Effects of Welding Flux Additions on 4340 Steel Weld Metal Composition

An investigation was undertaken to better understand the transfer mechanism of flux systems and to quantify their oxygen potential

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ABSTRACT. The effects of CaF_2, CaO and FeO additions on weld metal chemistry were evaluated for the manganese–silicate flux system. Comparisons were made between AISI 4340 steel and low-carbon steel welds to understand the weld metal chemistry. The results show that the elemental transfer from the slag to the weld metal and vice versa cannot be consistently explained using thermodynamic data; *e.g.*, the carbon/oxygen partition is apparently controlled by a CO reaction in the 1010 steel welds, but the AISI 1020 and 4340 steel welds show constant carbon contents despite increasing oxygen levels. In addition, data are reported as a resource for future analytical and comparative purposes.

Introduction

Submerged arc welding of high integrity can be achieved through proper selection of the wire and flux combination for the specific base metal and welding parameters. Small amounts of alloying elements such as nickel, chromium and molybdenum are added to steels to increase strength, hardness or toughness, as is the case with AISI 4340 steel. Generally, welding low-alloy steels requires more careful control of procedures and selection of consumables than welding the carbon steels. Moreover, the oxygen potential of the flux influences the loss or gain of alloying elements during welding, the weld-deposit oxygen content, and the type, size and distribution of oxide inclusions in the solidified weld metal.

The effective application of the submerged arc welding process for joining high-strength, low-alloy steels depends heavily upon understanding the behavior of the flux. Understanding the elemental transfer mechanisms between the flux and the weld metal can be attained by studying the influence of each chemical additive on the flux behavior.

To determine the many slag/weld metal chemical reactions occurring simultaneously during welding, a state of thermodynamic equilibrium has been assumed to be attained. The basis for this assumption is that the high temperatures and high surface-to-volume ratio associated with the welding process counteract the short time available for a reaction to be completed (Ref. 1).

Chai and Eagar (Ref. 2) reported that the very short times and the large thermal gradients involved in the process prevent overall slag-metal equilibrium from being reached. They also reported that an understanding of kinetics, in combination with the thermodynamic limits of the process, would be necessary to determine the final weld metal composition. Blander and Olson (Ref. 3) also discussed the influence of kinetics, the role of interfacial reaction, and the degree to which equilibrium is approached.

This paper is a part of the systematic investigation undertaken by the Colorado School of Mines (Refs. 3–7) to better understand the behavior of different flux additions to the manganese-silicate and lime-silicate flux systems. The influence of FeO, CaO and CaF_2 additions to a manganese-silicate flux on AISI 4340 steel weld metal chemistry is reported here. In addition, a comparison of the effects of CaF_2 and FeO additions to a manganese-silicate flux on welds on AISI 1020 and 4340 steels was made in an effort to understand the effect of alloying elements on weld metal chemistry. The results presented in this paper should be a useful database for future analytical modeling and comparisons.

KEY WORDS

Welding Flux Effects
Flux Additions
4340 Steel Weld Metal
Weld Composition
Submerged Arc Fluxes
1020 Steel Weld Metal
Ca_2/CaO/FeO Addition
Mn-Silicate Fluxes
SAW Flux Systems

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Materials and Procedure

Single pass, bead-on-plate welds were made using the submerged arc welding process on AISI 1010, 1020 and 4340 steel base plates. The dimensions of the plates were 73 × 203 × 13 mm (2.9 × 8 × 0.5 in.). The welding wires used were AWS Type E70S-3 for welds produced on AISI 1010 and 1020 steels, and Type EM12K for AISI 4340 steel welds. Compositions of the base plates and welding wires are given in Table 1.

The submerged arc welding process was performed using direct current, electrode positive. The welding parameters were maintained constant at 30 V, a travel speed of 8 mm/s (19 in./min), and the wire speed was varied to give 500 A. All welds were made with a heat input of 1.9 kJ/mm (48 kJ/in.).

Three different flux systems were used in this investigation: SiO_2-MnO-FeO, SiO_2-MnO-CaO and SiO_2-MnO-CaF_2. The fluxes were prepared using reagent grade chemical powders. The flux compositions were reported as wt-% MnO because MnO_2 decomposes to form MnO during the melting operation used to produce the fused flux. The iron ion in the fused flux was determined to be in the Fe^{++} state and is reported as wt-% FeO (Ref. 10).

The reagent-grade powders were weighed and mixed prior to induction melting. The powders were then placed in a graphite crucible for the melting operation. All fluxes were brought to 1773 K. The crucible was then removed from the furnace and the flux poured onto a stainless steel plate to solidify. After cooling, the fused fluxes were crushed and sized. Fluxes sized 14 to 100 mesh were used for

Table 1—Composition of Base Metals and Welding Wires (wt-%)

Elements	AISI 1010 Base Metal	AISI 1020 Base Metal	AISI 4340 Base Metal	E70S-3 Filler Wire	EM12K Filler Wire
C	0.10	0.23	0.41	0.08	0.31
Mn	0.9	0.54	0.65	1.16	0.55
Si	0.3	0.3	0.20	0.43	0.65
Mo	–	–	0.21	–	0.50
Cr	–	–	0.76	–	1.25
Ni	–	–	1.65	–	–
S	0.04 max	0.019	0.04	0.018	0.01
P	0.035 max	0.027	0.01	0.011	0.01
N	–	0.012	0.016	0.003	–
O	–	0.024	0.027	0.024	0.008
Fe	Balance	Balance	Balance	Balance	Balance

this experiment. The fluxes were then baked at 973 K in air atmosphere for two hours to remove any residual graphite picked up from the crucible and to ensure moisture removal.

Chemical analysis of the welds was made using Leco interstitial analyzers to determine weld metal carbon, oxygen and nitrogen contents. An emission spectrometer was used to determine weld metal manganese, silicon, chromium, nickel and molybdenum contents.

Results and Discussion

The effect of each flux system on weld metal composition was determined by first obtaining the composition of the weld metal analytically. The nominal composition of each weld was then calculated considering only the dilution effects of the filler wire and base metal composition. The difference between the analytical and nominal compositions, the delta quantity, indicates the contribution the flux makes to the weld metal composition. A positive delta quantity indicates element transfer from the flux to the weld metal. A negative delta quantity indicates element transfer from the weld metal to the slag. A zero value for a delta quantity indicates that the ion of interest in the flux has no thermodynamic desire and/or kinetic ability to react with the weld metal, since the slag and flux have the same specific ion composition.

The Effect of Flux Additions on AISI 4340 Steel Weld Metal

The effect of CaF_2, CaO and FeO additions to a manganese-silicate flux on AISI 4340 steel weld metal composition will be discussed first. Weld metal element content (wt-%) was plotted as a function of additions to the flux (wt-%) at the expense of MnO. The silica content of the flux was held constant at 40 wt-%.

The weld metal carbon content is seen in Fig. 1 to have an average value of about 0.32 wt-% for the different flux additions that were used. Weld metal carbon content appeared to be independent of a particular flux composition. Weld metal silicon content as a function of flux composition is reported in Fig. 2. The CaO flux addition showed in general a loss of silicon from the weld metal to the slag as indicated by the negative delta quantities in Fig. 3. Silicon was seen to be transferred from the flux to the weld metal with additions of CaF_2. The silicon transfer with FeO additions was found to have intermediate behavior, between that of CaO and CaF_2 additions.

The FeO flux additions produced the highest weld metal oxygen content, as seen in Fig. 4, while the CaF_2 additions produced the lowest weld metal oxygen content. The oxygen content in the weld metal increased with increasing FeO flux additions; this is expected since FeO is more unstable than MnO. The CaO addi-

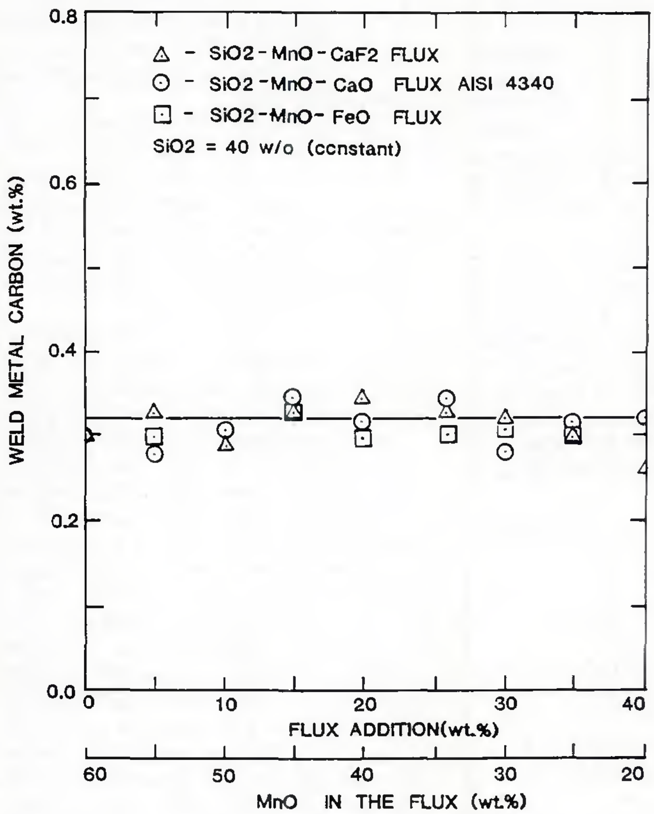

Fig. 1 — Weld metal carbon as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

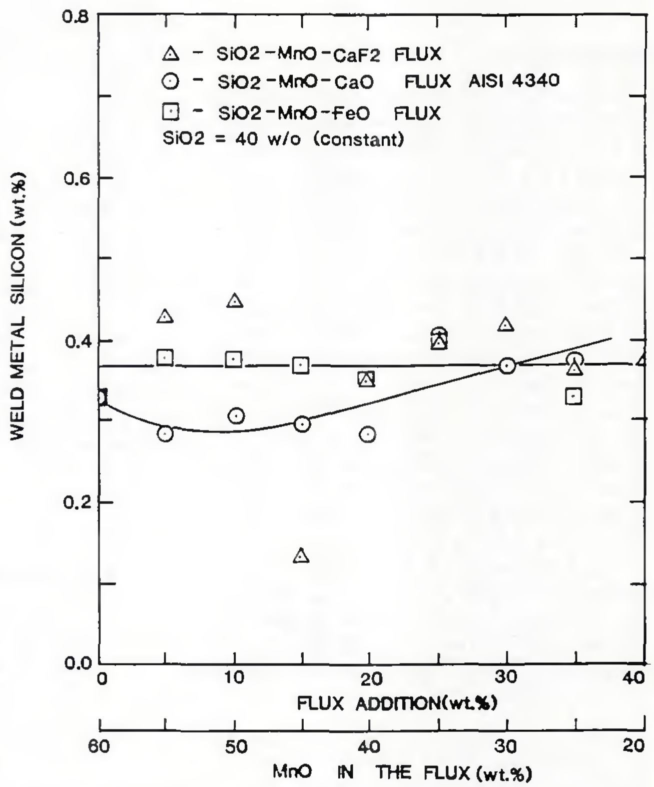

Fig. 2 — Weld metal silicon as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

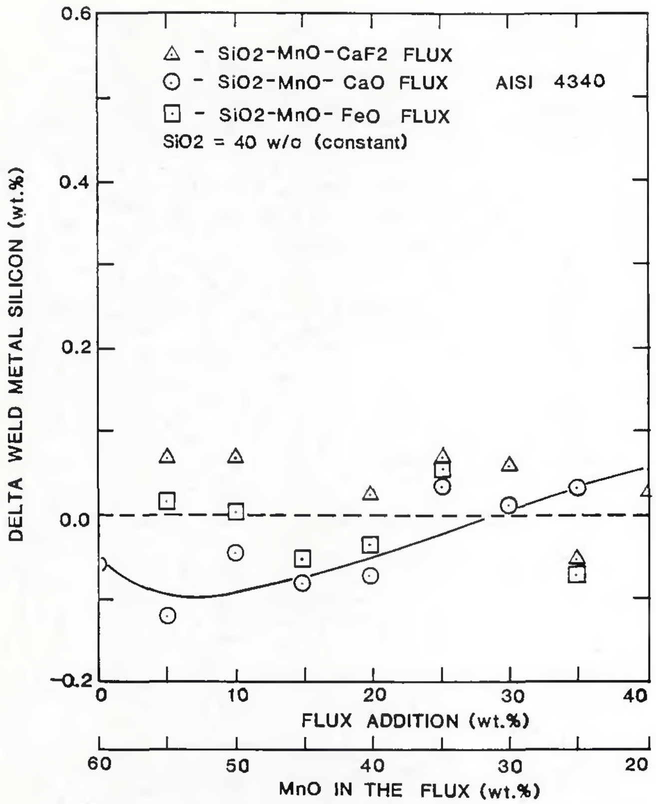

Fig. 3 — Delta weld metal silicon as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

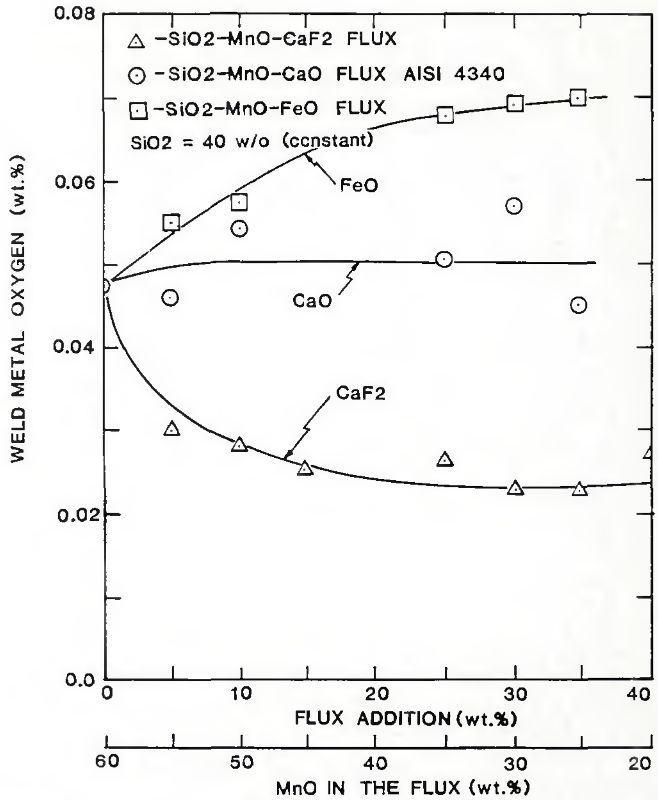

Fig. 4 — Weld metal oxygen as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

tions, at the expense of MnO, increased slightly the oxygen level of the weld metal, but then it remained constant for additions greater than 10 wt-%. Such results would be expected since CaO is a very stable oxide with strong bonding to oxygen. There was a slight decrease in weld metal oxygen content with increasing CaF_2 flux additions after an initial major decrease. For all the fluxes investigated, oxygen was observed to be transferred from the flux to the weld metal as seen by the positive delta quantities in Fig. 5.

The effect of three different flux additions, CaF_2, CaO and FeO on the AISI 4340 steel weld metal manganese contents, is seen in Fig. 6. It is interesting to note that the manganese content decreased with CaF_2 and FeO additions but remained constant with CaO additions. There is some expectation of this behavior from steel-making thermodynamic data. Even though the manganese oxide content of the CaO-MnO-SiO_2 flux decreased, the activity of the manganese oxide in the slag remained relatively constant with CaO additions, as seen in Fig. 7 (Ref. 8), and consequently, the manganese activity in the weld metal would be constant, too. The oxygen available for the oxidation of manganese in the weld metal also remained constant, as shown in Fig. 4. The activity of MnO was found to decrease with increasing FeO additions, as suggested in Fig. 8 (Ref. 9). These equilibrium data are consistent with the observed de-

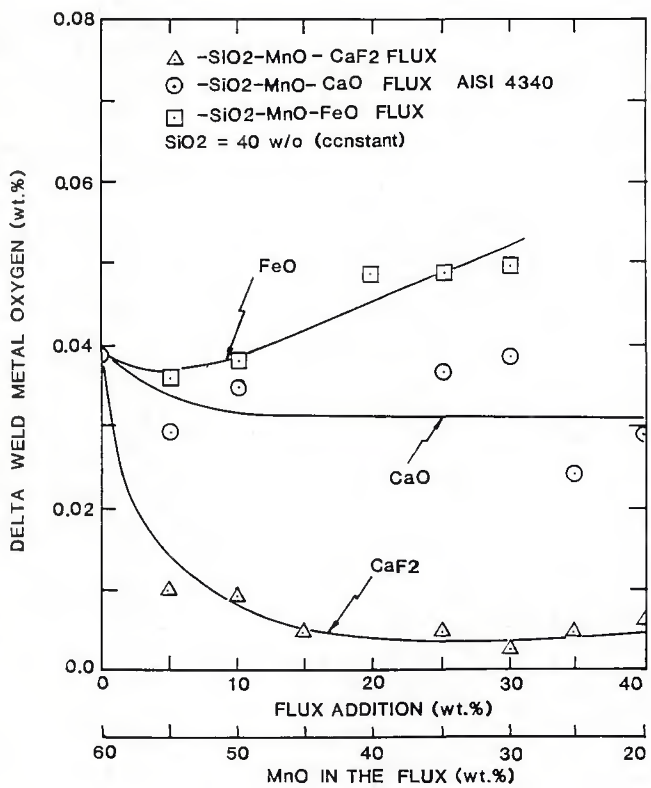

Fig. 5 — Delta weld metal oxygen as a function of flux additions to manganese silicate flux used in submerged arc welding of AISI 4340 steel.

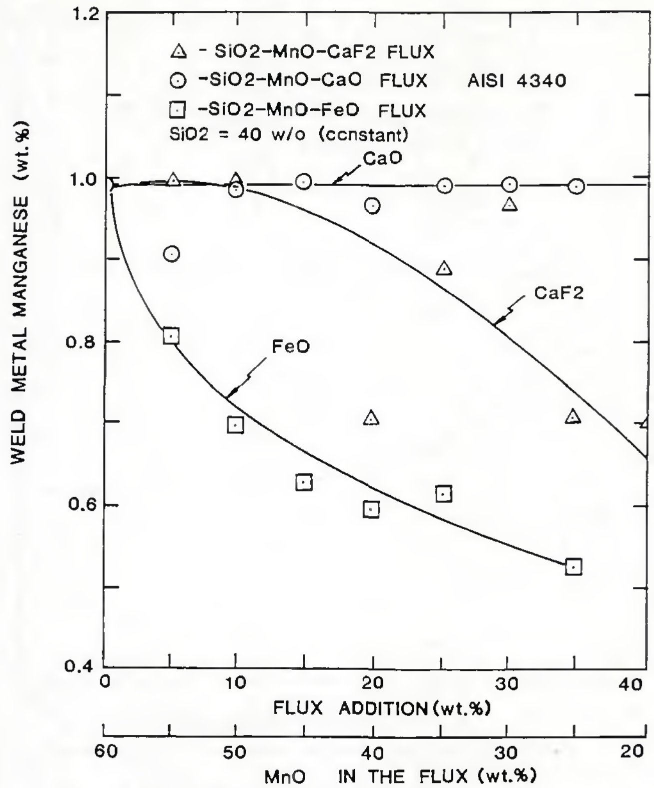

Fig. 6 — Weld metal manganese as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

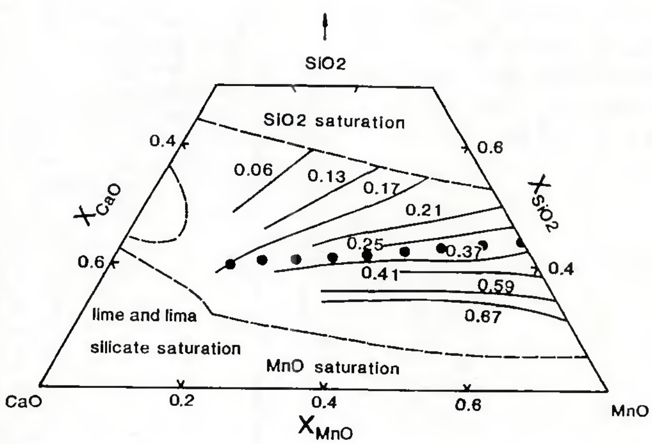

Fig. 7 — Activity of MnO(S) in CaO-MnO-SiO₂ melts at 1500°C (Ref. 8).

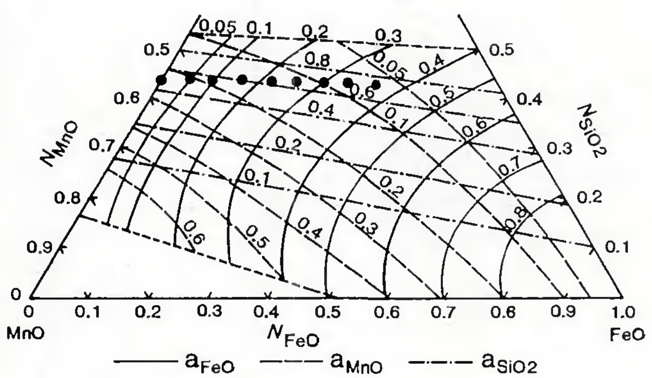

Fig. 8 — Activities in the FeO-MnO-SiO₂ system at 1500°C (Ref. 9).

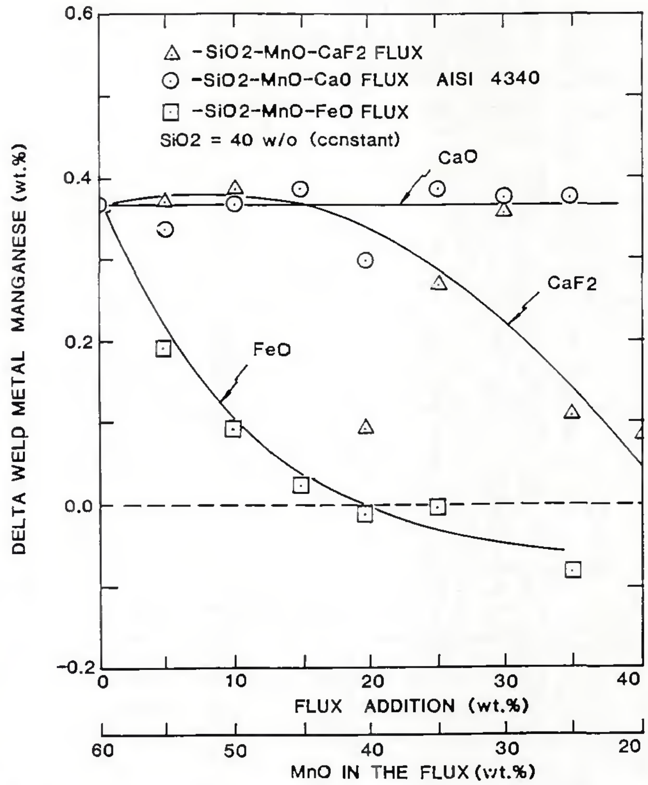

Fig. 9 — Delta weld metal manganese as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

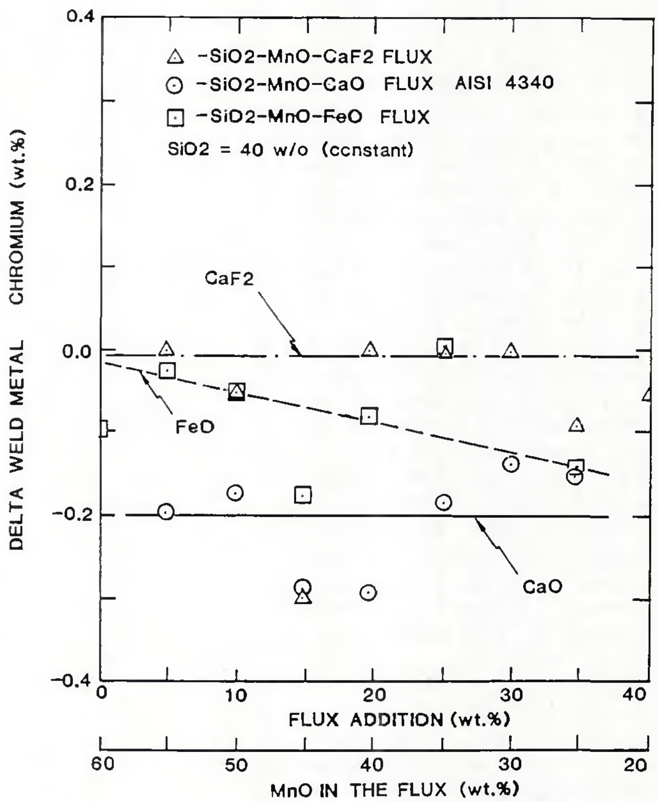

Fig. 10 — Delta weld metal chromium as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

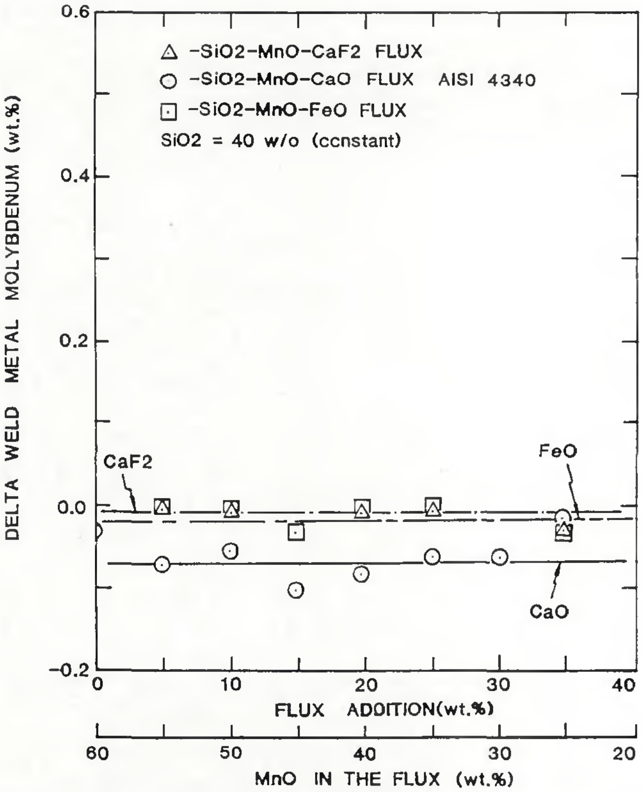

Fig. 11 — Delta weld metal molybdenum as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

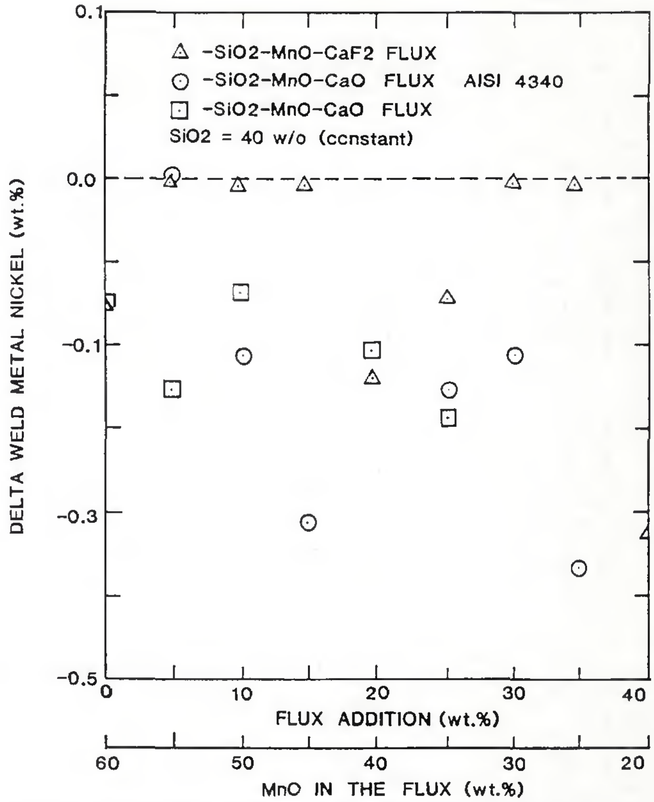

Fig. 12 — Delta weld metal nickel as a function of flux additions to a manganese silicate flux used in submerged arc welding of AISI 4340 steel.

crease in weld metal manganese as a function of FeO additions as seen in Fig. 6. Steel-making thermodynamic activity data appear to be able to provide a qualitative explanation for the behavior of the FeO and CaO additions to a manganese silicate flux on the activity of weld metal manganese.

Manganese was transferred from the flux to the weld metal for the CaF_2 and CaO flux additions, as seen by the positive delta values for both flux systems in Fig. 9. The delta manganese changed from a positive to a negative value with increasing FeO additions. These results suggest that with low FeO additions, manganese is transferred to the weld metal from the flux, but at approximately 20% manganese oxide in the SiO_2-MnO-FeO flux, the behavior reverses and manganese is transferred from weld pool to the slag.

The effect of flux composition on the typical alloying elements of the AISI 4340 steel plate, *i.e.*, chromium, nickel and molybdenum, has been determined. It was found that CaO additions to the manganese-silicate flux produce the greatest overall losses in terms of weld metal chromium, molybdenum and nickel, as shown in Figs. 10, 11 and 12, respectively. The FeO additions to the flux only cause the losses of weld metal chromium and nickel with no effect on weld metal molybdenum. But no significant metal losses are found for these elements with the additions of CaF_2 to the flux.

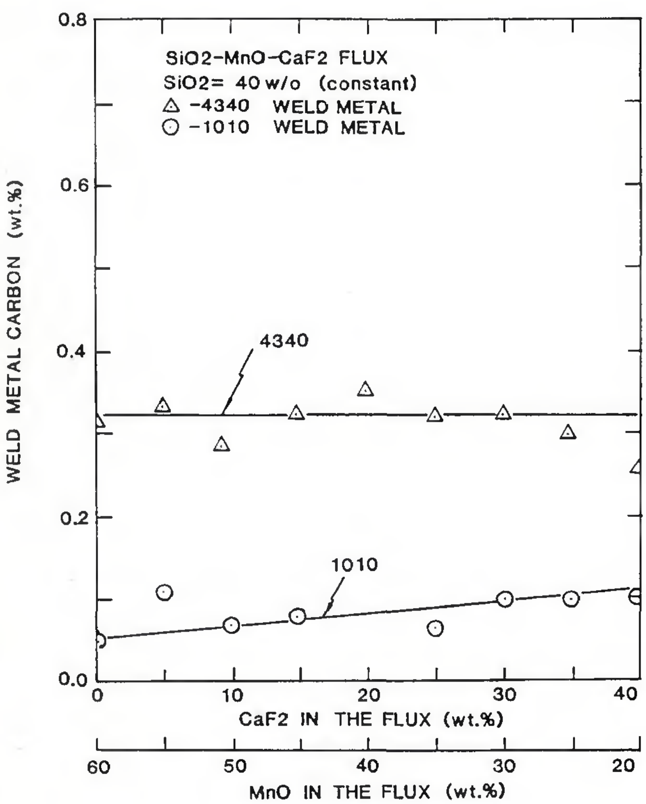

Fig. 13 — Comparison of weld metal carbon as a function of CaF_2 additions to manganese silicate in submerged arc welding of AISI 1010 and 4340 steels.

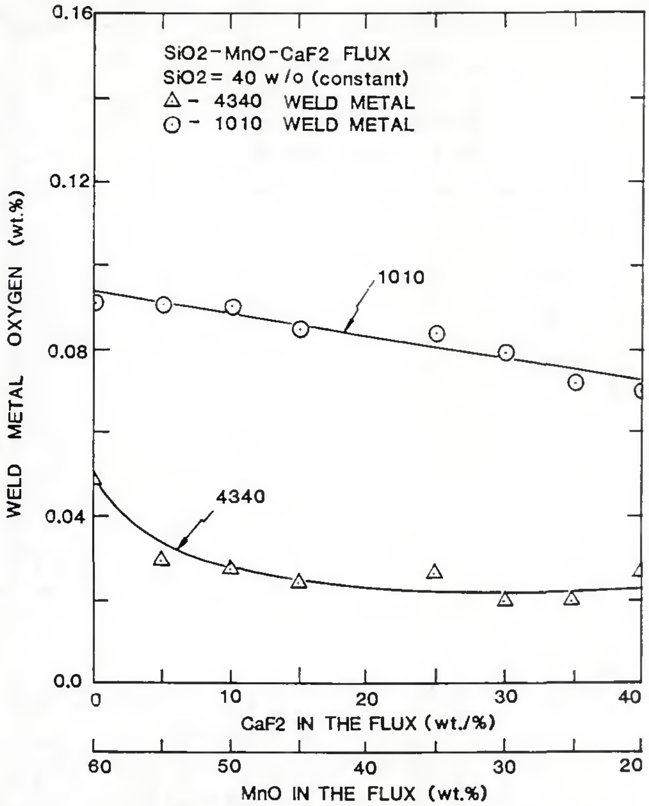

Fig. 14 — Comparison of weld metal oxygen as a function of CaF_2 additions to manganese silicate in submerged arc welding of AISI 1010 and 4340 steels.

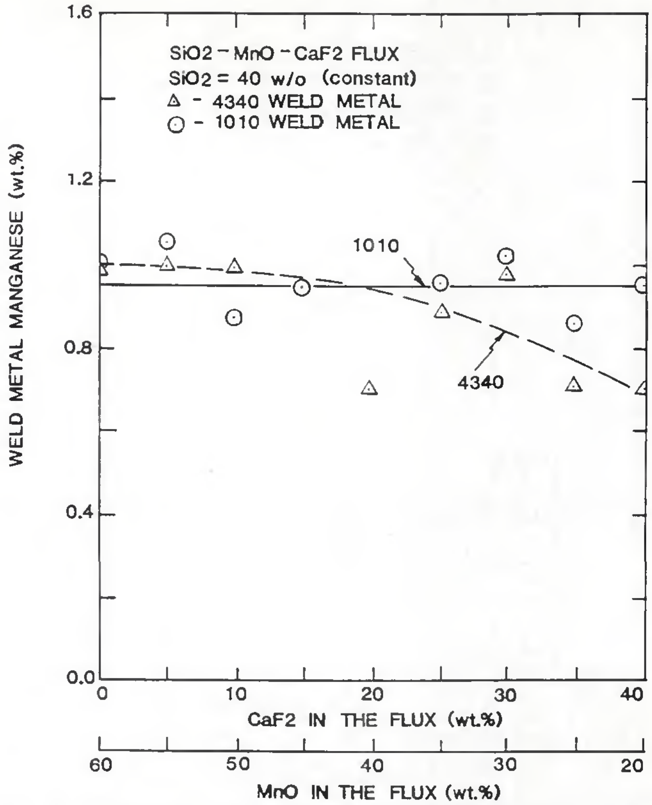

Fig. 15 — Comparison of weld metal manganese as a function of CaF_2 additions to manganese silicate in submerged arc welding of AISI 1010 and 4340 steels.

Comparative Effects of Flux Additions on AISI 1010, 1020 and 4340 Steel Weld Metal

A comparison of the effect of FeO and CaF_2 additions to a manganese-silicate welding flux on AISI 1010, 1020 and 4340 steel weld metal composition was made in an effort to study the effects of the alloying elements present in the AISI 4340 steel on the flux-metal reactions. Furthermore, the metal elemental content (wt-%) was plotted as a function of additions to the flux (wt-%) at the expense of MnO. The silica content of the flux was held constant at 40 wt-%.

The comparative effects of additions of CaF_2 to the flux on AISI 1010 and 4340 steel will be discussed in the following section, followed by the effect of FeO additions to the flux.

CaF_2 Flux Additions

The CaF_2 additions to a manganese-silicate welding flux at the expense of the MnO appears to have a small effect on the carbon content of the weld in the AISI 1010 steel plate over the flux composition range studied, as shown in Fig. 13.

The weld metal silicon content remained fairly constant at 0.35 wt-% for the AISI 1010 steel welds, similar to the behavior seen for AISI 4340 steel in Fig. 2. A significant difference in weld metal oxygen content can be seen in Fig. 14 comparing the AISI 1010 steel welds to the AISI 4340 steel welds, with the AISI 1010 steel welds having the higher oxygen content. The weld metal oxygen was apparently gettered in the weld pool by an alloying addition in the AISI 4340 steel, although for the case of the CaF_2 flux additions it was observed that losses of chromium, nickel and molybdenum were minimal. This raises the possibility that carbon and oxygen partition may be controlled by a CO reaction, since the decrease of oxygen experienced by the AISI 4340 and 1010 steel welds varied according to the carbon change. For the 1010 steel welds, the decrease in oxygen content with CaF_2 additions corresponds to an increase in the carbon content, as observed in Figs. 13 and 14, respectively. The 4340 steel welds, on the other hand, showed constant carbon and oxygen contents (Figs. 13 and 14) except for the original drop in oxygen for the 5 wt-% CaF_2 addition. Since no corresponding change was found in the weld carbon content, it may be speculated that the extra oxygen found in the weld corresponds to the eutectic $MnO-SiO_2$ flux.

In general, the weld metal manganese content of the AISI 1010 steel welds remained fairly constant, as shown in Fig. 15. In addition, a decreasing trend was observed with increasing flux additions in weld metal manganese content for the AISI 4340 steel welds, as seen in Fig. 15, but is difficult to quantify due to the scatter in the results.

FeO Flux Additions

Carbon contents in both the AISI 1020 and 4340 steel welds with additions of FeO to the flux are shown in Fig. 16. The amount of the weld metal carbon was constant as a function of flux composition. The weld metal oxygen content increased with increasing FeO additions as shown in Fig. 17, for both steel weld metals. The delta values for oxygen suggest a transfer of oxygen to both the AISI 1020 and 4340 steel weld metal. More oxygen was transferred to the AISI 1020 steel weld pool than to the AISI 4340 steel weld pool. There was a significant difference between weld metal oxygen contents for the AISI 1020 and 4340 steel welds with both CaF_2 and FeO additions to the flux. This is believed to be due also to the oxidation of chromium in the AISI 4340 steel welds made with the SiO_2-MnO-FeO fluxes. The loss of chromium for the SiO_2-MnO-FeO flux system as seen in Fig. 10 would tend to confirm this suggestion.

In both the AISI 1020 and 4340 steel welds, the weld metal silicon remained fairly constant with increasing additions of FeO in the flux, as seen in Fig. 18. These results suggest that the pyrometallurgical reactions involving silicon are the same. The delta values for silicon indicate that more silicon was transferred from the flux to the weld metal for the AISI 1020 steel compared to the AISI 4340 steel, as seen

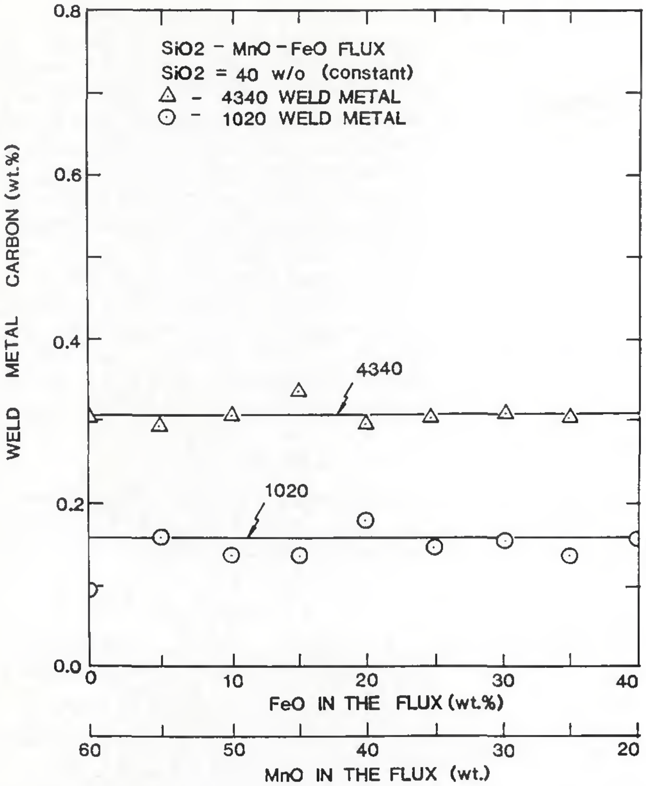

Fig. 16 – Comparison of weld metal carbon as a function of FeO additions to manganese silicate in submerged arc welding of AISI 1020 and 4340 steel.

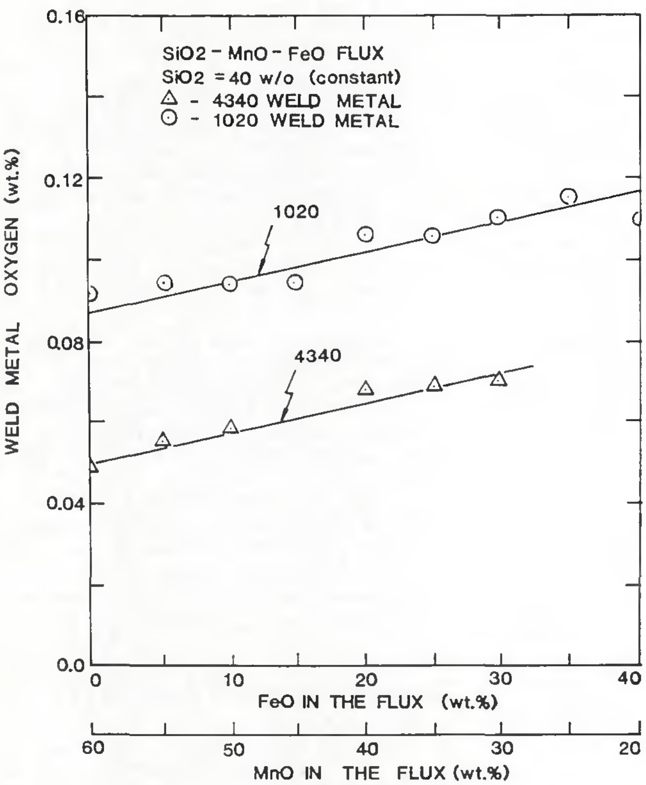

Fig. 17 – Comparison of weld metal oxygen as a function of FeO additions to manganese silicate in submerged arc welding of AISI 1020 and 4340 steels.

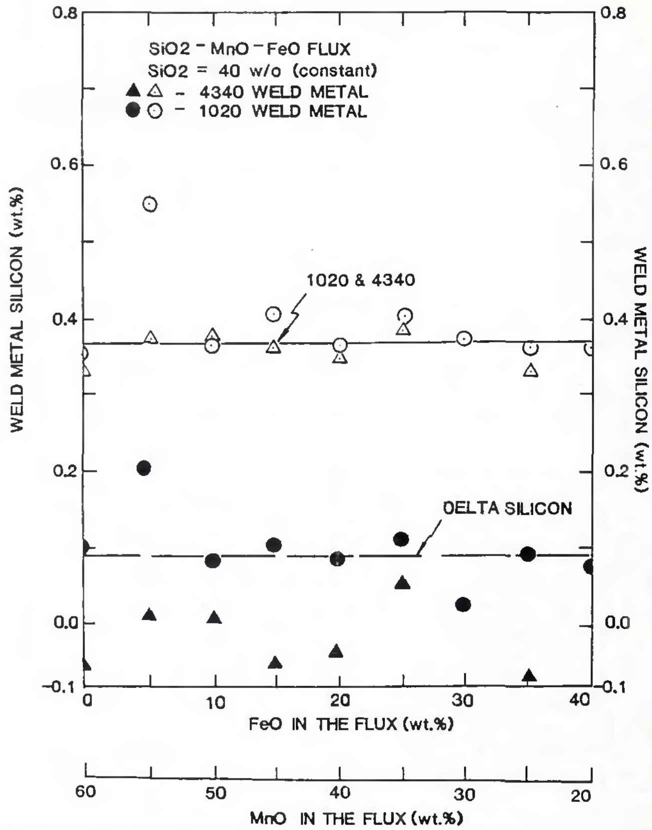

Fig. 18 – Comparison of weld metal silicon as a function of FeO additions to manganese silicate in submerged arc welding of AISI 1020 and 4340 steels.

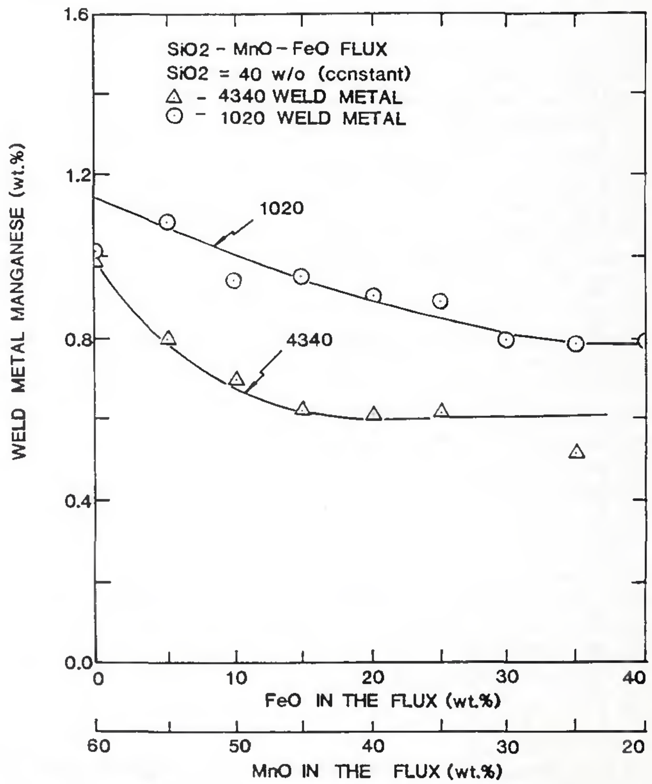

Fig. 19 – Comparison of weld metal manganese as a function of FeO additions to manganese silicate in submerged arc welding of AISI 1020 and 4340 steels.

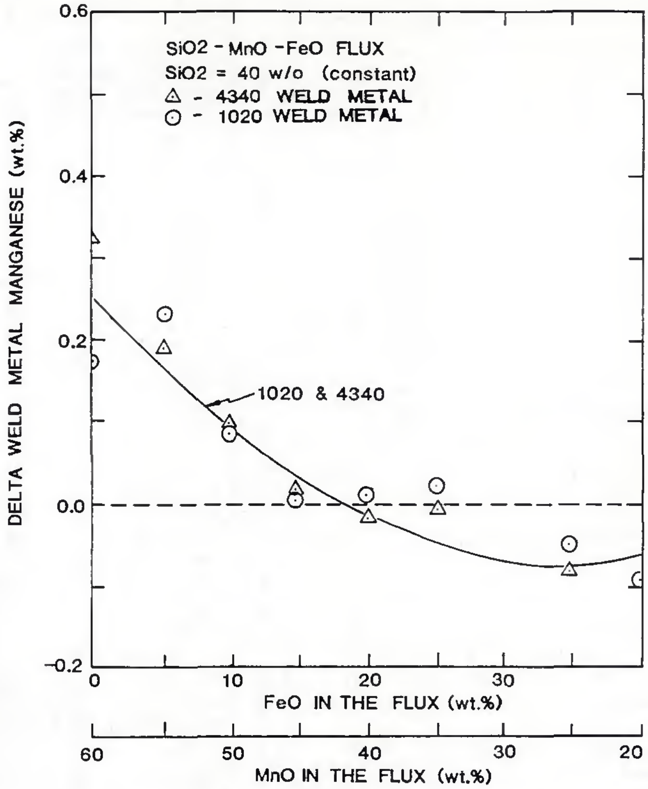

Fig. 20 — Comparison of delta weld metal manganese as a function of FeO additions to manganese silicate in submerged arc welding of AISI 1020 and 4340 steels.

in Fig. 18. These results suggest that silicon is influenced by the alloying elements in the AISI 4340 steel.

The oxygen content of the AISI 4340 steel welds with increasing FeO additions to the flux did increase, while the manganese content decreased. However, the carbon and silicon content remained constant with increasing flux additions. This suggests that the FeO addition in the flux was controlling the oxygen reaction.

In Fig. 19, weld metal manganese content is seen to have decreased as the FeO flux additions increased. The AISI 1020 steel welds did have a higher manganese content. This result is expected since the AISI 1020 welding wire has twice the manganese content of the AISI 4340 welding wire. The identical manganese transfer behavior shown in Fig. 20 for both steels suggests that the same controlling reactions are working. Even though the filler wire had different manganese contents or activities, the manganese reaction proceeded to the same degree of completion.

The work of both Grong and Christensen (Ref. 10) and Chai and Eagar (Ref. 11) attributed manganese losses to evaporation. In this investigation, manganese loss was observed both in the AISI 1020 and 4340 steel welds with FeO flux additions greater than 20 wt-% as shown in Fig. 20. Note in Fig. 9 that for AISI 4340 welds the manganese content did decrease with decreasing amounts of MnO in the flux with both the FeO and CaF_2 flux additions. However, it is important to remember that no decrease in manganese was observed for the CaO flux additions.

Loss of nickel, chromium and molybdenum in the AISI 4340 steel welds with additions of CaO in the flux demonstrates the need to exercise care in selection of a flux in welding alloy steels. Loss of carbon should also be considered in welding low-carbon and alloy steels. With heat-treatable alloy steels such as AISI 4340 steel, the control of weld metal composition would be even more important since the desired final microstructure is martensite, which is influenced by both alloy composition and thermal experience.

Summary

The additions of CaF_2, CaO and FeO to a manganese-silicate flux and their effects on the element transfer from the slag to the weld metal and vice versa can be qualitatively explained, in some cases, using thermodynamic data. The carbon/oxygen partition appears to be controlled by a CO reaction in the 1010 steel welds, while the manganese level remains constant for the SiO_2-MnO-CaF_2 flux system. Meanwhile, the welds processed with the SiO_2-MnO-FeO flux system on the AISI 1020 and 4340 steel plates, show constant carbon contents despite increasing oxygen levels. Apparently, the excess oxygen oxidizes manganese in the 1020 steel welds and both chromium and manganese in 4340 steel welds.

The welds processed with the SiO_2-MnO-CaO flux system on AISI 4340 steel, show constant carbon, oxygen and manganese contents while the same fluxes caused the greatest oxidation of the alloying elements for these welds.

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June 12-13, 1990

Welding engineers and researchers will want to attend one of these identical presentations to stay up-to-date on the latest developments in materials joining technology, including advanced experimental techniques for characterizing weldments, new perspectives on hot and cold cracking, and weldability advances for stainless steels, HSLA steels, and advanced materials, including ceramics. This unique symposium offers a rare opportunity for researchers, educators, engineers, executives and other representatives worldwide to learn about the latest in these advances in welding metallurgy.

The two-day symposium will include papers by 19 renowned international researchers, and was developed cooperatively under the direction of Professor Fukuhisa Matsuda, Welding Research Laboratory, Osaka University (Japan) and Dr. Stan A. David, Oak Ridge National Laboratory (USA). The two international presentations are designed to maximize the dissemination of these important technical advances around the world. The program is jointly sponsored by the American Welding Society, the Japan Welding Society, and The Japan Welding Engineering Society.

Papers on **"New Developments in Welding Metallurgy"** are: "Characterization of Weldments Using Advanced Experimental Techniques" by Dr. J. M. Vitek and Dr. S. A. David, Oak Ridge National Laboratory; "Hot Crack Susceptibility of Weld Metal" by Professor Fukuhisa Matsuda, Osaka University; "Test Methods for Evaluating Hot-Cracking - Review and Perspective" by Dr. G. M. Goodwin, Oak Ridge National Laboratory; and "Hardenability and Cold Cracking Susceptibility of HAZ of Steel," by Dr. Nobutaka Yurioka, Nippon Steel Corporation.

Papers on **"New Developments in the Weldability of Advanced Materials"** are: "Welding and Welding Metallurgy of Ductile Intermetallic Alloys" by Dr. S. A. David, Oak Ridge National Laboratory; "Research on Joining of Ceramics in Japan" by Professor Yoshikuni Nakao, Osaka University; "Weldability of Al-Li Alloys" by Dr. J. R. Pickens, Martin Marietta Corporation; and "Welding of Some Advanced Materials in Japan" by Dr. Susumu Shono, Mitsubishi Heavy Industries, Ltd.

Papers on **"Advances in Weldability of High-Strength Low-Alloy Steel"** are: "Recent Developments in HSLA Steel Welding" by Professor G. R. Edwards and Dr. S. Liu, Colorado School of Mines; "Toughness Improvement in HAZ of HSLA Steels in Japan" by Dr. Chiaki Shiga, Kawasaki Steel Corporation; "HAZ Microstructures in HSLA Steel Weldments" by Professor K. Challenger, University of Cincinnati; and "Toughness Improvement in Weld Metal of Carbon and HSLA Steels in Japan" by Dr. Yasuto Fukada, Sumitomo Metal Industries, Ltd.

Papers on **"Advances in Weldability and Welding Metallurgy of Stainless Steels" are:** "Weldability and Phase Transformations of Duplex Stainless Steels" by Dr. D. J. Kotecki, The Lincoln Electric Company; "Development of Stainless Steel Welding Electrodes in Japan" by Dr. Yutaka Nishikawa, Kobe Steel Ltd.; "Weldability of Austenitic Stainless Steels for the 1990s and Beyond" by Professor C. D. Lundin, University of Tennessee; and "Performance of Duplex Stainless Steel Weldments" by Dr. Toyofumi Kitada, NKK Corporation

For additional information and registration materials, please contact either:

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AN INVITATION TO AUTHORS

To the Members and Friends of AWS:

The American Welding Society will hold its 72nd Annual Convention and International Welding Exposition in Detroit, Mich., on April 14-19, 1991. One of the most important events of our 72nd Annual Convention will be its five-day-long Professional Program for engineers, welders, researchers, metalworking fabricators, and all others with a working interest in welding and related processes. Another important event will be a one-day Education Program for educators, welding instructors and school administrators, with up-to-date information on techniques and tips for training welders and inspectors, and individuals considering a career in welding.

It is indeed a pleasure to invite you as Authors to be participants in the Professional Program of our 72nd Annual Convention. On this occasion, the Society is offering an opportunity to Authors to bring the results of outstanding work on their part to the attention of our entire membership, the welding industry, and the nation's metalworking industries.

To this end, the appropriate review committees will be happy to receive your application for participation in our 72nd Annual Convention — the Technical Papers Committee for the Professional Program, and the AWS Education Committee for the Education Program. In the case of the Professional Program, the Technical Papers Committee is inviting papers in, basically, two categories:

1) *Applied Technology* — unusual industrial or field applications of welding, new process or significant equipment developments, surfacing, unique welding case histories, education, safety and health, cost studies — also related topics such as nondestructive testing of weldments — as well as maintenance and repair.

2) *Research Oriented* — results of significant laboratory research and/or development projects, welding metallurgy, weldability studies, weld cracking or fracture, new test methods, arc physics — also related topics such as fracture mechanics.

To apply for participation in our 72nd Annual Convention Program, please complete both sides of the Author Application Form on the facing page. Also, please prepare a 300- to 500-word summary of what you intend to say in your paper, and mail it with the completed form to AWS.

The appropriate review committee will screen all Author Applications and summaries (also the manuscripts of completed papers, if included), and we expect to notify Authors in late October or early November concerning acceptance. Completed Author Application Forms and accompanying 500-word summaries must be mailed by June 29, 1990, to ensure consideration for the 72nd Annual Convention Professional Program.

Please note that, as it screens Author Applications and summaries, the review committee will be looking for: 1) the newness of information and need for the information in its field, 2) technical accuracy, 3) clarity of presentation, and 4) adaptability for oral presentation (a paper consisting basically of complicated tables would not be suitable for oral presentation).

Finally, please note also that the Technical Papers Committee expects to continue its Poster Session program in Detroit for those papers whose contents lend themselves better to first-hand examination and study than to oral presentation. A separate invitation for participation will appear in a future issue of the *Welding Journal.*

Sincerely yours,

F. DeLaurier

Frank G. DeLaurier
Executive Director

March 1, 1990

AMERICAN WELDING SOCIETY
P.O. Box 351040, Miami, FL 33135