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Rodabaugh and His Contribution on the Piping Codes

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1. Introduction

I worked in the field of the piping design and analysis for about ten years in Japan, but now I am in a software company in Columbus, Ohio. Through literature survey on the piping analysis in Japan, I identified Mr. Rodabaugh as an important person of the field since he wrote numerous meaningful papers. Especially I was impressed that his fruits on stress indices of piping products had been reflected soon to the ASME codes, which might be different from the system in Japan.

Mr. E. C. Rodabaugh

Since his papers inform that he had long worked for the Battelle Institute in Columbus, I imagined that he probably lives in Columbus or its suburbs. Actually, I was able to know his address in the phone book. Then I asked him questions about a historical background on piping codes, which may be not explicitly mentioned in literature.

This article summarizes the question and answer and includes a list of his 48 papers and his latest photograph which were given by him. I hope this article will be useful in understanding piping codes and its history.

2. Mr. Rodabaugh’s Background

Arimoto: Would you tell us your background briefly?

Rodabaugh: I worked for Joseph E. Seagram Co. for two years and for E. I. Du Pont for two years, after I received my B. S. degree from Iowa State College, Ames, Iowa in 1939. For those four years I was engaged in power plant operations. From 1943 to 1946 I was with the U. S. Maritime Service, working as Engineer on steam-powered ocean going ships. I obtained a Chief Engineer’s license and served as Chief Engineer on both turbine and reciprocating engine ship. In 1946, I joined Tube Turns in Louisville, Kentucky. I remained with them for over 15 years, engaging in research and development work on programs relative to piping and pressure vessel components. I also served as a piping system design consultant and participated in the preparation of technical publications on piping system designs. In 1959, I received my M. S. from the University of Louisville.

I joined the Battelle-Columbus Laboratories, Columbus, Ohio in 1961. I remained with them for 20 years, during which time I continued to work in the field of design of piping and pressure vessels. I has developed theoretical solutions to a number of complex problems involved in the design of piping and pressure vessel components and has written a number of computer programs applicable such components. In 1981, I retired from Battelle and started my own consulting firm, E. C. Rodabaugh Associates, Inc. I continued my work on piping and pressure vessels. In 1991, the firm was dissolved and since then, I have continued my work as a consultant.

Arimoto: What is the U. S. Maritime Services?

Rodabaugh: Merchant Marine Act of 1936, enacted by Congress, created the U.S. Merchant Marine and the U.S.

Maritime Service to "serve as a naval or military auxiliary in time of war or national emergency." U.S. Maritime Service operated four basic training bases for teaching seamanship and weapons training; officer candidate schools; specialized training, and ten vessels to train over 200,000 men recruited throughout the country. USMS administered by U.S. Coast Guard and U.S. Navy. During World War II many young men were sent to U.S. Maritime Service by Navy and Coast Guard recruiters. The USMS was the only Service that did not discriminate racially.

Arimoto: Why did you work for Tube Turns after the U.S. Maritime Service?

Rodabaugh: During the war, Louisville, KY, was my “home” city. After the war, I return to Louisville and, as a result of a job interview with Mr. Markl, I was offered a job at what was then a good salary.

Arimoto: What company was Tube Turns, Inc.?

Rodabaugh: Tube Turns, Louisville, KY, was a manufacturer of metal piping components. Tube Turns had a patented method of manufacturing high-quality elbows. In 1945, the competition was small and Tube Turns could make large profits. They gradually expanded into other piping products such as tees, reducers and metal-bellows expansion joints. Tube Turns was closed in about 1985.

Arimoto: I have heard that Tube Turns was taken over by Sumitomo Metal, a Japanese steel maker. Do you know the story?

Rodabaugh: I left Tube Turns and Louisville in 1961. I think Sumitomo Metal bought Tube Turns around 1970. Apparently, Tube Turns was not sufficiently profitable, hence Sumitomo closed Tube Turns.

3. Mr. Markl and ANSI Code

Arimoto: We can learn easily early research works of piping analysis through papers in the following two books published by ASME.

Pressure Vessel and Piping Design Collected Papers 1927-1959, 1960, ASME

Pressure Vessel and Piping: Design and Analysis A Decade of Progress, 1972, ASME

I have some questions that I wanted to know answers in Japan from some papers in the above books. First, why was Kellogg Company so active to do researches on the piping design at that time?

Rodabaugh: Kellogg was a major designer and fabricator of piping system. Their commercial interests were served by their research work.

Arimoto: I think Mr. Markl contributed a lot for specifying the ANSI Code according to his papers. I guess he created the concept of the simplified method of piping analysis by using stress intensity and flexibility factors at Kellogg. Is it true?

Rodabaugh: When Markl was at Kellogg, there were several methods of simplified piping system analysis by other-than Markl.

Arimoto: Was it possible for Kellogg to carry out a lot of fatigue experiments for specifying stress intensity factors of each piping component? Actuary did the Tube Turns does?

Rodabaugh: Kellogg did not carry out the fatigue tests which form the basis for Code rules. These fatigue tests were carried out at Tube Turns. Results were published in the Papers:

“Fatigue Tests of Welding Elbows and Comparable Double-Mitre Bends”, A. R. C. Markl,

Trans. ASME, Vol. 69, 1947, pp.869-879

"Fatigue Tests on Flanged Assemblies", A. R. C. Markl and H. H. George, Trans. ASME, Vol. 72, 1950, pp.77-87

"Fatigue Tests of Piping Components", A. R. C. Markl, Trans. ASME, Vol. 74, 1952, pp.123-133

Discussion of Code rules and an extensive Bibliography (as of 1955) are contained in the paper:

"Piping-Flexibility Analysis", A. R. C. Markl, Trans. ASME, February, 1955.

Arimoto: Why did Mr. Markl move to Tube Turns, Inc.?

Rodabaugh: Tube Turns was prepared to undertake substantial research work to further the selling of their products. Markl was presumably offered a better salary than he was getting at Kellogg.

Arimoto: What was Mr. Markl like?

Rodabaugh: Markl was a highly competent engineer and an excellent technical writer. He did high-quality work and insisted on high-quality from those who worked for him.

Arimoto: If possible, would you give us episodes about him?

Rodabaugh: In the last few years of Markl's career, he worked at Tube Turns to develop and test metal bellows expansion joints. His last published paper is: "On the Design of Bellows Elements", A. R. C. Markl, Presented at the National Distinct Heating Association's 55th Annual Meeting, June 1964, Niagara Falls, Ontario, Canada.

Arimoto: I know you did the research on the effect of internal pressure on flexibility and stress-intensification factors of elbows at Tube Turns. What was the purpose of the research? I think the effect is significant when the ratio of thickness to diameter become small. Did industry need such elbows at that time?

Rodabaugh: In about 1955, Tube Turns was routinely making and selling elbows with ratio of thickness to diameter of around 0.01.

Arimoto: What kind of experiment was carried out for specifying the pressure-temperature ratings of flanged joint? I remember reports on the rating would be just for Tube Turns, so that I could not get them in Japan.

Rodabaugh: For pressure-temperature ratings of ANSI B16.5 flanged joints, see Reference (10),(18),(28),(33) and (34) of " Papers Authored or Co-Authored by E. C. Rodabaugh".

4. At Battelle laboratory and ASME Code

Arimoto: Why did you move the Battelle Laboratories in 1961?

Rodabaugh: By 1960, Tube Turns patent had expired; they were making less profit and beginning to cut back on research work. I had worked with an engineer at Battelle, thus I was aware that Battelle was doing research in my field. They offered a salary that was better than at Tube Turns thus, when invited to move to Battelle, I did so.

Arimoto: At that time, ANSI B31.7, a nuclear-piping-system code had been preparing for a commercial nuclear plant. Do you know who created equations for the simplified analysis of the Code?

Rodabaugh: The equations in B31.7 for Class 1 piping were a result of B31.7 Code Committee work. The chairman of the piping group, and principal contributor, was D. F. Landers, now with Teledyne Brown Engineering.

Arimoto: You specified the stress indices of the B31.7 relating the ORNL piping program in less than 6 months according to the following article by S. E. Moore.

S. E. Moore, “The Contributions of the ORNL Piping Program to Nuclear Piping Design Codes and Standards”, Trans. ASME, Journal of Pressure Vessel Technology, pp224, 1977

Would you tell us in detail about the ORNL piping program and a background of specifying the stress indices?

Rodabaugh: The ORNL Piping Program was started since 1967 to develop and qualify stress indices and flexibility factors for several years under the B31.7 Committee at Oak Ridge National Laboratory (ORNL) as shown in the article by S. E. Moore. Details of the work are described in several of reports listed in “Papers authored or co-authored by E. C. Rodabaugh”. For example, Reference (26) is a 104 page report giving details of the background of B-indices.

Arimoto: How long did the ORNL program last?

Rodabaugh: To about 1980.

5. Outlook

Arimoto: What do you expect young piping engineers and researchers?

Rodabough: Hopefully, young engineers will be aware of the tremendous background of data that exists at present. Elastic-plastic analysis methods are expected to be developed, validated and widely used in the not too distant future. These analyses should provide a better basis for the evaluation and design of piping components and piping systems.

The “validation” part of using elastic-plastic analyses may be the major impediment to confident use of such analyses. Probably additional, carefully planned and conducted testing will be needed for adequate validation.

Papers Authored or Co-Authored by E. C. Rodabaugh, Partial List as of January 1997

(1) A Stress Indices for ANSI B16.11 Socket-Welding Fittings, ONRL-TM-4929, August 1975;with S. E. Moore

(2) Review and Evaluation of Design Analysis Methods of Calculating Flexibility of Nozzles and Branch Connections, NUREG/CR-4785, December 1987; with S. E. Moore, K. Mokhtarian, R. C. Gwaltney

(3) Comparisons of ASME Code Fatigue Evaluation Methods for Nuclear Class 1 Piping with Class 2 or 3 Piping, NUREG/CR-3243, June 1983

(4) Preparation of Design Specifications and Design Reports for Pumps, Valves, Piping and Piping Supports Used in Safety-Related Portions of Nuclear Power Plants, NUREG/CR-4943, June 1987

(5) Comments on the Leak-Before-Break Concept for Nuclear Power Plant Piping Systems, NUREG/CR-4305, August 1985

(6) Stress Indices and Flexibility Factors for Concentric Reducers, ORNL-TM-3795, February 1975

(7) Stress Indices and Flexibility Factors for Nozzles in Pressure Vessels and Piping, with S. E. Moore, NUREG/CR-0778, June 1979

(8) Evaluation of the Plastic Characteristics of Piping Products in Relation to ASME Code Criteria, NUREG/CR-0261, July 1978

(9) Review of Elastic and Fatigue-to-Failure Data for Branch Connections and Tees in Relation to ASME Design Criteria for Nuclear Power Plant Piping Systems, with Moore, Gwaltney, NUREG/CR-5359, May 1994

(10) FLANGE: A Computer Program for the Analysis of Flanged Joints with Ring Type Gaskets, ORNL-5035, January 1976

(11) Stress Indices for Girth Welded Joints, Including Radial Weld Shrinkage, Mismatch and Tapered Wall Transitions, NUREG/CR-0371, September 1978

(12) Flanged Joints with Contact Outside the Bolt Circle－ASME Part B Design Rules, ORNLSub-2913, May 1976

(13) Relevance of Fatigue Tests to Cold Leg Piping, with Mayfield, Eiber, NUREG/CR-0325, September 1978

(14) Design and Strength of Welded Pipe Line Branch Connections, with H. H. George, Proc. ASCE, J. of Pipeline Div., PL-1, March 1957

(15) Simplified Second Stage Creep/Relaxation Analysis of Moderately Complex Spatially Three - Dimensional Piping Systems, with G. Workman, ASME Paper 74-PVP-27

(16) Stresses in Tapered Transition Joints in Pipelines and Pressure Vessels, with Atterbury, Trans. ASME, J. of Engr. for Industry (1962)

(17) Evaluation of the Bolting and Flanges of ANSI B16.5 Flanged Joints, ASME Part A Design Rules, with S. E. Moore, ORNL/Sub/2913-3, September 1976

(18) Performance of 6061-T6 Aluminum Flanged Pipe Assemblies Under Hydrostatic Pressure, with George, Holt, ASME Paper 56-PET-19

(19) Functional Capability of Piping Systems, with Terao, NUREG-1367, November 1992

(20) Interpretation with Respect to Code Case N-318 of Limit Moments and Fatigue Test of Lugs Welded to Pipe, Report to Texas Utilities, Comanche Peak 8/9/89

(21) Review of ASME Code Cases N-122 and N-318, Lugs on Straight Pipe, August 1990, PVRC Grant 90-8, Transmitted to S. E. Moore, 10/2/90 Letter

(22) Stress Indices for Elbows and Branch Connections Used in General Electric Company Advance Boiling Water Reactor Piping, March 1988

(23) Stresses in Out-of-Round Pipe Due to Internal Pressure, ORNL-TM-3244, January 1971

(24) Fragility Tests of Welded Attachments as Compared to ASME Code Case N-318 (U), Rawls, Rodabaugh and Wais (WSRC-MS-90-359), ASME 1991 PVP-Vol. 214, pp.107-110

(25) Interpretation, with Respect to ASME Code Case N-318, of Limit Moment and Fatigue tests of Lugs Welded to Pipe, with Foster, Van Duyne, Budlong, Muffett Wais, G. Steck, 1990 ASME Pressure Vessels and Piping Conference; June 1990, Nashville

(26) Review of ASME Code Criteria for Control of Primary Loads on Nuclear Piping System Branch Connections and Recommendations for Additional Development Work, with Gwaltney, Moore, NUREG/CR-5358, ORNL/TM-11572, November 1993

(27) Tests of Pups Support “Bridging Effect” Pipe Line Industry, October 1959

(28) Rating Procedure for ANSI B16.5 Flanged Joints－Task Force Steel Ratings of ANSI B16.5, November 1971

(29) Effect on Internal Pressure on Flexibility and Stress-Intensification Factors of Curved Pipe or Welding Elbows,

with H. H. George, Trans. ASME, May 1957

(30) Functional Capability criteria for Essential Mark II Piping, General Electric (San Jose) NEDO-21985, September 1978

(31) The Internal Pressure Capacity of Butt Welding Elbows, with Duffy, Atterbury, Battelle to AGA, September 18, 1969

(32) Assessment of the Plastic Strength of Pressure Vessel Nozzles, ASME Paper 68-PVP-8, 1968, with R. L. Cloud

(33) Background of ANSI B16.5 Pressure-Temperature Ratings, API Preprint No. 54-72, May 1972

(34) Development of Pressure-Temperature Ratings for Flanged Joints, September 1977, Energy Technology Conference, Houston, 1977

(35) Thermal Expansion Evaluations of Low Temperature Piping Systems, with Ed Wais, Arkansas Nuclear One, SES-21, 12/17/92

(36) Recommended Seismic Design Criteria For HWR-NPR Piping, PVP Vol.2, ASME 1991, Slagis, Moore and Rodabaugh

(37) Design Guidelines and Procedure for Evaluation of Welded Attachments on ASME Class 1,2 or 3 Piping, with Chang, Adams, Paper Number F1 7/3, 8th Smirt Conference

(38) Evaluation of the Capacity of Welded Attachments to Elbows as Compared to the Methodology of ASME Code Case N-318, PVP-VOl. 237-2, Seismic Engineering－Volume 2, ASME 1992, Rawls, Wais, Rodabaugh

(39) End Effects on Elbows Subjected to Moment Loadings, with Iskander, Moore, ORNL/Sub-2913/7, March 1978

(40) Strain Concentration in an Elbow in a Piping System Under High Temperature Relaxations Conditions, with Workman, Proceedings, Second International Conference on Pressure Vessels and Piping, San Antonio, October 1973

(41) Simplified Second Stage Creep/Relaxation Analysis of Moderately Complex Spatially Three Dimensional Piping systems, with Workman Trans. ASME, J. of Pressure Vessel Technology, August 1974

(42) Report on Tests of Two 4-inch sch. 10 Elbow Assemblies, with Griffith, ORNL-Sub-3651-2, December 1,1974

(43) Development of Stress Intensification Factors, with Minichiello, PVP Conference, 1995

(44) Pressure Capacity of MXX SP-75 Fittings, with Eiber January 1995, Battelle Report to AGA

(45) Comparisons of Test Data with Code Methods for Fatigue Evaluation, with Moore, ORNL-TM-3520, Phase Report No. 115-10, November 1971

(46) Evaluations of Inelastic Strain Concentrations Within Simple Piping Systems, with Workman; Rockwell Corp., ESG-DOE-13327, August 29, 1980

(47) Evaluation of Branch Connections with r/R less than 0.5 Subjected to Through-Rum Moments, with Wais, PVP Vol. 338, 1996

(48) Flexibility of Branch Connections and B31.3 Allowable Stresses, with Wais, PVP Vol. 338, 1996