cased in a thick wood-lath covering which remained in place throughout installation, Fig. 30. This lagging was not removed until the assembly was insulated.

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DISCUSSION

Harry S. Blumberg[2]

The authors are to be complimented on a well-written paper, which summarizes a wealth of experimental data. Together with a preceding paper on this subject (Reference [1] in their bibliography), there is disclosed the background of the problem and the results to date of five years of an extensive, continuous metallurgical investigation by the piping fabricator in an effort to fill certain gaps in knowledge. Such background is required for the sound, practical selection of materials, their properties, and their satisfactory behavior in service, which culminates in the recognition of important requirements for specifications. The data presented extend knowledge in this field to a considerable degree. The paper furnishes much added assurance regarding the original selection four years ago of the Type-316 composition for main steam piping at Eddystone No. 1 Unit. Further, it will provide a deeper technical basis for materials selection for newly contemplated units than was available when the Eddystone Unit was first engineered. The Utilities Industry will welcome the publication and application of these findings.

These authors have summarized their findings excellently. A full treatment of the subject would require textbook handling, with descriptions of details of test techniques, their general significance, and specific interpretation as related to Eddystone No. 1 Unit. Such treatment, although of value to some, would have been too detailed for engineering application. Accordingly the summary method employed by the authors is well suited for the needs of utility engineers. The conclusions drawn are direct and it is reassuring to learn that the program results show that after long exposure at the accelerating test temperature of 1300 F, Type-316 base metal joints welded with 16-8-2 electrode possess satisfactory high temperature strength, ductility, hardness, and stability, as well as metallurgical structure.

The direct comments which I offer are as follows:

1 The authors did not report on the surface condition of the test pieces exposed for 1000 and 10,000 hours at 1300 F, which is considered equivalent to a time acceleration factor of about 15 times beyond that at 1200 F. There are still those in the metallurgical engineering field who are concerned with the possibility of surface deterioration in the form of "catastrophic oxidation" of molybdenum bearing austenitic stainless steels. The authors are in a position to state the results of their findings and thus add to experience.

2 The rupture test data reported are an important contribution. Information is given for 1000-hour-aged specimens. These data and those for specimens aged 10,000 hours at 1300 F (considered equivalent to about 150,000 hours at 1200 F) are of value in assessing the high temperature strength of the welded joints in the program. This information will furnish added bases for the Subcommittee on Allowable Stresses.

3 It would be interesting if the authors would advise what part of their program is still to be completed and whether these findings will soon be available.

4 The paper emphasizes the many planned precautions which were exercised during three of the four main phases of "The Useful Cycle of Steam Piping Materials," which this discusser summarized in Table 1, Reference [1] of the bibliography. These three phases are steel manufacture, conversion to piping, and fabrication. The eleven summary points in the Caughey-Benz paper crystallize the care taken in materials procurement and show the extensive quality controls utilized, which extend considerably beyond the requirements of conventional ASTM Specifications. These procedures have undoubtedly played an important part in the procurement of material which has behaved so satisfactorily in fabrication, as reported. The procedures described will undoubtedly be used in the future in specifications for materials to be used in high temperature high pressure units.

5 The practical value of the paper is enhanced by the description of the fabrication procedure.

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A. B. Wilder[3]

The authors have emphasized the importance of the proper selection of material and their fabrication for high pressure steam service. In selecting AISI Type-316 austenitic stainless steel they have chosen material which has been used for a number of years both in chemical processing and petroleum refining industries. Comments by the authors regarding the following items will be appreciated.

1 What metallurgical factors were responsible for the superior properties of 16-8-2 weld metal in comparison with AISI Types-316 and 347 weld metal?

2 What effect has grain size of AISI Type-316 steel in the cast and forged conditions on the results obtained with the RPI hot ductility test?

3 The completed welds were treated at 1950 F. What is the nature and significance of the transition zone in the piping material due to this localized heat-treatment?

Authors' Closure

The authors appreciate very much the comments of both Mr. H. S. Blumberg and Mr. A. B. Wilder and the opportunity to reply to the interesting and significant questions which they have posed.

On the question of the resulting surface condition of the specimens which were subjected to 1000 and 10,000 hours at 1300 F in the air atmosphere of the laboratory furnaces, no evidence of excessive or "catastrophic oxidation" was observed. The thickness of the scale formation was not specifically measured. It was a uniform, tightly adherent scale. It was noted not to be abnormally heavy in any case.

Still to be reported are the results of the stress rupture tests on those specimens of Type 347 and 316 which previously were subjected to the 10,000-hour aging treatment. These will be made available as soon as they are completed. In addition to this, it should be noted here that the test program is being continued to include similar tests on three additional alloy steel compositions, namely: Babcock & Wilcox 15-15N, Armco 17-14 Cu/Mo, and Jessop Gl8B. It may be expected that this work will be made the subject of an additional paper.

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It is believed that the metallurgical factor responsible for the superior properties of the 16-8-2 weld metal, compared with the Type 316 and Type 347, is its chemical-physical stability when subjected to long-time aging at elevated temperature both with and without stress. The higher ductility values of the 16-8-2 and the lack of evidence for any marked embrittlement are the significant features of this material.

The separate effect of grain size in the RPI hot ductility experiments which compared the as-cast and forged properties of the Type-316 composition was not made a part of this investigation. Although it would be possible to distinguish the as-cast from the forged material on the basis of grain size comparing only ASTM numbers, the forged material being slightly finer, it is doubtful that this effect alone was responsible for the improved ductility observed. It is certain that the additional and proved effects of hot forging or the improvement in the chemical and physical homogeneity of the metal were equally important.

On the question of the nature and significance of the transition zone in the austenitic stainless steel weld joint due to the localized induction heat-treatment at 1950 F, it should be emphasized that this practice is used only where it is not possible, due to available shop furnace size, to heat-treat the welded pipe assembly as a unit and in the field on field-made butt welds.

A study was not made to determine the exact nature or physical structure existing in the transition zone of the Type-316 fabricated pipe assemblies represented in this program. Past experience, however, on Type-347 piping similarly heat-treated has shown it to be made up of the austenite matrix in which carbide precipitation in varying degrees and form has taken place. At the low temperature end of this zone, the typical "dot-like" intergranular carbides are evident, at the upper temperature levels certain coalescence of the carbides may be seen.

This has been a practice of long standing or since about 1953 on Type-347 piping. Accordingly, there are many weld joints which have been in continuous service at temperatures of 1050 and 1100 F which have been heat-treated in this manner in addition to those which were subjected to a complete furnace heat-treatment in the shop. No difficulty has been experienced in service from any of the welded joints heat-treated in either manner. It does not appear, therefore, that the transition zone resulting in the pipe from the localized heat-treatment has had any significant effect on the critical properties of the material in this particular service.