# Welding a Cast Silicon Hardened Stainless Maraging Steel

*Procedures based on GMAW and SMAW with matching composition filler metals produced 100% joint efficiencies in the IN-833 alloys*

**BY E. P. SADOWSKI**

ABSTRACT. Consumables for a new cast stainless maraging steel, IN-833, were developed. Both the bare and covered electrodes are also useful for welding alloy CA6NM.

Simulated major casting defects were repaired successfully and butt joints up to one inch thick were made with the GMAW and SMAW processes. Weldment tensile properties in the range of 110 to 160 ksi (824-1104 MPa) were obtained with post-weld heat treatment. This high tensile strength was accompanied by high toughness. The weldments had tensile and impact properties equal to or better than the unwelded base metal.

The IN-833 weldments had rust resistance equal to CA-15.

## Introduction

A maraging cast stainless steel, IN-833, has been developed which combines strength, toughness and corrosion resistance with good founding characteristics (Ref. 1). The alloy has a nominal composition of 7%Ni, 11.5%Cr, 0.75%Si, balance essentially Fe, and is hardened by a simple solution anneal of 1900 F (1038 C), 1 h, air cool and an aging treatment of 850 F (454 C) for 3 h. The microstructure after this treatment is a typical maraging steel massive martensite (Ref. 2). When fully hardened, IN-833 is designed for 135 ksi (931 MPa) yield strength and 145 ksi (1000 MPa) tensile strength. However, by aging at various temperatures above 850 F (454 C), good combinations of properties can be obtained over a range of tensile strength.

The purpose of the work reported here was to develop gas metal-arc and shielded metal-arc process capability for repair of major casting defects and to make sound weldments for structural purposes in section sizes up to 1 in. thick. The target was for the weldments to have strength and toughness approximately equal to those of the base metal, and corrosion resistance equivalent to that of alloy CA-15 (13%Cr).

After this objective was met, the new IN-833 filler metals were also used to examine their suitability for welding alloy CA6NM (13%Cr, 4%Ni).

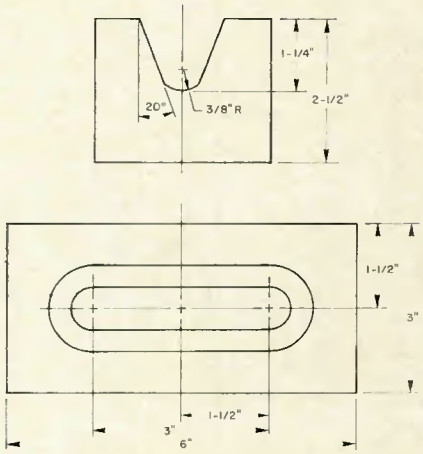


*Fig. 1 — Specimen design for cast repair specimens from keel block legs*

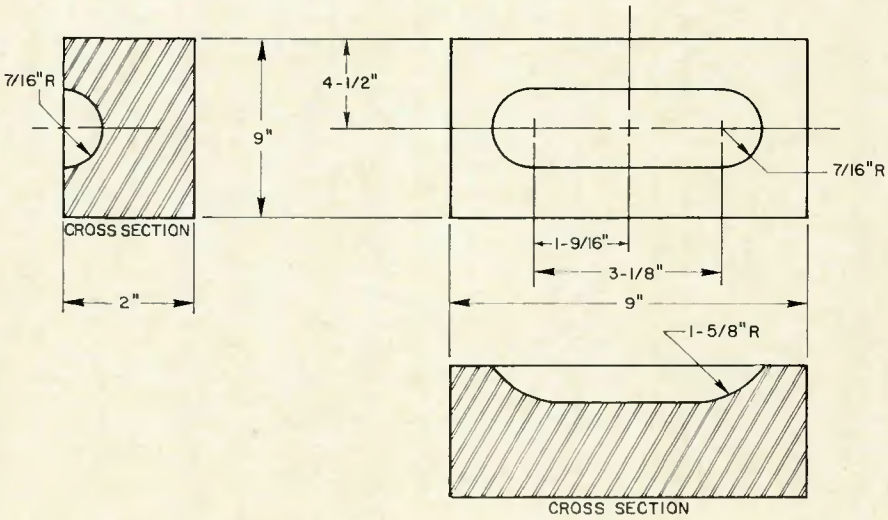


*Fig. 2 — Crack sensitivity test weld specimen Heat 6*

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**Table 1 — Base Metals**

| Code | Type | Melt size lb | Source | Section size, in. | C | Si | Mn | Ni | Cr | Mo | Al | Ti | S | P | Ca |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | IN-833 | 33 | PDMRL | 2-1/2×3×6 [a] | .037 | .43 | — | 6.6 | 13.1 | — | .030 | .045 | .008 | .005 | — |
| 2 | IN-833 | 33 | PDMRL | 2-1/2×3×6 [a] | .019 | .67 | — | 6.8 | 12.1 | — | .050 | .070 | .016 | .003 | — |
| 3 | IN-833 | 33 | PDMRL | 2-1/2×3×6 [a] | .019 | .60 | — | 6.8 | 11.9 | — | .047 | .070 | .016 | .003 | — |
| 4 | IN-833 | 100 | PDMRL | 4×4-1/2×6 [a] | .023 | .71 | .07 | 6.8 | 12.5 | — | .040 | .068 | .005 | .010 | .034 |
| 5 | IN-833 | — | A [d] | 3/4×5×12 [b] | .021 | 1.12 | .002 | 7.4 | 11.9 | — | .070 | .080 | .012 | <.01 | — |
| 6 | IN-833 | — | B [d] | 4×8×1-1-1/2 [a] | .018 | .72 | .08 | 7.1 | 10.9 | — | .10 | .08 | .015 | .009 | — |
| | | | | 2×9×9 [c] | .018 | .72 | .08 | 7.1 | 10.9 | — | .10 | .08 | .015 | .009 | — |
| 7 | CA6NM | 100 | PDMRL | 4×4-1/2×6 [a] | .020 | .50 | .51 | 4.0 | 13.2 | .69 | — | — | .012 | .020 | .006 |
| 8 | CA6NM | 100 | PDMRL | 4×4-1/2×6 [a] | .030 | .49 | .49 | 3.8 | 14.0 | .69 | — | — | .005 | .019 | .031 |
| 9 | CA-15 | 100 | PDMRL | 4×4-1/2×6 [a] | .13 | .70 | .81 | <.10 | 13.2 | — | — | — | .015 | .039 | — |

(a) Keel block leg (c) Plate
(b) Beveled weld plates (d) A, B — Commercial foundries

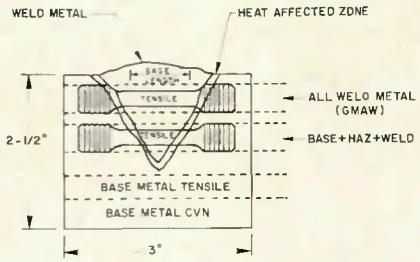


*Fig. 3 — Specimen location in cast repair tests; also used for hardness traverses. About 1/3 actual size*

## Experimental Procedure

### Materials

The compositions, melt size, source and section sizes of the castings investigated are given in Table I, Codes 1-9. Casting sizes varied from 3/4 × 5 × 12 in. weld plate (19 × 127 × 30 mm) to 2 × 9 × 9 in. plate (51 × 219 × 219 mm).

The compositions of the filler metals, electrode core wires and weld deposits obtained from the covered electrodes are given in Table 2. Matching composition filler metal was used for the GMAW process. The same composition was also used for electrode core wire and covered with a lime-titania flux for the SMAW process. The filler metals, Codes 10-13, were obtained from 33 pound vacuum induction melted heats.

### Welding

Weldability was established by the repair of simulated major casting defects and by the welding of butt joints. The depth of the defects were in the range of 22 to 50% of the thickness of the castings (Figs. 1 and 2). A minimum of 20% is required to qualify as a major casting defect (Ref. 3). Different specimen designs were used to change the degree of restraint.

Preheating was not necessary except for the CA-15 weldments which were preheated at 400 F (204 C) (Ref. 4).

The heat treated conditions of the castings prior to welding are given in Tables 5 through 8.

### Examination

All castings were radiographed before welding. After welding, the weldments were radiographed, cut into slices, polished, etched, and examined for defects at a magnification of 30 times.

Side bend tests were made over a 1-1/4 in. (32 mm) diam mandrel on 1/8 in. thick slices of the 1 in. thick joints.

### Testing

Measurements were made of hardness, tensile properties, Charpy V-notch impact and corrosion resistance. The specific tests run on each weldment are given in Table 3.

The hardness measurements were obtained in 1/4 in. (6 mm) intervals traversing the base metal, heat-affected zone and weld. An average of 36 base metal readings, 18-26 readings in the heat-affected zone and 12-14 readings in the weld were obtained on the cross sections of the large cast repair specimens (Fig. 3).

Tensile specimens were obtained from transverse slices of the cast repair weldments (Fig. 3) from both transverse and all-weld-metal sections of butt joints (Fig. 4) and from the unwelded base metal. The specimens from the cast repair weldments which were machined from the upper portion of the weldment had a reduced section consisting of all-weld-metal and a threaded section which was base metal. The specimens obtained from the lower portion of the cast repair weldments and the butt joints had a reduced section which contained base metal, heat-affected zone and weld metal. All-weld-metal specimens were also obtained in the longitudinal direction from the 1 in. thick weldment made by the SMAW process.

The Charpy V-notch impact specimens were obtained from unwelded base metal and from butt joints in which the notch was in the plane perpendicular to the welding direction and through the thickness of the weld metal.

Atmospheric corrosion tests were made on the IN-833 and CA-15 weldments (Fig. 5). The reinforcements were removed by machining prior to exposure. The samples were exposed for one year at the 800-foot lot of The International Nickel Company's Francis L. LaQue Corrosion Laboratory at Kure Beach, North Carolina.

### Postweld Heat Treatments

The postweld heat treatments used are listed with properties in the appropriate tables.

## Results and Discussion

The results are discussed in two parts. The first section discusses the welding of IN-833 with the welding products developed for the alloy, and the second discusses the welding of CA6NM with IN-833 welding products.

### Welding of IN-833

*Soundness.* All IN-833 weldments welded with matching filler metal and the covered electrode were sound. Six to 24 faces were examined in each weldment. Some minor porosity was observed radiographically, but the

**Table 2 — Filler Metal, Core Wire and Deposits**

| Code | Type | C | Si | Mn | Ni | Cr | Al | Ti | S | P |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Bare wire | .021 | .78 | .05 | 7.6 | 11.5 | .04 | .09 | .008 | <.002 |
| 11 | Bare wire | .024 | .74 | <.10 | 7.6 | 11.8 | .05 | .06 | .005 | .002 |
| 12 | Core wire | .043 | .79 | .04 | 7.5 | 11.1 | .07 | .07 | .005 | .003 |
| 13 | Bare and core | .008 | .70 | .07 | 7.1 | 11.3 | <.02 | <.02 | .005 | .002 |
| 14 | Weld deposit from Code 12 core [a] | .040 | .32 | .71 | 7.4 | 12.4 | <.005 | <.005 | .006 | .017 |
| 15 | Weld metal, Code G | .018 | .38 | .62 | 7.4 | 11.6 | .01 | .02 | .006 | .012 |

(a) Undiluted weld metal composition

**Table 3 — Weldments and Applicable Tests**

| Weld code | Base metal type | Base metal code | Filler metal code | Process | Type weld | Tests |
|---|---|---|---|---|---|---|
| A | IN-833 | 2 | 10 | GMAW | Repair (Fig. 1) | a, b, i |
| B | IN-833 | 3 | 10 | GMAW | Repair (Fig. 1) | a, b, c, l |
| C | IN-833 | 1 | 10 | GMAW | Repair (Fig. 1) | a, b, c, i |
| D | IN-833 | 6 | 12 | GMAW | Repair (Fig. 2) | a |
| E | IN-833 | 5 | 10 | GMAW | 3/4 in. butt joint | a, b, d |
| F | IN-833 | 6 | 11 | SMAW | 5/8 in. butt joint | a, b, d, h, i |
| G | IN-833 | 6 | 13 | SMAW | 1 in. butt joint | a, b, c, d, f, h |
| H | CA6NM | 8 | 13 | GMAW | 1 in. butt joint | a, b, d, e, i |
| I | CA6NM | 8 | 13 | SMAW | 1 in. butt joint | a, b, d, e, i |
| J | — | — | 11 | SMAW | Weld Pad | f |
| K | IN-833 | 6 | 12 | GMAW | Repair (Fig. 5) | g |
| L | IN-833 | 6 | 12 | GMAW | Repair (Fig. 5) | g |
| M | IN-833 | 6 | 13 | SMAW | Repair (Fig. 5) | g |
| N | IN-833 | 6 | 13 | SMAW | Repair (Fig. 5) | g |
| O | CA-15 | 9 | None | GTAW | Autogenous bead on plate | g |
| P | CA-15 | 9 | None | GTAW | Autogenous bead on plage | g |
| R | — | — | E-308-16 | SMAW | Weld Pad | h |

(a) Visual examination at 30X of prepared slices
(b) Transverse tensile properties
(c) All weld metal tensile properties
(d) Charpy V-notch impact strength
(e) Bend tests
(f) Composition
(g) Corrosion
(h) Operability
(i) Hardness traverse

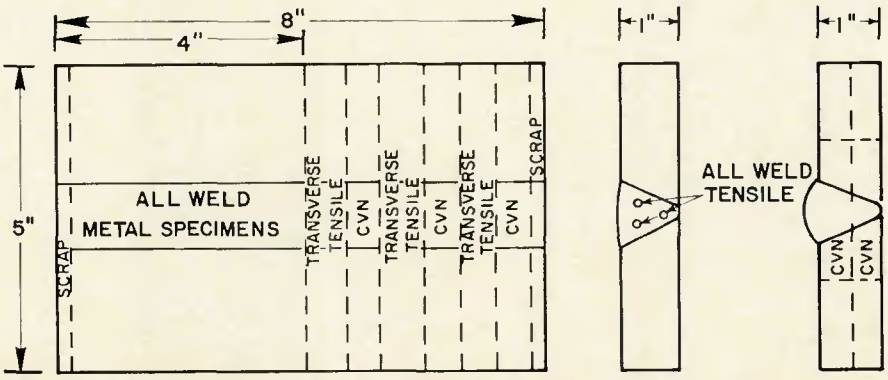


*Fig. 4 — Location of tensile and CVN impact specimens, 1 in. thick joints*

degree of porosity was within the allowable limits of Section VIII of the Unfired Pressure Vessel Code.

The prior condition of the castings (as-cast, fully hardened, or over-aged) did not affect the welding response.

*Operability.* The covered electrode operated satisfactorily. The welders rated the electrode in the downhand position for arc stability, melting rate, slag coverage, slag removal, slag fluidity, weld fluidity, bead appearance, and transfer. The operating characteristics were noted when making joints and also when preparing weld pads for chemical analysis. Qualitatively, the operability of the experimental covered electrode was rated slightly below the E308-16 electrode. However, sound joints were made without difficulty.

*Deposit Composition.* The compositions of the deposits obtained from two covered electrode welds are given under Codes 14 and 15 (Table 2). Both deposits had slightly lower silicon and higher manganese contents than the original core wire, Codes 12 and 13.

**Mechanical Properties**

*Hardness.* Hardness traverses were obtained on the IN-833 weldments coded A, B, C and F. The multipass welds (15 passes for SMAW and 24 passes for GMAW) had higher hardness than the base metal, Code 6, whether tested as-deposited on as-cast or heat treated base metal or heat treated after welding. The higher hardness of the weld metal in these multipass welds was probably due to aging during the welding operation.

A difference in hardness within the heat-affected zone was observed on as-welded material when welded in the overaged condition, 1h 1900 F (1038 C) plus 4h 1100 F (593 C) Weld C. The average hardness adjacent to the weld metal was 4 Rockwell C points harder than the area near the unaffected base metal. The hard layer etched differently than the remainder of the heat-affected zone and was probably age hardened martensite formed and aged during the welding operation. This phenomenon was not observed with the other preweld treatment, 1h, 1900 F (1038 C) plus 3h, 850 F (454 C) Weld A, or with any post-weld heat treatment including over-aging, Weld B.

*Base Metal Tensile and Impact Properties.* The unwelded base metal properties are given in Table 4. All heats had the desired 145 ksi (1000 MPa) minimum tensile strength when aged for 3 h at 850 F (454 C). Charpy V-notch impact energy varied with this aging treatment from 26 to 45 ft-lb. When aged at 1000 or 1100 F (538 or 593 C), a good combination of strength and toughness was also obtained. Tensile strength varied be-

tween 122 and 142 ksi (842 to 980 MPa) and toughness was in the range of 23 to 60 ft-lb (31 to 81 J).

*Weldment Tensile and Impact Properties.* Transverse tensile and all-weld-metal properties were obtained from repaired castings and butt joints (Tables 5, 6 and 7). The results are discussed separately below.

*Transverse Tensile Properties of Cast Repair Weldments — GMAW Process.* The results are given in Table 5. These specimens were machined from the lower portion of the weldment (Fig. 3). Specimens from weldments A and C were tested in the as-welded condition, with the base metal heat treated before welding. Code B was welded in the as-cast condition and specimens were tested as-welded and with a post-weld heat treatment. All specimens failed in the base metal with 100% tensile strength efficiency.

*Transverse Properties of Butt Joints — GMAW and SMAW Processes.* Excellent tensile and impact properties were obtained with all aging temperatures tried on a 3/4 in. (19 mm) butt joint (Code E, GMAW process) and on 5/8 in. (16 mm) (Code F) and 1 in. (25 mm) (Code G) thick butt joints made with the SMAW process. With one exception, all tensile failures occurred in the base metal (Table 6).

Joint efficiencies were 97-100% with the 3 h at 850 F (454 C) age, and tensile strength was higher than the 145 ksi (1000 MPa) target. The high tensile efficiencies were obtained in conjunction with high toughness, 49 ft-lb (66 J) for the GMAW process weldment and 30 to 34 ft-lb (41 to 45 J) for the SMAW weldments.

Some low values of ductility were obtained on one weldment, Code G, when aged at 1000 and 1100 F (538 and 593 C); however, these were attributed to failure location and specimen design rather than inherent poor ductility.

*All-Weld-Metal Properties.* Tensile properties were obtained on all-weld-metal specimens taken from the 1 in. butt joints (SMAW) process) after aging at 850, 1000 and 1100 F (454, 538 and 593 C) and on as-deposited specimens obtained from three GMAW casting repair weldments (Table 7).

The latter specimens were machined from the upper portion of the casting repair weldments (Fig. 3) and consisted of weld metal in the reduced section and base metal in the threaded area.

Tensile strength of the SMAW process weld metal ranged from 127 to 159 ksi (876 to 1097 MPa), depending upon the aging treatment used. Charpy V-notch impact energy varied inversely with tensile strength and ranged from 35 to 71 ft-lb (47 to 96 J).

The as-deposited tensile properties obtained from the GMAW process weld metal taken from three different casting repair weldments were consistently high, 151 to 152 ksi (1041 to 1048 MPa). Charpy V-notch impact energy was not determined on these three weldments.

*Rust Resistance.* The results obtained after one year's exposure at Kure Beach, North Carolina are given in Table 8. The face of the corrosion panel exposed skyward consisted of both weld and base metal (Fig. 5). The

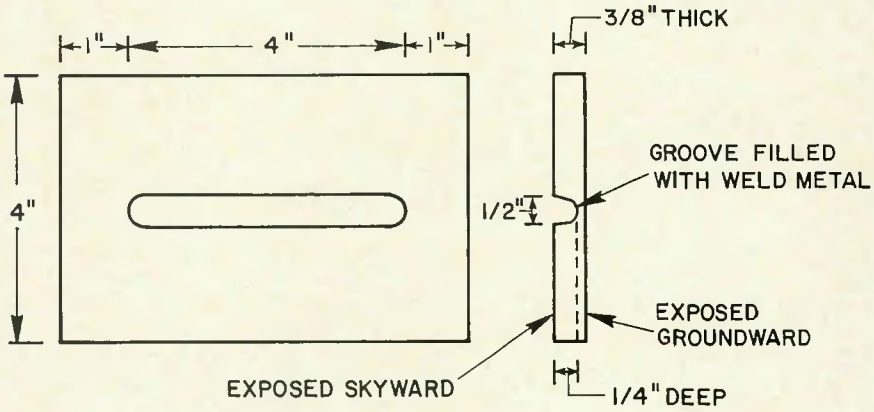


*Fig. 5 — Corrosion specimen*

**Table 4 — Base Metal Properties**

| Code | Aging[a] temp. F | 0.2% YS, ksi | UTS, ksi | % elong. 1 in. | % RA | Charpy V-Notch ft-lb | Charpy V-Notch lat. exp. mils |
|---|---|---|---|---|---|---|---|
| | | | IN-833 | | | | |
| 3 | (b) | 126 | 141 | 2 | 6 | — | — |
| 2 | 850 | 138 | 145 | 11 | 29 | 45 | — |
| 3 | 850 | 135 | 146 | 13 | 53 | — | — |
| 4 | 850 | 145 | 157 | 16 | 56 | 37 | 22 |
| 5 | 850 | 144 | 159 | 11 | 53 | 26 | — |
| 6 | 850 | 138 | 155 | 13 | 51 | 30 | — |
| 5 | 1000 | 135 | 142 | 10 | 30 | 23 | — |
| 6 | 1000 | 122 | 129 | 18 | 61 | 45 | — |
| 1 | 1100 | 80 | 122 | 19 | 54 | 55 | — |
| 4 | 1100 | 77 | 127 | 17 | 64 | 53 | 41 |
| 5 | 1100 | 82 | 125 | 16 | 38 | 41 | — |
| 6 | 1100 | 102 | 122 | 19 | 59 | 60 | — |
| | | | CA6NM | | | | |
| 8 | 700[c] | 132 | 166 | 11 | 32 | 33 | 19 |
| 8 | 1100[c] | 95 | 117 | 24 | 68 | 75 | 62 |

(a) 1 h, 1900 F, air cool, then aged 3 h as shown
(b) As cast
(c) 1 h, 1825 F, air cool, then tempered 2 h as shown

**Table 5 — Tensile Properties of Transverse Weldments from Repaired Castings — GMAW Process[a]**

| Weld code | Preweld base plate cond. | Postweld condition | UTS ksi | % RA |
|---|---|---|---|---|
| B | As cast | As welded | 143 | 8 |
| A | 1 h/1900 F + 3 h/850 F | As welded | 145 | 31 |
| C | 1 h/1900 F + 3 h /1100 F | As welded | 135 | 47 |
| B | As cast | 1 h/1900 F + 3 h/850 F | 159 | 38 |
| B | As cast | 1 h/1900 F + 3 h/850 F | 155 | 52 |

(a) Joint efficiency (tensile) for all joints was 100%; all failures were in the casting.

**Table 6 — Tensile Properties and Impact Resistance of Butt Joints**

| Weld Code | Process | Base metal | Thickness, in. | Temper or age[a] | Arbitrary 0.2% YS,[b] ksi | UTS, ksi | Elong. % | RA % | Failure location | Joint eff., % | CVN[c] ft-lb | CVN[c] Lat. exp., mils |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E | GMAW | IN-833 | 3/4 | 3 h/850 F | 147 | 162 | 19 | 65 | Weld | 100 | 49 | — |
| | | | | 3 h/1000 F | 141 | 145 | 14 | 57 | Casting | 100 | 53 | — |
| F | SMAW | IN-833 | 5/8 | 3 h/1100 F | 76 | 126 | 21 | 61 | Casting | 100 | 87 | — |
| | | | | 3 h/850 F | 139 | 160 | 15 | 51 | Casting | 100 | 30 | — |
| | | | | 3 h/1000 F | 129 | 137 | 18 | 60 | Casting | 100 | 40 | — |
| | | | | 3 h/1100 F | 97 | 126 | 16 | 59 | Casting | 100 | 69 | — |
| G | SMAW | IN-833 | 1 | 3 h/850 F | 143 | 150 | (d) 10 | 49 | Casting | 97 | 35 | — |
| | | | | 3 h/1000 F | 132 | 134 | (e) 2 | 15 | Casting | 100 | 48 | — |
| | | | | 3 h/1100 F | 108 | 111 | (d) 4 | 10 | Casting* | 90 | 71 | — |
| H | GMAW | CA6NM | 1 | 2 h/700 F | 141 | 157 | 15 | 68 | Weld | 94 | 77 | 47 |
| | | | | 2 h/1100 F | 90 | 121 | 24 | 76 | Weld | 100 | 127 | 83 |
| I | SMAW | CA6NM | 1 | 2 h/700 F | 138 | 163 | 14 | 56 | Weld | 97 | 33 | 18 |
| | | | | 2 h/1100 F | 107 | 125 | 8 | 61 | Casting | 100 | 73 | 53 |

*Defect
(a) Welded in as-cast condition — Postweld heat treatment
IN-833 Weldments — 1 h/1900 F, air cool, then age as shown
CA6NM Weldments — 1 h/1825 F, air cool, then temper as shown
(b) Valid for weld failures
(c) CVN notched through thickness of weld
(d) Broke outside middle half
(e) Broke outside gage length

groundward side was base metal only.

Allowing for a ±5% accuracy in measurement, the IN-833 weldments made with both the GMAW and SMAW processes, and in either heat treated condition, were equivalent to or approximately equivalent to CA-15 in rust resistance.

The weld metal of the GMAW process weldments was more rust resistant than the weld metal of the SMAW process weldment, with both aging treatments used.

A definite effect of aging treatment was observed on the base metal rust resistance (groundward side). The fully hardened IN-833 (Condition 2) was equal to or more rust resistant than CA-15 in both tests and not as rust resistant when overaged (Condition 3). The IN-833 had scattered incipient pitting and the CA-15 had broad shallow areas approximately 2 to 4 mils deep.

**Welding CA6NM with IN-833 Filler Metal**

This part of the investigation was based upon the results obtained on 1 in. (25 mm) thick weldments represented by Codes H and I.

*Soundness.* The weldments were sound when examined visually and underwent a 180 deg bend test successfully in both heat treated conditions.

*Hardness.* No unusual hardening or softening was observed in the heat-affected zone of any of the weldments.

*Mechanical Properties.* Tensile and CVN impact test results for the unwelded base plates are given in Table 4 and for the weldments in Table 6. The impact resistance of the weldments was either equal to or higher than the unwelded base metals in both heat treated conditions with 100% tensile joint efficiency at the lower tensile strength level (117 ksi, 807 MPa) and 94-97% joint efficiency at the higher tensile strength level (166 ksi, 945 MPa).

The IN-833 welding products, therefore, appear to be suitable for welding CA6NM.

## Summary and Conclusions

IN-833 can be welded by the GMAW and SMAW processes with a matching composition bare filler wire and a covered electrode consisting of a matching composition core wire plus a lime-titania flux. No preheating is required.

Simulated major casting defects ranging in size from 22 to 50% of the thickness of the casting were repaired without difficulty. These repairs were made on castings in the

**Table 7 — All Weld Metal Properties**

| Weld code | Process | Postweld heat treat | 0.2% YS, ksi | UTS ksi | % Elong. 1 In. | % RA | CVN (ft-lb) |
|---|---|---|---|---|---|---|---|
| B | GMAW | None [a] | 143 | 151 | 15 | 58 | — |
| A | GMAW | None [a] | 140 | 152 | 17 | 65 | — |
| C | GMAW | None [a] | 143 | 152 | 16 | 61 | — |
| G | SMAW | (b) | 137 | 159 | 18 | 64 | 35 |
| G | SMAW | (c) | 132 | 137 | 18 | 62 | 48 |
| G | SMAW | (d) | 104 | 127 | 22 | 67 | 71 |

(a) As deposited tensile properties obtained from 3 different weldments consisting of weld metal in gage length and base metal in threaded section (Fig. 3)
(b) 1 h, 1900 F, air cool, plus 3 h, 850 F, air cool
(c) 1 h, 1900 F, air cool, plus 3 h, 1000 F, air cool
(d) 1 h, 1900 F, air cool, plus 3 h, 1100 F, air cool

**Table 8 — Rust Resistance Compared to CA-15 [a]**

| Code | Process | Base metal | Condition [b] | % Covered, Skyward overall | Skyward weld | Groundward overall [c] |
|---|---|---|---|---|---|---|
| O | GTAW | CA-15 | 1 | 75 iR | 75 iR | 45 XR |
| P | GTAW | CA-15 | 1 | 75 iR | 75 iR | 50 XR |
| K | GMAW | IN-833 | 2 | 80 SR | 60 SR | 45 iR |
| L | GMAW | IN-833 | 3 | 80 R | 60 R | 65 XR |
| N | SMAW | IN-833 | 2 | 60 SR | 70 SR | 30 SR |
| M | SMAW | IN-833 | 3 | 80 R | 75 R | 90 XR |

(a) After 1 yr exposure in 800-foot lot at Kure Beach, N.C.
(b) Condition: (1) 2 h, 1850 F, air cool + 2 h, 1300 F, air cool before welding + 2 h, 1300 F, air cool after welding
(2) 1 h, 1900 F, air cool + 3 h, 850 F, air cool
(3) 1 h, 1900 F, air cool + 3 h, 1100 F, air cool
(c) Groundward side was all base metal.

Codes: R = Rust; SR = Slight Rust; iR = moderate rust; XR = Heavy Rust

as-cast, fully hardened and overaged conditions.

Sound butt joints were made up to 1 in. (25 mm) thick with tensile properties and impact resistance equal to or better than the unwelded castings. Useful properties can be obtained on IN-833 weldments at strength levels from 120 to 145 ksi (827 to 1000 MPa) tensile strength by varying the aging temperature. The IN-833 weldments had rust resistance equivalent to CA-15 based on one year atmospheric exposures at Kure Beach, North Carolina.

The welding products are also useful for welding alloy CA6NM.

*Acknowledgment*

The corrosion work was reported by K. L. Money of the Francis L. LaQue Corrosion Laboratory at Harbor Island, North Carolina.

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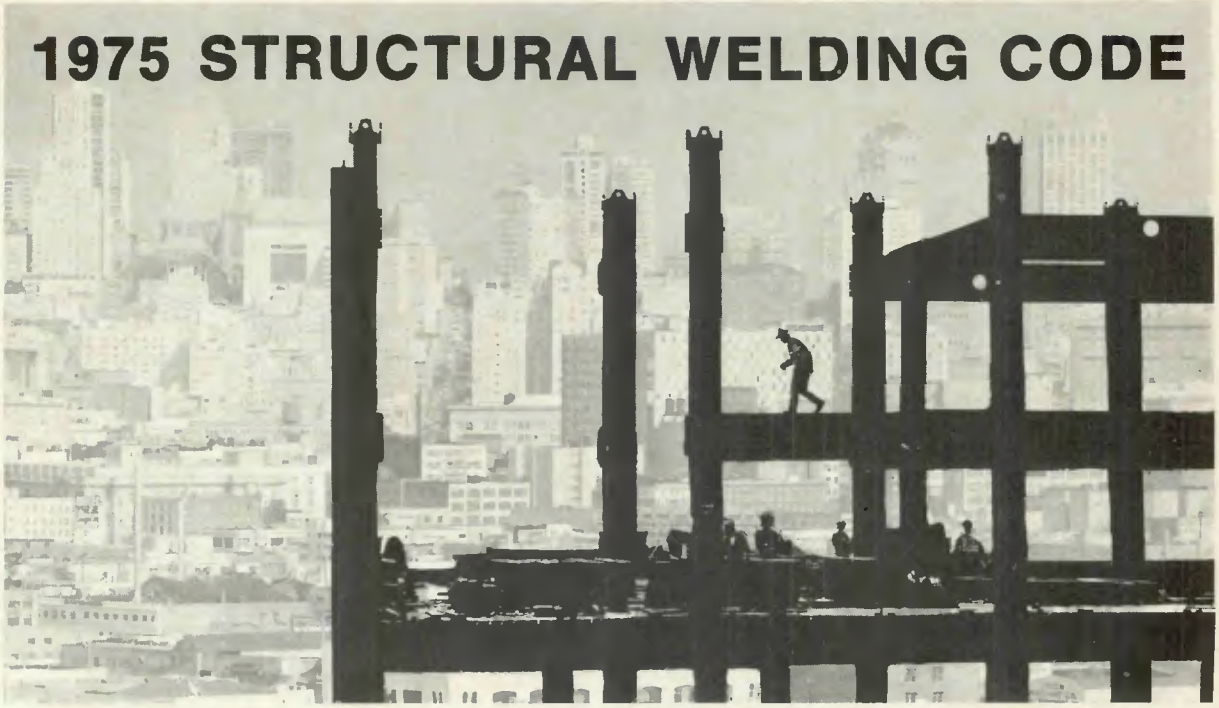
# 1975 STRUCTURAL WELDING CODE



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