

A COMPARISON OF THE PROPERTIES OF BASIC OXYGEN AND OPEN HEARTH STEELS

INTRODUCTION

The Advisory Committee of ASTM Committee A-1 on Steel has given consideration to the question of approving the basic oxygen steelmaking process for inclusion in ASTM specifications. Since resistance to the approval of this process is based on test data insufficient to support producer claims that the product is at least equivalent to open hearth steel, a special task group was authorized to conduct an investigation and cooperative testing program intended to provide such additional information. The special task group consisted of C. L. Kent, chairman, H. E. Berger, J. E. Carney, G. T. Jones, J. R. LeCron, T. B. Linn, E. E. Powell, and L. H. Wilson. The laboratories which performed tests and contributed data for this project were American Oil Co., Armco Steel Corp., Babcock & Wilcox Co., Bethlehem Steel Co., General American Transportation, Jones & Laughlin Steel Corp., Kaiser Steel Corp., Republic Steel Corp., Sharon Steel Corp., and U.S. Steel Corp. The data were assembled into this report and edited for publication by R. L. Clark, ASTM Staff.

The importance of this project and the attendant special efforts to encourage prompt action by A-1 subcommittees for approval of the basic oxygen steel making process through revised specifications cannot be over-emphasized. Since this process was first intro-

duced in 1954, its growth rate has been phenomenal. The records for 1962 show production of 5,552,697 tons of basic oxygen steel in the United States, covering a broad range of steel mill products. All of this tonnage was produced in grades previously made by the open hearth process, and experience has clearly demonstrated the product quality to be fully equal to basic open hearth steel.

This trend and the importance accorded the basic oxygen process by its listing as an approved process in ASTM specifications is further indicated by the current annual ingot capacity and the further planned installation of this process by the steel industry. Ten such plants are now in operation on the North American continent with total ingot capacity of approximately 12 million tons annually. Twelve additional plants now under construction, or announced, will progressively raise this figure to approximately 15 million tons in 1963, 23 million tons in 1964, and 33 million tons in 1965. It seems certain that continuing expansion of basic oxygen steelmaking capacity will gradually displace a sizable proportion of the steel industry's older open hearth furnaces.

The term "basic oxygen steelmaking" is used generically to describe processes in which molten iron is refined into steel

under a basic slag in a cylindrical furnace lined with basic refractories, by directing a jet of high-purity gaseous oxygen onto the surface of the hot metal bath.

This report covers two phases of investigation comparing basic oxygen with open hearth steels. The first phase, Project A, comprised comparative evaluation of semikilled, ASTM Tentative Specification A 285,¹ grade C, firebox-quality steel produced in hot-rolled plates in thicknesses of $\frac{3}{16}$, $\frac{3}{4}$, $1\frac{1}{4}$, and 2 in. The second phase, Project C, comprised comparative evaluation of silicon-killed, fine-grain steel, ASTM Tentative Specification A 442,² grades 55 and 70, and ASME Case 1280³ flange-quality steel produced in hot-rolled plates of 1-in. thickness.

A continuation of this investigation is represented as Project B, covering comparative evaluation of silicon-killed coarse-grain steel, ASTM Tentative Specifications A 201⁴ and A 212,⁵ firebox-quality, grades 55 and 70. This latter project, which includes creep and rupture testing, is in progress and data will be presented in a separate ASTM publication when information becomes available.

All tests were taken with the longitudinal axis of the specimen parallel to the direction of rolling except when otherwise noted. When required (Project

C), tests were normalized at 1625 F for 1 hr and stress relieved at 1125 F for 1 hr. The tests included the following:

1. *Ladle and Check Analysis for Chemical Composition*.—Residual elements, including nitrogen. See Tables 1 and 9.

2. *Ferritic Grain Size*.—As rolled and normalized (ASTM A 442, Project C). See Table 9 and Figs. 6, 7, and 9.

3. *McQuaid-Ehn Grain Size*.—ASTM A 442, Project C. See Table 9 and Fig. 8.

4. *Photomicrographs*.—As rolled, normalized, and carburized (ASTM A 442, Project C). See Figs. 6 to 9.

5. *Bend*.—See Tables 1 to 4 and 9.

6. *Homogeneity*.—See Tables 1 to 4 and 9, and Figs. 2 and 5.

7. *Tension*.—Longitudinal and transverse tests in as-rolled and normalized conditions. See Tables 1 to 5 and 9 and 10.

8. *Impact*.—Charpy V-Notch (full-size specimen), longitudinal and transverse in as-rolled conditions for Project A, ASTM A 285, and in as-rolled and normalized conditions for Project C, ASTM A 442. Transition temperatures from ductile to brittle fracture were determined. See Tables 1 to 4 and 9 and 10, and Figs. 1, 3, and 4.

9. *Weldability*.—ASME Procedure Qualification Tests,⁶ basic oxygen only. As far as is practicable, each test heat was rolled into one or more additional plate thicknesses within the range of involved specifications for additional weldability tests. See Tables 8 and 13.

10. *Elevated-Temperature Short-Time Tension*.—In as-rolled condition for Project A, ASTM A 285, and as-rolled and normalized conditions for Project C. Run at ambient to 1000 F in 100 F steps. Yield strength was determined at 0.2 per cent offset. Tests were conducted at strain rates in accordance with ASTM

¹ Tentative Specification for Low and Intermediate Tensile Strength Carbon-Steel Plates of Flange and Firebox Qualities (Plates 2 In. and Under in Thickness) (A 285), 1961 Book of ASTM Standards, Part 1.

² Tentative Specification for Carbon-Steel Plates with Improved Transition Properties (A 442), 1961 Book of ASTM Standards, Part 1.

³ Case 1280, Interpretations of the ASME Boiler Code, Am. Soc. Mechanical Engrs.

⁴ Tentative Specification for Carbon-Silicon Steel Plates of Intermediate Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels (A 201), 1961 Book of ASTM Standards, Part 1.

⁵ Tentative Specification for High Tensile Strength Carbon-Silicon Steel Plates for Boilers and Other Pressure Vessels (A 212), 1961 Book of ASTM Standards, Part 1.

⁶ ASME Boiler and Pressure Vessel Code, Section IX, Am. Soc. Mechanical Engrs., 1959.

Tentative Recommended Practice E 21.⁷ See Tables 6 and 11.

11. *Strain Aging*.—Effect of strain aging (10 per cent plastic strain, followed by aging at 450 F for 2 hr) on tensile and room-temperature impact properties. See Tables 7 and 12.

The data presented under this study, identified as Projects A and C, show

⁷ Tentative Recommended Practice for Short-Time Elevated-Temperature Tension Tests of Materials (E 21), 1961 *Book of ASTM Standards*, Part 3.

mechanical properties and response to welding for the two steelmaking processes, basic oxygen and open hearth, to be closely comparable. The opinion of the task group was, therefore, that, within the limits defined for the basic oxygen process, similarity between steels made by the open hearth and basic oxygen processes has been established.

Refer to Contents listing (p. iii) for compilation of data presented in this paper.