NASA TM-85733

NASA Technical Memorandum 85733

NASA-TM-85733 19840005508

Pressure System Recertification At NASA-Langley Research Center

C. Michael Hudson and James W. Ramsey, Jr.

DECEMBER 1983

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

PRESSURE SYSTEM RECERTIFICATION AT NASA-LANGLEY RESEARCH CENTER

C. MICHAEL HUDSON* AND JAMES W. RAMSEY, JR.**

NASA-LANGLEY RESEARCH CENTER

HAMPTON, VA 23665

SUMMARY

NASA's Langley Research Center is the oldest of all the NASA Centers. Many of its pressure systems were fabricated in the 1920's, and are still in service today. To ensure the continued safe operation of these systems, NASA-Langley has initiated a pressure-system recertification program. The procedures for recertifying these pressure systems are reviewed in this paper. Generally, the analysis and inspection requirements outlined in the appropriate national consensus codes are followed. In some instances the requirements of these codes are not met. In these instances, the systems are analyzed further, repaired, modified and/or tested to demonstrate their structural integrity.

*Head, Fracture Mechanics Engineering Section, Structural Design Branch, Facilities Engineering Division

**Head, Structural Design Branch, Facilities Engineering Division

N84-13576 #

INTRODUCTION

NASA's Langley Research Center is the oldest of all the NASA Centers. Many of its pressure systems were fabricated in the 1920's, and are still in service today. To ensure the continued safe operation of these systems, NASA-Langley has initiated a pressure-system recertification program. This program employs modern analyses and the latest inspection techniques to evaluate the structural integrity of these systems. This paper describes (a) the rationale behind NASA-Langley's recertification program; and (b) some procedures for dealing with problem areas.

RATIONALE FOR PRESSURE VESSEL ANALYSIS

Under NASA-Langley's recertification program, pressure vessels fall into two general categories: (1) vessels carrying the ASME Boiler and Pressure Vessel Code Stamp; and (2) vessels which do not carry the Code stamp. The procedures for recertifying both categories of vessels are described as follows:

Code-Stamped Vessels

Code stamping of a vessel by a manufacturer certifies that the vessel has been designed and fabricated in accordance with a section of the ASME Boiler and Pressure Vessel Code (ASME B&PV Code). No additional analysis is performed in recertifying Code-stamped vessels. However, these vessels are inspected as described in the Nondestructive Examination section of this paper.

Non-Code-Stamped Vessels

These vessels are analyzed using the criteria of the current issue of either (1) Section VIII, Division 1; (2) Section VIII, Division 2; or (3) Code Case 1205-5 of the ASME B&PV Code, References 1, 2, and 3 respectively. Use of these criteria does not qualify the vessels for Code stamping. However, these criteria do provide a rational guide for evaluating the integrity of the vessels, and the criteria are used as such.

Section VIII, Division 1 (referred to hereinafter as Division 1): Welded and riveted vessels are initially analyzed using the criteria of Division 1. This Division generally requires (1) continuum analyses of the vessels; and (2) that numerous design rules be followed. Depending upon the materials and joint efficiencies used, Division 1 allows a range of 0 percent to 100 percent radiographic inspection of structurally significant welds. Division 1 does have stringent requirements on vessel configuration, e.g. on the slopes at head-to-cylinder and cone-to-cylinder junctions and on the radii on the outside-corners of nozzles.

Section VIII, Division 2 (referred to hereinafter as Division 2): In some instances, welded vessels satisfy the requirements of Division 1 only when their maximum allowable working pressures are reduced below NASA's operational requirements. In these instances, the vessels are analyzed using Division 2. This Division permits higher allowable stresses, and consequently higher pressures, in a given vessel. However, Division 2 generally requires detailed stress, thermal and fatigue analyses of the vessels. It is (1) more restrictive on configurations and materials than Division 1; and (2) generally more expensive and time-consuming than Division 1. Further, Division 2 generally requires 100 percent radiographic inspection of structurally significant welds.

Examples: Reference 4 describes in detail the recertification of a 135 psig (0.93 MPa) wind tunnel by using the Division 1 criteria. Reference 5 describes the recertification of twelve 6000 psi (41.4 MPa) laminated air storage vessels by using the Division 2 criteria.

Code Case 1205-5 (referred to hereinafter as CC 1205-5):
Integrally forged vessels are initially analyzed using the criteria of CC 1205-5. This Code Case (1) applies only to integrally forged vessels and (2) severely restricts the construction, configuration and usage of the vessels. For example, (1) the vessels must be fabricated of SA-372, Class I, II, III, IV or V steel only; (2) the maximum inside diameter of the vessels is 24 inches (609.6 mm); and (3) the usage temperature range of the vessels is minus 20°F to plus 200°F (244 to 367K).

CC 1205-5 is used in recertifying integrally forged vessels because it permits higher allowable stresses than Division 1, but does not require the expensive and time-consuming analyses which Division 2 requires.

Integrally forged vessels which do not meet the criteria of CC 1205-5 are analyzed using the Division 2 criteria.

RATIONALE FOR PIPING ANALYSIS

Piping components are analyzed using the criteria of the current issue of the Chemical and Petroleum Refinery Piping Code (referred to hereinafter as ANSI B31.3), Reference 6. This Code applies to piping handling all liquids and gases. It requires a detailed analysis of the piping, and radiographic inspection of 5 percent of all butt welds, except for welds subjected to severe cyclic stresses. These latter welds require 100 percent radiographic inspection.

RECERTIFICATION PRACTICE

Field Survey

NASA Management Instruction NMI 1710.3A requires that, to the maximum extent possible, pressure systems be designed and fabricated in accordance with the applicable codes. (Deviations are permitted, but additional analyses and tests are required to demonstrate that the safety of personnel and equipment are not compromised.) The first step in meeting these regulations is to identify every component in a given system. For the older systems, there is rarely any documentation on these components. Consequently, field surveys must be made to assemble data on pressure vessel configurations, pipe sizes and schedules, flange and valve pound-class ratings, and manufacturers' pressure ratings. These field surveys also identify the location of all welds and support structures.

Frequently, the information required for component analysis is simply not available. The following paragraphs cite several ways of dealing with this lack of information.

- The materials used to fabricate components are frequently not identified. Whenever feasible, sections of these materials are removed and both hardness and x-ray fluorescence tests conducted. These tests generally yield good indications of the tensile strength and chemical properties of the materials.

  In some cases, it is infeasible to remove a section of material. The material is then assumed to be fabricated of the lowest strength material available in the applicable Code. Table 1 presents the materials assumed for various applications.

- Flanges are occasionally found which cannot be reasonably analyzed using the criteria of Division 1. In one case, 616 identical flanges were found. The maximum allowable working pressure for these flanges was established by proof testing one flange according to the procedures outlined in Paragraph UG-101, Proof Tests to Establish Maximum Allowable Working Pressure, of Division 1.

- Many components are located which are made of known, but not Code-approved materials. For these components, the "Basis for Establishing Stress Values" section of the appropriate Code is used to determine allowable stresses.

The Charpy impact energies for these materials are obtained from the technical literature. System operating temperatures are modified, if necessary, to ensure that these materials have the impact energies required by the Codes. See References 4 and 5 for example.

Evaluation

Once all of the components have been identified, they are analyzed. The maximum allowable working pressures for vessels and piping are determined using the procedures described in the RATIONALE sections of this paper. The maximum allowable working pressures for components, e.g. switches, flow meters, gages, etc., are determined from the manufacturers' pressure ratings for the components.

If the analysis shows that all components are adequate for the system working pressure, the analysis portion of recertification is complete. The components that are not adequate are either replaced or the system operating pressure is reduced.

Nondestructive Examination

Table 2 describes the nondestructive examinations which are normally performed during pressure system recertification. If no unacceptable indications are found during these examinations, a system is considered as recertified. If unacceptable indications are found, some action is taken to ensure personnel safety and system integrity. The following section of this paper describes some of the actions taken.

Unacceptable-Indication Management

Normally unacceptable indications are either ground out and repair welded, or the component is removed from service. In some cases, however, such repairs are not desirable--for example, when greater damage may be done by repairing the indication than by leaving it, when the repair costs are excessive, or when repair funds are not available. The procedures followed in dealing with several of these cases are described in the following paragraphs.

An unacceptable slag inclusion was found in a 3 1/8-inch (79.4 mm) thick flange-to-pipe weld. This inclusion was approximately 2 3/4 inches (69.9 mm) from the outside surface of the pipe and inaccessible from the inside of the pipe. To repair the inclusion, a large quantity of weld metal would have to be ground away and the ground-out area repair welded. Because the repair welding was so localized, NASA-Langley's engineering staff was concerned that the flange might warp and no longer match its mating flange. The stresses introduced in forcing these flanges together could easily be more deleterious than the slag inclusion. Consequently, a fracture mechanics analysis was performed to determine whether the inclusion compromised the integrity of the weld. Tri-stereo radiographs were used to determine the dimensions of the inclusion. These dimensions were subsequently confirmed using ultrasonic techniques. The stresses acting across the defect were determined from a detailed stress analysis of the defect area. The procedures specified in

Section XI of the ASME B&PV Code, Reference 7, were then followed for the fracture mechanics analysis. This analysis showed (1) the inclusion would cause a leak-before-burst failure of the pipe; and (2) the flaw could experience over 300,000 full-pressure cycles before reaching an unacceptable length according to Reference 7 (i.e. before the flaw reached one-tenth of the critical flaw size). Based on this analysis, the inclusion was left in the weld, and its size is monitored regularly to detect any anomalous growth.

Similar procedures were followed in certifying a bearing-case support strut in NASA-Langley's National Transonic Facility (NTF). A slag inclusion was found in one of the welds in the support strut. Removal of the inclusion and repair welding of the resulting gouge would probably misalign the bearing case. This misalignment would be difficult, if not impossible, to correct. Consequently, tri-stereo radiographs were used to determine the dimensions of the inclusion, a detailed stress analysis of the defect area was performed and a fracture mechanics analysis completed. The predicted life of the strut exceeds the expected operating life of the NTF by a factor of seven. Thus the slag inclusion was left in the strut.

Numerous cracks were found in the longitudinal welds of 167 air storage vessels at NASA-Langley. These vessels were fabricated by rolling the cylindrical portions of the vessels to the desired radius and flash welding the longitudinal seams together. Unfortunately, this process left large numbers of cracks (20 to 80 per vessel) in the longitudinal welds. Repairing all of these cracks would be extremely expensive. Consequently, fracture mechanics analyses were performed to determine if some of the cracks could be safely left in the vessels. The analysis showed that nearly three-quarters of the cracks would not propagate to failure in 100,000 full-pressure cycles (20 times the required life of the vessels).

In order to verify the results of the fracture mechanics analysis, a test vessel was fabricated from one of the existing vessels. This test vessel contained a number of cracks which were predicted to have lives greater than 100,000 cycles. The test vessel was fatigue cycled for 100,000 full-pressure cycles and none of the cracks did propagate to failure. Thus the fracture mechanics analysis was verified, and only one-quarter of the cracks in the longitudinal welds will be repaired.

Fracture mechanics is a relatively new science and has only been used extensively in the aircraft industry. However, the ability of fracture mechanics to accurately predict flaw growth and fracture has been demonstrated frequently. (See References 8 and 9 for example.) Consequently this analysis tool will be used with increasing frequency in other industries as well.

FUTURE INSPECTIONS

Once a system has been recertified, a future inspection plan is developed. Under this plan, the areas experiencing high and/or cyclic stresses are regularly inspected to locate any defects which might subsequently develop. As appropriate, dye penetrant, magnetic particle, ultrasonic, radiographic and visual techniques are used in these inspections. Reference 10 presents the recommended inspection intervals for systems having different system volumes and contents. (Table IX, Reference 5 shows the details of a typical inspection plan.)

CONCLUDING REMARKS

The procedures for recertifying pressure systems at NASA-Langley Research Center are reviewed in this paper. Generally, the analysis and inspection requirements outlined in the appropriate national consensus codes are followed in recertifying these systems. In some instances the requirements of these codes are not met. Usually, these systems are modified so that the requirements are met. However, where repair costs are excessive or good judgement indicates that repairs may do more harm than good, additional analyses and/or tests are performed to recertify the system.

REFERENCES

1. Rules for Construction of Pressure Vessels, Division 1, Section VIII, ASME Boiler and Pressure Vessel Code, current issue.

2. Rules for Construction of Pressure Vessels, Division 2 - Alternative Rules, Section VIII, ASME Boiler and Pressure Vessel Code, current issue.

3. Code Case 1205-5, Boilers and Pressure Vessels, 19XX Code Cases, ASME Boiler and Pressure Vessel Code, current issue.

4. Taylor, J. T.; Lewis, P. E.; and Ramsey, J. W., Jr.: A Procedure for Verifying the Structural Integrity of an Existing Pressurized Wind Tunnel, J. Engineering Materials and Technology, Vol. 96, Series H, No. 4, October, 1974, pp. 283-291.

5. Hudson, C. M.; Girouard, R. L.; Young, C. P., Jr.; Petley, D. H.; Hudson, J. L., Jr.; and Hudgins, J. L.: Recertification of the Air and Methane Storage Vessels at the Langley 8-Foot High-Temperature Structures Tunnel, NASA TN D-8329, February, 1977.

6. Chemical Plant and Petroleum Refinery Piping, ANSI/ASME B31.3, ASME Code for Pressure Piping, B31, current issue.

7. Rules for Inservice Inspection of Nuclear Power Plant Components - Division 1, Section XI, ASME Boiler and Pressure Vessel Code, current issue.

8. Chang, J. B., Editor: Part-Through Crack Fatigue Life Prediction, American Society for Testing and Materials STP 687, 1979.

9. Chang, J. B., and Hudson, C. M., Editors: Methods and Models for Predicting Fatigue Crack Growth Under Random Loading. American Society for Testing and Materials STP 748, 1981.

10. Anon.: Guide for Inservice Inspection of Ground-Based Pressure Vessels and Systems, NASA NHB 1700.6, January 18, 1976.

TABLE 1. Materials Assumed for Various Applications

Application	Material Assumed
Carbon steel pipe	ASTM A53 Gr. A
Carbon steel fittings	ASTM A234 Gr. WPA
Carbon steel forgings	ASTM A181 Gr. I
Stainless steel pipe	ASTM A312 Gr. TP304L
Stainless steel fittings	ASTM A182 Gr. 304L
Stainless steel forgings	ASTM A182 Gr. F304L

TABLE 2. Nondestructive Examinations Normally Performed During System Recertification

Component	Nondestructive Examination
Code-Stamped Vessels	High stressed areas and fillet welds are surface inspected using visual, magnetic particle and/or dye penetrant techniques.
Non-Code-Stamped Vessels, Section VIII, Division 1 Analysis	Same as Code-Stamped Vessels, plus a minimum of 10% of all structurally significant welds are radiographed. A higher percentage may be radiographed if higher joint efficiencies are required.
Non-Code-Stamped Vessels, Section VIII, Division 2 Analysis	Same as Code-Stamped Vessels, plus 100% of all structurally significant welds are radiographed.
Non-Code-Stamped Vessels, CC 1205-5 Analysis	The nozzles are surface inspected using visual, magnetic particle and/or dye penetrant techniques.
Piping	Same as Code-Stamped Vessels, plus 10% of all welds are radiographed.
All	100% of all structurally significant welds are radiographed if unacceptable defects are found in initial inspections.

1. Report No.
NASA TM-85733

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Pressure System Recertification at NASA-Langley Research Center

5. Report Date
December 1983

6. Performing Organization Code
023-22-00-56-00

7. Author(s)
C. Michael Hudson and James W. Ramsey, Jr.

8. Performing Organization Report No.

9. Performing Organization Name and Address
NASA Langley Research Center
Hampton, VA 23665

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, DC 20546

13. Type of Report and Period Covered
Technical Memorandum

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

NASA's Langley Research Center is the oldest of all the NASA Centers. Many of its pressure systems were fabricated in the 1920's, and are still in service today. To ensure the continued safe operation of these systems, NASA-Langley has initiated a pressure-system recertification program. The procedures for recertifying these pressure systems are reviewed in this paper. Generally, the analysis and inspection requirements outlined in the appropriate national consensus codes are followed. In some instances the requirements of these codes are not met. In these instances, the systems are analyzed further, repaired, modified and/or tested to demonstrate their structural integrity.

17. Key Words (Suggested by Author(s))
Unacceptable Indications, Pressure Systems, Future Inspections, Recertification, Analysis, Inspection

18. Distribution Statement
Unclassified-Unlimited
Subject Category 37

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
15

22. Price
A02

N-305

For sale by the National Technical Information Service, Springfield, Virginia 22161