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November 28, 2017

FILED ELECTRONICALLY (VIA EDIS)

NONCONFIDENTIAL VERSION

The Honorable Lisa R. Barton
Secretary
U.S. INTERNATIONAL TRADE COMMISSION
500 E Street, S.W., Room 112-A
Washington, D.C. 20436

USITC Inv. Nos. 701-TA-573–574
and 731-TA-1349–1358 (Final)

Number of Pages: 137

Confidential Business Information Has Been Deleted from Pages 4–8 and 14–15, and CBI Exhibits 3–8 and 15 Have Been Omitted from This Posthearing Brief.

Confidential Version May Be Released under APO.

Re: *Carbon and Certain Alloy Steel Wire Rod from Belarus, Italy, Korea, Russia, South Africa, Spain, Turkey, Ukraine, the United Arab Emirates, and the United Kingdom: Posthearing Brief*

Dear Madam Secretary:

On behalf of the American Wire Producers Association ("AWPA"), we respectfully submit the nonconfidential version of a *Posthearing Brief*, pursuant to 19 C.F.R. §§ 201.8(d) and 207.3(c). The confidential version of this *Posthearing Brief* was filed with the U.S. International Trade Commission ("Commission") on November 27, 2017.

Confidential business information ("CBI") has been deleted from pages 4–8 and 14–15, and CBI Exhibits 3–8 and 15 have been omitted from this *Posthearing Brief*. Pursuant to 19 C.F.R. §§ 201.6(c) and 207.3(c), we have marked these pages in which proprietary information has been deleted with "PUBLIC VERSION," and the CBI exhibits have been omitted from the nonconfidential version. This deleted proprietary information concerns or relates to the actual experiences of individual AWPA member companies as purchasers of the products subject to these investigations. None of this information is generally available to the public, and its disclosure would cause substantial harm to the competitive position of the companies which provided the information. Accordingly, it is appropriate to grant confidential treatment of this proprietary information in accordance with 19 C.F.R. § 201.6(d).

Pursuant to 19 C.F.R. §§ 201.16(b) and 207.3(b), the nonconfidential version of this *Brief* has been served upon the parties listed on the attached *Public Certificate of Service*.

The undersigned counsel for the AWPA certify that the factual information contained in this *Brief* is, to the best of our knowledge, accurate and complete.

Respectfully submitted,

Frederick P. Waite
Kimberly R. Young

Counsel for
the AMERICAN WIRE PRODUCERS ASSOCIATION

FPW:KRY:daj

Attachments

cc: All Parties Listed
on the attached *Public Certificate of Service*

CERTIFICATION OF ACCURACY AND COMPLETENESS

CARBON AND CERTAIN ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

I, FREDERICK P. WAITE, certify that I have read the attached *Posthearing Brief* (Nonconfidential Version) on behalf of the AMERICAN WIRE PRODUCERS ASSOCIATION. Based upon the information made available to me, I have no reason to believe that this submission contains any material misrepresentation or omission of fact, and I certify that the confidential information omitted from this submission is not available in substantial form to the public.

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DISTRICT OF COLUMBIA) SS:

Sworn to and subscribed before me this 28th day of November, 2017, in the District of Columbia.

DOLORES JACKSON NOTARY PUBLIC EXP. 5-31-21 DISTRICT OF COLUMBIA

Dolores Jackson
(Notary Public)

DOLORES JACKSON
NOTARY PUBLIC DISTRICT OF COLUMBIA
My Commission Expires May 31, 2021

My Commission Expires: May 31, 2021

NONCONFIDENTIAL VERSION

Confidential Business Information Has Been Deleted from Pages 4–8 and 14–15, and CBI Exhibits 3–8 Have Been Omitted from This Posthearing Brief.

Total Pages: 131

Confidential Version May Be Released under APO.

BEFORE
THE UNITED STATES INTERNATIONAL TRADE COMMISSION
WASHINGTON, D.C.

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF: **CARBON AND CERTAIN ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM**	USITC INV. NOS. 701-TA-573—574 AND 731-TA-1349—1358 (FINAL)

POSTHEARING BRIEF ON BEHALF OF THE AMERICAN WIRE PRODUCERS ASSOCIATION

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Dated: November 28, 2017

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WASHINGTON, D.C.**

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POSTHEARING BRIEF ON BEHALF OF THE AMERICAN WIRE PRODUCERS ASSOCIATION

I. INTRODUCTION

The evidence on the record of this investigation contradicts Petitioners' claims that: (a) subject imports drive the prices of domestic wire rod, (b) the domestic wire rod industry did not realize the price increases it announced in 2016 and 2017, (c) the downstream wire operations of the domestic rod mills are "small" and insignificant, and (d) the closure of ArcelorMittal Georgetown and Republic's Lorain mill was caused by imports.

In fact, the price of scrap is the determinant factor in the domestic mills' pricing of their rod products; the domestic wire rod industry realized most and often all of their announced price increases during 2016 and 2017; the domestic rod mills' downstream operations are substantial and have a direct effect on the amount of wire rod available to independent wire producers; and the closure of the ArcelorMittal and Republic operations was the result of factors other than subject imports of wire rod.

Furthermore, the facts show that subject imports have not had a negative price or volume impact on the domestic industry.[1] Accordingly, the American Wire Producers Association ("AWPA") respectfully urges the Commission to make a negative final determination.[2]

[1] The American Wire Producers Association endorses the position of the posthearing briefs submitted on behalf of Kiswire Ltd., Kiswire America Inc., Bekaert Corporation, and POSCO that grade 1080 and higher wire rod for tire bead and tire cord is a separate like product.

II. MOVEMENTS IN SCRAP PRICES—NOT THE PRESENCE OF SUBJECT IMPORTS IN THE U.S. MARKET—EXPLAIN DOMESTIC ROD PRICING OVER THE PERIOD OF INVESTIGATION ("POI")

During the hearing, Petitioners attempted to downplay the significance of scrap prices in explaining the changes in domestic wire rod prices during the period of investigation ("POI"). But the witnesses from the AWPA explained the importance of movements in scrap in determining the prices that they paid for rod from their domestic suppliers. Ultimately, Petitioners acknowledged that they do announce price increases whenever scrap prices rise, as shown by increasing rod prices during 2016 and 2017. Despite this acknowledgment, Petitioners nevertheless blame any declines in their rod prices on the presence of subject imports—notwithstanding clear evidence that it was dropping scrap prices in 2014 and 2015—not subject imports—that caused rod prices to decline in the first half of the POI.

Purchasers at the hearing testified about the direct relationship between scrap and rod prices. Mr. Moffitt of the Heico Wire Group emphasized the key role that movements in the price of scrap have on domestic rod prices:

> Domestic rod pricing is driven by monthly changes in the price of steel scrap, specifically the price of Chicago shredded as reported by American Metal Market. . . . When the AMM publishes their scrap analysis, the U.S. rod mills use the scrap price in their wire rod pricing for the subsequent month. As a result, purchasers closely monitor scrap prices for any indication of likely changes in rod prices. The trends in scrap prices between 2014 and today are closely correlated with wire rod prices and show that domestic prices declined in 2014 and '15 as a direct result of declines in the prices of steel scrap. Scrap prices began to increase in 2016 and they have continued to rise in 2017. Wire rod prices have followed this same trend as evidenced by the numerous price increase announcements issued by the domestic mills in 2016 and 2017.[3]

(Continued)

2 Attached as Exhibits 1 and 2 are responses to questions from Vice Chairman Johanson and ITC staff to AWPA witnesses at the hearing.

3 *Transcript of Hearing in the Matter of Carbon and Certain Alloy Steel Wire Rod from Belarus, Italy, Korea, Russia, South Africa, Spain, Turkey, Ukraine, the United Arab Emirates, and the United Kingdom,* *(Continued)*

Mr. Stauffer of Insteel Industries Inc., who testified that the four Petitioners are his largest rod suppliers, agreed that "{r}od prices fluctuate based on a monthly change in scrap and other metallic prices published by the American Metal Market." Consequently, "{n}egotiations with the domestic mills always start with the price of scrap. Did the scrap price go up or did it go down compared to last month?"[4] Mr. Johnson of Mid-South Wire Company also explained that the close link between scrap and rod prices impacts the way in which wire rod is sold: "domestic rod mill prices are generally tied to scrap prices, which can be extremely volatile and unpredictable," which means that "{t}hey are not willing to lock in a rod price for us when scrap prices are continuing to rise."[5]

In response to questions at the hearing, Petitioners acknowledged the correlation between scrap prices and rod prices—at least when scrap prices are going up. Mr. Nystrom of Nucor agreed that his company raises its rod pricing when scrap prices increase: "{W}hen scrap goes up, yes, we raise prices."[6] Mr. Nystrom further testified that "there may be pricing increases that are—that correspond to when a scrap change occurs," and that it is Nucor's "goal to raise our prices above and beyond what scrap prices are able to do."[7] Mr. Ashby of Keystone generally conceded that there is a relationship between scrap and rod prices: "{P}rices certainly have moved up and down with that independently, based on what happens with scrap."[8]

(Continued)

Investigation Nos. 701-TA-573–574 and 731-TA-1349–1358 (Final) (November 16, 2017) (hereinafter "*Transcript*") at 157–158.

4 *Id.* at 152.

5 *Id.* at 148.

6 *Id.* at 80.

7 *Id.* at 116.

8 *Id.* at 115.

Attached as CBI Exhibit 3 is a table that tracks monthly changes in scrap prices during 2016 and interim 2017 and compares those scrap increases to monthly price increase announcements from Petitioners during the same period. As this table clearly shows, Petitioners announced price increases in lock-step with rising scrap prices and in some cases even more than the increase in scrap. In [ ], the price of scrap [ ], respectively, and Petitioners announced comparable increases in their rod prices in those same months. Petitioners followed a similar pattern of rod price increases when scrap prices [ ] and again in [ ].[9] This table provides indisputable evidence that changes in the price of scrap resulted in increases in the price of domestic wire rod. Even Petitioners' counsel conceded that rod price increases in 2016 were caused by increases in the price of scrap: "2016 was all scrap increase driven, as far as I can tell in terms of the attempts to get price increases."[10]

Although Petitioners grudgingly admit that the upward swing in scrap prices in 2016 and 2017 led to higher rod prices, they attribute the declining rod prices during 2014 and 2015 entirely to the effects of subject imports. Mr. Canosa of Gerdau completely rejected the notion that downward movements in scrap prices had any impact on rod prices:

> {B}ecause of the low priced imports in the market, it's like people would say that we fluctuate price announcements and price changed with scrap. We're actually chasing the low price imports of the subject countries. That's what makes our price go down throughout the period of investigation, not scrap.[11]

However, the direct correlation between scrap and rod prices—both up and down—is clearly illustrated in CBI Exhibit 4 which covers the entire period of investigation ("POI").

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[9] Between [ ], but Petitioners announced price increases [ ], apparently bolstered by the filing of trade cases in March 2017.

[10] *Transcript* at 80.

[11] *Id.* at 78.

This exhibit graphs the actual monthly rod prices paid by [ ] and overlays monthly scrap prices.[12] Between January 2014 and December 2015, scrap prices [ ]. The declines in actual rod prices paid by [ ] is closely correlated to the decline in scrap. Scrap prices then increased irregularly over 2016 and 2017, and the actual rod prices paid by [ ] track scrap closely [ ].

At the hearing, Mr. Armstrong of Keystone blamed his customers for expecting declining scrap prices to translate into declining rod prices: "Personally, it's the customers that try and drive the relationship between scrap and the prices, it's not us. … And whenever scrap goes down, it's the customers who come knocking on the door and say, hey, scrap has gone down. You should lower your price."[13] But as Mr. Moffitt noted: "{W}e did not on our side create the concept of tying wire rod pricing to the Chicago shred number. That was their idea when the prices were going up. Of course when they go down, they seem to forget that."[14]

III. THE DOMESTIC WIRE ROD INDUSTRY, INCLUDING THE FOUR PETITIONERS, HAVE BEEN IMPOSING AND CONTINUE TO IMPOSE NUMEROUS, FREQUENT, AND SIGNIFICANT PRICE INCREASES ON ALL WIRE ROD PRODUCTS IN 2016–2017.

As documented by members of the American Wire Producers Association ("AWPA") in their prehearing brief and confirmed by AWPA witnesses at the hearing, the Petitioners have imposed numerous, frequent, and significant price increases for all of their wire rod products

12 [ ]

13 *Transcript* at 75.

14 *Id.* at 188.

throughout 2016 and continuing into late 2017.[15] These successful price increases began more than a year before the petitions were filed, and they are continuing today as Petitioners Gerdau, Keystone, and Nucor have issued price increase announcements—and imposed these increases in their transactions with customers—whenever scrap prices increased.

At the hearing, Petitioners and their counsel disputed whether Petitioners' wire rod price increase announcements resulted in higher prices actually paid by their customers. For example, Nucor's representative stated that "just because we announce it {a price increase} in no way, shape, or form does that mean we capture what we announce."[16] He further elaborated that "it's our goal to raise our prices above and beyond what scrap prices are able to do."[17] Speaking on behalf of Petitioners collectively, their counsel asserted: "{D}espite the thick stack of price increase announcements that AWPA and others have referred to, most of those did not stick and it's only been in this year after the filing of the cases that they've been any price increases that have stuck."[18]

However, the domestic mills' price increases were sticking even before the cases were filed. In March 2017, [ ]—a significant purchaser of wire rod from the domestic mills—pointed out to [ ] that its price increases actually exceeded the increases in scrap prices and that [ ].

15 *See Carbon and Certain Alloy Steel Wire Rod from Belarus, Italy, Korea, Russia, South Africa, Spain, Turkey, Ukraine, the United Arab Emirates, and the United Kingdom: Brief Prehearing Brief on Behalf of the American Wire Producers Association* (November 9, 2017) (hereinafter "*AWPA's Prehearing Brief*") at 6–-9 and Exhibit 3. Charter Steel, the remaining Petitioner, does not issue price increase letters; instead it adjusts its prices based on an index calculated from the price of busheling scrap. *Id*. at 8.

16 *Transcript* at 80.

17 *Id*. at 116.

18 *Id*. at 79.

[

][19]

Other purchasers confirmed that they paid all or most of the domestic mills' announced price increases. For example, CBI Exhibit 6 contains a graphic representation of the movement of scrap prices between January 2016 and September 2017 compared with the monthly rod prices paid by [

]. [

]. The [ ] in scrap prices beginning in the first quarter of 2016 through September 2017 is [ ] in the rod prices paid by [ ].

In CBI Exhibit 7, the monthly rod prices paid by [ ] to Petitioner [ ] are juxtaposed against the monthly changes in scrap prices. This table shows that this Petitioner announced price increases in response to rising scrap prices and in some cases even more than the increase in scrap. For instance, in May 2016, scrap [ ] and [

], but [ ].[20] However, in July, [ ] paid a rod increase of [ ] since May. Scrap [ ] in November 2016 and [ ] increased its rod price by [ ] for December, but [ ]

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19 *See* CBI Exhibit 5.

20 [ ] so the changes in scrap prices and the amounts of the rod price increase announcements have been converted to the same basis for comparison.

[ ]. In January 2017, [ ], and [ ].

Similarly, CBI Exhibit 8 presents the monthly rod prices paid by [ ] between January 2016 and September 2017, and it highlights the correlation between the monthly changes in scrap prices, the amount of the price increase announcements by Petitioners, and the prices actually paid by [ ]. This exhibit indicates that in most cases, the price increases announced by Petitioners were directly linked to a corresponding increase in scrap prices, and it also shows that the rod prices paid track both the changes in scrap and the price increase announcements from the U.S. rod industry.

The public version of the *Prehearing Report* regarding the pricing of individual wire rod products provides further confirmation that there were significant price increases during 2016 and 2017—starting before the petitions were filed and tracking with increases in scrap prices.[21] For example, the unit price of Product 1—a ubiquitous low-carbon industrial grade widely used by independent wire producers—increased from $438 per short ton in the first quarter of 2016 to $549 per short ton in the third quarter of 2017—an increase of more than $100 per short ton.[22] Similarly, the unit prices of Product 2—another commonly used low-carbon industrial grade of wire rod—and Product 3—a mesh quality wire rod—increased by more than $120 per short ton from the first quarter of 2016 to the third quarter of 2017.[23]

21 *See Carbon and Certain Alloy Steel Wire Rod from Belarus, Italy, Korea, Russia, South Africa, Spain, Turkey, Ukraine, the United Arab Emirates, and the United Kingdom*, Investigation Nos. 701-TA-573–574 and 731-TA-1349–1358 (Final): *Prehearing Report (Public)* (November 2, 2017) (hereinafter "*Prehearing Report*") at V-9, V-11, and V-13.

22 *Id*. at V-9.

23 *Id*. at V-11.

IV. MOST OF THE DOMESTIC WIRE ROD PRODUCERS, INCLUDING ALL OF THE PETITIONERS, ARE VERTICALLY INTEGRATED AND COMPETE WITH THEIR CUSTOMERS—INDEPENDENT AMERICAN WIRE PRODUCERS—IN DOWNSTREAM WIRE AND WIRE PRODUCTS MARKETS

All four Petitioners have substantial captive operations to manufacture wire and wire products in direct competition to their customers in the U.S. wire industry. Exhibit 9 shows that Petitioner Charter operates three wire companies; Petitioner Gerdau—two; Petitioner Keystone—three; and Petitioner Nucor—four. As the following table confirms, the domestic wire rod industry allocates a substantial percentage of its overall rod production to its captive wire and wire products companies:

U.S. PRODUCERS' U.S. SHIPMENTS AND THE IMPORTANCE OF INTERNAL CONSUMPTION AND TRANSFERS TO RELATED FIRMS FOR DOWNSTREAM PRODUCTION OF WIRE AND WIRE PRODUCTS

	2014	%	2015	%	2016	%	JAN–SEPT 2016	%	JAN–SEPT 2017	%
COMMERCIAL U.S. SHIPMENTS*	2,627,360	72%	2,591,398	71%	2,469,373	70%	1,876,485	69%	1,998,927	70%
INTERNAL CONSUMPTION AND TRANSFERS	**1,019,495**	**28%**	**1,050,450**	**29%**	**1,079,127**	**30%**	**859,761**	**31%**	**851,099**	**30%**
U.S. SHIPMENTS*	3,646,855		3,641,848		3,548,500		2,736,246		2,850,026	

* *Source: Public Prehearing Report* at III-9 (Table III-5).

During each of the three full years of the POI, one-third of U.S. rod production—amounting to at least one million tons of rod annually—went to the domestic rod mills' wire operations or related companies to produce wire and wire products. In interim 2017, that figure was 850,000 tons for nine months or 1,100,000 tons annualized.

The downstream wire operations of Petitioners are important for three reasons. First, the substantial downstream wire and wire products operations of the U.S. wire rod industry are insulated from the impact of imports of wire rod. Second, the U.S. wire rod industry's captive consumption of wire rod limits the availability of wire rod to its customers. Third, the diversion of wire rod to the producers' own downstream operations is another compelling reason why independent wire companies must have multiple sources for this essential raw material which is indispensable to their survival.

At the hearing, witnesses for the U.S. rod industry sought to diminish the scale and importance of their downstream operations—despite their company's very public promotion of the downstream wire and wire products in the marketplace. For example, Nucor's representative claimed that "{t}he downstream business that we have on wire rod is very small in terms of tons" and further "{t}he amount of downstream business that we have that's internal is very small."[24] Yet Nucor's financial report for 2016 lists the production at Nucor's wire products facilities which make steel mesh, grating, and fasteners at over 350,000 tons—hardly a "very small" number.[25] In addition, Nucor's product catalog devotes several pages to its offerings of wire and wire products and notes that the Nucor Wire Products Group provides "a large variety of wire products from coast to coast."[26] The representative from Gerdau likewise testified that "{w}e have very small proportion of what we produce goes to our own wire operations, very small, and they're separate P&Ls."[27] Yet Gerdau's website promotes its wire and wire products for the agricultural, automotive, construction, and general industrial sectors, including various types of drawn wire, wire rope, mesh, staples, and nails.[28] The representative of Keystone was the only Petitioner witness to acknowledge its considerable downstream operations.[29] Keystone's operations include the Bartonsville, Illinois, plant which turns out the company's Red Brand products at "one of the largest wire mills in the world with over 2,000,000 square feet of manufacturing space on over 1,000 acres."[30] Keystone's Engineered

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24 *Transcript* at 72 and 122.

25 *See* Exhibit 10.

26 *AWPA Postconference Brief* at 17 and Exhibit 5.

27 *Transcript* at 119.

28 *See* Exhibit 11. *See also AWPA Postconference Brief* at 16 and Exhibit 3.

29 *Transcript* at 69.

30 *See AWPA Postconference Brief* at 17 and Exhibit 4.

Wire Products Division makes welded wire mesh for steel reinforcement applications, and Keystone recently acquired Strand-Tech Martin which makes prestressed concrete ("PC") steel wire strand and high-carbon wire.[31] Although Petitioner Charter Steel did not appear at the hearing, its sister division Charter Wire manufactures drawn wire for numerous end use applications.[32]

Independent wire producers testified at length about the competition they face from their wire rod suppliers.[33] Mr. Johnson of Mid-South Wire noted that his company competes with all four Petitioners on a range of products.[34] Mr. Stauffer of Insteel concurred that his company also "must compete with our domestic rod suppliers in downstream wire and wire products."[35]

What also concerns these and other independent wire producers is the ability to obtain sufficient quantities of wire rod in the event of shortages or other disruptions in supply. Mr. Johnson observed that, in the competition for a finite supply of wire rod, "the U.S. rod mills will take care of their internal and related wire operations before they ship to outside customers like Mid-South and other independent wire drawers."[36] Mr. Stauffer agreed that his company is "certain if wire shortages or delays develop as a result of these cases rod mills will give preference to their own downstream wire facilities."[37] Finally, Mr. Johnson observed: "{I}t is

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31 *See* Exhibits 12 and 13. *See also AWPA Postconference Brief* at 17 and Exhibit 4.

32 *Id.* at 17 and Exhibit 6.

33 *See Prehearing Brief* at Exhibit 6.

34 *Transcript* at 149.

35 *Id*. at 153.

36 *Id*. at 149.

37 *Id*. at 153.

never a good practice for any business in any industry to be wholly dependent upon your competitors for all your raw materials."[38]

Petitioners tried to downplay these concerns at the hearing by claiming that "we will place on hold, push back our own internal needs of rod to satisfy external rod requirements" and "{w}e've very careful to treat everybody fairly including external compared to our internal {customers}."[39] However, these claims ring hollow given the enormous investment by the domestic rod mills in their downstream wire operations. As the table above shows, these mills already dedicate one third of their rod production to their captive operations. In fact, Charter Steel probably captured the true position of the domestic rod mills in promoting its wire products by pointing out that it is a vertically integrated so there is "virtually no risk of service interruption."[40] Thus, when push comes to shove, domestic rod mills will supply their own downstream wire and wire products operations first so that service to those customers will not be interrupted.

V. SUBJECT IMPORTS DID NOT CAUSE THE IDLING OF REPUBLIC'S BAR MILL IN LORAIN, OHIO, OR THE CLOSURE OF ARCELORMITTAL'S MILL IN GEORGETOWN, SOUTH CAROLINA

Petitioners claim that the idling of Republic Steel's bar mill in Lorain, Ohio, and the closure of ArcelorMittal's mill in Georgetown, South Carolina, were the result of subject imports of wire rod that entered the U.S. market as Chinese imports exited. However, Republic's decision to idle its Lorain bar mill was due to lost demand for steel rounds and bar resulting from imports of pipe and tubes—not wire rod. And although ArcelorMittal cited, *inter alia*, "imports" in its public closure announcement for the Georgetown mill, ArcelorMittal's senior management

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38 *Id*. at 149.

39 *Id*. at 121–122.

40 *See AWPA Postconference Brief* at Exhibit 6.

told the mill's most significant customer prior to the closure that the real reason for the decision to close was high input costs caused by the lack of port access to the mill. In short, neither of these closures was caused by wire rod imports from the subject countries.

Republic idled its bar mill in Lorain, Ohio in March 2016. Prior to this, public statements from the company attributed the problems at the mill to the dramatic decline in the domestic oil and gas markets and the loss of the mill's primary customer, U.S. Steel Tubular Division. Mr. Shields, former sales manager for Republic Steel, testified that imports of wire rod had nothing to do with the closure of the Lorain mill. Instead, the collapse of the domestic oil and gas sectors in 2015 resulted in the idling of U.S. Steel's tubular operations in Lorain, depriving Republic of its primary customer.[41] Because demand for the steel rounds and bar produced in Lorain became "almost nonexistent" due to "depressed demand levels" in the oil and gas sector, Republic shut down the Lorain mill in March 2016.[42]

The petition for trade adjustment assistance ("TAA") filed on behalf of the workers at the Lorain mill confirmed that: "The reason for separation of workers are due to the drop in orders from Republic Steel's primary customer, US Steel. Republic Steel is located on the property next to US Steel, providing USS with steel rounds for the pipe and tubular market. Republic has also experienced a cessation of orders from other customers due to the drop in oil pricing and the continued dumping of pipe in tubular rounds from China and Korea."[43]

Furthermore, Republic's Lorain mill was a bar mill, not a rod mill. As Mr. Stauffer of Insteel testified: "Lorain never produced sizes that we could consider to be relevant in

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41 *Transcript* at 141.

42 *Id.*.

43 *See* Exhibit 14. Notably, in the petition for TAA, Republic described the products produced at the Lorain mill as "steel rounds and bars"; there is no mention of wire rod.

the U.S. domestic rod market."[44] This was confirmed by Mr. Shields, who testified that the Lorain mill stopped producing standard wire rod sizes over 15 years ago.[45]

Thus, the idling of the Lorain bar mill was caused by the decline of the domestic oil and gas markets, depressed demand for steel rounds and bars, and the loss of the mill's primary customer—US Steel. None of these factors had anything to do with subject imports of wire rod.

Similarly, subject imports were not the reason for the closure of ArcelorMittal's Georgetown mill in May 2015. The record of these investigations is replete with contemporaneous and more recent press articles describing the logistical problems caused by the silting of the channel in the Georgetown port. Attached as CBI Exhibit 15 is an affidavit of

[

]

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44 *Transcript* at 154.

45 *Id.* at 142.

[ ].[46]

As noted in the affidavit, [ ].

Mr. Stauffer of Insteel testified that ArcelorMittal officials were candid with Insteel about the reasons for the closure of the Georgetown mill—and it was not due to subject imports: "{T}he Georgetown mill had insurmountable problems that significantly increased its costs. We were told by ArcelorMittal's management that high input costs as well as increased domestic competition from Nucor's state-of-the-art rod mill in Darlington were the main factors that caused the shutdown of the Georgetown mill."[47] According to Mr. Stauffer, "{t}hese factors would have led to the closure of the mill with or without imports in the market."[48]

VI. CONCLUSION

For the foregoing reasons, we respectfully urge the Commission to make a negative determination in these investigations.

Respectfully submitted,

/ s / Frederick P. Waite

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November 28, 2017

46 *See* CBI Exhibit 15.

47 *Transcript* at 153.

48 *Id.* at 153.

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THE UNITED STATES INTERNATIONAL TRADE COMMISSION
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IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF: **CARBON AND CERTAIN ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM**	USITC INV. NOS. 701-TA-573—574 AND 731-TA-1349—1358 (FINAL)

EXHIBITS

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

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Dated: November 28, 2017

EXHIBIT LIST

EXHIBIT 1	RESPONSE TO QUESTION FROM VICE CHAIRMAN JOHANSON REGARDING DIFFERENCES BETWEEN STEEL PRODUCED BY BASIC OXYGEN FURNACE ("BOF") VERSUS ELECTRIC ARC FURNACE ("EAF") PROCESSES	Public Exhibit
EXHIBIT 2	RESPONSE TO QUESTION FROM DOUGLAS CORKRAN, OFFICE OF INVESTIGATIONS, REGARDING PRICES FOR IMPORTED WIRE ROD BEING HIGHER THAN PRICES FOR DOMESTIC WIRE ROD	Public Exhibit
EXHIBIT 3	MONTHLY SCRAP CHANGES AND ROD PRICE INCREASE ANNOUNCEMENTS	Confidential Business Information ("CBI") Exhibit
EXHIBIT 4	CORRELATION OF SCRAP AND ROD PRICES OVER THE PERIOD OF INVESTIGATION ("POI")	CBI Exhibit
EXHIBIT 5	EMAIL CORRESPONDENCE BETWEEN AWPA MEMBER AND ONE PETITIONER	CBI Exhibit
EXHIBIT 6	MONTHLY SCRAP CHANGES AND ROD PRICES PAID BY AWPA MEMBER	CBI Exhibit
EXHIBIT 7	MONTHLY SCRAP CHANGES AND ROD PRICES PAID BY AWPA MEMBER	CBI Exhibit
EXHIBIT 8	MONTHLY SCRAP CHANGES AND ROD PRICES PAID BY AWPA MEMBER	CBI Exhibit
EXHIBIT 9	ROD MILLS' AFFILIATED WIRE COMPANIES	Public Exhibit
EXHIBIT 10	NUCOR'S 2016 FINANCIAL STATEMENT	Public Exhibit
EXHIBIT 11	GERDAU'S DOWNSTREAM WIRE AND WIRE PRODUCTS OPERATIONS	Public Exhibit
EXHIBIT 12	KEYSTONE—WIRE PRODUCTS OPERATIONS	Public Exhibit
EXHIBIT 13	KEYSTONE—STRAND TECH	Public Exhibit
EXHIBIT 14	PETITION FOR TRADE ADJUSTMENT ASSISTANCE FOR REPUBLIC'S LORAIN MILL	Public Exhibit
EXHIBIT 15	AFFIDAVIT REGARDING REASONS FOR CLOSURE OF ARCELORMITTAL'S GEORGETOWN MILL	CBI Exhibit

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

This Public Exhibit Does Not Contain Confidential Business Information.

<u>EXHIBIT 1</u>

RESPONSE TO QUESTION FROM VICE CHAIRMAN JOHANSON REGARDING DIFFERENCES BETWEEN STEEL PRODUCED BY BASIC OXYGEN FURNACE ("BOF") VERSUS ELECTRIC ARC FURNACE ("EAF") PROCESSES

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AMERICAN WIRE PRODUCERS ASSOCIATION

RESPONSE TO QUESTION FROM VICE CHAIRMAN JOHANSON REGARDING DIFFERENCES BETWEEN STEEL PRODUCED BY BASIC OXYGEN FURNACE ("BOF") VERSUS ELECTRIC ARC FURNACE ("EAF") PROCESSES

QUESTION —

Vice Chairman Johanson:

> *Could all please explain how the use of a blast oxygen furnace versus an electric arc furnace to produce raw steel in imparts differences in the resulting wire rod produced from the raw steel? And do you all have any industry or metallurgical literature that supports and describes the differences that you identified, particularly as they relate to tire cord?* (*Transcript at 239, 241.*)

RESPONSE —

Attached is an article which discusses residual or tramp elements in EAF-produced steel, causing decreased drawability and surface defects.

ATTACHMENT TO EXHIBIT 1

JERNKONTORETS FORSKNING

D 819
(IM-2006-124)

Opportunities and dangers of using residual elements in steels: a literature survey

Report by Olivier Rod, Christian Becker, Margareta Nylén, KIMAB

Keywords:
Steel scrap, recirculation, residual elements, micro alloying, properties, iron and steel industry

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Abstract

The growing recirculation of steel scrap coming mainly from the collection of obsolete products may result in a substantial increase of residual elements in steel, which is often considered as a problem. However, residual elements in scrap are used as effective micro alloying elements if the appropriate production is used.
The current restrictions on levels of residual elements have often been set from a cautious viewpoint. With a deeper understanding of the dynamics behind the interactions of different elements, it is reasonable to believe that the level of residual elements can be increased in some high quality steel products.

This study is aimed to give an overview of the situation and state of the art concerning residual elements in low alloy low carbon steels, their effect on processing and final properties of the steels and the way they are used today.

An overview of the possible effects of residuals elements on down-stream process and end properties of steels, classified by their nature in the steel, is proposed through a summarising figure.

The most remarkable trend in the literature is the dominance of Cu in the elements studied: most of the studies are concerned by the influence of copper, alone or in combination with other elements.

The effect of residual elements is presented in respect to their effect on:
Hot working: mainly hot-shortness problem related to Cu are studied, but even grain boundary segregation mainly of Sn.
Cold working: study of elongation and drawability. Residual elements mainly contribute to harden the matrix (Ni, Cr, Cu, Mo, Sn and As). Copper was shown in some cases to have positive effects on formability when processing and heat-treating the material properly.
Hardenability: most residual elements increase the hardenability by slowing down the ferrite and pearlite reactions.
End properties: most residual elements increase the strength and decrease the ductility, which is mainly due to solid solution hardening and also to precipitation.
Grain boundary embrittlement, is due to the segregation of elements at the grain boundaries during cooling, coiling and final annealing (mostly Sn, Sb, As, P).
Welding: most of the residual elements contribute to the hardenability in the HAZ in a more or less negative way.

Table of Contents

1. Introduction

The aim of this literature survey, together with feedback from the Swedish steel industry, is to give a basis for further investigations about residual elements in steel.
It is aimed to give an overview of the situation and state of the art concerning residual elements in steels, their effect on processing and final properties of the steels and the way they are used today. Focus is put on low alloy low carbon steels. Stainless steels are not considered.

2. Searching motor

Search was done using mainly CSA Metadex database, and even Weldresearch, IIW, and CORDIS (database about EU projects).
Search criteria shown in Table 1 have been used.

Table 1 Search criteria used. The red crosses indicate the search combinations that were studied. The red lines show the combination for which no reference was found.

	Residual elements	Tramp elements	Copper	Nickel	Tin	Vanadium	Manganese
Corrosion	X	X					
Formability	X	X	X		X	------	------
Hardenability	X	X	X		X	X	X
Strength	X	X	1990->				
Ductility	X	X	------		X	X	X
steel	X	X					
Weldability	X	X	X	X	X		
Machinability	X	X	X	X	X		

3. Recycling of steel – general facts

Steel is one of the more recycled materials. Iron and steel industry in Sweden is in a great extent based on scrap use. [1] The growing recirculation of scrap coming mainly from the collection of obsolete products may result in a substantial increase of tramp elements in steel. [2].
Scrap is not a waste material but a valuable raw material with a high energy content. Every ton of recycled steel scrap saves 1134 kg iron ore, 635 kg coal and 54 kg lime. The production of new steel from scrap in EAF (electric arc furnace) consumes about half of the energy necessary for producing steel from iron ore. Production of steel from scrap compared to the production based on reduction of iron ore with coke reduces the emission of CO_2 and other harmfull gases and consumes less water too. Scrap purification has also economical aspects regarding the value of residual elements in steel.

Long products are manufactures usually with EAF route, while BOF (basic oxygen furnace) plants mainly produce flat products. Steel scrap makes for almost 100% of the iron-bearing charge in EAF steelmaking, while basic oxygen furnaces can process only up to 20% scrap. Europe and North America are increasing the skare of EAC steelmaking at the expense of integrated steel production and the trend appears to be long term. The driving forces for this change are strong: availability of scrap, social pressure to recycle materials and economic benefits to be reaped from the small structure associated with this short and slim production route. [3]

According to [4], the residual elements problem do not surface as long as steel scrap is used for making shapes, bars and other steel products that have lenient residual elements restrictions. Such a situation has been maintained until the obsolete accounted for 30% or less of all ferrous raw materials.
In Japan the generation of obsolete is predicted to exceed 40% of total steel production in 2010. In that case the steel scrap generation will surpass the demand unless steel scrap is used to make steel products other than shapes and bars, for example sheets. Composition of various steel grades available on the Japanese market is given in Table 2.

Table 2 Examples of composition of various grades of scrap on Japanese market.

Grade		Cu	Sn	Cr	Ni	Pb	Zn
heavy	HS	0.13	0.012	0.05	0.08	–	–
	H1	0.09	0.003	0.07	–	–	–
	H2	0.24	0.018	0.10	0.10	–	–
	H3	0.33	0.015	0.19	–	–	–
pressed	A pressed	0.64	–	0.03	0.11	–	–
	C pressed	0.64	0.40	0.05	0.06	–	–
	new punched	0.04	–	0.04	0.02	–	–
shredded		0.23	0.01	0.28	0.07	0.026	0.22
turnings		0.19	–	0.27	0.09	–	–

The most spread way of thinking is that the problem to be solved is the economic removal treatment of residual tramp elements in the steelmaking process. [5]
Copper and tin are the residual elements that adversely affect the hot workability of steel. According to some authors, in order to prevent the occurrence and accumulation of unrecyclable scrap, new technologies ensuring removal ratios of 55% for copper and 30% for tin have to be developed by 2010. [6]

Steel scrap is divided into home scrap, process scrap and obsolete scrap.
Since home and prompt scrap quantities are limited, an increase in scrap demand obviously leads to the following dilema. On one hand, the EAF intends to conquer new, higher quality steel markets, but on the other hand, it has to rely more on obsolete scrap, the quality of which decreases. [7]
In 1996, of a new Scrap Grading System (SGS) based on a clear description of scrap quality was introduced in Europe (Table 3). Quality has 2 components: scrap purity expressed in terms of metal (or iron) content and of level in tramp elements and scrap size and density [8]. This grading system is referred to in the Swedish system, where the scrap is even divided in different classes depending on the shape, size, state and origin (see reference [9]).

Table 3 European scrap grading system.

Type of scrap	Specification code	Impurity content in %		
		Cu	Sn	Cr, Ni, Mo
Obsolete scrap	E 3 E 1	≤ 0.250 ≤ 0.400	≤ 0.010 ≤ 0.020	Σ ≤ 0.250 Σ ≤0.300
Home scrap with low content of tramp elements, free from coated steel	E 2 E 8 E 6	Σ ≤ 0,300 Σ ≤ 0,300 Σ ≤ 0.300		
Shredded scrap	E 40	≤ 0.250	≤ 0.020	
Steel turnings	E 5 H E 5 M	subject of additional specification ≤ 0,400	 ≤ 0,030	 Σ ≤ 1,0
Scrap with high content of tramp elements	EHRB EHRM	≤ 0.450 ≤ 0.400	≤ 0.030 ≤ 0.030	Σ ≤ 0.350 Σ ≤ 1.0
Shredded scrap from municipal waste incinerators	E 46	≤ 0,500	≤ 0,070	

4. Residual elements

An element can be regarded either as an alloying element or as a tramp element depending on its content in steel and on the steel grade being produced.
Residual elements in steel are usually defined as those elements left in the steel after refining which are not specifically required and in many cases are considered harmful to the product properties when present in a too high concentration. The most important residual elements are: Cu, Sn, Zn, Pb, Bi, Sb, As, Ni, Cr, Mo and V. [10]
There are 3 main mode of existence of residual elements in scrap: in pure state, as coating material and as alloying additions.[6]
Some metallurgical phenomena related to an increase in the level of tramp elements are clearly unfavorable, but some may be beneficial, depending on the final application of the product.[3]

In the following chapters, the modes of existence and effects of residual elements on processing and final properties of steels are treated, in a general matter and also through some more specified relevant case studies.
Tables in chapter 7 are summarising the results presented in some general studies on the influence of residual elements.

4.1 Sources of residual elements

Reference [6] lists sources of the main tramp elements in steel scrap:
The main sources of Cu are discarded passenger cars, structural steel with up to 0.5%Cu (mild resistance to corrosion and precipitation hardening), sheet.
The main sources of Sn are post-consumer tinplate packaging and solders.
The main sources of Zn is protective coating.

The main sources of Pb (decreasing) are free-machining steels, solders and pigment in some paints.
Cr, Ni, Mo and V are used as alloying elements in numerous steel grades. Ni is moreover used as a constituant of the ZnNi coating of galvanised steel sheets.

This list is completed by Table 4, where the source of residual elements not usually monitored in steel making is given.

Table 4 Sources of tramp elements not usually monitored in steel making [57]

Elements	Sources
Antimony	Bearing Metals, Lead Shrapnel, Storage Battery Plate, Roofing Gutters and Tank Lining, White Pigment, Antimony Black
Arsenic	Arsenical Copper, Pig Iron
Bismuth	Component of Fusible Alloy with Lead
Boron	Steel Scrap, Refractory
Cadmium	Electroplating of Aluminium. Steel and Iron, Yellow Pigment, Cd, Cu.
Lead	Steel Scrap, Railroad Locomotive Wheels, Batteries
Zinc	Galvanizing, Metal for Diecasting, Dry Batteries, Zn Rich Paint to Steel

Table 5 presents a summary of the main categories of market scrap and their typical contents of residuals. Car shredded and heavy scrap contains an average of 0.25% of copper.

Table 5 Main categories of market scrap with typical content of residual elements [8]

Category of market scrap			Chemical compositions after melting (%)				
			Cu	Sn	Ni	Cr	Zn*
Market scrap	Obsolete	Car shredded scrap	0.23	0.052	0.069	0.123	(0.050)
		Heavy scrap	0.234	0.017	0.070	0.130	(0.210)
		Can scrap	0.050	0.128	0.032	0.061	(0.00)
	Factory bundle		0.027	0.002	0.020	0.031	(0.70)
	Home scrap		0.021	0.01	0.050	0.030	(0.01)
Pig iron scrap			0.01	0.002	0.02	0.02	(0.002)

* Before melting

4.2 Residual elements in steel making

Figure 1 shows the different possible ways of production of steel from ore or scrap. The most usual way to process scrap is by melting in electric arc furnace (EAF). Scrap is also added into steel produced from ore in the oxygen furnace.
Long products are manufactures usually with EAF route, while BOF (basic oxygen furnace) plants mainly produce flat products.
Steel scrap makes for almost 100% of the iron-bearing charge in EAF steelmaking, while basic oxygen furnaces can process only up to 20% scrap.

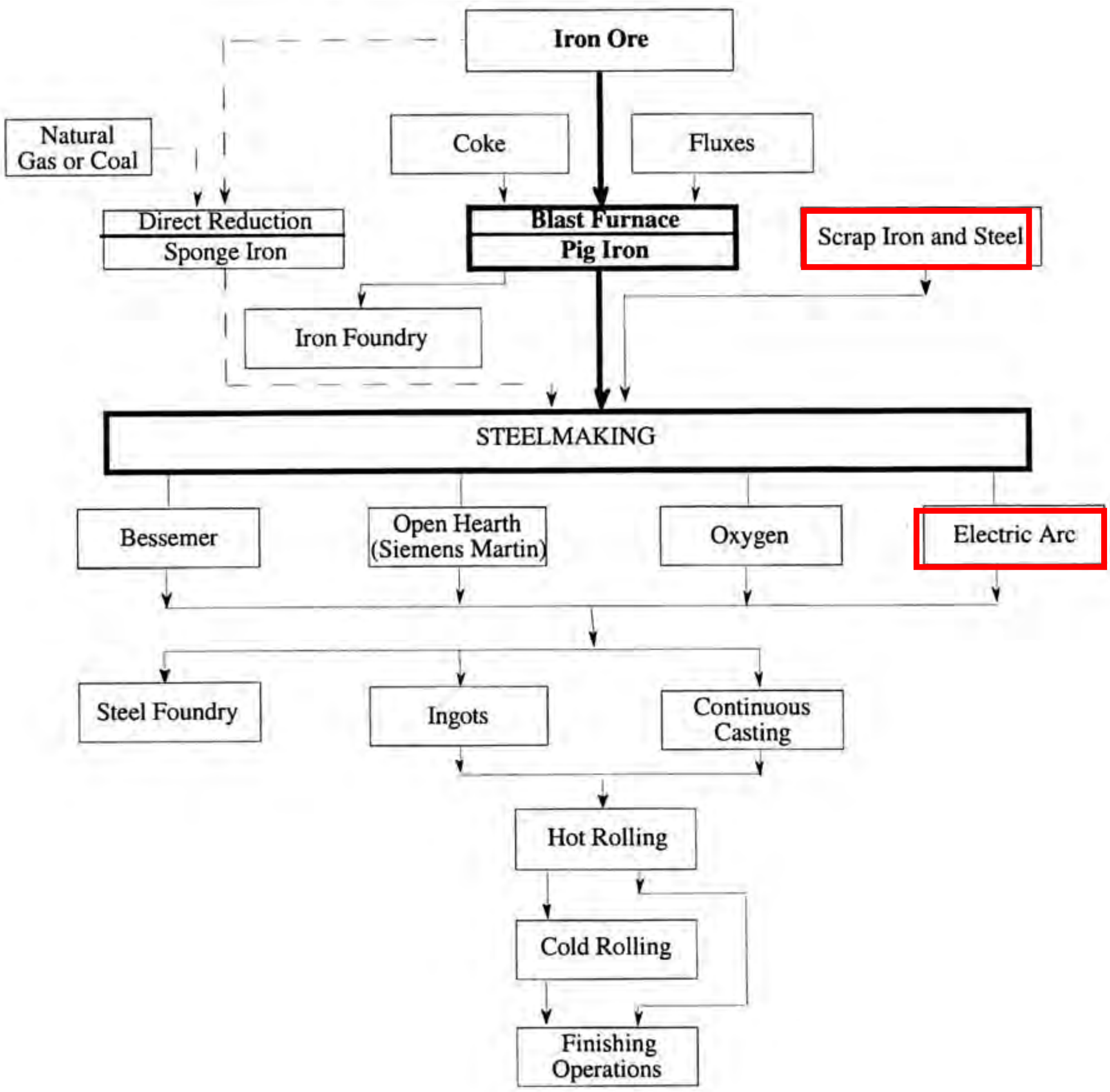


Figure 1 Iron and steel making processes [11]. The red marks show the most common way of processing scrap. It should be noted that recycled material containing large amounts of residuals are even often used in foundry to produce low-value cast iron products.

During melting operation, the different residual elements show different behaviours. Some mostly remain in molten steel while others mostly go to the slag or to gases. Figure 2 shows for the main residual elements a summary of these behaviours, which are related to the oxidation and reduction reactions of each element and to their physical state, see Figure 3. Note that **Figure 2** could be completed by adding Hg to the elements moving to gases.

Elements remaining in the molten steel bath are the one, which are most relevant to study when considering effects of residuals on steels products and down stream process.

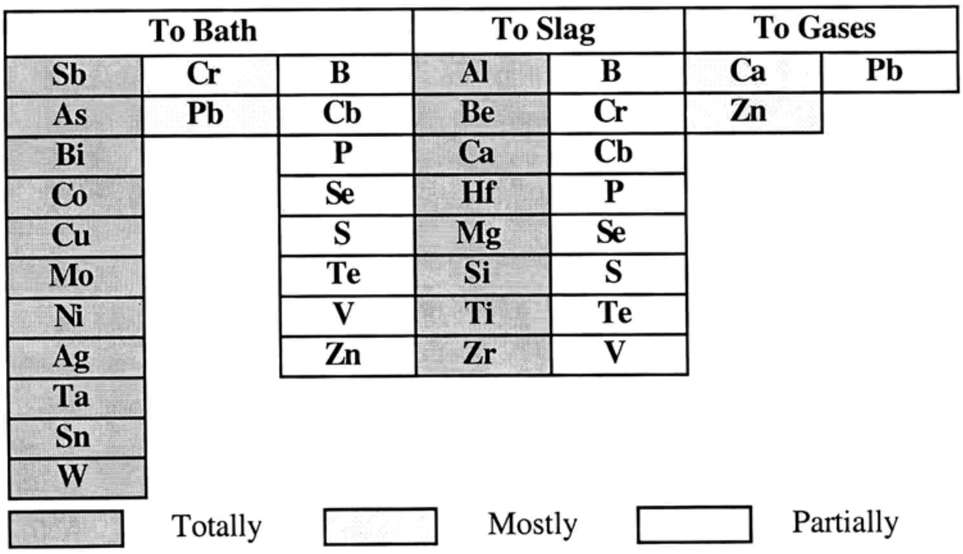


Figure 2 Some residual elements present in commercial grades and general behaviour under meltdown conditions in EAF operation [11].

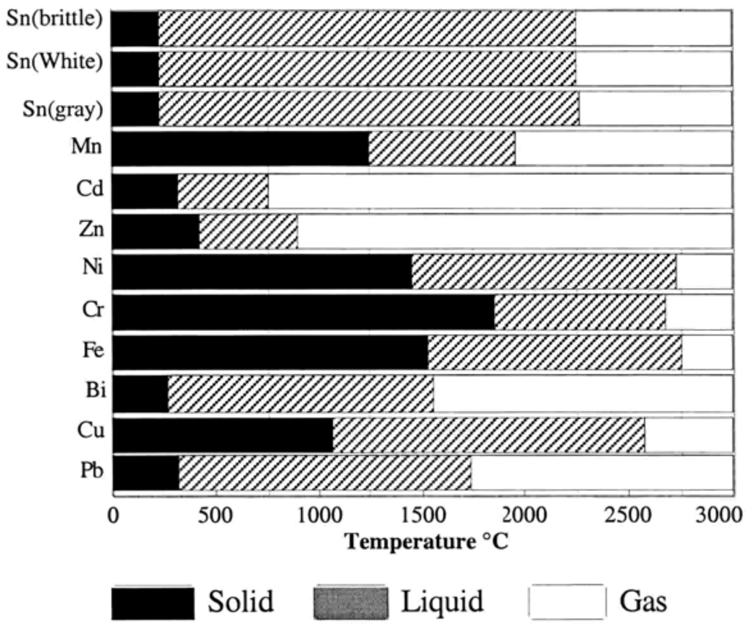


Figure 3 Physical states of some residual elements [11].

4.3 Removing of residual elements

Removing of residual elements is a broadly studied field, which is treated in many articles. As it is not the topic of this review, only some references are named here.

All of the various methods for the removal of residual elements from liquid steel or solid scrap are more or less costly and time-consuming steps in the production chain from scrap to steel. Different techniques of removal of residual elements are reviewed in reference [10]

Article [4] deals about how to remove the residuals elements copper and tin from steel scrap and change them into such form that they are stable and exert no adverse effect on the environment and presents the results of common work of two research groups in Japan.

A number of technologies for removal of Cu are named in article [12] and a new way is proposed based on:

- oxidation of solid ferrous scrap in air or other oxidizing environments
- followed by fluxing of the copper oxide in the oxidized solid scrap by using molten slag at temperatures below steel scrap melting point.

The available thermodynamic data of the tramp elements in molten steel are summarized in reference [5]. The possibility of the removal of tramp elements from molten steel by using calcium-metal halide fluxes is thermodynamically estimated. The calcium-metal halidefluxes have an excellent refining ability.

Finally, Table 6 lists possible methods used to sort steel scrap and eventually to remove residual elements.

Table 6 Possible removal methods of residual elements [11]

Scrap Treatment
Magnetic separators
Heavy-media separators
Electrostatic separators
Eddy-current separators
Hydrometallurgy
Electrochemistry
Zone refining
Fractional solidification
Melt filtration
Volatilization
Vacuum arc refining
Inert gas injection
Reactive gas injection
Pyrometallurgy
Slag-metal reactions
Powder injection

4.4 Different modes of existence of residual elements

Reference [6] makes a distinction between residual elements, having an influence on the processing conditions and on the final mechanical properties of steel products, because of their presence in solid solution (mainly Mo, Cr, Ni, Cu) and because of their segregation at interfaces (mainly Cu, Sn, As, Sb). This is reviewed in this chapter.

Residual elements in solid solution

All metallic residual elements increase the strength/hardness and the hardenability of carbon and low alloy steels to different degrees when present in solid solution. hardness is related to the increase of strength when residuals are present in solid solution in the ferrite matrix while hardenability is related to the ability of the material to get hardened structures (bainite, martensite) when temperature treated.

The increase of hardeness is coupled with a general decrease in ductility. Toughness is little affected by Cr, Mo, Ni and Cu in solid solution excepted Ni which have a beneficial effect on the transition temperature of low-carbon ferritic steels.

As named, all metallic residual elements increase the hardenability of carbon and low alloy steels to different degrees when present in solid solution. Cr and Mo are the most efficient in this respect, Ni and Cu less. The effect of Cr is ambivalent and depends on the C concentration and its partioning between ferrite and carbides.

Residuals can also modify the microstructure of different phases. For eutectoid steels, Cr and Mo reduce the lamellar spacing of perlite. Cu reduces the degree of regularity of perlite and Ni has the opposite effect.

Precipitation

Residual elements can also precipitate and form inclusions in the steel matrix, alone or in combination with carbon (carbides), sulfur (sulfides) or N (nitrides). V, Nb, Ti, Zr, W, Mo, Cr and Mn are typical carbides builders and Mn and Ti are typical sulfide builders. The amount, distribution and size of the inclusions depends on the composition of the steel and on the treatment during down-stream process. Inclusions, if fine, mostly increase the hardness and strength of low alloyed steels. However, large inclusions can results in a more brittle material, and cause problems during production and final use.

Ti for example is used both as a dispersion hardener through the forming of titanium carbide particles, and as a sulphur binder to form hard sulphides and thereby improving cold working abilities. Titanium can also form precipitates that can act as nucleation sites for grains, contributing to a finer grain size.

Cu may precipitate at relatively high concentrations (>0,5%) during ageing treatment in the form of ε-Cu and thus impart a large increase in hardness. This effect is used in several steel grades (low alloyed steels used in the offshore, high resistance martensitic stainless steels). Increase of hardness depends on the Cu concentration in the steel, its degree of supersaturation and the time and temperature of ageing and of the preliminary structure of the steel.

Intergranular segregation

Residual elements may segregate to the grain boundary during cooling and coiling in the strip mill, or during final annealing after cold rolling. An important related aspect is the

ability of the elements to reduce grain boundary cohesion, which makes fracture more likely. Of particular interest for interface segregation are solid solutions atoms with an atom size larger than the iron atoms. residuals elements such as Sn, Sb and As, are of prime importance, see Figure 4. Tin is reported to segregate to grain boundaries of thin steel sheet and P, Sb and Sn are reported to segregate in high strength C-Mn steels and provoque temper embrittlement.
The lower the carbon content of the steel, the greater the segregation of residual elements on grain boundaries. Ni, Mn and Cr enhance the segregation of residuals while Mo, Ti and rare earth can combat it.

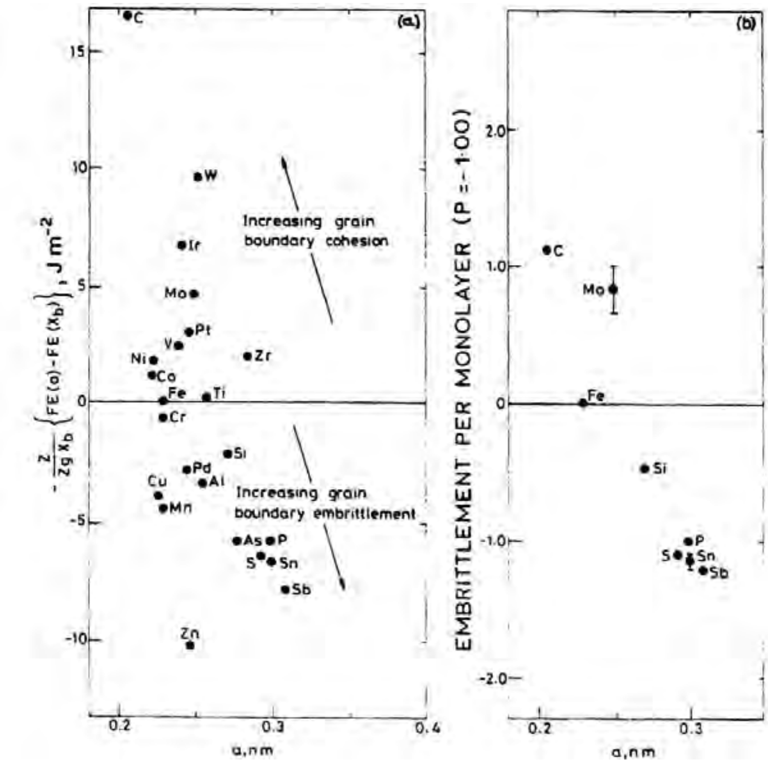


Figure 4 Relative grain boundary for different elements in iron at a given level of segregation. The more positive the ordinate value the more the element improves the grain-boundary cohesion and vice versa. (a) theoretical predictions. (b) experimental measurements.

<u>Surface segregation</u>
Surface hot-shortness is the result of the presence of liquid Cu at the scale-metal interface and the application of mechanical or thermo-mechanical stress. At high temperature the non-oxidized copper is progressively rejected at the scale-metal interface. Under oxidizing conditions and at concentrations of Cu no higher than 0,2%, the solubility limit of Cu in the austenite can be easily reached and Cu precipitates in liquid form, creating a liquid phase in the grain boundaries. The cracking severity is increased by the presence of other residuals elements such as Sn and Sb which lower the solubility of Cu as well as the melting temperature of the Cu-rich phase.
Nickel produces the reverse effect and is considered as the principal remedy against surface hot-shortness. Different studies present different values for the effect of Cu/Ni.
The addition of Si and Ni has some drawbacks, more adherent scale due to the presence of metallic Ni-rich phases which are mechanically anchored to the metal surface and create surface defects and increase wear of the process tools.

Segregation of Cu at the surface can however present certain advantage, which are useful in weathering steels [3]

The different nature of residual elements and their possible effects are summarised in Figure 5. This is developed in more details in following chapters.

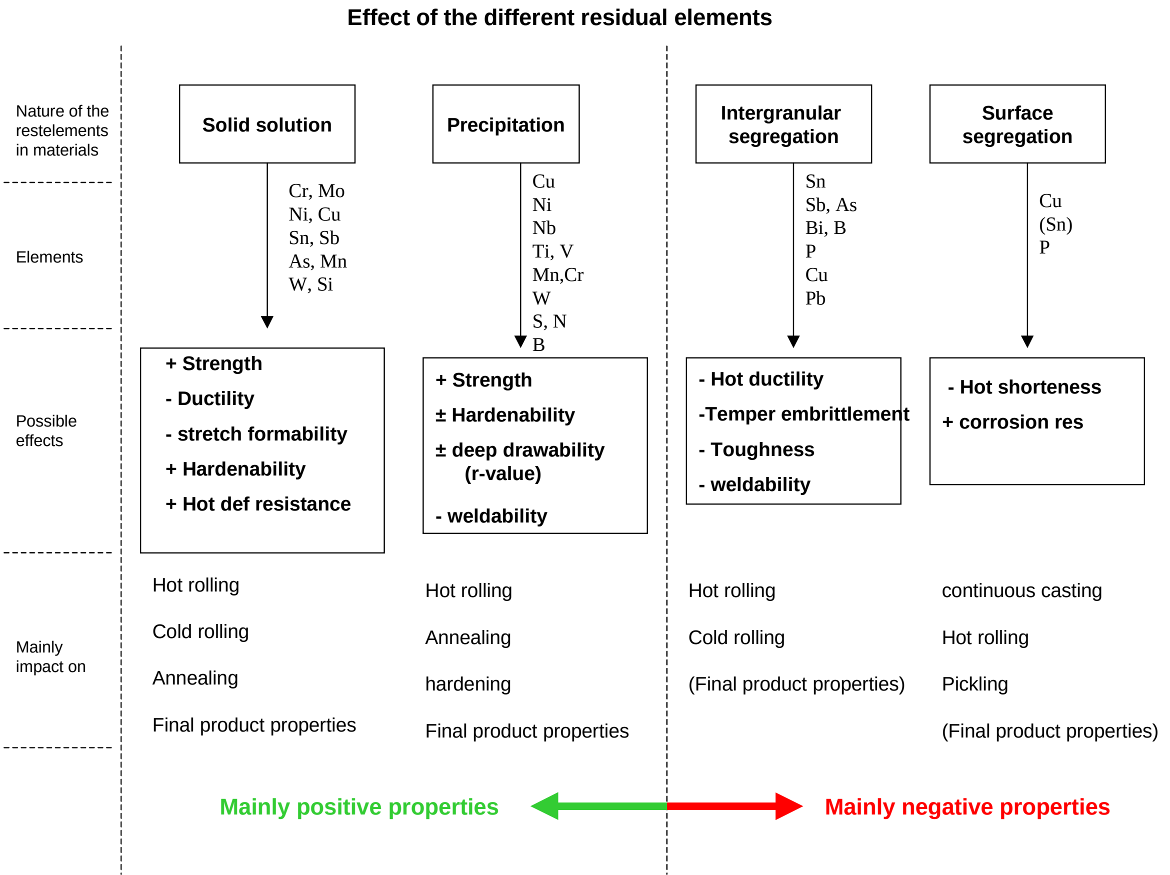


Figure 5 Overview of the nature of residual elements in steels and of their possible effects on down-stream process and end properties.

5. Influence of residual elements on down – stream process and end -properties

As a general statement, it is generally accepted that residual elements have a more pronounced effect on down-stream process and final properties for all applications that require low carbon clean steels than for the medium and high alloyed steels. (Extra low carbon ELC, low carbon LC and ultra low carbon ULC-IF).
The different steps of the down-stream processing, such as hot rolling, cold rolling, drawing, annealing, hardening, welding, and the final properties of the material are considered in this chapter. Tables summarizing the effects of residual elements given in literature are then presented in chapter 7.

5.1 Hot working

The general effect of residual elements in steel, in relation to the hot-working properties, has mostly been made in relation to copper. In reference [13] for example, it is stated that Cu is of main concern since, as a rule, if copper specifications are met the specifications for Sn, As and Sb are also met. This is because copper has been found to be the critical element in causing problems during hot-working (mainly hot-shortness) and has therefore been more extensively researched. In several cases however, it has been noted that copper have beneficial effects on the end products in regards to a finer grain structure and increased yield strengths. Consequently, this chapter is mostly discussing the influence of copper.

The influence of cooling rates and copper content on the microstructure of low carbon steel is shown in
Figure **6**. The microstructure after hot-working has a direct effect on the mechanical properties of the steel and its behaviour during cold working.

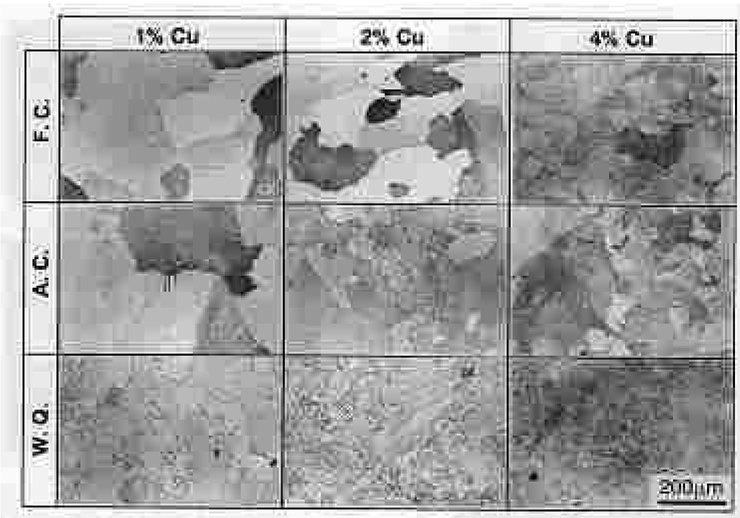


Figure 6 Differences in microstructure depending on cooling rate and copper content. The sample were solution treated at 1523 K for one hour and were either furnace cooled (F.C.), air cooled (A.C.) or water quenched (W.Q.) [14].

Only few studies show the effect of residual elements independently of copper. In reference [7], small additions of Sn, Mo, As and Cr were reported to modify the resistance to deformation during hot rolling of low carbon steels and ELC. Sn and Mo have the larger effect, while Cr and As show smaller effects (see Figure 7). The increase of the rolling force is to be related with a higher flow stress coupled with a retardation of the austenite recrystallisation. Therefore variations in residuals contents will do higher rolling loads and hence higher mill power consumption necessary, induce problems for the setup of the mills, and will contribute to a scatter of the steel properties

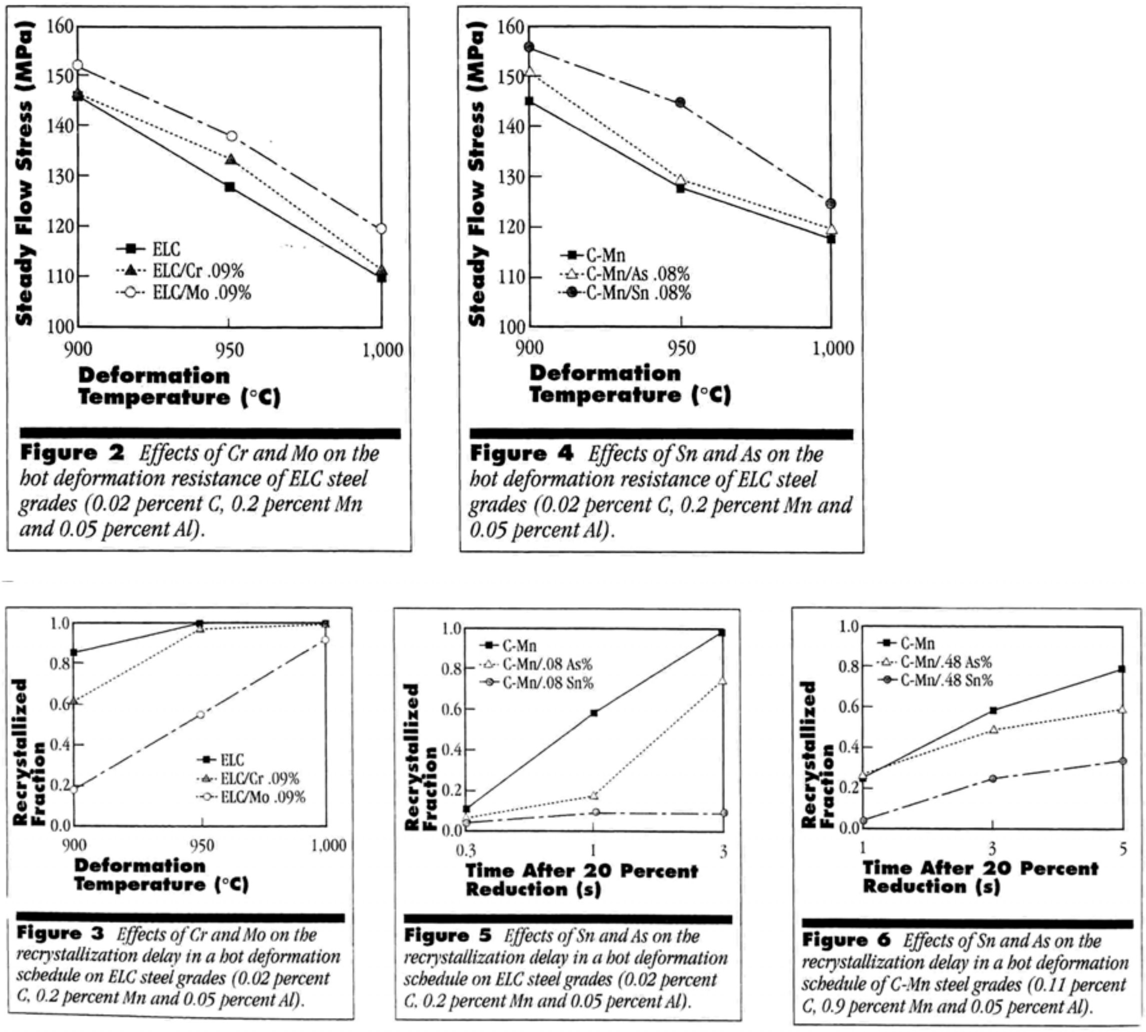


Figure 7 Influence of residual elements on the resistance to deformation and recrystallisation during hot rolling.

5.1.1 Surface defects, hot-shortness

Effect of copper – hot-shortness

It is considered that copper is the key element related to surface defects of steel. The preferential oxidation of iron on the surface causes enrichment of Cu and then formed liquid Cu penetrates into the austenite grain boundaries to tear the grains, leading to a loss of ductility in the temperature range 1050-1200 [16]. This can occur for copper contents over 0.1 – 0.2 % and is called for hot-shortness. [17].

Due to preferential oxidation of Fe at the surface, Cu is enriched in the grain boundaries creating a liquid phase. The enriched phase becomes liquid over 1090 ^oC. The liquid can then infiltrate the austenite grain boundaries (Figure 8) causing severe cracking (Figure 9).

The solubility of copper in iron increases significantly with temperature increasing the dispersion of copper into the grains. At 1193^o C the solubility of copper in austenite is reported to be about 10 w% and about 0.1 w% at 521^o C [18]. Although increasing the temperature will also increase the rate of oxidation of the surface. The forming of the copper rich phase occurs mainly in the struggle of two competing forces: copper enrichment in the grain boundaries due to preferential oxidation of iron at the surface, and dispersion of copper in to the grains through diffusion [19]. As the temperature increases the dispersion of copper becomes dominant, at longer oxidation times a steady state is reached and the enrichment and dispersion rates of copper along the grain boundaries becomes constant. It has been found that there is a critical temperature where maximum cracking occurs that is dependent on copper content. However at temperatures above 1200^o C up to 1300^o C there was a marked reduction in surface cracking at Cu levels up to 0.39 w% [15] to the point where no cracking could be found. These results are consistent with observations of Cu-enrichment in metal/oxide interface of plain carbon steels.

It has also been found that there is a critical heating temperature where maximum cracking occurs that is directly related to copper content [15] (Figure 10).

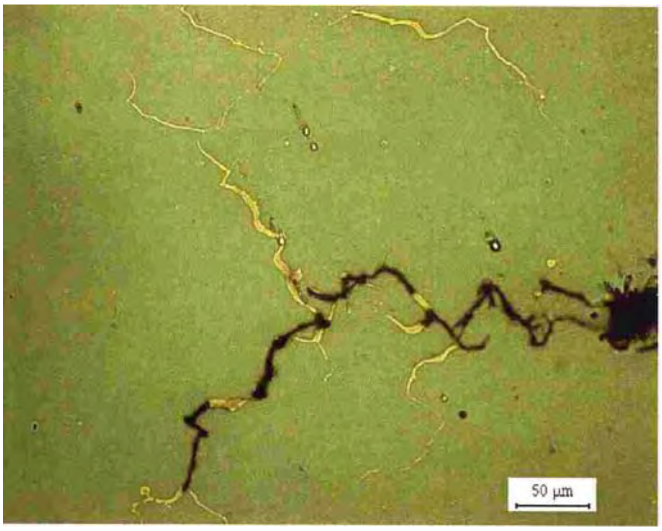


Figure 8 Cracks following austenite grain boundaries that has been infiltrated by liquid copper in a 2.5 w% Cu steel.

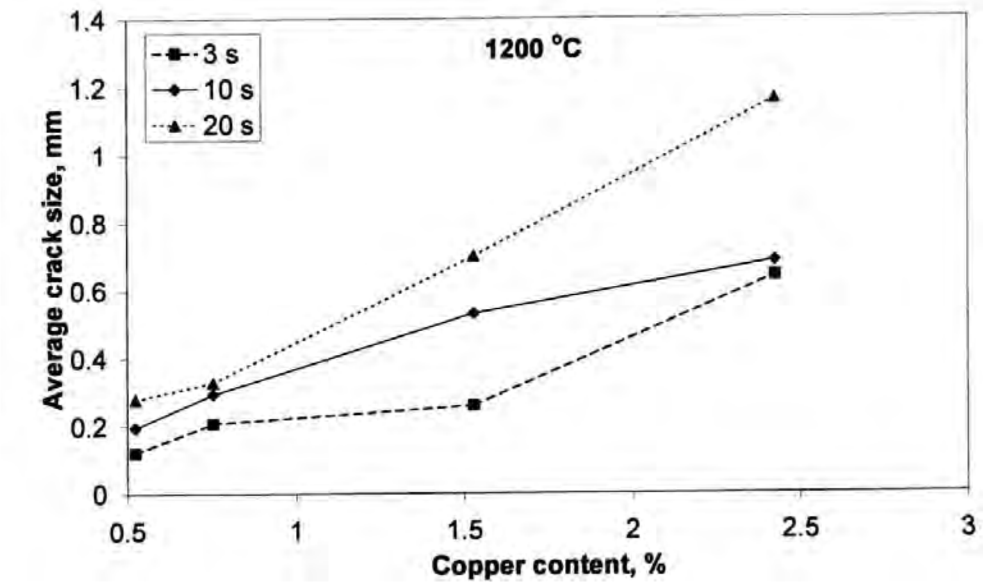


Figure 9 The effect of copper content on the average crack size in the hot ductility tests at varying oxidation times in air.

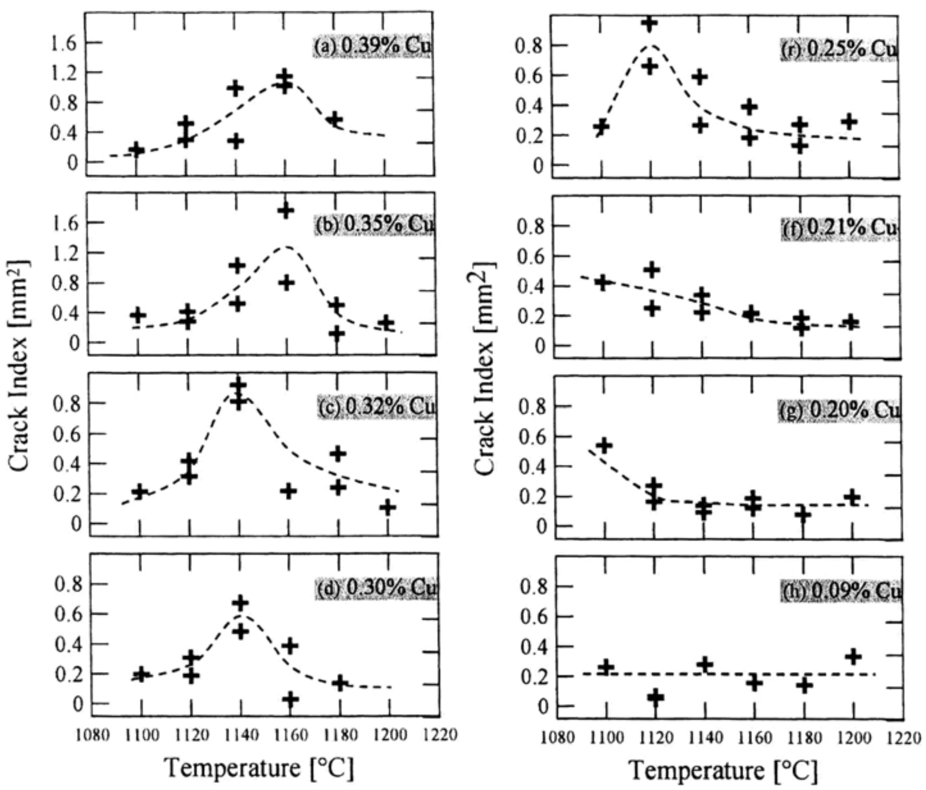


Figure 10 Crack index measurement for steels containing different levels of copper illustrating maximum cracking at a critical temperature. All samples were heated and oxidized for 10 min and deformed, cracking was then quantified by average crack surface area.

Different hot working steps – copper influence

A broad study of steel processing when Cu and Sn is added is presented in reference [3] This study is interesting to refer to more in details as it reviews in detail the different step of hot-working. It concludes that the complete production process from the steel shop to the wire drawing bench can accept levels as high as 0,8% Cu and 0.05% Sn. The different metallurgical phenomena related to residual elements seem to vary linearly with the increase in their contents. No discontinuity has been observed for copper levels between 0,15 and 0,8%. For low-carbon steels, the small effects for copper concentrations up to 0.35% can easily be compensated by minor process changes. Control of the re-heating process (atmosphere, T, t) offers way of reducing the intergranular brittleness induced by copper segregation.

The following observations were done for the different processing operations.

The cracks induced in engineering steels during **continuous casting** were intergranular in nature whose number increased with Cu content. The maximal crack depth was in the order of one γ grain. The cracks were preferentially located in the areas under mechanical stress, i.e. pinch roll or withdrawal roll. In the case where Ni was intentionally introduced, in the amount corresponding approximately to the Cu content, the billet had no cracks.

The most damaging conditions with respect to the surface product quality arise when secondary cooling induces a long hold time at 1100°C.

It is possible to suppress surface cracking by strong cooling after mould extraction. The process has two effects: avoids long holding time of the surface at 1100°C (ideal temperature for Cu segregation at scale-metal interface) and allows formation of a new finer and more equiaxed γ grain

The **reheating furnace** introduces two self-opposing characteristics where their relative importance depends on the mode of use. The furnace enables to some extent the rectification of pre-existing defects in the bloom, by consuming metal in primary oxidation. A long hold time is thus useful in reducing the number of cracks. Prolonged hold time can also give rise to a new array of low depth intergranular defects, which appears only in high Cu steels. This can be attributed to an enrichement in Cu of the scale-metal interface and possibly of the garin boundaries in the reheating furnace. The grain boundaries become sensitized and brittle and oxidize during the first passage through the rollers. This is function of the Cu content and process and can be adjusted so that it do not present an obstacle for processing.

The increase in oxidation rate with increasing tramp elements content has the advantageous effect of removing a thicker layer of the outer cracked metal. Higher heating temperatures, longer heating times or more oxidized furnace atmospheres also favour metal consumption. Removal of the cracks by this means however, induces new accumulation of Cu at the scale-metal interface.

Studies on wire rod in low carbon produced by **hot rolling**, consisting in mechanical studies, defect analysis and pickling resistance, were done.

Relative insensitiveness of the hot rolling process on the quality surface of billets was observed. New defects are created at the beginning of hot rolling, but their depth is limited to an acceptable range for copper contents up to 0,35%. Concerning the mechanical characteristics of wire rod, Cu affect tensile properties through solid solution strengthtening but the effect is small. 0.1wt% Cu increases the strength by some 8 Mpa. The increase in strength is accompanied by a small decrease in ductility: elongation is reduced by 0,3% with an addition of 0.1%wt Cu.

Chemical **pickling** and mechanical **descaling** was not affectde by the copper content of the wire rod.

Effect of the other residuals on copper hot-shortness

Other residual elements modify the effect of Cu on hot-shortness in a complex way. Several studies are defining a Cu equivalent that could have the form Cu + aSn + bSb – Ni, where a and b are constants ranking respectively from 5 to 10 and 8 to 10, according to different authors.

In reference [20], a similar equation was derived describing the hot shorteness tendency as a function of steel composition.

$$Cu_{equ} = \%Cu + 1/n\ [\ 0.4\ (5Mn+\%Cr) + 8\ (\%Sn+\%Sb) + 2\%As - \%Ni] \leq A$$

Where n is the number of elements in the equation and A is a value depending on experimental and production parameters and on the type of steel.

Reference [21] investigated the effect of alloying elements on the solubility of Cu in solid Fe. An addition of Co, Ni and Al results in an increase of the solubility of Cu, while that of V, Cr, Mn, Si and Sn decreases the solubility. Increasing the solubility of Cu may decrease hot-shortness as less copper should build a liquid film at the surface.

As seen in the equation above, the elements, which have stronger influence on Cu hot-shortness, and thus which are most extensively reviewed in literature, are Sn and Ni.

Tin in combination with Copper is highly detrimental for the susceptibility to hot-shortness in the steel. Tin lowers the melting point of the copper phase and decreases the solubility of copper in iron causing further enrichment [22]. However in low copper steels tin by itself does not seem to affect surface hot shortness and no significant enrichment seems to occur.

On the other side, Ni increases the solubility of Cu in iron lessening the susceptibility to hot-shortness. Ni affects the solubility of Cu in austenite and raises the melting point of the copper enriched phase. Adding 0.5 w% Ni to a low-carbon steel containing 0,5% Cu decreases the susceptibility to hot shortness. Moreover, in combination with an addition of 0.4 w% Si, only 0.26 w% Ni is needed to reach the same reduction of hot-shortness as if only 0.5 w% Ni is added. [22]

The effect of these three key-elements, Cu, Ni and Sn, on the hot-workability of mild steels was investigated and illustrated in papers [23] and [24] A hot rolling condition was simulated by oxidizing followed by tensile-deforming and the hot workability was assessed by measuring the number of surface cracks. The phases formed at the steel/scale interface were analysed and modelled, which is presented in Figure 11.

Sn as low as 0.04%increased the number of cracks in an 0.3% Cu bearing steel. Sn decrease the solubility limit for Cu in Fe, thus increasing the amount of liquid Cu enriched alloy and enhancing the surface cracking by Cu liquid embrittlement.

0.3% Ni supressed the cracking in an 0.3%Cu-0.04%Sn bearing steel. The phase calculation at an oxidation temperature 1100°C showed that the Cu and Ni enriched layer was solid. Therefore, the addition of 0.3%Ni suppressed the surface cracking in the Cu-Sn bearing steel.

For a 0.3%Cu bearing steel, the surface hot cracking occured only at 1100°C oxidation due to a liquid Cu enriched phase formed at the scale/steel interface. An addition of 0.15%Ni suppressed the surface cracking of 0.3%Cu bearing steel by eliminating all the Cu enriched liquid phases.

Cu (mass%)	Sn (mass%)	Ni (mass%)	Number of cracks (1/cm²)	Scale/steel interface	Alloys at scale/steel interface
0.3	0.04	–	11.4	scale 82%Cu-7%Sn-Fe penetration steel	**Liquid**
0.3	–	–	7.7	87%Cu-Fe penetration	**Liquid**
–	0.04	–	0	not observed (Sn diffusion into steel)	–
0.3	0.04	0.15	2.6	64%Cu-9%Sn -12%Ni-Fe penetration	**Liquid**
0.3	0.04	0.3	0.6	63%Cu-12%Sn -12%Ni-Fe 12%Cu-19%Ni-Fe	*Liquid* **Solid**

Cu (mass%)	Ni (mass%)	Oxidation temp. (°C)	Number of cracks (1/cm²)	Scale/steel interface	Phases at scale/steel interface
0.3	0.02	1000	0	scale 87%Cu-2%Ni-Fe steel	**Solid**
		1100	7.7	87%Cu-1%Ni-Fe penetration	**Liquid film**
		1200	0	87%Cu-2%Ni-Fe 9%Cu-2%-Fe	*Liquid droplets* **Solid**
0.3	0.15	1100	0.9	66%Cu-15%Ni-Fe 16%Cu-16%Ni-Fe	*Solid* **Solid**
		1200	0.6	16%Cu-27%Ni-Fe 10%Cu-10%Ni-Fe 6%Cu-1%Ni-Fe	*Solid* **Solid**

Figure 11 Relationship between Cu, Ni and Sn enriched phases and surface cracking

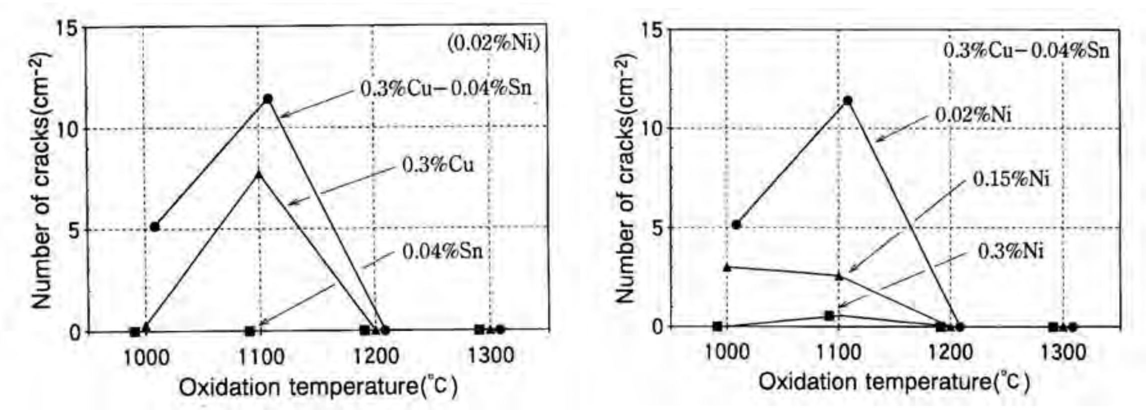


Figure 12 Influence of Cu, Ni and Sn on the surface cracking.

In reference [25] it was found that in 0.1 w% C steels, boron in amounts about 7 ppm seems to reduce the susceptibility to hot-shortness by altering the ability of the Cu phase to wet the surface of the austenite grain boundaries. One theory is that boron segregates to the grain boundaries and influences the surface boundary energy in the steel. However, to control the alloying to such an exact degree may be difficult.

The effects of Si and P on surface hot shortness due to Cu in low carbon steels are examined in reference [26] using a method based on tensile tests.
At 1100°C, single additions of 0.4%Si and 0.02%P were effective to decrease susceptibility to surface hot shortness, although these increased the oxidation rate. Duplex addition of 0.4%Si and 0.02%P decreased the oxidation rate and exhibited substantial effect on a decrease in the susceptibility. Addition of Si decreased the amount of Cu-

enriched phase at steel/scale interface, which may be due to internal oxidation of Si. The forming of a molten phase of iron and silicon oxide in the scale can work favourably to occlude any liquid copper into the scale, not allowing it to penetrate the steel is also suggested. Si also contributes to a decrease in the growth rate of the crack created by the penetration.
Addition of P seems to increase slightly the amount of Cu-enriched phase.
A critical stress exists to fracture the specimens by Cu-enriched liquid phase. The additions of Si and P increase this critical stress.
The influence of silicon on the evaporation rate of copper has also been studied 27. The affinity of silicon to iron in the melt affects the activity of copper in the bath. The evaporation of copper from the bath was found to be promoted by the decarbonization of the melt that caused turbulence in the gas/metal interface.

Avoiding hot-shortness
In order to avoid surface hot shorteness, the experimental critical levels tolerated in steels have to be adapted according to the process conditions. Thus, the most common way to avoid the problem is to dilute the contaminated steels by virgin iron sources, but it is costly.

Reference [17] propose two solutions to avoid hot shortness, based on that it is due to the fact that the preferential oxidation of iron on the surface causes enrichment of Cu and then formed liquid Cu penetrates into the austenite grain boundaries to tear the grains.
The first solution is to avoid oxidation and mechanical stress at the temperature around 1150°C. The second is to enhance the heterogeneous nucleation of liquid Cu at MnS precipitates inside the austenite grains. The behaviour of the heterogeneous nucleation of ultra-fine Cu precipitates using Fe-10mass% Cu alloys with or without MnS are compared.
The Cu precipitates are classified into 3 types:

- Liquid Cu at the garin boundariesw
- Globular Cu particles nucleated at MnS or inclusions
- ε-Cu of the FCC structure in the size 20-200nm which may be effective for physical properties.

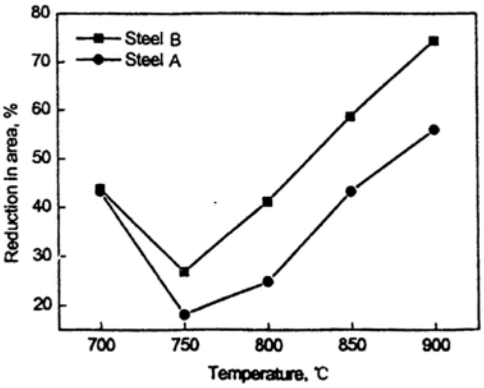
According to the authors, once the hot-shortness problem is solved, Cu or Sn may be utilized as effective micro-alloy elements.

Finally, reference [28] presents a review of russian studies on the effect of copper on structural steel and the problem of hot-shortness. Suppression of hot shorteness is achieved by introducing elements lessening the copper rich-phase and raising its melting point. Another direction is to change the heating and deformation temperature interval to decrease the oxidyzing power of the gas atmosphere and to shorten holding of the metal at high temperatures. Studies on different grades of structural steels showed that the allowable copper content in structural steels may be increased to 0,5%.

5.1.2 Grain boundary segregation

Low hot ductility in the temperature range 600-950°C met in some low carbon and low alloys steels is an industrial problem. Sn and also Cu are, even in that case, the critical elements.

The effect of Sn on the hot ductility of has been studied (continuous-casting thermal simulating tests). The hot ductility of a low carbon steel (0.15%) decreases with increasing Sn content and there is a trough in the RA-temperature curve, which is situated at 750°C (Figure 13 A). Non-equilibrium grain-boundary segregation of Sn produced during cooling is primarily responsible for the decrease in the hot ductility of the steel doped with Sn. There is a critical cooling rate for the tin segregation being between 5 and 20K/s at which the maximum segregation of Sn would be obtained (Figure 13 B).[30]



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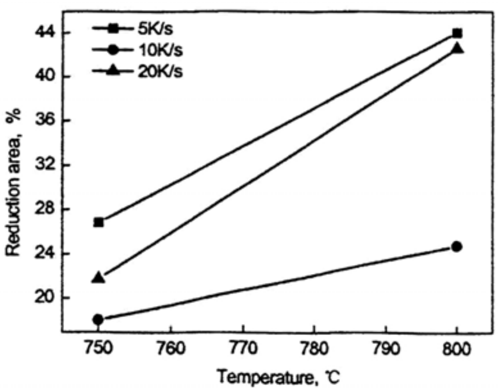


B

Figure 13 A) Hot ductility curves for a cooling rate of 10K/s. B) Effect of the cooling rate on the hot ductility of steel B. Steel A and B are low-carbon steels, steel B contains 0.061% Sn whereas steel B contains less than 0,005% Sn.

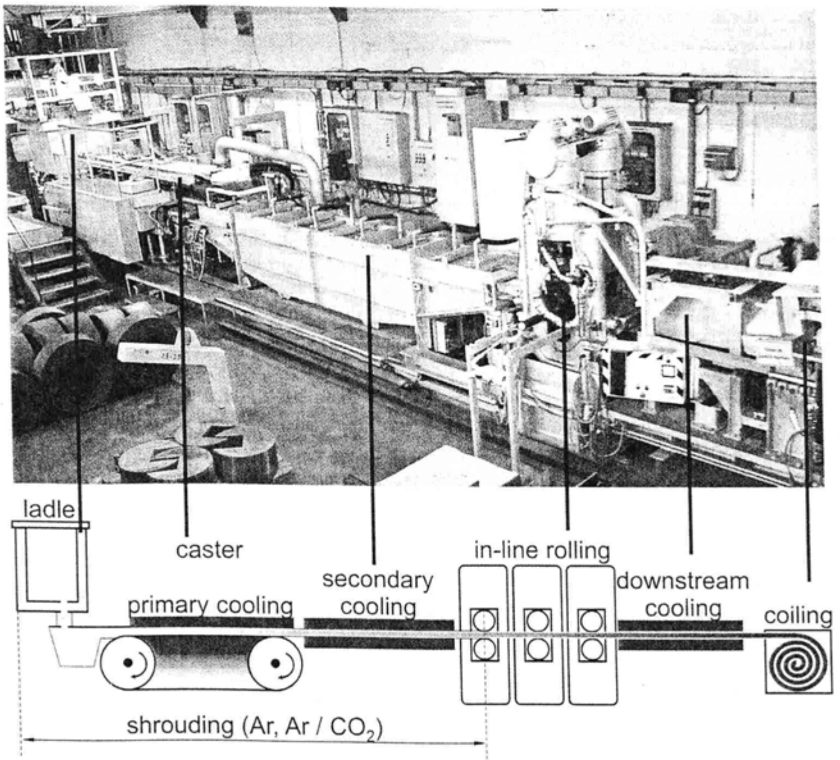
In reference [31], the influence of Cu and Sn on the hot ductility at the strain rate of 10^{-3} for steels with C contents from 0.002 to 0.15%w was investigated. The hot ductility dropped at austenite + ferrite two phase region just below A_3, namely 800 to 900°C. The hot ductility deteriorated more at higher C content, and furthermore with the co-addition of Cu and/or Sn. It was considered that the deterioration at austenite + ferrite two phase region in the Cu, Sn bearing steel was caused by the combined effect of following factors:

- The formation of proeutectoid ferrite along the austenite grain boundaries.
- The segregation of Sn at the interface between proeutectoid ferrite and austenite or at the austenite grain boundaries.
- The increase in the difference of the deformation strength between austenite and proeutectoid ferrite.

5.1.3 Direct Strip Casting

Direct near-net shape casting is an attractive process for the production of sheet metal. Post-treatment (heating/rolling) is omitted and faster solidification rates may produce new microstructures. This process may have some advantages as one of the future approaches for the efficient utilisation of steel scraps because it considers the detrimental effect caused by the impurities in scraps, mostly hot-shortness caused by copper. Thus, a higher content of tramp elements (Cu, Sn) is tolerable without quality loss (surface cracking). Moreover, it has economical advantages.

A detailed description of the DSC (Direct Strip Casting) process, technical features, solutions, advantages and possibilities is given in reference [32], from which the schematical representations of a DSC pilot plant shown in Figure 14 are reproduced.



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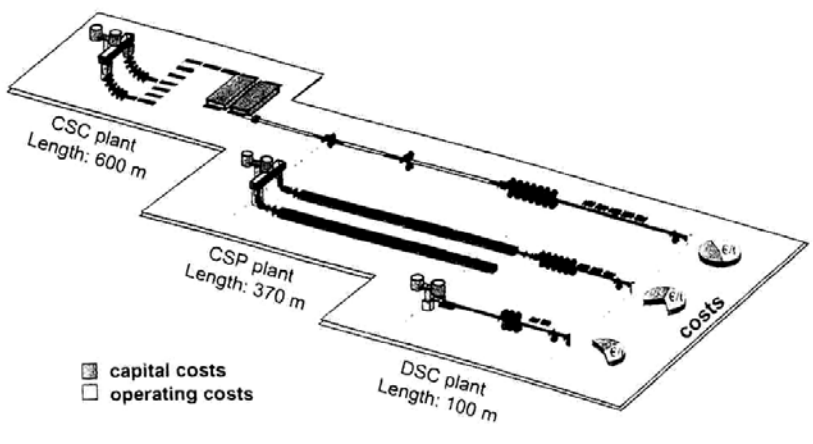


B

Figure 14 (A) DSC pilot plant. (B) Comparison of traditional and DSC casting plants.

Direct Strip Casting (DSC) is a method that combines short oxidation times with rapid cooling and direct rolling. This means that there is very little oxidation of the surface compared to conventional hot-rolling. Avoiding oxidation also means that there is less material loss and the enrichment of copper in the surface is avoided. From a ladle the melt is fed on to a water cooled conveyor belt. The sides are contained by water cooled copper blocks that move along with the melt in a block-chain [20]. The Ar/CO_2 protective gas is used as a rake to ensure a uniform distribution of the melt across the casting belt. The rapid cooling from the combination of the conveyor, acting as a continuous casting form, and the Ar/CO_2 gas rake makes it possible to produce steel grades previously considered to be infeasible. This method is currently only developed for flat products and has been tested for a width of 300 mm of the cast strip.

In order to investigate this method, difference in mechanical properties between direct cast and annealed strips of steel with high Cu, P and S contents were investigated in reference [33]. It was observed that the process produce fine microstructure and nano-scale copper sulfides. As cast and annealed have higher balance of strength and work hardening ability compared to strips without impurities.
As-cast strip has higher yield and tensile strength and maintains high work hardening ability at higher stress levels than that of the annealed strip. The nano-scale copper sulfide particles in the as-cast strip contributed most to the increase in yield strength.
It is finally believed that further improvements in strength and work hardening ability can be attained by controlling the particles size and the volume fraction in the strip.

A study was carried out at KIMAB and reported in reference [34] to ascertain how the situation could be improved when using strip casting in conjunction with direct hot rolling. This has included steels having copper contents up to 2.5% and in some cases also tin levels up to 0.1%. Laboratory simulations have been carried out to simulate the process conditions from the outlet of the strip caster through hot rolling, and the resulting materials have been examined with regard to their hot cracking behaviour and microstructural condition. Mechanical properties have also been measured on samples having different simulated coiling temperatures following hot deformation.
Susceptibility to hot cracking depends on the copper content of the steel and also on the process conditions of time, temperature and oxygen potential that apply after the strip exits the caster. Intermediate temperatures in the range 1100 - 1200°C are most dangerous and process windows for avoiding hot shortness can be defined on the basis of the present results, see Figure 15. In general, it should be possible to process steel containing much higher copper levels by strip casting than in current commercial production.
Copper-rich liquid films that penetrate the austenite grain boundaries are responsible for the loss of hot ductility in the steel surface. The presence of tin as an additional impurity to copper has not been found to be deleterious under the present conditions.
Conditions can be established to avoid hot shortness even in steel containing high copper contents, due to the short time that is available for oxidation
With sufficiently high contents of copper (above approximately 1%) precipitation occurs in ferrite leading to significant increase in strength in the final product and some reduction in total elongation. This strengthening, which is greatest when the steel is coiled at low temperatures in the vicinity of 450°C, could be well utilised in recycled steel manufactured from severely contaminated scrap. The refinement of the microstructure by precipitation of small copper particles (
Figure **17**) contributes to the hardening and strength by lowering the mean free path of dislocation travel.

Depending on the steel composition and coiling temperature it is possible to achieve very significant strengthening due to precipitation of copper-rich particles, see Figure 16.

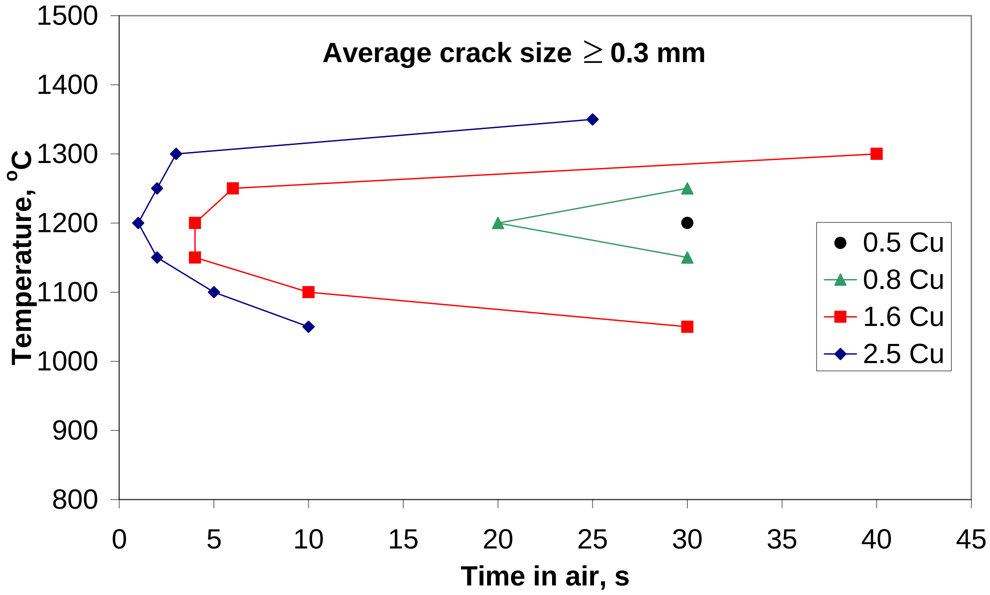


Figure 15 Compression temperature vs. time in air before hot deformation. The lines indicate when the cracks exceed 0.3 mm for the different steels

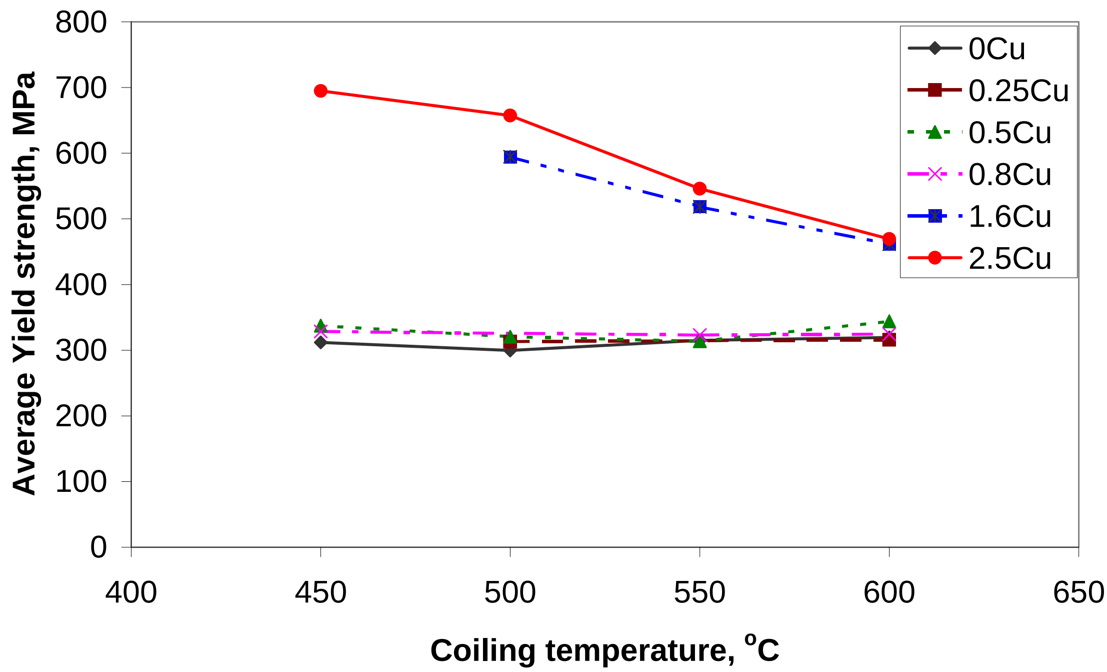


Figure 16 Yield strength vs. coiling temperature for steels with different copper contents

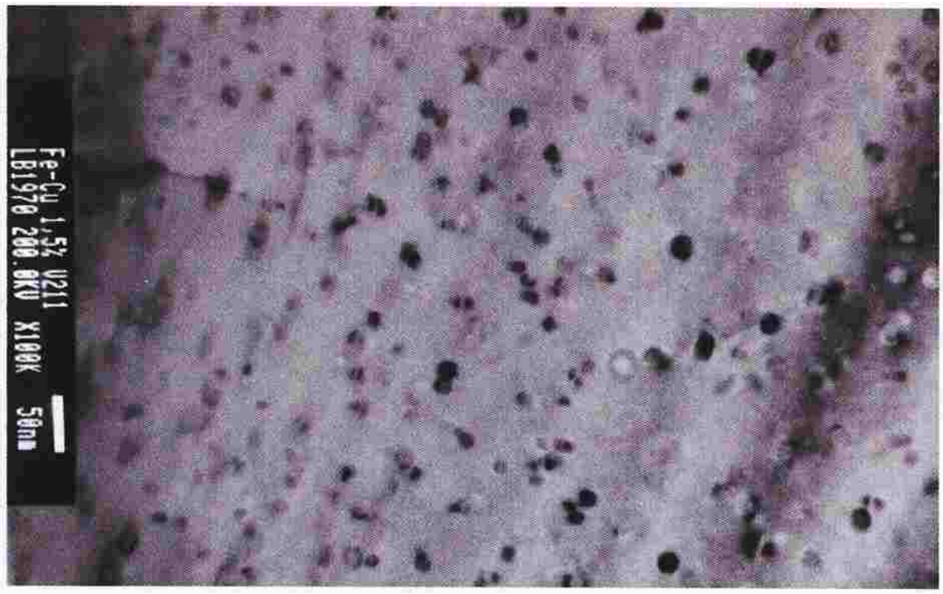


Figure 17 TEM picture of a 1.53 w% Cu alloyed steel after simulated hot rolling and coiling at 873 K . The dark spots are precipitates of ε-Cu 8-16 nm in size.

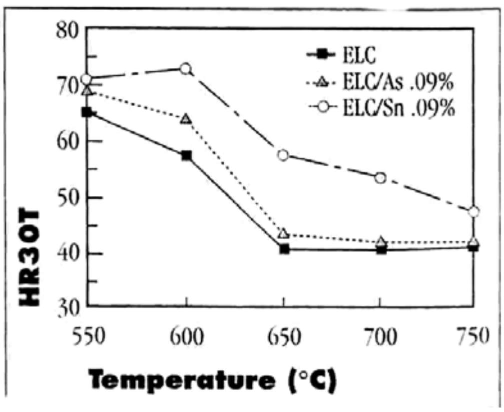
5.2 Cold working, Hardenability and end properties

Strength and final mechanical properties are often in close relation and inversely proportional with elongation and forming properties. Annealing and hardening is usually performed after cold-rolling. Residual elements affect in a complex way these different operations and parameters.
Which properties are desired and which amount of residual elements may be allowed depends on the type of steel, the production way and the aimed final use. A number of reported effects and limitations for residual elements with respect to cold working and hardenability, and effect on final strength, are given here.

5.2.1 Cold working

The material properties desired to favour cold working operations are often good elongation and drawability. The drawability of the material is quantified by the so-called r-value. The r-value is the quota between the contraction of the material in the width direction and the contraction of the material in the thickness direction.
In general, the harder the material the more likely it is to exhibit brittle behaviour while deformed, which is negative for cold working. Residual elements are mainly reported to contribute to hardening in some degree.

For materials intended for deep drawing or good formability, such as press sheets for car bodies etc, a low yield strength and long elongation are desirable. Thus, as reported in [16], Ni, Cr, Cu and Mo, which increase the resistance of cold rolled and annealed sheets, could become a problem for the production of soft drawable steel grades
Even reference [2] note that, for cold-rolled and annealed sheets, all residual elements, at the exception of Nb and Ti, adversely affect the crystallografic textures and partially the r-value (Lankford coefficient). Sn and As are the more detrimental in this respect (a significant effect is observed for a Sn content of 0.3%, see
Figure **19** A).

A


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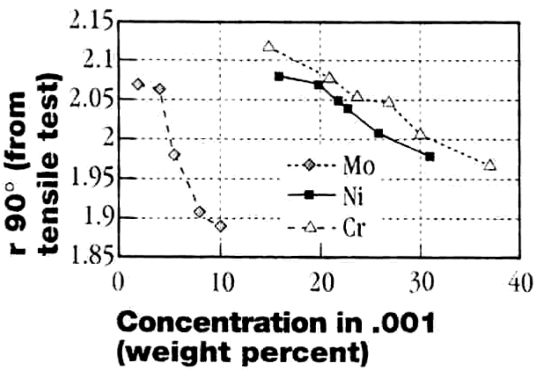
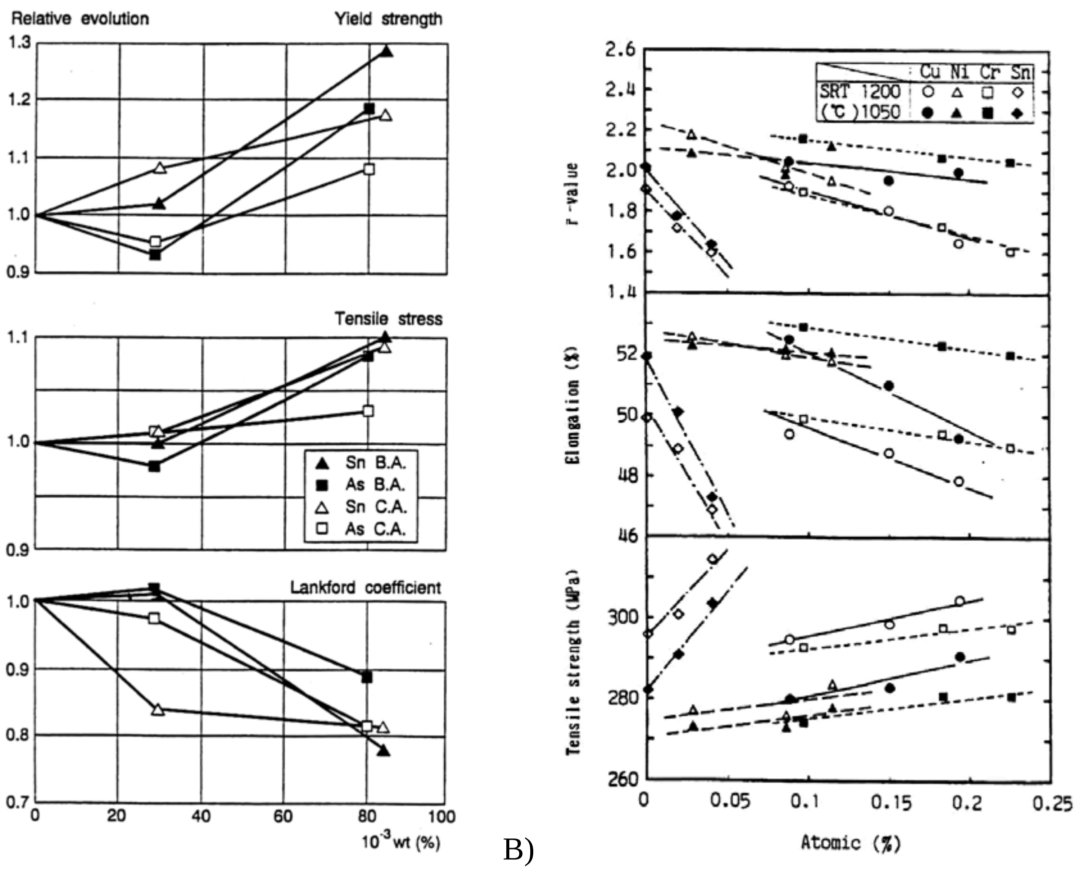


Figure 18 A)Effects of Sn and As on the recrystallization delay in a continuous annealing process on cold rolled ELC steel grades (0.02% C, 0.2% Mn, 0.05% Al, cold rolling 75%, continuous annealing, soaking for 1 minute). B) Effect of Cr, Ni and Mo on the drawability properties of 0.03% C steels (annealing temperature 680°C)

Sn, As, Cu, Ni, Cr and Mo have adverse effets on drawability, decreasing the r value and, to some extent, the ductility of ULC-IF and ELC grades (see
Figure **18** B). [2].
Sn and As also have adverse effects on recristallization kinetics during the continuous annealing of cold rolled ELC steel grades (see
Figure **18** A). The temperature for full recrystallisation increases, which implies that process conditions have to adapted to raise the annealing temperature. [16]

The tensile properties however were only little affected for residual elements up to 0.03%. However, a marked increase in tensile and yield stress was observed for concentrations of 0.08%. See
Figure **19** for the effect of Sn and As.[2].
According to reference [3], Cu, Ni, Cr and Sn decrease grain size and increase solid solution hardening of thin steel sheet (IF Ti), thus decreasing anisotropy factor r and elongation (see
Figure **19** B).



A) B)

Figure 19 A) Impact of residual elements on the mechanical properties of annealed cold-rolled sheets (BA = batch annealing, CA = continuous annealing).
B) relationship between atomic % and mechanical properties of Cu, Ni, Cr and Sn-containing titanium bearing extra low-carbon steel sheets.

In a study presented in reference [35], Cu and P bearing high strength cold rolled steel sheets with superior drawability have been developed. Cu and P contents are 0.6% and 0.08% respectively. The tensile strength of these steels are 500-550Mpa and the r-values are as high as 1.5-1.7. The excellent r-values are obtained by precipitation treatment of

650°C x 10h before cold rolling. Cu precipitates occured during heat treatment. Si and Mn strenghtened bearing steels are investigated. High Si steels have better elongation than high Mn steels. As to the r-value however, the latter are superior. In order to obtain excellent r-value, high reduction in cold rolling and slow heating in annealing are required in addition to the precipitation treatment before cold rolling (see Figure 20).

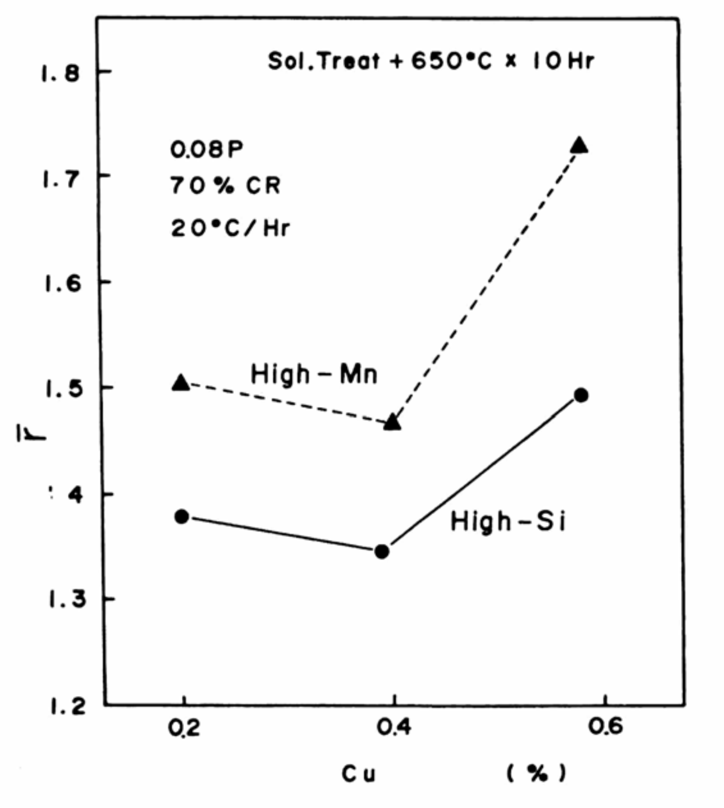


Figure 20 Effect of copper contents on r value

The cold-workability of low alloyed C-steels (XC10, XC42, 20M5) was studied in [39], and it was concluded that only Sn for concentrations higher than 0.04% and P for concentrations higher than 0.05% affect sensibly the ductility.

The effects of Cu (0.5%), Sn (0.12%) and Sb (0.11%) on tensile ductility and cold forgeability of a 0.5%C steel are investigated in [36]. The microstructures were not affected by the addition of Cu, Sn and Sb less than the contents given above. Similarly, these elements had no harmful effect on tensile properties and cold forgeability of the steels. The tempering at 500°C after quenching did not deteriorate cold forgeability of steels containing up to 0.1% Sb, and did not reveal an intergranular fracture on a cracked surface after upsetting test. Thus the authors state that cold forgeability of 0.5% C steel is mainly dominated by the existence of inclusions rather than by adding an impurity element of 0.5% Cu, 0.1% Sn or 0.1% Sb.

In a study made at KIMAB on the effects of copper on the properties of annealed thin sheet products, it was found that a moderate amount of copper in the material seemed to eliminate the Lüders elongation. This was only seen in material that had been batch annealed (

Figure **21** A). This effect was not seen in the continuously annealed specimen with the same copper content (
Figure **21** B). The elimination of the Lüders elongation is of interest for press sheets and steels that are intended for deep drawing and cold forming.

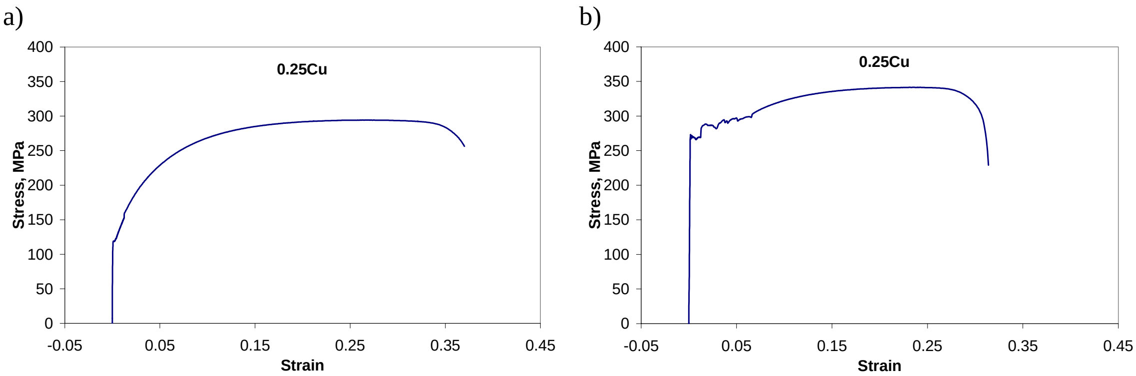


Figure 21 Stress-strain curve for a batch annealed steel, containing 0.25 w% Cu, showing no Lüders elongation. b) Stress-strain curve of same material as in a) but continuously annealed and showing a clear Lüders elongation.

Finally, almost no articles were found on the effect of residuals on machining of low alloyed steels. The effect of sulphur on machining, reported in [37], is mainly due to the formation of sulphides with other elements such as Mn. MnS can act as a nucleation site for microcracks, which raises stress in the material and further shear instability.

5.2.2 Hardenability

Reference [38] gives a summary of the most important variables, which influence hardenability, which are austenite grain size and composition, the second being discussed in this chapter.
Carbon has a marked influence on hardenability, but its use at higher levels is limited, because of the lack of toughness which results, the greater difficulties in fabrication and, most important, increased probability of distortion and cracking during heat treatment and welding.
Likewise, most metallic alloying elements slow down the ferrite and pearlite reactions, and so also increase hardenability. Exceptions are Co, because it increases the rate of nucleation and growth of pearlite, Ti because it reacts with C to form TiC and S because of MnS.
The most economical way of increasing the hardenability of plain carbon steel is to increase the manganese content, from 0.60 wt% to 1.40 wt%, giving a substantial improvement in hardenability. Chromium and molybdenum are also very effective, and amongst the cheaper alloying additions per unit of increased hardenabilily. Boron has a particularly large effect when it's added to fully deoxidized low carbon steel, even in concentrations of the order of 0.001%, and would be more widely used if its distribution in steel could be more easily controlled.

The effect of the main residual elements (Cu, Cr, Ni, Mo, P, Si, Sn) on the hardenability of low alloyed C-steels (XC10, XC42, 20M5) is also given in reference [39]. The effect on hardenability was ranked as follows: P>Mo>Cr>Si>Ni/Cu. The effect of Ni and Cu is neglectible under 0.3%. From that, it was assessed that elements coming from scrap (Cr, Si, Mo) allow enonomy of adding elements such as Cr, often necessary to increase hardenability of carbon steel produced from ore.

According to reference [28], copper somewhat increases the allotropic and martensite transformation temperatures, the increase of temperature being proportional to its content. As an element weakly stabilizing austenite, copper impedes the decomposition of austenite and thereby increases the hardenablility of steel.

In reference [40], the derivation of carbon equivalents to assess hardenability of steel has been examined. This equivalent was derived from the incubation time before the transformation to ferrite, pearlite or bainite, which is illustrated in **Figure 22** and is given in the equation below (note that the 1,8 is written 1·8 and so on):

$$\%C_{eq,cal} = \%C + \frac{\%Si}{38} + \frac{\%Mn}{6{\cdot}0} + \frac{\%Cr}{1{\cdot}8} + \frac{\%Mo}{2{\cdot}3} + \frac{\%Ni}{12} + \frac{\%Cu}{9{\cdot}1} \quad . \; . \; . \; . \; . \; . \; . \; .$$

It was compared with experimental results from other studies, which is shown in **Table 7**:
The comparison reveals that the calculated coefficients for silicon, manganese, copper and nickel in the carbon equivalent equation are in good agreement with the experiments, whereas the agreement for the molybdenum and chromium coefficients is poor.

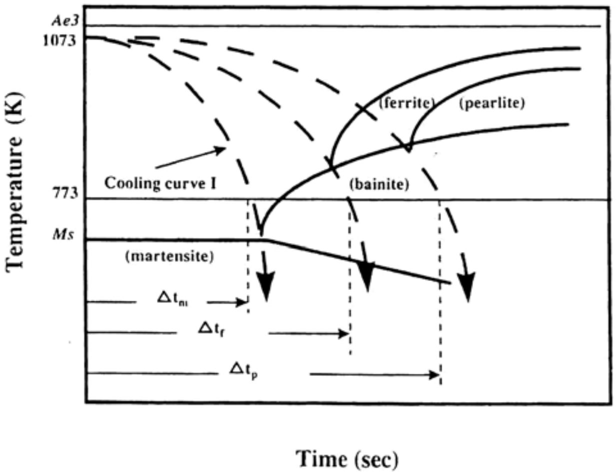


Figure 22 Critical cooling curves for ferrite, pearlite and bainite transformations on CCT diagram.

Table 7 Summary of coefficients for alloying elements in carbon equivalent equation. (Note that the 1,8 is written 1·8 and so on).

Element	A_X	A_X/A_C in $\%C_{eq,cal}$ (equation (12))	$\%C_{eq}$ (Bastien) (equation (15))	$\%C_{eq}$ (Yurioka) (equation (16))
C	−3·02	1	1	1
Si	−0·08	1/38	...	1/24
Mn	−0·50	1/6·0	1/4·1	1/6·0
Cr	−1·64	1/1·8	1/8·5	1/8·0
Mo	−1·30	1/2·3	1/6·5	1/4·0
Ni	−0·25	1/12	1/7·9	1/12
Cu	−0·33	1/9·1	...	1/15
N	0·087	−1/35	...	...

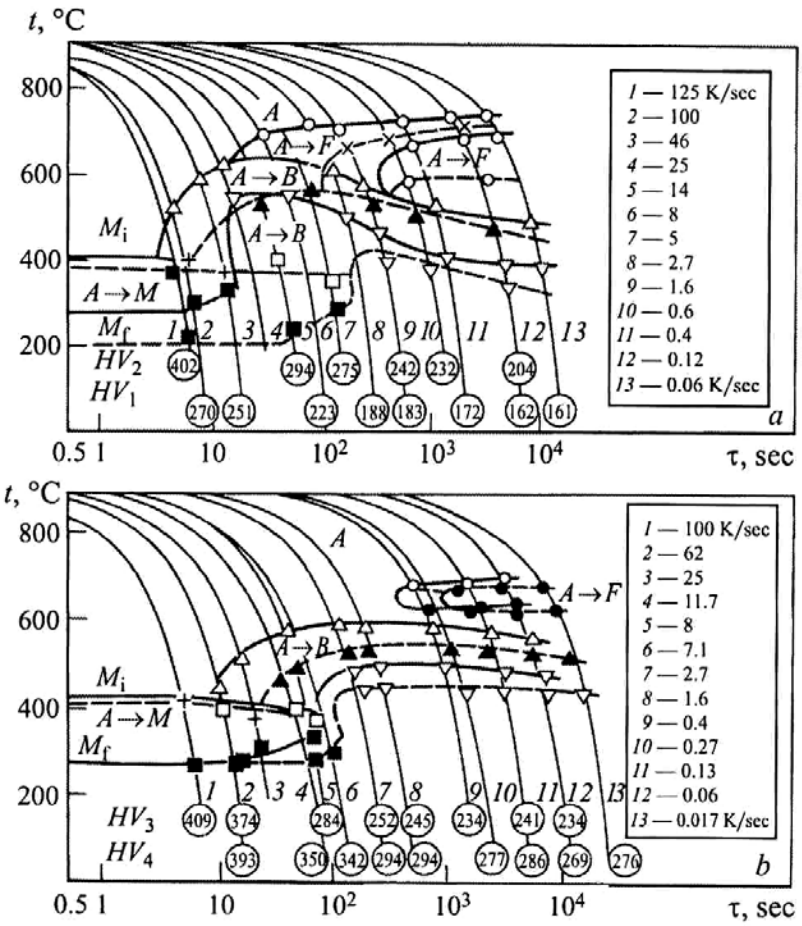
In reference [41], the influence of copper on quenching of high strength low alloy steels with 1.6% Cu, which composition is given in Table 8, is discussed.

Table 8 Composition of the steel studied in reference [41].

C	Mn	Ni	Cr	Cu	Mo	Nb	Si	Al	N	P	S
0.036	0.91	3.59	0.59	1.60	0.59	0.025	0.24	0.022	0.0097	0.008	0.005

An austenitizing temperature of 900°C was used, which allows to have all Cu in solution. On quenching from this temperature, a supersaturated solid solution was obtained with all of the Cu in solid solution in martensite. Cu slightly lowers the allotropic and Ms (martensitic start) temperatures, the extent being proportional to the Cu content. In addition, other solute elements present in the steel (especially Ni) are also considered to be austenite stabilizing elements. Therefore the decomposition of the austenite in such a steel is delayed. Because of the very low carbon content of this steel, only highly dislocated lath martensite structure was observed. Further discussion on the effect of Cu on properties from this reference is given in the next chapter.

Reference [42] is dealing with shipbuilding high-strength steels, which should provide high strength, ductility, and toughness in combination with a high resistance to brittle fracture and a good weldability. It is stated that when the carbon content is diminished in order to improve weldability, complex alloying becomes very important for the provision of hardenability, elimination of the formation of ferrite-pearlite structures, hardening and elevation of the resistance to brittle fracture. The complex effect of alloying elements in low-carbon heat-treatable Cr – Ni – Cu – Mo steel on the phase transformations that occur in quenching and tempering was studied. Results as well as the corresponding compositions are shown in Figure 23.



Heats	Content of elements, %*								M_i, °C	Ac_1, °C	Ac_3, °C	P_{cm}^{**}
	C	Si	Mn	Cr	Ni	Mo	Cu	V				
1	0.12	0.34	0.62	1.07	2.00	0.17	0.49	0.07	410	730	860	0.291
2	0.07	0.30	0.41	0.42	1.92	0.30	0.46	0.02	410	740	855	0.199
3	0.11	0.40	0.48	–	2.70	0.50	0.61	0.02	406	721	836	0.258
4	0.12	0.31	0.37	0.71	2.73	0.40	0.62	0.03	403	727	840	0.290

* The metal of the studied heats contained 0.008 – 0.01% sulfur, 0.005 – 0.013% phosphorus, 0.01 – 0.06% aluminum, and 0.03% calcium (as calculated).

** $P_{cm} = C + \frac{Mn + Cr + Cu}{20} + \frac{Mo}{15} + \frac{Ni}{60} + \frac{Si}{30} + \frac{V}{10}$.

Figure 23 Thermokinetic diagrams of low-carbon Cr-Ni-Cu-Mo steels with various contents of C and Cr. HV1-4 given in figures a and b correspond to the compositions of heat 1-4.

Quenching causes the formation of a composite martensitic - bainitic structure with predominant lath martensite, lower bainite, and bainite without visible carbide phase

segregations. 0.4% of Mo added suppresses the segregation of ferrite. Cr between 0.7-1.1% decreases the critical cooling rate in the intermediate range; in combination with 3% Ni and 0.3-0.5% Mo, it provides the formation of a martensitic – bainitic structure.
By reducing the concentration of C to 0.07%, Cr to 0.4% and Ni to 2%, baintic structures will be formed. These structures posses an elevated resistance to tempering as compared to steels quenched for martensite, are characterized by a high level of strength and posses a quite high resistance to brittle fracture. This makes it possible to have a high-strength Cr – Ni – Cu - Mo steel bearing 0.06-0.07%C with a bainitic structure that provides an excellent weldability without heating at a yield strength of up to 700 Mpa.

Finally, the 2 following studies present some more fundamental research on the effects of Cu addition on the structure and transformation of steel, for isothermal transformation and during cooling, which is even relevant considering hardenability.
In reference [43], the effects of Cu addition on the isothermal transformation behaviour and the transformed structure have been investigated in Fe-1.48Mn-0.48Si-0.15C-(0, 1.51)Cu % wt steels. The transformation behaviour, was shown to be retarded by the addition of Cu in the temperature range of 873 to 973K. The isothermally transformed structure at 903K is mainly acicular ferrite in 0 Cu steel, but is equiaxed ferrite with lots of subgrains in 1.5% Cu steel. Both the nucleation rate and growth rate of ferrite are decreased by the addition of Cu and this is considered to be caused by the reduction in austenite grain boundary energy due to segregation of Cu and the solute drag effect by Cu.

In article [44], Fe-(0.5-4)w %Cu alloys were cooled from γ field under various cooling conditions and phase transformation mechanisms were investigated.
In all of the cooling conditions, hardness of the alloys becomes higher with increasing Cu content. Effect of cooling conditions on hardness tends to be significant in alloys with Cu more than 1 wt %. Strength of alloys depends not only on a difference of matrix, martensite or ferrite, but also on dispersion of ε-Cu particles. In the case of air cooling for a Fe-4mass%Cu alloy, the alloy undergoes preferentially $\gamma \rightarrow \alpha$ massive transformation and then ε-Cu particles precipitates finely within the massive ferrite matrix. This leads to a large strengthening with a moderate ductility. Strength of Cu bearing steels can easily be controlled by varying cooling condition after a solution-treatment: steels are soft enough to be deformed and machined after furnace cooling, but strengthened after resolution-treatment followed by air-cooling.

5.2.3 End-properties

Tensile properties, strength

In reference [6], which reviews the influence of residual elements on mechanical properties of low-carbon steels, it is observed that all residual elements increase strength and decrease ductility and drawing properties. These effects are more pronounced for low carbon clean steels (low-carbon, extra low carbon and ULC-IF steel grades) than for medium and high carbon steel grades.
For cold rolled and annealed sheet, the major part of the product mix is low carbon or ULC steel. These steel grades are very sensitive to the content of residual elements. Sn, Cu, Ni and Cr increases the tensile strength of ULC-Ti steel grades and decrease their ductility (elongation). Sn, As, Cu, Ni and Mo decrease ductility of ULC-IF and ELC.

Thereafter are presented results of studies about mechanical properties on specific types of LC steels.

The effects of some residual elements on the properties of low carbon steel sheets containing titanium are reported in reference [45]. Copper specifically lowers the elongation of the material and increases the yield strength (Figure 24 A) while contributing to a refinement of the microstructure Tin increases the tensile strength of and lowers elongation and r-value (Figure 24 B). A refinement of the grain size was observed with increasing tin content. The change in tensile strength was reported to be approximately 45 MPa / 0.1 w% tin. Tin has a larger difference in atomic radius versus iron compared to copper, nickel and chromium. This causes tin to have a larger effect in both solid solution and as a precipitate.
The influence of nickel is at about the same magnitude as copper with respect to tensile strength increase. Only minor influences on elongation and r-value were observed at varying nickel content and at different heating temperatures, though the small changes is likely closer related to the low carbon content in combination with the presence of titanium. In total the influence of nickel contents up to 0.12 w% have little effects on the mechanical properties of low-carbon titanium containing steel sheet.

The effect of residuals on tensile properties and microstructure of low-carbon (0.04%) and medium carbon (0.2%) steel grades was studied in [46]. An increase in tensile strength and a slight decrease in ductility (combination of solid solution hardening and grain refinement) was observed for both types of steel The high tensile strength of steel containing more Mn and Si is thought to be mainly associated with increased pearlite content. For low carbon steels, the ferrite grain-size decreases from 24 to 18,5 µm for 0.04%Sn. But further addition (0.08%Sn and 0.05%P) and addition of 1.2%Mn and 0.3% Si only slightly decrease ferrite grain-size. For medium C steels (with 1.2%Mn and 0.3% Si), the ferrite grain-size decreases from 14 to 10µm for residuals increasing (0.08%Sn, 0.4%Cu, 0.4%Ni).

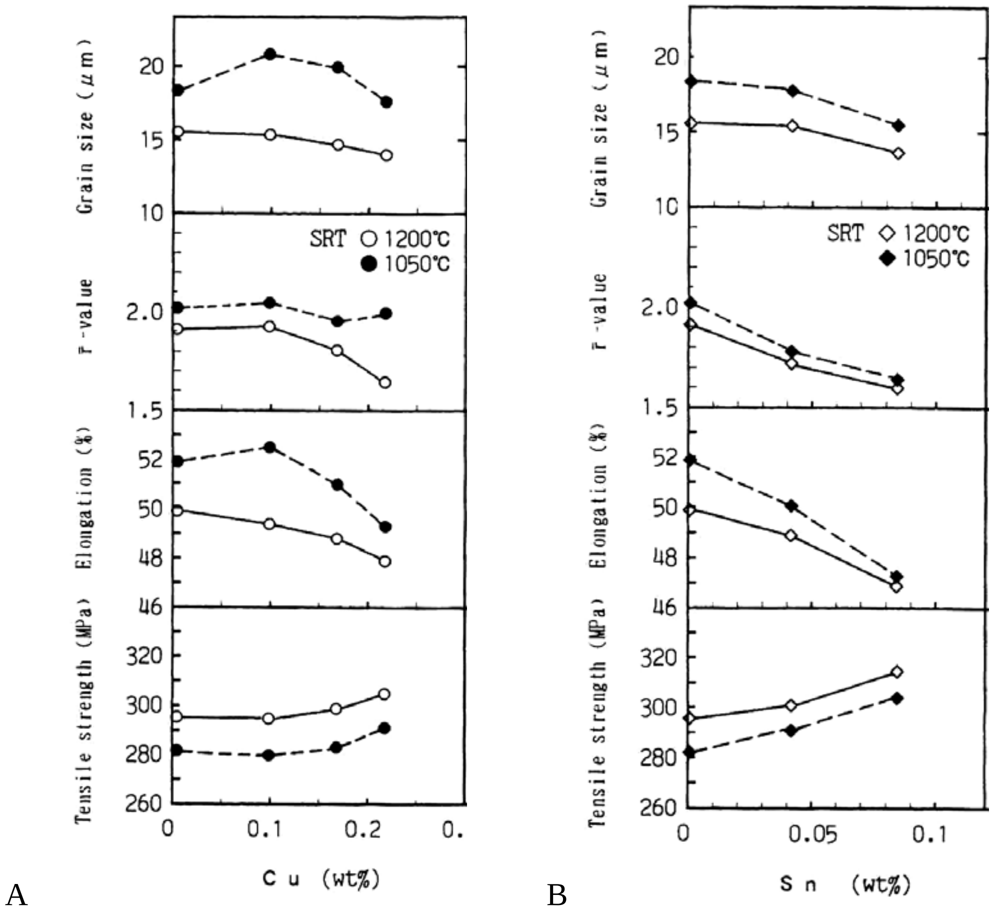


Figure 24 A) Mechanical properties as a function of copper content in titanium-bearing extralow-carbon steel sheets. B) Influence of tin on mechanical properties in titanium-bearing extralow-carbon steel sheets.

The properties of steels with additions of Cu (0.5%), Cr (0.4%) and Ni (0.4%) to the basic composition of 0.2C-1.5Mn-1.5Si were investigated in reference. [47] for high strength hot-rolled plates and [48] for TRIP-aided cold-rolled sheets.
The microstructures and mechanical properties of high strength hot-rolled steel plates were investigated in reference [47] for different coiling temperatures.

- When coiling temperature (CT) is low (around MS point), the fraction of retained austenite is low. Steel with additions of Cr (alone or with Ni) have % of retained austenite above 10%, but show the characteristics of dual phase steels, whereas when Cr is not added a discontinual yielded is observed.
- At CT = 450°C, retained austenite increase. Compared with CT400, tensile strength increase or maintains at the same level and elongation improves to greatly enhance the strength-elongation balance.
- When Cr is added as a tramp element, it works favorably for the formation of retained austenite at low CT. However, because of the increased hardenability of austenite and the formation of a large amount of martensite, cooling rate after hot rolling or coiling should be set low.
- As an austenite-stabilizing element, Ni works favorably for the formation of retained austenite, and increases the fraction of retained austenite at high CT, thereby improving both tensile strength and elongation.

TRIP-aided cold-rolled sheets, intercritically annealed at 780-790°C and isothermally treated at 430°C were investigated in [48]. The formability (measured with limiting dome height test) as well as the tensile properties of the Cu and Ni-containing cold-rolled steel sheets was greatly improved as the strain-induced transformation of retained austenite was actively sustained up to the high strain region, because of high volume fraction and stability of retained austenite. The cold-rolled steel sheets with Cr added alone or in combination with Ni showed a dual phase structure, together with low-volume fraction and stability of retained austenite resulting from a large amount of transformed martensite. These results indicate that when elements such as Cu, Ni, Cr are positively used, low-carbon TRIP-aided cold-rolled steel sheets having mechanical properties suitable for various application purposes and excellent formability may be achieved.

An ULC steel alloyed with Ni, Mn, Mo and Cu and microalloyed with Mb and Ti was subjected to a three-stage controlled rolling operation followed by water quenching in reference [49], and the effect of thermomechanical processing on the microstructure, mechanical properties, and age-hardening behavior of the steel was evaluated.
The high-strength values obtained are due to the fine-lath martensite structure along with tiny precipitated of microalloying carbide and carbonitride of Ti and Nb at all finish rolling temperatures. The increased strength value at the lower final rolling temperature (FRT) is due to the finer lath width and packet size of martensite. The large TiN and the coarse martensite-austenite constituents impaired the impact-toughness value of the steel at subambiant temperature. At low ageing temperatures, coherent Cu particles form and a peak strength is obtained due to the formation of fine ε-Cu precipitates. On increasing ageing temperature, the Cu particle size increase, decreasing dislocation density in the matrix resulting in a decrease in strength, see Figure 25.

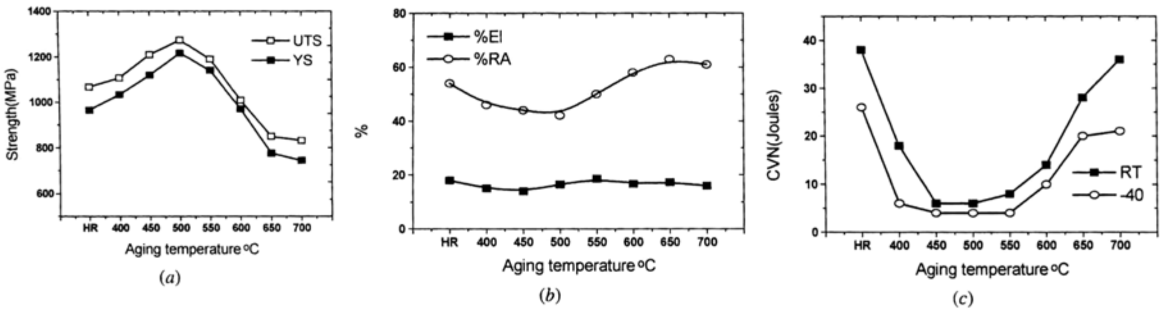


Figure 25 Variation in mechanical properties of the TMCP steels at different FRT. (a) Hardness, UTS and YS. (b) pct elongation and % reduction in area. (c) Impact toughness values at room temperature and at -40°C.

Reference [28] presents a review of Russian studies on the effect of copper on structural steels. Precipitation hardening processes are observed in copper-containing structural steels which are caused by a change of it’s solubility in ferrite depending on temperature: up to 400-600°C the solubility of copper does not change and is 0,2 – 0,4%, the hardening process is noted at 0,5% Cu and more. Weak matrix solid-solution hardening of ferrite is noted in copper-containing steels: each 0,1% Cu increases the yield strength by 3,5 Mpa, whereas due to precipitation hardening – by 24,8 Mpa. The maximum effect is achieved during tempering at 500°C for 4 hours: the hardness HB increases from 145 to 245 in steel with 0.19% C and 1.07% Cu.

Reference [41] presents high strength low alloy (HSLA-100) steels with copper additions, which were developed in order to reduce production costs while simultaneously improving the quality of structural steels. The composition of this steel is given in Table 8 (see previous chapter) The role of copper in contributing to the developments in microstructure and mechanical properties of this steel is summarized as follows:

1. Cu, when in solution in austenite at 900°C, will act to lower the transformation temperature (Ms or Bs) upon quenching. This will lead to an overall increase in strength at all ageing conditions.
2. Cu, when in the form of precipitates, will contribute to the overall strength by precipitation hardening when aged near 450°C.
3. Cu, when in the form of precipitates, will act to retard the recovery and recristallization of the as-quenched matrix. This will also lead to higher strength levels at all ageing conditions.
4. As the ageing temperatures increases, the amount of Cu in the austenite also increases. This acts to lower the Ac_1 and leads to the formation of new austenite at lower ageing temperatures.

The retardation of recovery and recrystallization together with the low temperature formation of stable austenite combine to give the aged structure an excellent combination of strength and low temperature toughness.

Grain boundary embrittlement

Residual elements can induce embrittlement due to garin boundary segregation [16]. Residuals may segregate to the grain boundary during cooling and coiling in the hot strip mill, or during final annealing after cold rolling. An important related aspect is the ability of the elements to reduce grain boundary cohesion, which makes fracture more likely. It was calculated [50] that the grain boundary cohesion in ferrite is reduced in proportion to the excess size of the segregated atoms (see Figure 26 B). Cold embrittlement in steels occurs at the so called transition temperature (TT), at which deformation mode changes from dislocation displacement to grain boundary decohesion. This prevails at lower temperatures. Residuals such as Sn, Sb, As and P increase the TT, whereas Be, C and B decrease it.

A

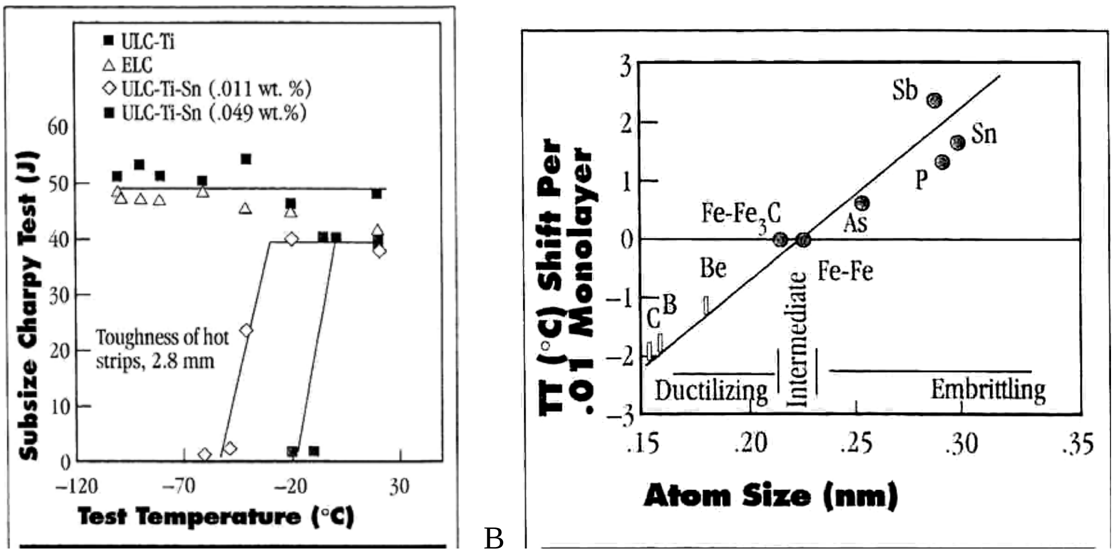


Figure 26 Influence of Sn on the toughness of hot-rolled strips (A). Relation between atom size of residual elements and embrittlement (B).

Sn, Sb, As, Cu, F, P, S, An, Zn, Pb and Bi tend to segregate at surfaces, which reduces the grain cohesion and causes grain boundary embrittlement in steel when they are present in sufficient high concentrations.([7] and [6])

According to reference [16], the thoughness of hot rolled strips is drastically reduced by P due to grain boundary segregation during slow cooling after transformation (medium C steels and vacuum degased IF steels). No remarkable effect caused by Sn, As and Sb were detected in medium C steels. This may be due to the protection by soluble C diffusing to grain boundaries. However, Sn drastically reduces the toughness of hot rolled ULC-IF steel grades (see Figure 26 A). In that case, all C atoms are tied up by Ti or Nb additions.

Corrosion

The segregation of copper to the surface is often considered as a problem due to hot-shortness. It can however present advantages for corrosion resistance, which are useful in weathering steels. This range of alloys is designed to corrode uniformly with the re-precipitation of Cu^{++} at the surface. Cu also has the property of being electroreducible, deposition as Cu^0 and forming complexes with iron at the surface of carbon steels which prevent further corrosion. In even quite aggressive atmospheres, the beneficial effect of Cu (0.2 – 0.4%) is important, see Figure 27. [3]

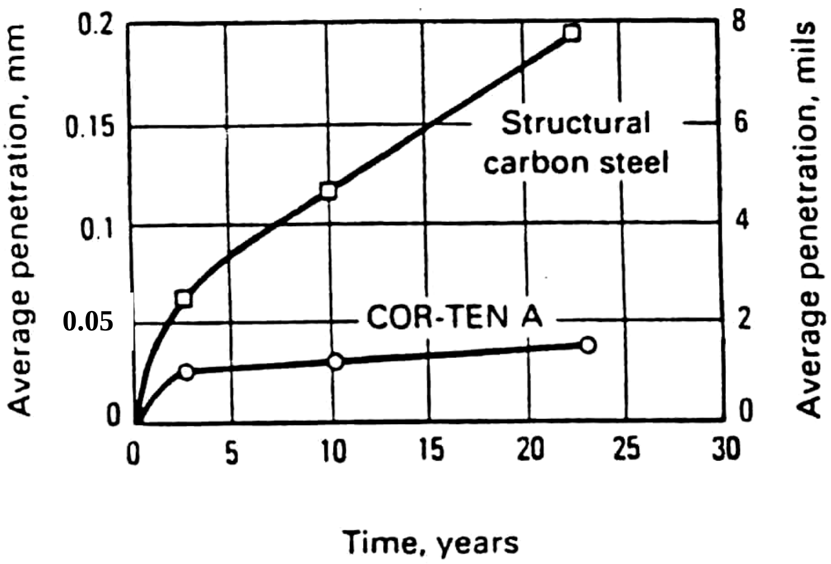


Figure 27 Time/corrosion curves showing relative performance in a semi-industrial environment.

Also according to reference [28], the resistance of steel to atmospheric corrosion increases considerably with copper addition. Losses from corrosion of structural steel decrease almost twofold with increase of copper content from 0,1 to 0,3%.

5.3 Welding

The effects of residual elements on the welding properties of low alloyed steels are widely varied. Most residual elements contribute to the hardenability in the HAZ of a welded material in a more or less negative way. The weldability of a material, as listed in reference [18], can be judged by its properties in relation to:

1. Hot cracks during solidification.
2. Lack of fusion, blowholes and spatter.
3. Cold cracking, hydrogen embrittlement.
4. Lamellar tearing.
5. Weldment strength.
6. HAZ toughness.
7. Weld metal toughness.
8. Loss of toughness during stress relief treatment.
9. Reheat cracking
10. Weldment fatigue strength.
11. Preferred corrosion for example due to formation of Chromium carbides in the grain boundaries, causing chrome or other carbide formers to be leeched from the grain boundaries.

Hot cracking, also called solidification cracking, occurs in the boundary between the weld metal and the base material. When the melted material cools down, grains grow from the material in towards the thermal centre of the weld. The composition of the material in this zone is dependent on both the base- and the weld material, as the part of the base metal is melted along with the weld metal. As the melt solidifies segregation and solidification shrinking occurs. This can cause low melting phases to be present as the material solidifies, which can cause tearing and cracking in the weld.
In different models developed to calculate the so called ‘carbon equivalent’, used to estimate among others the susceptibility to cold cracking, there is a great variation in coefficients for a specific element in the different formulae [51], showing that it is difficult to estimate the effect of any given element.

The effect of copper on the weldability of steel is quantified through its contribution towards the material tendency for hot and cold cracking. Copper has a tendency to cause hot cracking. Usually the hot cracks associated with copper are small but can serve as initiation points for future cracking and stress corrosion cracking. Hot cracking occurs when a critical strain is applied at elevated temperatures. The problem of hot cracking can generally be avoided as long as the applied strain at high temperature remains below the critical value for the given material.

The solubility of copper in austenite is higher than in ferrite; this causes the matrix to become supersaturated with copper as austenite transforms to ferrite during sufficiently high cooling rates. If the cooling rate is slow the copper will form precipitates in the bulk matrix of the steel. The hardening of the material by dispersed fine grains of precipitated copper is one of the reasons for alloying steels with copper. The hardenability of the HAZ is inversely related to the weldability: higher hardenability leads to lower weldability. The finely dispersed precipitates can also contribute to a refinement of the grain size in the HAZ. The refinement of the microstructure contributes to increasing the toughness in the weld. It is not only the copper content of the bulk material that has to be considered

though, but also the copper content of the welding rod that together with the bulk material make up the total copper content in the weld.
Copper by itself seems to have a limited effect on the weldability of C-Mn steels, but in combination with Sn, Sb and As copper has a strongly negative effect. This can partly be attributed to the lowered solubility of copper in austenite when the austenite is containing Sn, Sb and As. It is suspected, but not extensively researched, that the same problem as with hot shortness, i.e. presence of a liquid copper phase, is responsible for the poor welding qualities in this case. It has been observed according to [52] that the addition of copper, from scrap in steels produced through EAF route, does not seem to have any negative effects on either the base material or on the welded metal in the HAZ concerning levels up to 1 w% Cu.

The presence of sulphur is known to have adverse effects on cracking in the heat affected zone (HAZ) of welded materials. However, when the levels of sulphur are too low, problems with hydrogen cracking in C-Mn steels, or improper penetration in specific Cr-Mo-V steels have been reported [53]. The hardenability of the HAZ is increased with lower oxygen lower sulphur steels and it's considered being the cause of the increased risk of hydrogen cracking. Also it can be noted that sulphur act as a surface reactant and decreases the rate at which nitrogen is picked up [54]. Therefore higher nitrogen levels can be found in low sulphur steels. Sulphur has affinity towards manganese but can form FeS in low manganese steels. FeS melts at 988 ^{o}C and act much like copper in that it forms a film in the grain boundaries. This behaviour cause hot-tearing which is seen during solidification of the weld material. The sulphide film causes material separation between the grains as they are cooled and undergo solidification strain.

In welded material tin acts together with antimony and arsenic to change the surface energy of the grains, since they have a tendency towards grain boundary segregation. Tin like boron can affect the wetting angle of a copper liquid and lessen the penetration in to the grain boundaries. This decreases the susceptibility to hot-tearing and hot-shortness. But in contrast tin also lowers the solubility of copper in austenite and lowers the melting point and can thereby be severely detrimental in the case of hot tearing.
The decrease in sulphur and oxygen contents in steel has not been only beneficial. Boron is often present as a residual element in steel but has not existed in an active form in steel that was not intentionally alloyed with boron. Previously boron combined with oxygen and nitrogen to form an inactive state. In combination with more aluminum and titanium in modern steels and lower nitrogen and oxygen contents boron can exist in an active form. Even as low levels as 3-5 ppm can have a significant effect on the hardenability of a material. In relation to the amount for a given hardening effect, boron has a large effect [55].

Nickel in combination with manganese and chromium act to restrict occurrence of a copper liquid by increasing the melting point of the copper phase and increasing solubility of copper in the iron matrix.

6. Conclusion

An overview of the possible effects of residuals elements on down-stream process and end properties of steels, classified by their nature in the steel, was proposed, see Figure 28.

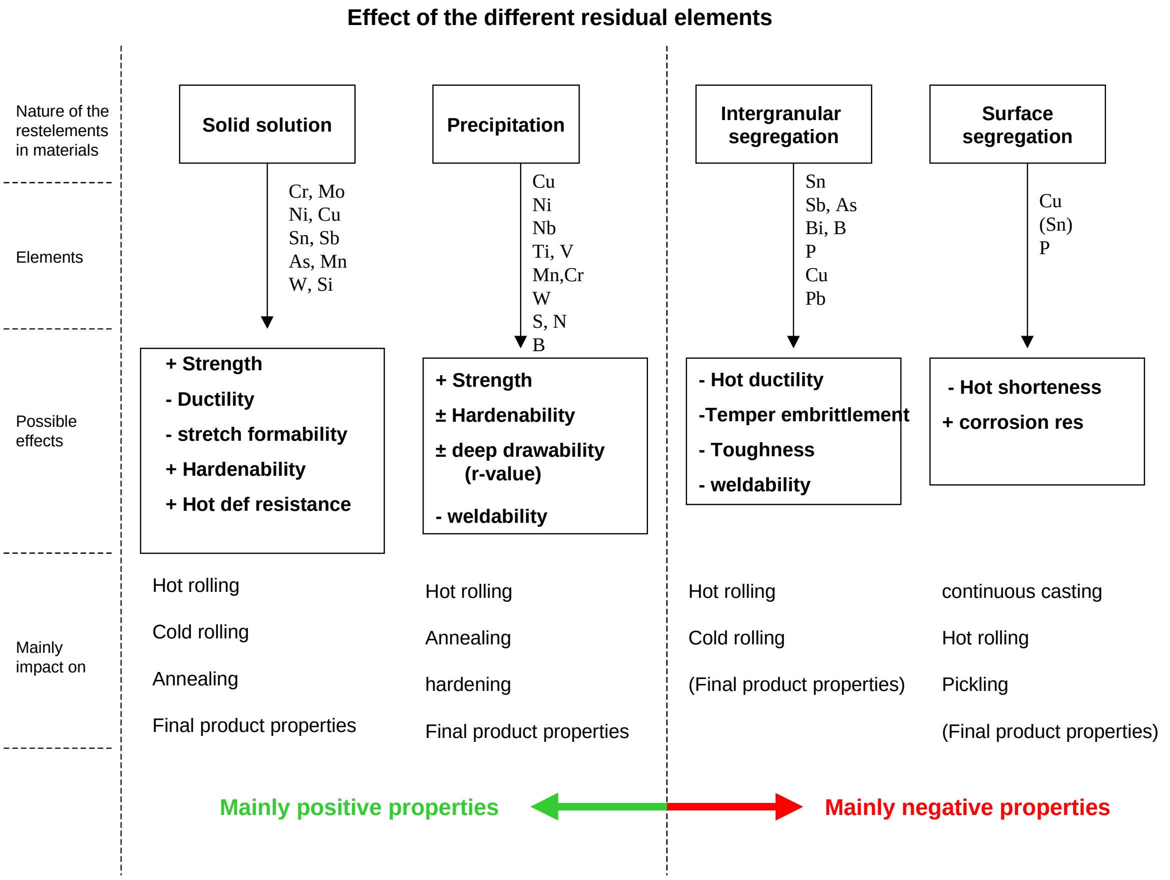


Figure 28 Overview of the nature of residual elements in steels and of their possible effects on down-stream process and end properties.

The effect of residual elements on down-stream process and end properties of low carbon low alloyed steels is a wide topic, which is consequently difficult to briefly summarise. Some general trends and features could however be found, which are presented here. The most remarkable trend is the dominance of Cu in the elements studied: most of the studies are concerned by the influence of copper, alone or in combination with other elements.

<u>Hot working</u>

- Most studies are related to the effect of Cu, which can cause hot-shortness during hot working, even for contents as low as 0.1% in some cases. The critical temperature for hot shortness is between 1100°C and 1200°C. Modifying the process can allow higher Cu contents, at least up to 0.8%.
- Several studies are concerned by the influence of other elements in combination with Cu on hot-shortness, $Cu_{\text{equivalents}}$ being presented in some cases. Mainly Sn, but even Mn, Cr, As and V are reported to increase hot-shortness whereas mainly Ni, but even Co, Al and Si are reported to decrease it.
- Grain boundary segregation, which is a non-equilibrium segregation at grain boundaries of mainly Sn, leads to a low hot ductility in the temperature range 600°C to

950°C. Cooling rates between 5 and 20 °C/s were shown to increase risk for grain boundary segregation.

- DSC (direct strip casting) allows higher contents of Cu and Sn in the material without hot-shortness problems, by combining short oxidation time with rapid cooling and direct rolling. Processing windows to avoid hot-shortness were studied at KIMAB.

Cold working

- Elongation and drawability are the main properties used to define cold workability. Residual elements mainly contribute to harden the matrix, which has a negative effect on cold workability. Ni, Cr, Cu, Mo, Sn and As were reported to decrease the ability to deep drawing and formability of LC steels whereas Ti and Nb showed the contrary effect.
- Copper was shown in some cases to have positive effects on formability when processing and heat-treating the material properly.

Hardenability

- Most residual elements, at the exception of Co, Ti and S, increase the hardenability by slowing down the ferrite and pearlite reactions. Mn is reported to be very effective in this purpose, as well as Mo, Cr and P, whereas Ni and Cu are less effective.
- Several studies are concern by copper, which is shown to increase hardenability by decreasing the transformation to ferrite.

End properties

- Most residual elements increase the strength and decrease the ductility, which is mainly due to solid solution hardening and also to precipitation.
- Copper lead to a weak solid solution hardening. However, a high strength was obtained due to the fine dispersion of ε-Cu particles after ageing at low temperatures (450°C to 500°C).
- Cu, Cr and Ni in low C – TRIP aided cold rolled sheets were reported to increase tensile strength and elongation by increasing the content of retained austenite.
- Reduction of the grain boundary cohesion, so called grain boundary embrittlement, is due to the segregation of elements at the grain boundaries during cooling, coiling and final annealing. Sn, Sb, As and P are reported to segregate to surfaces.
- Copper can act as a protection against corrosion in certain steels.

Welding

- Most residual elements contribute to the hardenability in the HAZ in a more or less negative way.
- Steels that contain up to 0.85 w% copper has not reported to be a problem. In fact the forming of precipitates is reported to be beneficial in regards to the toughness of the weldment.
- The combination of tin and copper is a problem both in hot rolling and welding, causing similar problems. The presence of a copper phase that has a low melting point compared to the base material can cause surface cracking during hot rolling and hot tearing during welding as the material solidifies.

7. Summarizing tables, effects of residual elements

The tables presented in this chapter are a summary of observed effects and limit contents of residual elements found in literature.

Table 9 Influence of copper and tin

REF	Steel type	Rest element	Critical content (%)	Operation	Property affected Problem	Comment
6		Cu	0.1		Surface defects	Sb, Sn, As increase problem Ni reduces problem More problems with lower C content
4		Cu	0,2		Hot workability	
3		Cu	0.2		Hot-shorteness	Sn and Sb increase the effect, Ni decrease it. Ni can be problem , adherent scale → surf. Defect → wear of process tool.
3	Engineering steels	Cu	0.35-0.47	Continuous casting	Intergranular cracks in areas under mech. Stress. Problem if hold time at 1100°C	Cracking severity f(casting process) Ni inhibit cracking (same amount as Cu) Solution: strong cooling after mold extraction
3	Low carbon steels	Cu, Sn	0,8 / 0.05	Continuous casting	Intergranular cracks, increase with Cu, Sn%	Cueq = Cu + 8Sn - Ni
3	Engineering steels, low carbon steels	Cu	0.26	Reheating furnace	Cracking if 0.26% Cu and long time	0.14% Cu and long time → less cracking. Two opposite effects.
3	Engineering steels, low carbon steels	Cu	0.4	Hot rolling	Increase ultimate tensile strength, decrease elongation.	Litte influence on the surface quality (cracking).
57	Flat products	Cu, Sn	0.1 + 0.025	Hot forming	Surface cracking	
57	LC steel (o.15% C)	Sn	0.061	Cont-cast, thermal simul tests	Hot ductility decreases (RA value). Lowest value at 750°C, not dependent on Sn content	Grain boundary segreagation during cooling. Maximum segregation for cool.rate between 5 and 20K/s.
57	Deep drawing steel	Cu	0.1	Cold forming / cold drawing	negative	
4		Sn	0,04		Hot workability	
7	ELC, 0.02%C	Sn, As	0,08 *		Static recrystallization delay	Temp 950°C
57	Deep drawing steel	Sn	0.02	cold drawing	Negative, increase yield and tensile strength,	impairs elongation and striction

Table 10 Influence of residuals on processing

REF	Steel type	Rest element	(Critical) content (%)	Operation	Property affected Problem	Comment
4		Zn			Forms white smoke during iron casting	Dust treatment required
4		Pb	0,001		Hot workability	
57		Pb	0.001 – 0.005	Hot forming	negative	
4		As	0,03		Hot workability	
57	LC steel	As	0.03	Hot forming	negative	
4		Bi	0,005		Hot workability	
57		Bi	0.0005	Hot forming	Harmful	
57		S		Hot forming	negative	
16	ELC steels	Mo, Cr	0.09 / 0.09	Hot compression tests	Increase hot def resistance, delay static recristallization	➔ higher rolling load
7	0,03%C	Cr, Ni, Mo			R 90 Decrease drawability	Annealing T 680°C
16	ELC steels	Ni, Cr, Cu, Mo		Cold rolled and annealed sheets	Increase the resistance	Could be a problem for soft drawable steel grades
16	ELC steels ULC-IF steels	Sn, As, Cu, Ni, Cr, Mo			Decrease r-value and ductility ➔ adverse effect on drawability	
57		Cr, Mo, N		cold drawing	negative	
16	ELC steels	As, Sn		annealing	Recrystallization delay for cold rolled steels	Both continuous annealing and batch annealing.
57	LC steels	P	0.03	Cold forming / cold drawing	Negative, increase yield and tensile strength	
57	LC steels	As	0.025	Cold forming / cold drawing	Negative, increase yield and tensile strength	

Table 11 Influence of residuals on end-properties

REF	Steel type	Rest element	(Critical) content (%)	Operation	Property affected Problem	Comment
4	Sheet product	Ni, Cr			Increase hardness	
3		Cr, Mo, Ni, Cu	Solid solution		Increase hardenability of C and low alloy steels	Cr and Mo stronger effect
3		Cr, Cu, Ni, Mo	Solid solution		Increase hardness, decrease ductility	Cr > Cu, Ni, Mo. Cr effects depends on C concentration
3	If-Ti, thin sheet	Cu, Ni, Cr, Sn	Solid solution		Decrease grain size, increase solid solution hardening	
3	Low alloyed steels, high res. martensitic stainless steel	Cu	0.5		Increase hardness	Precipitate during aging treatement in the form of ε-Cu.
57		Sb, P		Hardenability	increase	
57		As	0.045	Hardenability	decrease	
57		B	0.0005	Hardenability	Increase strongly	
57		Cr		Hardenability	Increase moderately, strong carbide former	
57		Mo		Hardenability	Increase strongly, carbide former	
57		Co		Hardenability	decrease	
57		Cu, Ni		Hardenability	Mildly increase	
57		N		Hardenability	decrease	Nitride former, decreases grain size dimension and hardenability.
57		W		Hardenability	Strong increase	
57		S		Hardenability	Decrease by removing manganese from solution	
3	Weathering steels	Cu	0.2-0.4		Resistance to corrosion	Cu at the surface ➔ better corrosion resistance.

Table 12 Influence of residuals on end-properties

REF	Steel type	Rest element	(Critical) content (%)	Operation	Property affected Problem	Comment
16	ULC-IF	Sn (even others)			Reduce drastically toughness of hot rolled steels	Embrittlement due to grain boundary segregation
3	High strength C-Mn steels	P, Sb, Sn	Grain boundary segregation	Tempering slow cooling, service (350 - 550°C	Temper embrittlement	Mn, Cr or Ni necessary to observe the phenomene. Mo can inhibit temper embrittlement if between 0.2-0.7%wt.
57		Sb		Notch impact strength	Promotes temper embrittlement	
57		As	0.045	Notch impact strength	Promotes temper embrittlement, decrease notch impact value	
57	Maraging steel	Pb, P, S	0.005 / 0.01 / 0.014	Notch impact strength	Promotes temper embrittlement, decrease notch impact value	
57		Sn	0.04	Notch impact strength	Promotes temper embrittlement, decrease notch impact value	Effect increase with C content.
7	ULC-Ti hot stripes	Sn	0,011/ 0,049 *		toughness decrease	
10		Cu, As, F, Sn, S, An, Zn, Pb			Grain boundary embrittlement	
3	Thin sheet	Sn			Segregate to grain boundaries	More pronounced with low C.

Table 13 Influence of residual elements on processing and end-properties of flat products, from reference [2]

Product	**Steel type**	**Operation**	**Residual element**	**Content**	**Comment**
Flat	Low carbon steel grades	casting	Mo, Cr Nb, Ni	0.05 0.1	OK
		Hot rolling	Sn, Mo, As, Cr		Problem Sn>Mo>As Cr OK
		Cold rolled and annealed sheets	All but not Nb and Ti		Bad for crystallografic textures and r-value. Tensile stress increase at 0.08 (inte så at 0.03)
	ULC, low strength	Hot rolling	Sn, Cu		OK
	ULC, high strength	Hot rolling	Cu Sn	0.3 0.05	Strenght +, elongation – Strenght -, elongation +
			Sn+Cu together		Sn moderates Cu effect
		Cold work			Embrittlement with both Cu and Sn
		weldability			OK with Cu and Sn

Table 14 Influence of residual elements on processing and end-properties of long products, from reference [2]

Product	Steel type	Operation	Residual element	Content	Comment
Long		Weldability, toughness, service properties	Cu Sn	0.585 0.03	No deterioration
	Heavy plate materials, CMnNb grade	Strength and elongation	Sn	0.02	Slight effect, OK
	42 CrMo4, 34 CrNiMo6, 15 CrNi6	hardenability	Mo Cu		Mo and Cu most important elements for hardenability
	LC steel 20 MnCr5, 7 MB6	Hot ductility	Cu Sn	0.4 0.03	Degradation over these contents. Harmfull effect ceases for T over 1100°C.
		Surface cracking	Cu	0.3	Critical Cu content. Lower if Sn, Sb present, higher if Ni present.
	LC direct quenched wire rods	Cold bright drawing	Cu	0.5	Very good results for Cu>0.5
		Cold bright drawing	Cr, Mo, Ni		No significant effect
	LC free cutting steel, 0.08C, 11Mn, 0.07P, 0.3S + Bi, Te	Cutting force, tool wear, hot ductility	Cu Sn	0.25 0.05	No effect
			Bi, Te		Strong influence on hot ductility
	High tensile pearlitic steel (0.8C, 0.2Si, 0.5Mn)	Segregation	Cu, Sn, P		Sn large tendency to segregate in hot rolled rods
		Mechanical properties	Cu Sn	0.15 0.05	Cu rises slightly tensile strength, no clear effect of Sn
	LC wire	Continuous casting	Cu 0.25		Precipitation of Cu-rich phase at metal/scale interface, oxide penetration in steel , eliminated by oxidation during billet reheating prior to rolling.
		Descaling			No deterioration
		Phosphationg prior to drawing			No significant effect
		Nickel coating			No significant effect

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<u>EXHIBIT 2</u>

RESPONSE TO QUESTION FROM DOUGLAS CORKRAN
OFFICE OF INVESTIGATIONS
REGARDING PRICES FOR IMPORTED WIRE ROD BEING HIGHER THAN PRICES FOR DOMESTIC WIRE ROD

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
<u>THE AMERICAN WIRE PRODUCERS ASSOCIATION</u>

NOVEMBER 28, 2017

EXHIBIT 2

AMERICAN WIRE PRODUCERS ASSOCIATION

RESPONSE TO QUESTION FROM DOUGLAS CORKRAN (OFFICE OF INVESTIGATIONS) REGARDING PRICES FOR IMPORTED WIRE ROD BEING HIGHER THAN PRICES FOR DOMESTIC WIRE ROD

QUESTION —

Mr. Corkran:

> *Thank you Vice Chairman Johanson, one question please for Mr. Stauffer. I believe you testified today that U.S. prices were now below global prices, was that the initial testimony?*

Mr. Moffitt:

> *Mr. Corkran, if I could just add very quickly to that, I believe Mr. Frey also mentioned this is as well but in a September the 28th article in the American Metal Market, they do address that very question and I mean I have it available and we can include it in the post-hearing Brief I guess and it does explain that they say flipped.*

Mr. Corkran:

> *Thank you very much.*

(*Transcript* at 239, 241.)

RESPONSE —

Attached is the article from *American Metal Market* to which Mr. Moffitt referred at the hearing. The article is dated September 28, 2017, and it reports that "US steel wire rod import prices are now selling at a roughly $60-per-ton premium to domestic rod, inverting longtime trends."

ATTACHMENT TO EXHIBIT 2

US rod import spread vs. domestic flips

Sep 28, 2017 | 11:42 AM | Nat Rudarakanchana

NEW YORK — US steel wire rod import prices are now selling at a roughly $60-per-ton premium to domestic rod, inverting longtime trends, market participants said.

Still, cfr prices remain mostly flat as this premium is calculated with respect to loaded truck or import selling prices, according to traders, buyers and mills.

By the time import rod travels “upriver” and is delivered or close to a buyer’s facility, starting from Gulf ports, loaded truck prices could be $32 per hundredweight, one trader said. He estimated fob export prices from Vietnam at $595 per tonne, a value he last obtained two weeks ago, which translates into $640 per tonne or so cfr. He hasn’t been active in the import market because US wire drawers aren’t interested in imports at present prices.

“I haven’t heard anything” with respect to attractive or new cfr prices, this trader said. “Domestic rod prices must go up first. ... The import business is not very strong right now.”

Domestic industrial-quality rod is at $29 to $29.50 per cwt, before implementation of the latest $40 per ton increase, this trader estimated, citing conversations with customers. That puts the spread at $60 per ton, favoring domestic rod, a figure in line with market estimates.

Some sources estimated that imported rod costs as much as $80 per ton more than domestic rod.

A second trader pegged domestic prices at $29.50 per cwt and import prices typically at $60 to $80 per ton above that, including from recent major exporters like Germany. He did not indicate cfr prices.

The $40-per-ton domestic price increase will see support from reduced import competition, the second trader said in echoing market chatter at the American Wire Producers Association’s government affairs conference that ended on September 27.

Lower global scrap prices have been offset by higher graphite electrode prices and reduced raw melt production, a third trader added, noting a major US electrode producer has declared *force majeure* and is no longer supplying electrodes.

Cfr prices are mostly flat, similar to trends seen two weeks ago, he added.

“I know scrap is down significantly, into correction territory, but no relief yet on wire rod numbers mainly due to reduced melt for want of graphite electrodes,” this trader said. “The gap is huge between offshore and domestic. Was $100 (per) ton plus ... now, perhaps $60 (per) ton.”

There's "still money being left on the table by US mills," he said before the recent price increase took full effect. "The price inversion will certainly have an impact on imports and eventually lead to pricing power for the domestic mills. ... Yet, wire drawing customers are seemingly not concerned as (US) lead times are short and (domestic) rod plentiful ... for now."

Rod imports look poised to total 86,429 tonnes for September, according to license data updated by the US Commerce Department's Enforcement and Compliance division on September 26. That's down from 105,292 tonnes licensed in August, in itself a low figure compared with the 2016 monthly import average of 118,600 tonnes.

Traditional rod suppliers to the US—like Turkey, Russia and Ukraine—disappeared entirely in September while Egypt, Morocco and Germany were among the major new spot suppliers.

Egypt was licensed to ship 14,486 tonnes to US shores in September, with Morocco licensed to supply 4,178 tonnes and Germany 8,272 tonnes. Egypt and Germany had been licensed to ship 10,487 tonnes and 13,109 tonnes, respectively, the prior month while Morocco provided no material in August.

Cfr prices are mostly unchanged from two weeks ago, typically at $600 per tonne fob export from several countries, a fourth trader noted.

Import availability will be an issue in the future, he said, citing import protection mechanisms such as an ongoing wire rod trade case and a pending Section 232 investigation.

This source also noted that market forecasts were split cleanly down the middle at the recent International Rebar Exporters and Producers Association (Irepas) biannual meeting in Athens, which ended on September 26. "No real good intel" at Irepas, he said on September 27. "Probably half (of the meeting attendees) see the world market softening and the other half see it going up."

Domestic mills "have room to move (rod prices) up for sure," the fourth trader added, echoing market chatter.

AMM assessment for imported low-carbon wire rod, which is on a cfr basis port of Houston, remains unchanged from two weeks ago at $572 to $581 per short ton ($630 to $640 per tonne).

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CBI EXHIBIT 3

MONTHLY SCRAP CHANGES AND ROD PRICE INCREASE ANNOUNCEMENTS

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
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NOVEMBER 28, 2017

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CBI EXHIBIT 4

CORRELATION OF SCRAP AND ROD PRICES OVER THE PERIOD OF INVESTIGATION ("POI")

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
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NOVEMBER 28, 2017

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CBI EXHIBIT 5

EMAIL CORRESPONDENCE BETWEEN AWPA MEMBER AND ONE PETITIONER

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

**POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION**

NOVEMBER 28, 2017

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CBI EXHIBIT 6

MONTHLY SCRAP CHANGES AND ROD PRICES PAID BY AWPA MEMBER

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

THE INFORMATION IN THIS CBI EXHIBIT

IS NOT SUSCEPTIBLE TO PUBLIC SUMMARY.

This CBI Exhibit Is Entirely Confidential, Completely Bracketed,
and Has Been Omitted from the Public Version.

CBI EXHIBIT 7

MONTHLY SCRAP CHANGES AND ROD PRICES PAID BY AWPA MEMBER

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

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CBI EXHIBIT 8

MONTHLY SCRAP CHANGES AND ROD PRICES PAID BY AWPA MEMBER

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

THE INFORMATION IN THIS CBI EXHIBIT

IS NOT SUSCEPTIBLE TO PUBLIC SUMMARY.

This Public Exhibit Does Not Contain Confidential Business Information.

EXHIBIT 9

ROD MILLS' AFFILIATED WIRE COMPANIES

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

EXHIBIT 9

U.S. WIRE ROD MILLS AND THEIR AFFILIATED WIRE COMPANIES

CHARTER MANUFACTURING CO. INC.		
Cleveland Rod Mill	Cleveland, OH	Rod Mill—U.S.
Saukville Rod Mill	Saukville, WI	Rod Mill—U.S.
Charter Wire	**Milwaukee, WI**	**Wire Company—U.S.**
Fostoria Plant	**Risingsun, OH**	**Wire Company—U.S.**
Charter Automotive	**Milwaukee, WI**	**Wire Company—U.S.**

GERDAU		
Gerdau Ameristeel	Jacksonville, FL	Rod Mill—U.S.
Gerdau Ameristeel/Beaumont	Beaumont, TX	Rod Mill—U.S.
Carrollton Wire	**Carrollton, TX**	**Wire Company—U.S.**
Beaumont Wire	**Beaumont, TX**	**Wire Company—U.S.**

KEYSTONE STEEL & WIRE COMPANY		
Keystone Rod Mill	Peoria, IL	Rod Mill—U.S.
Keystone Wire Mill	Peoria, IL	Wire Company—U.S.
Engineered Wire Products	**Upper Sandusky, OH**	**Wire Company—U.S.**
Strand-Tech Martin	**Summerville, SC**	**Wire Company—U.S.**
Keystone Calumet	**Chicago Heights, IL**	**Wire Company—U.S.**

NUCOR		
Nucor Steel—Nebraska	Norfolk, NE	Rod Mill—U.S.
Nucor Steel Kingman, LLC	Kingman, AZ	Rod Mill—U.S.
Nucor Steel—South Carolina	Darlington, SC	Rod Mill—U.S.
Nucor Steel Connecticut, Inc.	Wallingford, CT	Rod Mill—U.S.
Nucor Steel Connecticut, Inc.	**Wallingford, CT**	**Wire Company—U.S.**
Nucor LMP Steel Inc.	**Maryville, MO**	**Wire Company—U.S.**
Nucor Cold Finish & Wire Products Utah	**Brigham City, UT**	**Wire Company—U.S.**
Nucor Cold Finished Wisconsin, Inc.	**Oak Creek, WI**	**Wire Company—U.S.**

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EXHIBIT 10

NUCOR'S 2016 FINANCIAL STATEMENT

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

SEAN KENNY LAVALLEE KELSEY W LAVICKA RAPHAEL LAVIOLETTE MATHIEU LAVOIE ZACHARY LAVOIE CHRISTOPHER M LAW CHARLES R LAWHON MICHAEL T LAWHON SHAWN LAWHUN JEREMY LIVINGSTON LAWLESS
JOSEPH C LAWLESS BRAD A LAWRENCE CAROLYN LAWRENCE GLENN A LAWRENCE JAMES LAWRENCE JARON O LAWRENCE JEFF LAWRENCE JENNALEE LAWRENCE JONATHON L LAWRENCE MATTHEW JAMES LAWRENCE
MICHAEL B LAWRENCE QUENTIN A LAWRENCE ROBERT E LAWRENCE JR RYAN J LAWRENCE STEVEN LAWRENCE STEVEN COLBY LAWRENCE TONY E LAWRENCE JENNIFER LAWS MATTHEW JARED LAWS
JUSTIN LAWSHE DAVID S LAWSON GUY T LAWSON JEREMY M LAWSON JOHN A LAWSON JONATHON T LAWSON KEVIN SCOTT LAWSON SR MICHAEL LAWSON MICHAEL L LAWSON NATALIE LAWSON
RICHARD B LAWSON TYLER LAWSON GUY M LAWYER ROBERT LAWYER JR JORDAN S LAX STEPHEN D LAXTON CHRISTOPHER S LAY JAN LAY JOHN P LAY JR J MICHAEL LAYDEN BARRY LAYNE CHARLES J LAYNE
SID AHMED LAZLI ABELARDO LAZO PAUL D LAZZARO JOHN N LE MIKAEL LE CORRE SHERRIE LE GALL JEFFREY LEA DOROTHY LEACH GLEN LEACH MORGAN S LEADERS LAWRENCE LEADY BARNEY LEAF
DANIEL LEAHY MICHAEL J LEAK THOMAS C LEAKEY ANTHONY LEAL DANIEL LEAL MICHAEL C LEARY ROBERT W LEARY MYLES LEAS JOHN ANDREW LEATH LARSON J LEATY BRADLEY LEAVITT DAWN LEAVITT
JOSEPH LEAVITT V TORRICE LEAVY JAMES LEBISZCZAK ALLAN LEBLANC CHAD M LEBLANC JODI LEBLANC MARTIN LEBLANC NICHOLAS G LEBLANC SHAWN LEBLANC TIMOTHY LEBLANC TYLER LEBLANC
ROBERT T LEBO JR BUNYONG LECK AARON R LECOMPTE RICKEY JOE LEDBETTER KEVIN J LEDDY DAVID LEDESMA DONALD LEDFORD PAUL LEDUC KIMBERLY LEDWELL ASHLEY B LEE BLAINE WRIGHT LEE
BRIAN ROBERT LEE CHRISTOPHER LEE DANNY LEE DANNY O LEE DANNY WAYNE LEE DAVID LEE DAVID E LEE DENNIS G LEE DONALD LEE ERNIE LEE GARRY LEE GEORGE W LEE JACE LEE JACQUELINE PENNY LEE
JASON LEE JASON A LEE JASON R LEE JEFFREY L LEE JONATHAN J LEE JUSTIN M LEE KARLEAN A LEE KENNETH A LEE KRISTOPHUR L LEE LIONEL LEE MATTHEW LEE MATTHEW HEATH LEE MELVIN L LEE JR
MICHAEL LEE MICHAEL LEE MICHAEL D LEE MICHAEL J LEE SR PETERSON LEE RANDY C LEE ROBERT B LEE ROBERT D LEE RONNIE E LEE SHANE M LEE STEPHEN A LEE STEVEN P LEE TED HARRISON LEE
TERENCE LEE THOMAS J LEE JR TONY LEE WANDA C LEE YOUNGHAN LEE JASON LEECH JOHN F LEECH SHANE LEEPER ANDREW LEFFLER TERESA LEFKO CAROLE LEFRANCOIS COREY LEFRANCOIS
NICOLAS LEGARRETA WILLIAM T LEGATE DEREK LEGAULT JOY CALIGAN LEGAULT DEVIN T LEGER JASON ROWE LEGG BRAD DARIN LEGGETT COURTNEY LEGGINS BRIAN A LEGNARD LEN LEGRIS
CHARLES A LEGROS RONALD LEHAN BENJAMIN S LEHMAN JOHN LEHMAN JUSTIN LEHMAN LOREN J LEHMAN RUSSELL LEHMAN TODD W LEHMAN ROBERT G LEHN MAX J LEHRMAN WAYNE R LEHRMAN
RODNEY LEIGH LARRY A LEIGHTLEY BETTY J LEISE WILL LEISEY LYNN G LEISHMAN MICHAEL LEISURE AMY LAUREN LEJEUNE STEVEN RAY LEJEUNE TODD LEKEY JOSEPH LELYS DONALD R LEMAR IAN LEMAY
MELANIE F LEMBO JUSTIN LEMIEUX ROBERT F LEMMING ROBERT M LEMMING CLIFTON T LEMMON MITCHELL LEMOIGNAN EDMOND LEMONS JEFFREY L LEMONS MACAULEY LYNN LEMONS ROBERT J LEMONS
TIMOTHY S LEMONS CHRISTIAN LEMUS JORGE LEMUS POLANCO JOSE LEMUS VIVAR LISA LENDZIAN DENNIS LENEGAR JASON J LENGACHER KELLY R LENGACHER STEVEN LENNARTZ JEREMY LENNON
STEPHEN D LENOIR THEUNIS J LENSLEY AARON S LENTZ STEVE LENTZNER JAMES CLARK LENZ ADAM LEOHNER HECTOR LEON JAIME LEON CHAD M LEONARD CHADWICK LEONARD CHARLES E LEONARD JR
GUY LEONARD HARRY N LEONARD JENNIFER S LEONARD JOHNNY L LEONARD JONATHAN A LEONARD JOSEPH F LEONARD MICHAEL LEONARD ROBERT D LEONARD TIMOTHY LEONARD JOHN T LEONE
LESTER LEONHARDT BRENDA LEPHART-SLATE CHRISTOPHER LEPOER MICHAEL H LEPORE JACOB P LEPPER BRYAN A LERMA ANDREW R LEROY RANDY DALE LEROY MATTHEW LESAICHERRE ANDREW K LESLEY
HANK W LESLEY NATHANIEL C LESLEY SEAN LESLIE SHANE LESLIE TIMOTHY H LESLIE CAMERON S LESTER DOUGLAS L LESTER LISA LESUER KAREN S LETNER JERRI LYNN LETT ROBBY P LETT RAOUL LEUBA
GREGORY LEUGERS GARY M LEVANDUSKI LUC LEVESQUE JOSHUA E LEVI STACY L LEVI VINCENT J LEVI WILLIAM ANTHONY LEVI VIC LEVINSKY JON S LEVY PAUL E LEWBERG CHAD D LEWELLYN
CHRISTOPHE LYN LEWELLYNG BRAD LEWIS BRODY D LEWIS BUFORD DALE LEWIS CHARLIE W LEWIS CHRISTOPHER R LEWIS CHRISTY J LEWIS COREY LEWIS DANIEL LEWIS DANNIEL WADE LEWIS DAPHNE A LEWIS
DARREN LEWIS DAVID A LEWIS DAVID R LEWIS JR DEREK LEWIS DERRICK LEWIS EMILY PAULETTE LEWIS ERIC LEWIS FRANKLIN J LEWIS GREGORY S LEWIS JACOB LEWIS JACOB WILLIAM LEWIS JAMES K LEWIS
JAMES P LEWIS JASON LEWIS JOHN LEWIS JULIE LEWIS JUSTIN CHARLES LEWIS KENT LEWIS LARRY LEWIS LARRY D LEWIS LATANYA LEWIS MADYSON LESHEA LEWIS MATTHEW P LEWIS MICHAEL D LEWIS
MICHAEL R LEWIS MICHAEL W LEWIS MORGAN DAVID LEWIS NATHANIAL R LEWIS PAUL LEWIS ROGER LANCE LEWIS SAMANTHA LEWIS SHANE A LEWIS SHAWN A LEWIS TERENCE R LEWIS THOMAS DAVID LEWIS
TOBY ALLEN LEWIS WILLARD LEWIS WILLIAM R LEWIS BRENT J LEY DUSTIN LEYDE ERIC LI JINGAI LI KURTIS M LI ROBERTO LI DEREK LIBARIOS NORMAN R LIBENGOOD ELIZABETH P LIBERMAN
BRYCE E LIBERTY KEVIN LICCAR SARA B LICHTY KYLE LICKNESS SMITH J LIDDELL SUQUANNA LIDGE CHAD MICHAEL LIEBES JASON A LIEGL EDDIE D LIENEMANN HEATHER A LIEUGH JOSEPH LIGAJ
SCOTT LIGHT STUART LIGHT TYLER PAUL LIGHT JOHN LIGHTFOOT GARY LIGHTNER SARA LIGHTNER STEVEN K LIGHTSEY PATRICK E LIKINS FRANK B LILE DARRYL L LILIENTHAL GENE LILINOE ARNOLD G LILLARD
BRANNON J LILLARD DAVID L LILLIE RICHARD LILLIES STEVEN LILLIMAN GEORGE DAREN LILLIS MARVIN P LILLY NAKEI LILLY PATRICK W LILLY SUMMER K LILLY TRAWICK LILLY EDWIN S LIME RAE LIMERICK
JAIME LIMON RAMIREZ CARLOS LINARES JOSE LINARES RAFAEL LINARES FREEMAN L LINCOLN JR JEFFREY A LINCOLN SHIRLEY A LIND VICTORIA LIND CARL R LINDAHL DAVID C LINDAHL LEIF R LINDBERGH
MEREDITH E LINDELOF EVAN S LINDEMAN WHITNEY LINDEMAN KEITH LINDEMULDER CLAYTON LINDEN ANTHONY D LINDERMAN ROBERT D LINDERMAN JAMES J LINDHORST JAMES T LINDLER FREDERICK W LINDNER
JOHN LINDSAY ROBERT W LINDSAY THERON GLEN LINDSAY BOBBY LINDSEY CHRISTOPHER LEE LINDSEY JACKIE ALLEN LINDSEY JEREMY JOEY LINDSEY STEVIE L LINDSEY WILLIAM EDWARD LINDSEY
JASON LINDSTROM JASON A LINDSTROM NED LINDSTROM III SUZANNE LINDSTROM THOMAS LINDSTROM MARDEE JO LINE WESLEY LINEBARGER BLAKE J LINGMANN ALEXANDRE LINHARES SHERRY T LINK
J D LINKER WILLIAM LINKLATER COLTON LINN JODY D LINN MICHAEL LINN ROBERT L LINNELL JOHN LINT JAMES BRADLEY LINVILLE BRIAN E LINZIE SAMUEL LIPARI MATTHEW LIPHAM BENJAMIN PATRICK LIPIEC
JOSEPH R LIPP MICHAEL LIPP CHRISTOPHER D LIPPMAN RICHARD J LIPPMAN JOE ALLAN LIPPS CHARLES R LISEK MARCY LISH NICOLE LISI PAUL LISI SHAWN LISINSKI MATTHEW K LISK JAN LISNYJ
JOHN LISONBEE III DANIELL LISTON MARTIN W LISTON HAROLD J LITCHFIELD III JOHNNY L LITCHFIELD ROBERT LITLE PHILLIP A LITTELL II CALLIE LITTLE CASEY S LITTLE COURTNEY R LITTLE DANIEL C LITTLE
JOSHUA C LITTLE JOSHUA J LITTLE KENNETH LITTLE STEPHANIE LITTLE TIMOTHY LITTLE TIMOTHY LITTLE STEVEN LITTLECROW JOSHUA C LITTLEFIELD THOMAS C LITTLEFIELD JOHN CHRISTOPHER LITTLETON
JERED A LITTS SHANE S LITZENBERG CANDY LIVELY JAMES B LIVINGSTON JEFFREY LIVINGSTON SHARON LOUISE LIVINGSTON ALAN LIVINGSTONE ABEL LIWANAG KANANKE PERASHM LIYANAGAMAGE
DINESH LIYANAGE KATHARINE LLEWELLYN SHAWN E LLEWELLYN GORDON K LLOYD JAMES BRANDON LLOYD JEFFREY LLOYD MITCHELL LLOYD PATRICK W LLOYD KANFAY LO WINGHONG LO KELLY LO PRESTI
TRAVIS LOADHOLT LOREN V LOBERG ERIC LOBO KEVIN W LOBUE REILLY LOCASCIO CHRISTOPHER N LOCHMANN PAUL M LOCICERO IV CRAIG C LOCK JACOB A LOCK CHRISTOPHER N LOCKE ENNIS JOE LOCKE
AFIYA LOCKETT WILLIAM E LOCKETT JR AARON LOCKHART JEFFREY A LOCKHART MICHAEL LOCKHART SAMUEL W LOCKLAIR CALVIN LOCKLEAR KEVIN LOCKLEAR TERRY L LOCKSHIRE PAUL M LOCORE
KEVIN LOE JACK H LOEP CHRISTIAN LOERA JOSE MARTINEZ LOERA JESSE D LOEW DAVID K LOEWE DANIEL H LOFFER THADDEUS LOFTON DWIGHT LOGAN II JON DAVID LOGAN TANNER J LOGAN
ROY DOUGLAS LOGGINS JR ERIC LOGSDON JEFFREY DAVID LOGSDON MATTHEW D LOGSDON ANDREW LOGUE ANGELA MARIE LOGUE BLANCA LOGUE CHRISTOPHER DWAYNE LOGUE MICHAEL LOGUE AIGNER LOH
MATTHEW J LOHR RICHARD LOINA JAKE LOJEK ALFRED LOKELOKE JR JEROME E LOKKEN AUNDREA LOLLAR CHRISTIAN J LOMAS JAMES LOMAX JOHN CLEMMONS LOMAX III ARMANDO LOMELI JEFFREY D LONA
GERALD R LONDON LEVI LONDON AUSTIN C LONG BRYAN L LONG CRAIG LONG DANNY LONG HOLLIE C LONG JERRY F LONG JOSHUA SCOTT LONG JOSHUA T LONG KENNETH P LONG JR KEVIN LONG
KYLE PEYTON LONG LAURIN LONG MICHAEL A LONG PATRICK C LONG SHAWN E LONG STEVEN A LONG TERRY R LONG TRAVIS C LONG WILLIAM E LONG ADAM LONGBOAT JOHN MATT LONGMAN
PRISCILLA LONGORIA DALE LONO KEN LONSDALE GERSONN LOODS MICHAEL J LOOK ALEXANDER LOOKATCH ALEXANDER B LOOMIS JACK E LOOMIS TONIA R LOOMIS JOSEPH B LOOSLE ZAK Z LOOSLE
ANTHONY J LOPEZ BENJAMIN LOPEZ CHRISTINA D LOPEZ CHRISTY LOPEZ DANNY J LOPEZ DAVID J LOPEZ ERIC J LOPEZ ERNEST LOPEZ FILIBERTO LOPEZ FRANCISCO A LOPEZ GABRIEL LOPEZ GILBERTO LOPEZ
HORACIO LOPEZ JASON LOPEZ JEFRI LOPEZ JESUS LOPEZ JOSE J LOPEZ JUAN LOPEZ JUAN M LOPEZ KEITH A LOPEZ MARIO LOPEZ MOISES LOPEZ PHILLIP L LOPEZ RAFAEL LOPEZ RAUL LOPEZ JR
RAYMOND J LOPEZ REYNALD LOPEZ ROBERT LOPEZ SAMUEL R LOPEZ THOMAS LOPEZ WILSON T LOPEZ BIENVENIDO LOPEZ GONZALEZ XAYMARA LOPEZ ORTA IVAN LOPEZ SANCHEZ JUAN LOPEZ SANCHEZ
JOSUE LOPEZ-GARCIA DANIEL LOPEZ-RODRIGUEZ DOUGLAS M LORAINE RICHARD LOREN DAVID A LORENZ SCOTT LORENZO RICKY ALLEN LORICK DONALD LORING II MICHAEL B LORINO SUSAN J LORTIE
ROBERT W LOSER CASEY LOSINIECKI SCOTT LOTHAMER TODD LOTHAMER JESSICA B LOTHE NICHOLAS P LOUALLEN DYLAN LOUCKS KEVIN L LOUDIN BRADLEY S LOUGH BRIAN C LOUGH STEVEN J LOUIE
STEPHANIE M LOUNSBERRY IMMANUVEL LOURDUSAMY CHAD H LOUTZENHISER BRET M LOVE DEREK LOVE ED LOVE JACOB RYANN LOVE JASON ROBERT LOVE KEVIN JEROME LOVE KISHI DUSHONNE LOVE
MARLON K LOVE SHANDON LOVE STEPHANIE K LOVE KEITH LOVEJOY RICHARD G LOVELACE SR GARRETT D LOVELADY ROBERT LOVELADY KURTIS J LOVELAND RICKEY LOVELAND ROCKY LOVELAND
DAVID LOVELESS BRAD D LOVELLETTE DEAN LOVEWELL MARTIN ALEXANDER LOVINGOOD RANDALL KEITH LOVINS JOSEPH LOUIS LOVVORN III COLBY JUSTIN LOW ANTHONY G LOWE CHARLES B LOWE
JAMES E LOWE III LESLEY A LOWE WILLIAM P LOWE WILLIAM SETH LOWE ZACHARY PAUL LOWE ALAN RAY LOWERY KENNETH D LOWERY MELINDA LOWERY TARA M LOWERY TWAN LOWERY WILLIAM R LOWERY
RICK C LOWMAN IAN JAMES LOWREY JOHN M LOWRY KYLE LOWRY ZACHARY S LOWRY-SULLIVAN GEORGE T LOY CHARLOTTE A LOYD ROBERT M LOZA JOSEPH B LOZADA LOUIS LOZANO CESAR LOZANO RIVERA
GUILLERMO LOZANO VELAZQUEZ EVAN HAN-FANE LU JOSE LUA LUKE LUARKIE JACOB LUARTE LYNN P LUBASZEWSKI ROGER D LUBKE GEORGE T LUBY DEBBY LUCAS GREGG S LUCAS JEFFREY LUCAS
JEREMY LUCAS JOSEPH F LUCAS JR NATHANIEL LUCAS PATRICK COLBY LUCAS RONALD G LUCAS JR SHAD C LUCAS SHARON KAY LUCAS TYLER J LUCAS WILLIAM R LUCAS IV DANIEL LUCAS A LINDA LUCCI
COLTON LUCE DANNY W LUCE MICHAEL LUCE JOHN R LUCIER NELSON LUCINDO LINDA LUCK EARL LUCKEY MARK W LUCY ADAM KAYIN LUDWIG DERRYK LUDWIG DONALD T LUDWIG NATHAN M LUDWIG
DONALD A LUEBBEN DONALD A LUEBBEN JR KRISTY M LUEBBEN BRIAN LUIPPOLD MANNY LUIZ BERNADETTE LUJAN LEOBARDO LUJAN BRITTANY LASHAE LUKE CHARLES E LUKENS CHRISTOPHER L LUKER
JOSHUA R LUKER SEAN P LUKER JOHN LULICH NICOLAS L LUMBRERAZ CARL L LUMMUS EDWARD WAYNE LUMPKIN CARLOS FELIPE LUNA FRANKY LUNA RICHARD LUNBECK AMANDA K LUND ANTHONY HALE LUND
BRANDON LUND PHILLIP A LUND TRAVIS C LUND JOHAN LUNDBERG RODNEY H LUNDBERG JOHN LUNDGREN QUINCY LUNFORD TONY LUNG AARON E LUNING CHERYL KAY LUNING ROBERT E LUNING
DENNIS E LUNNING MATTHEW S LUNNING ALLAN LUNSFORD JAMES RYAN LUNSFORD TAMARA LEIGHANN LUNSFORD LINH LUONG BRIAN D LUPO BOBBIE M LUSCHEN KEITH LUSK ROGER LUSSIER
CHRISTOPHER LUTCKEN CHRISTOPHER M LUTES KAREN LUTHER SHAWN LUTHER BRUCE WAYNE LUTTRELL DAVID LUTZ JEFFERY D LUTZ JEREMY LUTZ MATTHEW LUTZ MEGHAN ALICIA LUTZ VICKI LUTZ
MATTHEW LUYMES COLBY C LUZIER GARY S LYCZAK KEITH LYDING NORMAN LYELL OLIVER J LYLES JAMES LYMAN AARON T LYNCH ALLEN LYNCH BILLY J LYNCH BRANDI J LYNCH BUDDY A LYNCH
DANIEL B LYNCH GEORGE W LYNCH GORDON J LYNCH GREG N LYNCH JAMES T LYNCH JAMIE LYNN LYNCH JESSE R LYNCH JIMMY R LYNCH JOSHUA TILMAN LYNCH KEVIN W LYNCH KRISTY E LYNCH
LANCE E LYNCH PAUL V LYNCH REGGIE L LYNCH RICHARD J LYNCH SARAH H LYNCH STEPHEN B LYNCH TARRANT T LYNCH WENDELL KEVIN LYNCH MARK LYNESS BART E LYNN CHRISTOPHER D LYNN
DONNIE WAYNE LYNN MICHAEL JOHN LYNN RYAN LYNN TERRY D LYNN TIMOTHY HEATH LYNN TIMOTHY WAYNE LYNN BRAD J LYON D RICKY LYON CHRISTOPHER MICHAEL LYONS MATTHEW J LYONS
TERESA J LYONS KYLE J LYSITT CHRISTOPHER LYSY WAYNE MA AASA MAAFALA HARSIMRANJEET S MAAN GARY A MABIS MARK A MABIS PHILLIP M MABREY BRANDON MICHAEL MABRY WILLIE L MABRY
FRANK MACALUSO RICKEY J MACARI II ERIC MACARIO BRIAN MACAULAY STEPHEN MACBETH DAN A MACBRIDE BRANDON MACDONALD DAN MACDONALD PAUL MACDONALD ROBERT MACDONALD
SAM MACDONALD STEVEN L MACDONALD THOMAS MACDONALD THOMAS J MACDONALD JESSICA MACDONNELL RON MACDOUGALL CODY AUSTIN MACE MARY JANE MACE AARON S MACELWEE PEDRO T MACEO
JENIFER MACFARLANE MICHAEL J MACFARLANE ROBERT MACHOWSKI RICARDO MACHUCA JUAN J MACHUCA-GARCIA JOSE M MACIAS REMBERTO MACIAS THOMAS W MACIEJEWSKI JAYMES MACIK
CHRISTOPHER MACINNIS DONALD MACINNIS JAMES M MACINTOSH JOE MACISAAC DANIEL R MACK DAVID L MACK HENRY C MACK MICHAEL L MACK ROBERT C MACK RONALD P MACK JR THOMAS W MACK
P TODD MACKABEN MICHAEL S MACKAY RAYLEEN MACKAY SELENA MACKAY BRIAN J MACKE JR SCOTT MACKEBEN COREY B MACKEY ROBERT MACKEY SEAN ANTHONY MACKEY BOB MACKIE PATRICIA A MACKIE
GREGORY L MACKLIN JAMES MACLEAN LUCY MACLEAN JOHN MACLELLAN WILLIAM MACLUCKIE RUSSELL F MACMANNIS WALLACE MACMURRAY TANYA MACNEILL DICKSON RS MACON BRAD MACPHERSON
BRANDON MACPHERSON BRIAN MACPHERSON NORMAN MACPHERSON SKIPPER MACRAE JOHN H MACZAK MATTHEW G MACZIK SANGEETA MADAN CYNTHIA MADDEN DALTON G MADDEN GARY D MADDEN
WILLIAM G MADDEN BILLY DANIEL MADDOX CHRISTOPHER MADDOX DAVID W MADDOX EMMANUEL T MADDOX HAMPTON TAYLOR MADDOX SAMUEL R MADDOX JR TERRY MADDOX TRAVIS MADDOX RYAN MADDY
AIRES MADEIRA AGATA MADEJ GINA MADERE LARISSA D MADEWELL NISHAN MADHUSANKA SEAN MADIGAN CLINTON N MADISON JOHN W MADISON LINDA MADISON TIMOTHY M MADISON EVARISTO MADRIGAL
MARK MADRIGAL JORGE MADRIGAL GUZMAN BENJAMIN MADRY DAVID C MADSEN FERRER MADUCDOC MICHAEL MADZUMA MANUEL MAES LOU H MAGALDI KARL MAGALLANES JAVIER O MAGALLON
ARTURO MAGANA RICHARD F MAGARGLE JOHN MAGEO JASON MAGERAN RANDY MAGERAN MICHAEL E MAGINN JORDAN MAGLINTI WAYNE MAGLINTI JOHN W MAGNAN CHARLIE MAGNAYE GARY MAGOULICK
DONALD J MAGUIRE SANDRA JEANNE MAGUIRE SHASTRI MAHABIR TIMOTHY P MAHAN BAZZARD MAHARAJ CHRISTOPHER MAHARAJ WAYNE MAHARAJ DENNIS R MAHARREY MAHSA MAHDAVIAN JACOB C MAHNKE
BRIAN F MAHONE WILLIAM M MAHONE JOSEPH A MAHONEY KEVIN J MAHONEY MATTHEW D MAHONY JOHN D MAHRENHOLZ HOWARD MAI STACEY T MAI JACOB MAILLOUX PETER P MAILMAN MARK MAIN
TROY MAIO AMBROSE MAIORIELLO DAVID MAJANO ENRIQUE MAJANO LUCAS MAJEWSKI BRYANT T MAJOR CINDY M MAJOR RYAN P MAJOR VICTOR C MAJOR ALONZO MAJORS ROBERT S MAJORS SIN MAK
LUCAS N MAKELIN DAVID E MAKER JEREMY MAKIN GAIL L MAKOWSKI CHANCE MAKU IKAIKAKAMANAOLA MAKUE BARBARA E MALAK BRADLEY W MALAYER EVA MALCOM ARMANDO L MALDONADO
DANNY O MALDONADO JEY MALDONADO RUBEN MALDONADO VICTOR MALDONADO AURELIO MALDONADO LARA JOSE MALDONADO ROJAS RYAN MALEY GAURAV MALHOTRA RYAN MALINOWSKI PATRICK M MALLANEY
MICHAEL S MALLARD JUSTIN R MALLETT ROBERT JORDAN MALLETT II VINAYAK MALLIKARJUN KORE DENNIS F MALLON DENNIS F MALLON II BROCK MALLORY CAMERON MALLORY MACK W MALLORY
TIM MALMBERG HEATHER L MALO RONNY MALO AUSTIN CARL MALONE BRENT A MALONE BRITISH S MALONE CARL DONOVAN MALONE CODY R MALONE JASON R MALONE JONATHAN D MALONE MATT R MALONE
MICHAEL MALONE MICHAEL W MALONE WILLIAM C MALONE SATHEESH R MALUR LUCAS T MALYS RICHARD MAMAJEK WILLIAM G MANAHAN NIZAM MANALAL CHASEN MANCHESTER DAVID A MANCHESTER
JESUS MANCILLAS LOZANO ADRIAN MANCINAS SHILPA MANDAPURAM JOHN M MANDEL TIMOTHY MANDL MATTHEW C MANELLI PARKER MANERS RANDHIR SINGH MANGAT L A MANGHAM DARON I MANGUM
GERALD MANGUNE SELVAKUMAR MANI MIKEL T MANION SARKIS MANISAJIAN RAJKUMAR MANISEKAR HARRISON MANLEY JONATHAN K MANLEY PARKER R MANLEY ANTHONY MANN AVERY PHILLIP MANN
CRAIG D MANN DON R MANN HARJEET SINGH MANN JACOB R MANN JAMES L MANN JASPAL MANN JERRY MANN KULBINDER MANN LESTER W MANN MAJOR MANN MELVIN MANN JR SHANTEL MANN
TINA R MANN VERKENEO MANN WILLARD DEAN MANN TODD MANNERING AMANDA L MANNING BROOKE M MANNING BRYAN EARL MANNING ELBERT T MANNING JACOB MANNING JOHN E MANNING
JONATHAN MANNING JORDAN MANNING JOSEPH C MANNING CHRISTOPHER G MANNIS ZACHARY J MANNON LUCAS R MANON PATRICK L MANON GARETH MANORE JONATHAN MANSBRIDGE RYAN K MANSFIELD
DEREK MANSON JON MANTEROLA SANTIAGO MANZO LOPEZ KHEY MAO DENNY MAODUS COLIN MAPLE LUCAS MAPLES RANDY LEE MARABLE GEORGE MARASCO DARRIN CADE MARBLE KENNETH RODNEY MARBUT
BRANDON MARCH MARTIN MARCH DARRELL MARCHELL ANTHONY MARCHESIN LOUIS MARCOLLA JOEL T MARCOTTE ALEC MARCUM GARY P MARCUM ERIC M MARCUS LUCIOUS JR MARCUS CHRISTOPHER MARDON
JOE MARES ESAKKIAPPAN MARIAPPAN FISHER MARIETTA KENNETH MARIGLIA VIDESH MARIMOOTOO CHRISTOPHER MARIN EDUARDO MARIN NOEL MARIN MITCHELL MARINCOVICH JR ANDREW MARINIG
NICOLA MARINO ROCKY MARINO ROBERT C MARINOS JONATHAN MARIONCU SREERAM C MARISETTY ARUNKUMAR MARIYAPPAN STEVE MARK JUSTIN A MARKEL SHANE MARKER IAN STUART MARKON
DALEDA MARKOS TONY MARKOWITZ ANDREW T MARKS BYRON DEAN MARKS DONOVAN E MARKS FREDERICK E MARKS GEORGE MARKS MATTHEW J MARKS PAUL P MARKS STEVEN D MARKS THOMAS M MARKS
DAVID M MARKSBERRY DAVID ANDREW MARKUS KYLE W MARKWARDT KEITH A MARLAR AUBREY A MARLOWE JR DOMENICK J MAROCCO JORDAN D MARQUES JAYSON MARQUEZ JESUS MARQUEZ JR
RODRIGO MARQUEZ III GILBERTO MARQUEZ CHAVARRIA GILBERTO MARQUEZ RAMIREZ HUGO MARQUEZ TORRES RODDY A MARRACCINI JAMES P MARRIER RONALD E MARRIER VICTOR E MARROQUIN
CHRISTINA MARRUJO NOAH CHARLES MARSALA BERTHA C MARSH BILLY MARSH DAVID W MARSH RICHARD WESLEY MARSH RODNEY D MARSH RONALD L MARSH AARON T MARSHALL DAVID L MARSHALL
DOUG MARSHALL EARL J MARSHALL GREGORY J MARSHALL HARRY L MARSHALL HEATH A MARSHALL JEFFERY L MARSHALL JESS P MARSHALL LEANNE MARSHALL LOUISE MARSHALL MICHAEL GLEN MARSHALL
NATHAN P MARSHALL NICHOLAS P MARSHALL PAUL J MARSHALL SCOTT MARSHALL TERRY L MARSHALL VELON D MARSHALL VINCENT D MARSHALL WILLIAM J MARSHALL ZACK MARSHALL JASON MARSON
FALLON MARSTON DANIEL MARTEL CARSON MARTELL MARK F MARTELL APRIL A MARTENS JEFF D MARTENS TOM G MARTENS ERIK MARTENSSON JORDAN MARTI KIM R MARTI ANTHONY MARTIN
BRANDON MARTIN BRANDON MARTIN JR BRUCE D MARTIN BRUCE D MARTIN II CAMERON J MARTIN CARL M MARTIN CHARLES C MARTIN CHARLOTTE MARTIN CHRISTOPHER D MARTIN CHRISTOPHER W MARTIN
CLIFFORD MARTIN CRYSTAL G MARTIN DANIEL MARTIN DAVID MARTIN DEAN MARTIN DENNIS L MARTIN DONALD E MARTIN JR DONNA B MARTIN EDWARD MARTIN ELISA MARTIN GLENN EDWARD MARTIN
GRANT W MARTIN JACOB WILLIAM MARTIN JAMES AUBREY MARTIN II JAMES B MARTIN JAMES D MARTIN JR JASON L MARTIN JEFFERY W MARTIN JEFFREY R MARTIN JEFFREY S MARTIN JOEY E MARTIN
JOHN C MARTIN JONATHAN AUSTIN MARTIN JOSHUA MARTIN JOSHUA ANDREW MARTIN JUDY LYLE MARTIN KIONNA MARTIN KOREY W MARTIN LEROY MARTIN LESLIE M MARTIN MARK A MARTIN MARVIN MARTIN
MATTHEW CHRISTOPHER MARTIN MERRILL T MARTIN MICHAEL MARTIN MICHAEL MARTIN MICHAEL S MARTIN MICHEAL MARTIN MITCHELL MARTIN RICHARD V MARTIN ROBERT MARTIN RYAN MARTIN
SCOTT ANDREW MARTIN SCOTT W MARTIN STEPHANIE LYNN MARTIN STEVEN MARTIN TAMRA ROSS MARTIN THOMAS L MARTIN TRAVIS RAY MARTIN W SCOTT MARTIN ZUZELL MARTIN DEBBIE MARTINEAU
JUSTIN MARTINEAU LEIGH-ANNE MARTINELLO AGUSTIN H MARTINEZ ALVARO MARTINEZ AMY M MARTINEZ ANTONIO MARTINEZ ANTONY MARTINEZ ARMANDO MARTINEZ CESAR MARTINEZ CHARLES D MARTINEZ
DANE MARTINEZ DAVID MARTINEZ EDWIN MARTINEZ ESTEVAN MARTINEZ EZEQUIEL MARTINEZ GABRIEL MARTINEZ HUGO O MARTINEZ IVANS MARTINEZ JEREMIAH B MARTINEZ JOSE MARTINEZ JOSE E MARTINEZ
JOSE L MARTINEZ JOSE R MARTINEZ JOSHUA MARTINEZ JUAN MARTINEZ JULIO MARTINEZ KIMBERLY MARTINEZ MAGDALENO MARTINEZ MARIO R MARTINEZ MICHAEL M MARTINEZ NICHOLAS MARTINEZ
NOE MARTINEZ OSCAR MARTINEZ RAMON MARTINEZ RAQUEL MARTINEZ SAUL MARTINEZ TOMMY MURRAY MARTINEZ YELIXA MARTINEZ HERIBERTO MARTINEZ DE LA SANCH DENNIS MARTINEZ ESPADA
PEDRO MARTINEZ PANIAGUA RIGOBERTO MARTINEZ PEREZ FRANCISCO J MARTINEZ PINEDO JOSE MARTINEZ-BELTRAN JOHN MARTINI MICHAEL R MARTINI ROBERT MARTINI BRIAN E MARTINON ANTONIO MARTINS
PAUL MARTINS ERIC L MARTINSON ROBERT MARTINSON MICHAEL MARTORANO ALINA MARUNTELU BRADY L MARUSKA TARA M MARUSKA TODD M MARUSKA MATTHEW D MARX CHRISTIAN R MARYOTT
GRANT L MARYOTT FRANCESCO MARZANO STEPHANIE LATISHA MARZETTE RAY MASCARENAS RICHARD AUGUST MASCHKE RICKY D MASK BRADLEY MASON JR CARRIE MASON JAMES MASON JOSEPH D MASON

STEEL PRODUCTS SEGMENT

REINFORCING PRODUCTS **Harris Steel fabricates, installs and distributes rebar for highways, bridges and other infrastructure, as well as commercial and multi-tenant residential construction markets.**

OPERATIONS

Harris Steel operates as a subsidiary of Nucor, fabricating, installing and distributing rebar in the United States and Canada. Harris Steel has been a significant growth platform for Nucor in the rebar fabrication business. Since the acquisition of Harris Steel in 2007, Nucor's total annual rebar fabrication capacity has more than doubled to over 1,700,000 tons.

In 2016, fabricated rebar sales were 1,115,000 tons, which is a 6% decrease from 1,190,000 tons in 2015.

MARKETS AND MARKETING

Reinforcing products are essential to concrete construction. They supply tensile strength, as well as additional compressive strength, and protect the concrete from cracking. Harris Steel bids on and executes a wide variety of construction work primarily classified as infrastructure, including highways, bridges, reservoirs, utilities, hospitals, schools, airports and stadiums. Harris Steel is also active in commercial office building and multi-tenant residential (high-rise) construction. In many markets, Harris Steel sells reinforcing products on an installed basis; i.e., Harris Steel fabricates the reinforcing products for a specific application and performs installation. Harris Steel operates over 70 fabrication facilities across the United States and Canada, with each facility serving a local market. Domestic construction markets have stabilized during the past few years but remain well below historical peak levels.

STEEL MESH, GRATING AND FASTENERS **Nucor manufactures wire products, grating and industrial fasteners.**

STEEL MESH

Nucor produces mesh at Nucor Steel Connecticut, Inc. and Nucor Wire Products Utah, Inc. Nucor also produces mesh in Canada at the Harris Steel operations of Laurel and Laurel-LEC. The combined annual production capacity of the steel mesh facilities is approximately 128,000 tons.

GRATING

Our grating business, which operates under the brand names Nucor Grating in the United States and Fisher & Ludlow in Canada, fabricates steel and aluminum bar grating products at facilities located in North America. Nucor Grating and Fisher & Ludlow serve the new construction and maintenance-related markets. In February 2017, Nucor acquired additional strategic assets in the bar grating business which will help us expand our geographic footprint, increase our North American market leadership position, and provide additional value to our customers. With the addition of these bar grating assets, Nucor has increased its annual production capacity to approximately 150,000 tons.

FASTENERS

Nucor Fastener's bolt-making facility in Indiana produces carbon and alloy steel hex head cap screws, hex bolts, structural bolts, nuts and washers, finished hex nuts and custom-engineered fasteners. Nucor fasteners are used in a broad range of markets, including demanding automotive, machine tool, farm implement, construction and military applications. Annual capacity is approximately 75,000 tons.

Images (clockwise from top left) One of the many product offerings of Nucor Grating. Nucor engineers use the latest 3D modeling technology to deliver increased value to customers. Metal building components are ready for a customer at the Nucor Building Systems division in Swansea, South Carolina. Box Elder County Fairgrounds building jointly manufactured by Nucor Buildings Systems and Vulcraft of Brigham City, Utah.

This Public Exhibit Does Not Contain Confidential Business Information.

<u>EXHIBIT 11</u>

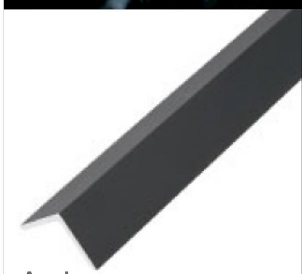
GERDAU'S DOWNSTREAM WIRE AND WIRE PRODUCTS OPERATIONS

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
<u>THE AMERICAN WIRE PRODUCERS ASSOCIATION</u>

NOVEMBER 28, 2017



Angle

Billet - Long Carbon Steel

Billet - Mechanical Construction Steel

Billet - Sheets, Blocks and Billets

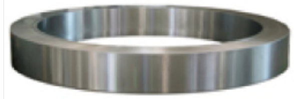
Blank

Bloom - Long Carbon Steel

Bloom - Sheets, Blocks and Billets

Built Up Crankshaft

C. G. F. Crankshaft



Casted parts

Cold Rolled Seamed Tubing

Cold drawn bar - Mechanical Construction Steel

Colled rolled plate and coil

Corrugated Sheet

Cross-tie

Drawn bar

Drawn wire

Drawn wire - Mechanical Construction Steel

Electrode

Flat bar

Forged bar

Forged bar - Mechanical Construction Steel

Forged parts

Galvanized plate and coil

Galvanized wire

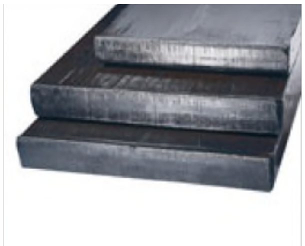
Grinded bar - Mechanical Construcción Steel

Ground bar

Hot Rolled Seamed Tubing

Hot rolled billet

Hot rolled billet - Sheets, Blocks and Billets



Hot rolled heavy plate

Hot rolled plate and coil

Ingot - Mechanical Construction Steel

Ingot - Sheets, Blocks and Billets

Machined bar - Steel Mechanical Construction

Mechanical bar - Long Carbon Steel

Mechanical bar - Mechanical Construction Steel

Merchant section - Mechanical Construction Steel

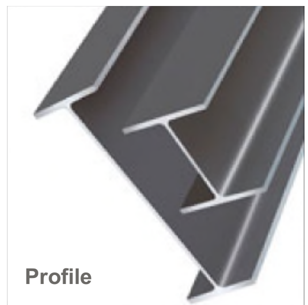

Milled bar

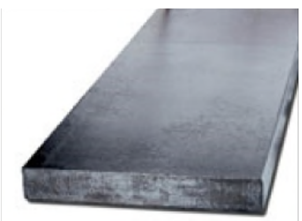

Peeled bar

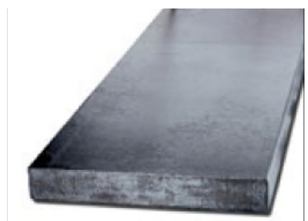

Peeled bar - Mechanical Construction Steel


Piatina


Plastic-coated wire


Profile


Profile Slab - Flat Steel


Profiling Slab - Sheets, Blocks and Billets

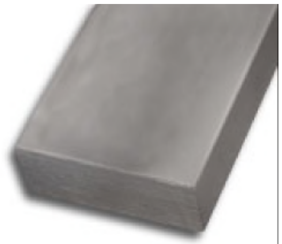

Rolled bar


Rolled bar - Mechanical Construction Steel


Rough turned bar


Slab


Slab - Sheets, Blocks and Billets


Square bar


Structural pipe


Turned bar - Mechanical Construction Steel


Welding wire


Wire rod - Long Carbon Steel

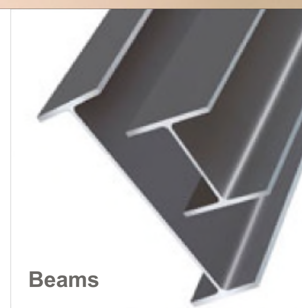

Wire rod - Mechanical Construction Steel

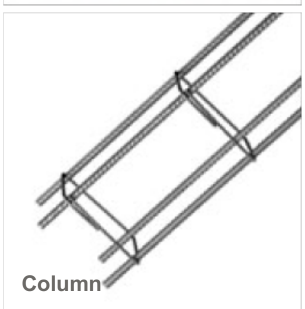

Wire rod - Stainless Steel

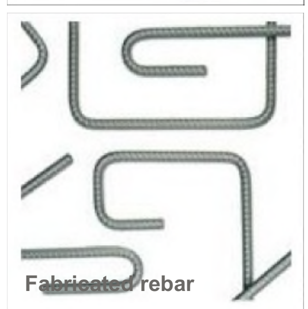
Wire rope

GERDAU

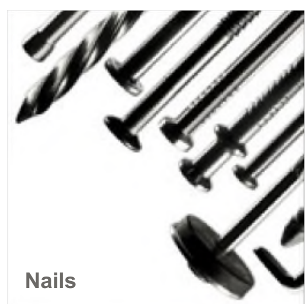

Annealed wire

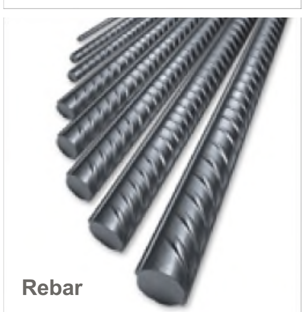

Beams


Column


Fabricated rebar

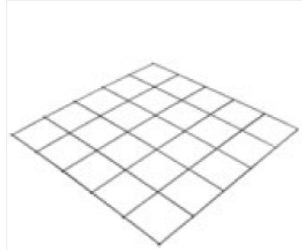

Galvanized roofing (calamine)


Nails

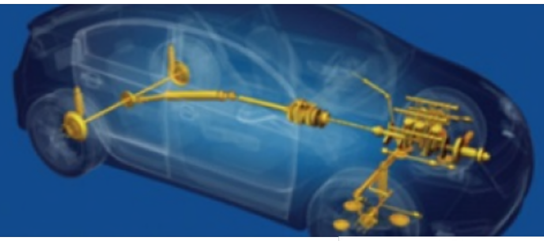

Rebar


Structural pipe


Truss frame


Wire mesh

GERDAU



Automotive

Blank

Built Up Crankshaft

C. G. F. Crankshaft

Casted parts

Cold drawn bar - Mechanical Construction Steel

Drawn wire - Mechanical Construction Steel

Flat bar

Forged bar - Mechanical Construction Steel


Forged parts


Grinded bar - Mechanical Construcción Steel

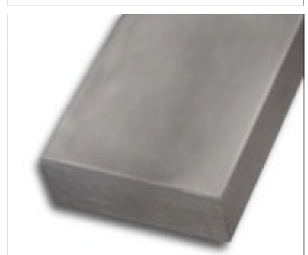

Machined bar - Steel Mechanical Construction


Mechanical bar - Mechanical Construction Steel


Merchant section - Mechanical Construction Steel


Peeled bar - Mechanical Construction Steel


Rolled bar - Mechanical Construction Steel


Square bar


Turned bar - Mechanical Construction Steel


Welding w

GERDAU

Fence post

Fence spacer

Galvanized wire

Gripple

Oval-shaped wire

Staple

Wire for vineyards and vines in general


Wire rope


Wire rope for cattle corral


Wire rope for vineyards and vines in general

This Public Exhibit Does Not Contain Confidential Business Information.

<u>EXHIBIT 12</u>

KEYSTONE—WIRE PRODUCTS OPERATIONS

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
<u>THE AMERICAN WIRE PRODUCERS ASSOCIATION</u>

NOVEMBER 28, 2017

Engineered Wire Products

Since 1969, Engineered Wire Products has been a leading manufacturer of welded wire reinforcement for the Cast in Place and Precast industries. Headquartered in Upper Sandusky, Ohio, and with production facilities in Las Cruces, New Mexico and Warren, Ohio, EWP is poised to supply steel reinforcement nationwide.

KCI KEYSTONE CONSOLIDATED INDUSTRIES (http://www.kci-corp.com/cms)

EWP produces rolled and flat mesh with wire sizes ranging from W2.1 to D31 and spacing of 2″ and greater. Utilizing the high yield strength of Grade 80 wire will reduce the cross-sectional area of the reinforcement. This will result in a weight savings of up to 25% compared to standard Grade 60 rebar. EWP steel reinforcement provides more strength and less labor.

Welded wire reinforcement can be used for an array of applications, including pipe mesh, box culvert, and girder mesh. Materials can also be used for walls and tilt up, and roadway fabric. Custom projects like bending, fabrication, epoxy and galvanized coating are also available.

Our steel is sourced from our sister facility, Keystone Steel & Wire in Peoria, Illinois. This alliance assures a reliable inventory and products that are 100% American made, and therefore Buy America Compliant. And, with an average of over 20 years of experience, customers can benefit from the extensive knowledge and experience the EWP sales and engineering team provides.

Contact us for additional information on Engineered Wire Products or to request a quote.

CONTACT EWP (CONTACT-US-EWP/)

(http://www.kci-corp.com/cms)

Capabilities

EWP serves the precast and cast-in-place market with steel mesh that is 100% made in America. All products are certified to ASTM Standard Specifications and exceed all industry quality standards.

Pre-Cast

Product/Application Sell Sheet (http://www.kci-corp.com/cms/wp-content/uploads/ksw-ewp-precast-sellsheet-082317-f.pdf)

Cast In Place

Product/Application Sell Sheet (http://www.kci-corp.com/cms/wp-content/uploads/ksw-ewp-castinplace-sellsheet-082317-f.pdf)

EWP Technical Documents

Safe Drinking Water (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-safedrinkingwater-082417.pdf)

Conflicting Material (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-conflictingmaterial-082417.pdf)

Industrial Wire (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-industrialwire-082417.pdf)

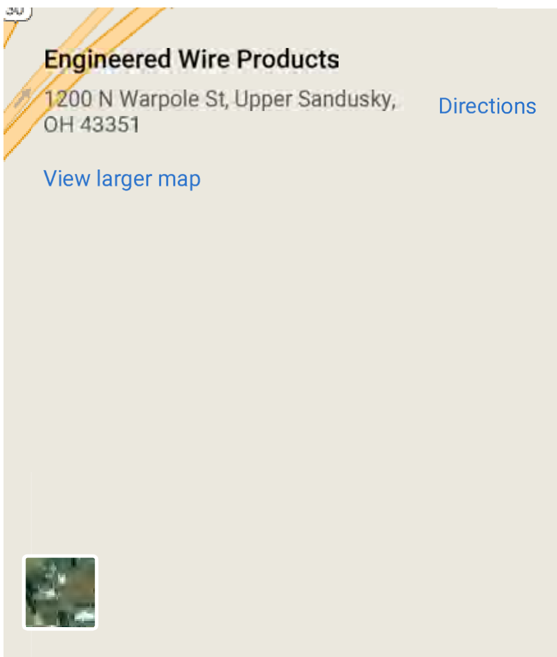
Rod and Rebar (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-rodrebar-082417.pdf)

Mercury Content (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-mercurycontent-082417.pdf)

- Recycled Steel Content (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-recycledsteelcontent-082417.pdf)

(http://www.kci-corp.com/cms)

- RoHS2 (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-rohs2-082417.pdf)
- Safety Data Sheet (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-safetydatasheet-082417.pdf)
- ISO 9001 (http://www.kci-corp.com/cms/wp-content/uploads/iso-9001-2015-certificate.pdf)



Location

- 1200 N Warpole St. Upper Sandusky, OH 43351
- 505 Venture Dr. Las Cruces, NM 88007
- 3121 W Market St. Warren, OH 44485

Contact

- Jeff Babcock
- jeff@ewpinc.com (mailto:jeff@ewpinc.com)
- 419.294.3817

NONCONFIDENTIAL VERSION

This Public Exhibit Does Not Contain Confidential Business Information.

EXHIBIT 13

KEYSTONE—STRAND TECH

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

Strand-Tech Manufacturing

Strand Tech Manufacturing (STM) is a leading domestic manufacturer of pre-stressed concrete strand and high carbon wire. Our materials are used for pre-stressed and post-tensioned construction applications. Incorporated in 1998, the state-of-the-art manufacturing facility located in Summerville, South Carolina, became a subsidiary of Keystone Consolidated Industries in 2016.

KCI KEYSTONE CONSOLIDATED INDUSTRIES (http://www.kci-corp.com/cms)

Recent facility advancements and upgrades have resulted in increased manufacturing capacity. We now produce in excess of 50,000 tons per year. Products include Grade 250, Grade 270 and Grade 300 in low relaxation strand. STM currently carries all sizes and grades listed in the latest revision of ASTM A-416. Furthermore, we are working with ASTM to revise the standards to include other Grade 270 and Grade 300 products that are commonly used in the market.

STM materials are used in bridges, commercial and industrial buildings, concrete poles, parking decks, commercial buildings and residential housing foundations.

Much of STM's high carbon steel rod feedstock comes from our sister company, Keystone Steel & Wire. In addition to providing a reliable, steady supply of quality steel, the mill is Buy America Compliant. Therefore, STM products meet the requirements for any project requiring materials that are "100% made in the USA".

Contact us for additional information on Strand-Tech Manufacturing or to request a quote.

CONTACT STM (CONTACT-US-STM/)

KCI KEYSTONE CONSOLIDATED INDUSTRIES (http://www.kci-corp.com/cms)

Capabilities

The facilities and equipment at STM are designed to allow for the greatest degree of freedom in new product development and improvement. We work in close partnership with our customers. As a result, we have developed new products and processes that have satisfied our customers' unique and individual needs.

Product/Application Sell Sheet (http://www.kci-corp.com/cms/wp-content/uploads/ksw-stm-sellsheet-082317-f.pdf)

STM Technical Documents

Safe Drinking Water (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-safedrinkingwater-082417.pdf)

Conflicting Material (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-conflictingmaterial-082417.pdf)

Industrial Wire (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-industrialwire-082417.pdf)

Rod and Rebar (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-rodrebar-082417.pdf)

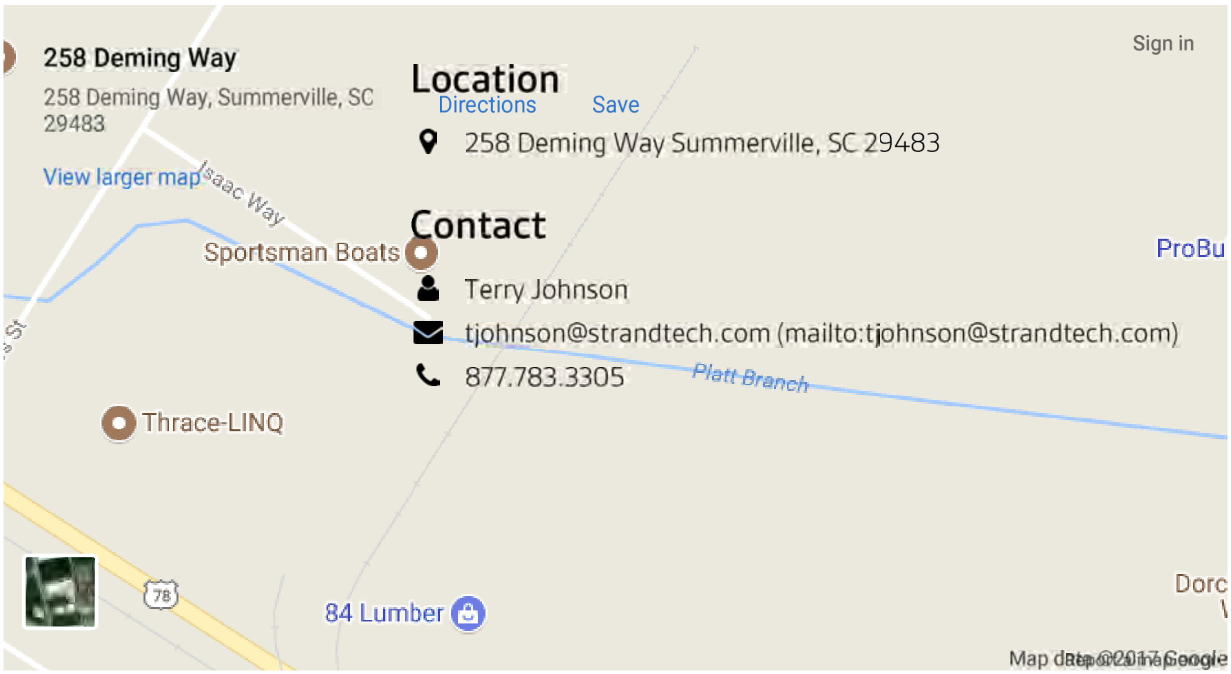
Mercury Content (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-mercurycontent-082417.pdf)

Recycled Steel Content (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-recycledsteelcontent-082417.pdf)

RoHS2 (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-rohs2-082417.pdf)

(http://www.kci-corp.com/cms)

- Safety Data Sheet (http://www.kci-corp.com/cms/wp-content/uploads/ksw-2877-safetydatasheet-082417.pdf)
- ISO 9001 (http://www.kci-corp.com/cms/wp-content/uploads/iso-9001-2015-certificate.pdf)



Location

258 Deming Way Summerville, SC 29483

Contact

Terry Johnson

tjohnson@strandtech.com (mailto:tjohnson@strandtech.com)

877.783.3305

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This Public Exhibit Does Not Contain Confidential Business Information.

EXHIBIT 14

PETITION FOR TRADE ADJUSTMENT ASSISTANCE FOR REPUBLIC'S LORAIN MILL

Petition for Trade Adjustment Assistance (TAA) and Alternative Trade Adjustment Assistance (ATAA)

About the Trade Adjustment Assistance (TAA) Program

The Trade Act of 1974 (19 USC § 2271 et seq.), as amended, established Trade Adjustment Assistance (TAA) to provide assistance to workers in firms hurt by foreign trade. Program benefits include long-term training while receiving income support. TAA provides both rapid and early assistance. Filing this petition is the first step in qualifying for benefits and assistance. After the petition is filed, the U.S. Department of Labor will determine whether a significant number or proportion of the workers of the firm have become total or partially separated or are threatened to become totally or partially separated, and whether imports or a shift in production to a foreign country contributed importantly to these actual or threatened separations and to a decline in sales or in production of articles. If a petition is approved and the workers are certified as eligible to participate in the TAA program, workers covered by a certification may contact their state workforce agency to apply for benefits. These benefits are provided at no expense to employers.

About the Alternative Trade Adjustment Assistance (ATAA) Program

Alternative Trade Adjustment Assistance (ATAA) for older workers is an alternative to TAA for trade affected workers 50 years of age or older. ATAA encourages qualified trade affected workers to quickly obtain full-time employment by providing a wage subsidy in lieu of training and income support. Submission of a completed Petition Form signifies a desire to file for both TAA and ATAA. If certified for both programs, workers will have the option of applying for TAA benefits and services and, if reemployment occurs within 26 weeks of the worker's separation, may be eligible to receive ATAA instead of TAA, if the worker desires.

Filing Instructions

- A group of three workers from the same firm, a union official, a state or local workforce agency representative in a local American Job Center (also known as a One-Stop Career Center or by a different name), an employer official, or a legally authorized representative must complete this Petition Form by answering all questions before submitting to the U.S. Department of Labor.

- You must date and submit the Petition Form ***within 1 YEAR from the date on which the workers were separated or had their hours and wages reduced***.

- You must file the Petition Form with **both** the U.S. Department of Labor in Washington, DC **and** the State TAA Coordinator or the dislocated worker office of the state where the firm is located. To file with both the U.S. Department of Labor and the State TAA Coordinator, electronically file the Petition Form on-line at http://www.etareports.doleta.gov/petition.

  To file with the U.S. Department of Labor, use one of the methods below:
  Fax the completed Petition Form to 202-693-3585, **OR**
  Mail the completed Petition Form to the U.S. Department of Labor at:

  U.S. Department of Labor
  Office of Trade Adjustment Assistance
  200 Constitution Ave NW, Room N-5428
  Washington, DC 20210

  To file with the State TAA Coordinator or the State Dislocated Worker Unit or State Workforce Agency
  Use the contact information below to find the appropriate filing address. If this Petition Form includes locations in different states, copies of this completed Petition Form must be filed in each state where firms are located.

  Toll-Free Helpline: 1-877-US2-JOBS (TTY) 1-877-889-5627
  Internet: http://www.doleta.gov/tradeact/contacts.cfm#State, or http://www.servicelocator.org

For assistance in preparing a petition
Petitioners may receive assistance in preparing the petition at their local American Job Center, by contacting the U.S. Department of Labor in Washington, D.C. at 202-693-3560 (Main Number), or by contacting their State Dislocated Worker Unit or State Workforce Agency through the telephone numbers or internet addresses provided above (29 CFR Part 90.11).

To check petition status
To check the status of your petition, please visit:
http://www.doleta.gov/tradeact/

Public Burden Statement

Persons are not required to respond to this collection of information unless it displays a currently valid Office of Management and Budget (OMB) control number. Responding is required to obtain or maintain benefits (19 USC 2321 and 2271). Public reporting burden for this collection is estimated to average 20 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, completing and reviewing the collection of information, and a state review. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the U.S. Department of Labor at the address provided above (Paperwork Reduction Project 1205-0342).

Section 1. Petitioner Information

Provide petitioner information below. Three workers from the same job location completing this Petition Form must fill in all three columns. Other petitioners need only fill in the Petitioner 1 column A. A union official completing this petition form should provide the name of the Union.

		Petitioner 1		
a)	Name	Brian Sealy		
b)	Title	USW STaff Representative		
c)	Street Address	2501 Broadway Avenue		
	City	Lorain		
	State, Zip	OH, 44052		
d)	Phone - Main	(419) 324-6300		
e)	Phone - Alternate	(440) 320-7000		
f)	E-mail	bsealy@usw.org		
g)	Worker Separation Date	03/29/2015		
h)	Petitioner Type:	Union Official: United Steelworkers		

i) Describe the worker group on whose behalf this petition is being filed:
Steelworkers

Section 2. Workers' Firm Information

Provide information on the firm employing the worker group. Complete items (a)-(g) regarding the employing firm. If the workers are doing work at a location that is different than the worker's employer (e.g., the petitioning workers are employed by a staffing agency but work at a manufacturing firm), also complete items (h) - (m) regarding the firm at which the workers perform their jobs.

NOTE: Workers completing this Petition Form must provide information for the locations where they work. All other petitioner types may apply on behalf of more than one location. State offices and One-Stop Operators/Partners may file for workers at multiple locations of a firm within their State. If you choose to file on behalf of workers at more than one location, please attach additional sheets as necessary.

Employer (Firm)

a)	Name of Firm	Republic Steel
b)	Street Address	1807 East 28th Street
	City	Lorain
	State, Zip	OH, 44055
c)	Phone	(440) 277-2000
d)	Website (if known)	http://republicsteel.com
e)	Describe the article(s) produced by this firm	steel rounds and bars
f)	How many workers have been or may be separated (if known)?	180
g)	Is the firm or any part of the firm closing (if known)? If yes, when?	No

If the workers work at a location that is different from that listed in item a) and b), then fill out items h) through m) for that location:

h)	Name of Firm	
i)	Street Address	
	City	
	State, Zip	,
j)	Phone	
k)	Describe the article(s) produced by this firm	
l)	How many workers have been or may be separated (if known)?	
m)	Is the firm or any part of the firm closing (if known)? If yes, when?	

Section 3. Trade Effects on Separations

1. To the best of your knowledge, provide reasons why you believe that separations that have occurred or may be threatened at the workers' firm are due to foreign trade. (Example: Production has been/is being shifted to a foreign country, increased imports of articles, loss of business with a TAA-certified firm.)

The reason for separation of workers are due to the drop in orders from Republic Steel's primary customer, US Steel. Republic Steel is located on the property next to US Steel, providing USS with steel rounds for the pipe and tubular market. Republic has also experienced a cessation of orders from other customers due to the drop in oil pricing and the continued dumping of pipe in tubular rounds from China and Korea.

2. If you possess any additional information or documents that you believe may assist in the determination of whether the worker group is eligible for TAA benefits, submit it as an attachment to the Petition Form. Check the box below if you have attached any additional information or supporting documents.

- I have not attached additional information or supporting documents.

3. Provide contact information for two company officials. Either separately or together, these officials should be familiar with all of the following: employment, job functions, and sales or production at each job locations.

		Official 1	Official 2
a)	Name	Rob Koury	Harry DeVilling
b)	Title	Associate General Council	Labor Relations Manager
c)	Phone - Work	REDACTION	

Section 4. Affirmation of Information

The information you provide on this petition form will be used for the purposes of determining worker group eligibility and providing notice to petitioners, workers, and the general public that the petition has been filed and whether the worker group is eligible. Knowingly falsifying any information on this Petition Form is a Federal offense (18 USC § 1001) and a violation of the Trade Act (19 USC § 2316). For this petition to be valid, each of the petitioners listed in Question 1 must sign below, and the Petition Form must be dated. By signing below, you agree to the following statements:

"I declare that to the best of my knowledge and belief the information I have provided is true, correct and complete."

a)	Signature	/s/ Brian Sealy		
b)	Name (Print)	Brian Sealy		
c)	Date of Petition	March 31, 2015		

The Petition Form will be made available for public inspection and copying under the Freedom of Information Act, as amended (5 USC § 552), Executive Order 12600, and 29 CFR Part 70, upon written request to the U.S. Department of Labor.

The Petition Form date will be recorded as the date that the petition is transmitted electronically via website to OTAA.

This CBI Exhibit Is Entirely Confidential, Completely Bracketed,
and Has Been Omitted from the Public Version.

CBI EXHIBIT 15

AFFIDAVIT REGARDING REASONS FOR CLOSURE OF ARCELORMITTAL'S GEORGETOWN MILL

BEFORE THE U.S. INTERNATIONAL TRADE COMMISSION

IN THE MATTER OF THE ANTIDUMPING AND COUNTERVAILING DUTY INVESTIGATIONS OF CARBON AND ALLOY STEEL WIRE ROD FROM BELARUS, ITALY, KOREA, RUSSIA, SOUTH AFRICA, SPAIN, TURKEY, UKRAINE, THE UNITED ARAB EMIRATES, AND THE UNITED KINGDOM
INV. NOS. 701-TA-573–574 AND 731-TA-1349–1358 (FINAL)

POSTHEARING BRIEF
ON BEHALF OF
THE AMERICAN WIRE PRODUCERS ASSOCIATION

NOVEMBER 28, 2017

THE INFORMATION IN THIS CBI EXHIBIT

IS NOT SUSCEPTIBLE TO PUBLIC SUMMARY.

VORYS
Legal Counsel

PUBLIC

CERTIFICATE OF SERVICE

I hereby certify that on this 28th day of November, 2017, I have caused to be served a true and complete copy of a *Posthearing Brief* (Nonconfidential Version), as filed with the U.S. INTERNATIONAL TRADE COMMISSION, on behalf of the AMERICAN WIRE PRODUCERS ASSOCIATION, in the matter of *Carbon and Certain Alloy Steel Wire Rod from Belarus, Italy, Korea, Russia, South Africa, Spain, Turkey, Ukraine, the United Arab Emirates, and the United Kingdom*, Inv. Nos. 701-TA-573–574 and 731-TA-1349–1358 (Final), by hand or electronic mail, upon the following parties:

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