that any proposal to change these criteria be supported by adequate data. Likewise, it is essential that this data permit a meaningful analysis. A Quality Control Systems Loop approach would permit such an analysis in the shortest time period."

2. "It is needed very much."

3. "Only as effective as its members."

4. "Adequate for weld defect tolerance."

5. "Not acquainted with it."

6. "A Quality Plan which establishes requirements, provides feedback data for re-evaluation and corrective action has long been in the ISD Quality System and is felt to be very beneficial."

This statistical survey is clearly reflective of the attributes of the welding processes which as of 1980 have dominated the scene in U. S. shipyards. In terms of weld discontinuities, this has meant a preponderance of slag inclusions and porosity. It follows quite naturally, that as the welding methodologies and technologies do change in years to come, so will there be a shift in the dominance of weld discontinuity types.

An implication being that weld acceptance standards ought to be re-validated from time to time because of the historic irrepressibility of changes in materials and technologies. QCSL assumes an effective use and combination of workers, managers, machines and technology to improve quality. In that sense, QCSL may be regarded as a modern quality control method. It may be well to remember that improved quality equals increased productivity. Better quality from the very beginning of manufacturing process means a lower cost . As inferior products are eliminated, savings can be realized in energy, materials and labor. In short, quality products *cost less* to produce than defective goods. Better quality also counters inflation.

QCSL is also predicated on *a* good labor-management relationship for the common good. The past adversary relationship must be brought under control. Both union and management must realize that they are interdependent. A high defect rate in a plant indicates the necessity for research and development. In reality, there is no virtue to bringing high speed technology into an industrial environment, where there is a high defect rate. It is because such an environment would merely turn out substandard products at a high speed. Hence, people must first be educated about the need, the importance and the wisdom of quality. We now have years and years of lessons to show that

machines or automation alone are not enough to boost productivity or raise the standard of living sufficiently. Japan and West Germany have proved that eloquently.

Unnecessary weld repair should also be looked at in the context of quality and productivity. When it comes to repairing spurious defects both quality and productivity go down. A stop in production to repair every little pore or every innocuous slag inclusion amounts to a stop sign along the highways of production. An inspection is like a "stop sign". As quality increases inspection decreases. Quality is everybody The realization of quality depends on the extent of participation and the intensity of dedication *to* it. At any rate, it is an evolutionary process.

## IV. CONCLUSION

From a statistical analysis of quality control data supplied from six major U. S. shipyards, the following observations can be derived.

1. Naval ships undergo a more extensive volumetric inspection than commercial ships. The benefits of this more extensive inspection are questionable.
2. Visual inspection is performed on all welds to the extent of 100%. Of this inspection, an average of 7% is defective to the point of being repaired. Typical discontinuities include porosity, undercut and slag.
3. The mid 3/5 of the hull assembly receives about 25% radiographic inspection: the mean defect rate and the amount of repair being 9% and 7.3%, respectively. Characteristic defects consist of slag and porosity.
4. The results of ultrasonic testing show a similar trend to that of radiography. The defect content is 8.5% for UT inspection amount of 25%. The amount of weld repair appears to be equal to the

defect content indications of mostly LOF/LOP.

5. A cumulative total for visual, RT and UT nondestructive examinations comes to an average value of 8% for defect detection and repair.

6. Predominant defects for SMAW, FCAW are slag and porosity, for SAW LOF/LOP and slag, for MIG porosity, slag and/or LOF/LOP.

Welding and QC experts consider about 1/3 of all weld repairs currently practiced in U. S. shipyards as unnecessary, due to the preponderance of slag and porosity both being small in size and least harmful in type from the point of view of structural significance..

The dominant failure mode in service of these types of naval ships built of "mild steel" is reported to be fatigue. The principal cause of fatigue failure is claimed to be undesirable design details.

Present NDT methods are considered adequate for the workmanship-type, but not for the fracture mechanics-type weld acceptance standards.

QCSL received a strong support from U. S. shipyards surveyed because of its potential for improving quality and productivity.

## V. ACKNOWLEDGEMENT

On behalf of Sun Ship, Inc., the author should like to thank Mr. John Mason, MARAD Program Manager, Bath Iron Works and the members of SNAME Panel SP-6 - Standards and Specifications - for supporting the continuation as Part II, Task S-26 of the original "Weld Defect Tolerance Study" project. Our gratitude is also extended to the U. S. Maritime Administration for a continued sponsorship of this Navy Weld Defect Tolerance Study.

A special tribute goes to six major U. S. shipyards which supplied quality control data for this study. It is through such cooperation that our understanding on the significance of weld discontinuities in shipbuilding is so vastly enriched.

The job of soliciting Q C information from the six shipyards was greatly facilitated through the help of Mr. Ivo Fioriti, Assistant for Materials Application, Naval Sea Systems Command, Department of the Navy, for which he deserves more than anonymous recognition.

## VI. RECOMMENDATION

This statistical survey is a reflection of welding processes used in U. S. shipyards in 1980. The evidence is strong that a trend away from the heavy use of SMAW towards “wire welding” processes has made a foothold in U. S. yards. Similar surveys should be made from the to time to monitor shifts in dominant weld defect types. It is therefore recommended that weld acceptance standards ought to be re-examined periodically in the future.

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TABLE I

**Ultrasonic or Radiographic Inspection Requirements for Surface Ships[1,2,3,4]**

| Category of structure | Extent of inspection | Applicable notes |
|---|---|---|
| **A Shell Plating** | | |
| A-1 Intersections of butt-welded joints in plating over 3/8 inch within the midship 3/5 length. | 10 percent. | |
| A-2 Intersections of butt-welded joints in the sheer stroke to other shell plating over 3/8 inch within the mid-ship 3/5 length. | All intersections. | (5) |
| A-3 Butt (transverse) joints in plating over 3/8 inch within the midship 3/5 length. | 1 random location in each 20-foot length. | |
| A-4 Seam (longitudinal) joints in plating over 3/8 inch within the midship 3/5 length. | 1 random location in each 40-foot length. | |
| A-5 Butt (transverse) joints in the flat and vertical keel within the midship 4/5 length. | 10 percent of the length of each joint. | |
| A-6 Butt (transverse) joints in the bilge and sheer stiaires within the midship 3/5 length. | 10 percent of the length of each joint.. | |
| A-7 Butt (tranverse) joints in shell plating over 1 inch outside the midship 3/5 length | 5 percent of the length of each joint. | |
| **B Strength Deck(s)** | | |
| B-1 Intersections of butt-welded joints in the stringer strokes to other deck plating over 3/8 inch within the midship 3/5 length of the main strength deck(s) or inner-bottom tank top. | All intersections. | (5) |
| B-2 Butt (transverse) joints in the stringer strakes of main strength deok(s) ~ inner-bottom tank top within the midship 4/5 length. | 10 percent of tbe length of each joint. | |
| B-3 Butt (transverse) joints in plating over 1 inch in main strength deck(s) cr inner-bottom tank top within the midstilp 3/5 length. | 5 percent of the length of each joint. | |

TABLE I (Continued)

Ultrasonic or Radiographic Inspection Requirements for Surface Ships [1,2,3,4] (Continued)

| Category of Structure | Extent of inspection | Applicable notes |
|---|---|---|
| **C Underwater Side Protective System or Ballistic Plating Over 3/8 Inch** | | |
| C-1 Butt-welded joints in plating. | 1 random location in each 20-foot length. | |
| C-2 Intersections of butt-welded joints. | 10 percent. | |
| C-3 Butt-welded joints welded from one side only. | 100 percent. | |
| **D Superstructure Designed for Blast Loading** | | |
| D-1 Intersections of butt welded joints in outside plating over 1/4 inch. | 10 percent. | |
| D-2 Butt-welded joints in outside plating over 1/4 inch. | 1 random location in each 20-foot length. | |
| D-3 Butt joints in supportiing structure stiffening member over 8 inches in depth and over 3/8 inch thick. | 10 percent of the length of each joint. | (6) |
| **E Mast and King Post Structure** | | |
| E-1 Circumferential full penetration butt welds. | 100 percent. | |
| E-2 Longitudinal (axial) full penetration butt welds. | 10 percent of the length of each joint. | |
| **F Rigging Fittings** | | |
| F-1 Full penetration butt welds attaching rigging fittings to decks, bulkheads, booms, kingposts, or masts, Provided the fitting supports or carries working loads in excess of 1 ton and is not proof tested after installation. | 1 random location in each attachment weld. | 1 |
| F-2 Full penetration butt welds in boat davit or crane material over 1/4 inch. | 100 percent. | |

TABLE II

Accumulated Quality Control Data Obtained From Six Major U. S. Shipyards

| NDT | Total Amount of Welds Inspected (Per Ship) (%) | Total Amount of Defects Found (Per Ship) | | | Total Amount of Defects Repaired (Per Ship) | | | Estimated Total Amount of Unnecessary Weld Repair (Per Ship: Per all NDTs) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Shipyard (%) | Range (%) | Average (%) | Shipyard (%) | Range (%) | Average (%) | Shipyard (%) | Range (%) | Average (%) |
| VISUAL | 90 - 100 of all welds (~ 95% as per yards) | 25, 3, 2 - 10, ?<5, 3 | 2 - 25 | 7 | 25, 3, 2 - 10, ?<5, 3 | 3 - 25 | 7 | | | |
| RT | See NAVSHIPS 0900 - 000 - 1000 Section 6, Table 6-1 (~ 25% as per yards) | 16, 20, 1 - 3, 10, 2, 4.3 | 1 - 20 | 9 | 16, 5 - 6, 6, 10, 2, 4.3 | 2 - 16 | 7.3 | 50, 0, 25 60, 15, 4 | 0 60 | 32 |
| UT | See NAVSHIPS 0900 - 000 - 1000 (~ 25% as per yards) | 10, 15, 2 10, 10, 3.8 | 2 - 1 | 8.5 | 10, 15, 3, 10, 10, 3.8 | 3 - 15 | 8.5 | | | |
| | | Overall Average: ~ 8 | | | ~ 8 | | | ~ 32 | | |

# APPENDIX I

# QUESTIONNAIRE FOR NAVAL WELD DEFECT TOLERANCE PROJECT

A survey in connection with Marad-sponsored "Weld Defect Tolerance Study" for the sole purpose of assessing the total amount of weld defect repair done and its cost expended in individual U. S. shipyards. This questionnaire is aimed at: (a) NAVAL SURFACE VESSELS made out of MILD-STEEL EXCLUSIVELY,

(b) HULL WELDS ONLY.

1. What NDT methods do you use for inspecting welds?

2. what areas of ship do you inspect and by what methods?

3. How much visual inspection do you do?

4. How much radiographic and UT inspection is done on a typical naval surface vessel?

5. What type and how much weld defects are you typically experiencing when welds are inspected by:

   5.1 Visual examination;

   5.2 Radiography;

5.3 UT;

6. How much inspection of welds is done to satisfy:

6.1 Your own QC requirement and by what method.

6.2 Code requirement and by what method.

6.3 Owner/Operator requirement and by what method.

6.4 Are there any differences among the above three requirements? If so, how much and which one is most strick historically speaking?

7. How much weld repair is done due to:

7.1 Visual inspection;

7.2 Radiography;

7.3 UT

8. What is the estimated total dollar value of all weld defect repairs done at your shipyard?

9. How much in terms of percentage of your weld defect repair in your opinion is unnecessary and why?

10. What is the most frequently observed weld discontinuity in your shipyard on the basis of:

    10.1 NDT methods used;

    10.2 Welding processes utilized;

11. Give a complete list of weld discontinuities in decreasing order of importance your shipyard experiences and their relative percentage amounts.

| Visual Examination | | | | X-Rays | | | | UT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SHOP | | SHIPWAYS | | MANUAL WELDS | | AUTOMATIC WELDS | | MANUAL WELDS | | AUTOMATIC WELDS | |
| Type | % | Type | % | Type | % | Type | % | Type | % | Type | % |

12. **What type(s) of weld discontinuities are now weld repaired which should not be repaired in your opinion, and why?**

13. **What type(s) of weld defects characterize the following arc welding processes?**

13.1 **Shielded Metal Arc (stick electrode)**

**a.**

**b.**

**c.**

**d.**

**e.**

**13.2 Submerged-Arc Welding**

**a.**

**b.**

**c.**

**d.**

**e.**

13.3 Flux-cored Arc Welding

a.

b.

c.

d.

e.

13.4 Gas Metal-Arc Welding (MIG, solid wire)

a.

b.

c.

d.

e.

13.5 Innershield (self-shielding) Wire Welding

a.

b.

**13.5 (cont.)**

**c.**

d.

**e.**

**14. What are the most troublesome locations on a given ship very likely to require weld defect repair after inspection by any NDT method?**

**Locations:**

**1.**

**2.**

3.

4.

**15. Do You feel that the present NDT methods used in the American Shipbuilding Industry" are reliable enough to satisfy the needs of accuracy obtained by Fracture Mechanics Principles?**

**Answer: Yes No**

**Comments:**

16. **Are you aware of "CRACKS" in ships caused EXCLUSIVELY by a weld** defect?

**Yes** _____ **No** _____

**Type of defect identified in causing "crack":** _____

**Failure mode: (1) fatigue:** _____

**(2) yielding:** _____

(3) **brittle fracture:** _____

17. **What is the predominant cause of failures ("cracks") in naval ships in your opinion?**

**Causes:**

**Failure mode(s)**

**Any Comments?**

OCT 29 1984



18. Do you always re-inspect the repaired weld?

19. What is your opinion about "Quality Control Systems Loop" approach to weld defect tolerance?

20. what is the predominant failure mode in hull welds of naval surface vessels?

21. Is there any information or documentation which would suggest that the more extensive inspection requirements of Navy surface vessels have resulted in fewer in-service failures than those in commercial ships. In other words, do you benefit from doing more inspection?

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THANK YOU FOR YOUR COOPERATION,

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