# Carbon and Stainless Steel Quality Results from ARMCO Mansfield's Thin Slab Casting and Direct Rolling Facility using VAI's CONROLL®–Technology

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## ABSTRACT

In the three years since its startup, ARMCO's Mansfield Operations has developed the practices required to produce high quality flat rolled steels at its thin slab casting and direct rolling facility. These practices were developed using advanced casting and rolling technologies to produce carbon and stainless grades from direct rolled slabs without surface treatment in order to meet demanding quality standards, such as those required for 430 bright annealed stainless applications.

The progress made in achieving these surface quality objectives for ferritic AISI 409 and 430 grades are presented and the mechanical properties of these direct rolled products are compared with products produced by conventional process routings. An in-depth investigation of AISI 1006 strip produced at Mansfield that has demonstrated excellent surface quality results and applicability to stringent automotive exposed standards is also presented. These results have been verified at VOEST-ALPINE Stahl Linz works and one car manufacturer, and will be discussed in detail.

## 1. INTRODUCTION

The existing electric furnace specialty steel ingot processing facility at ARMCO's Mansfield operations was modernized in 1995 to produce flat rolled carbon and specialty steels by a direct hot charge routing through the addition of a new LMF, thin slab caster, and reheat furnace. The plant started up in April of that year following a tight 17.5 month construction schedule. The centerpiece of the facility upgrade was the CONROLL® process, which is VAI's trade name for the direct hot connection of their thin slab casting and rolling processes. The compact layout of the Mansfield plant configuration, **Fig. 1**, enables just-in-time production, which allows liquid steel to be converted to hot strip in less than 1.5 hours.

The flexible VAI thin slab caster is the heart of the process. It was selected because it incorporates many of the design features, **Fig. 2**, that ARMCO believed were essential for the production of quality direct charged flat rolled specialty steel grades that ARMCO desired to produce at Mansfield without the need for slab conditioning[1,2].

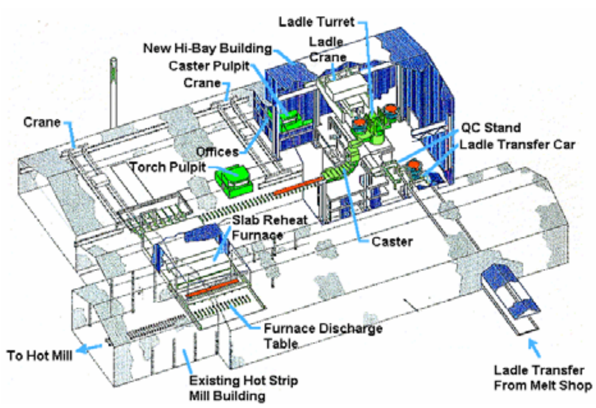



**Fig.1**: ARMCO's Mansfield Operations.

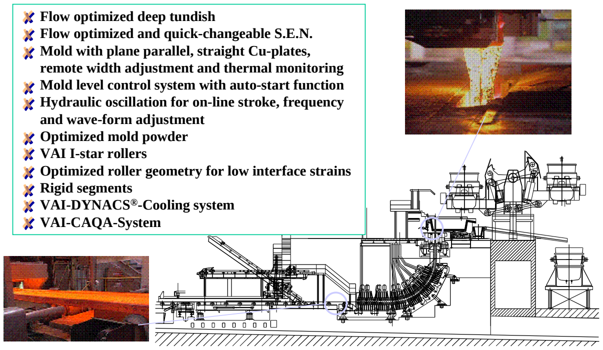



**Fig.2**: Thin slab caster features.

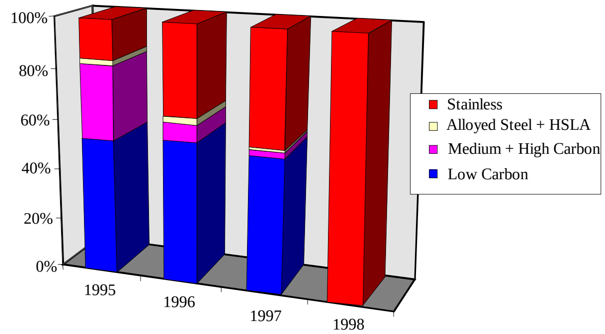



**Fig.3**: Product mix at ARMCO Mansfield since start-up.

During the first 32 months of operation, carbon steel was produced at the Mansfield facility to supplement production while the task of developing practices for direct hot charge stainless production at Mansfield was undertaken. It was during this time period that VAI conducted its study on carbon steel produced at the Mansfield facility.

The spectrum of carbon steel grades produced during this time frame ranged from low, medium and high carbon grades, to alloyed and HSLA grades. As these grades were being produced, development work was conducted to produce low and high chrome ferritic and martensitic grades at Mansfield. The shift of the product mix at Mansfield during this development period is shown in **Fig. 3**. During this period, ARMCO routinely demonstrated the ability to shift between carbon to stainless production in under 3 hours, which demonstrates the flexibility of the facility.

Today, Mansfield is operating on a 100% stainless product mix, making it the only specialty steel mini-mill in the world (using either thick or thin slab casting) that is successfully producing a 100% flat rolled stainless product mix by direct rolling without slab conditioning.

## 2. QUALITY OF CARBON STEEL GRADES

In the second half of 1997 VAI conducted a detailed investigation program on the quality of low carbon steel produced by the thin slab casting and direct rolling facility at ARMCO, Mansfield. The target of this investigation program was to confirm that the strips produced using VAI's CONROLL®–Technology were applicable for automotive exposed parts with regards to surface quality, mechanical properties and deep drawing characteristics. Hot rolled coils

**TABLE I**

Comparison Between Target and Actual Chemical Composition of a Low Carbon HRC.

| % | C | Mn | Si | P | S | Al | Cr | Ni | Cu | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Target | 0.035-0.065 | 0.17-0.25 | <0.05 | <0.015 | <0.015 | 0.040-0.070 | <0.05 | <0.08 | <0.06 | <0.0080 |
| Actual, HRC | 0.056 | 0.25 | 0.027 | 0.0057 | 0.0011 | 0.031 | 0.067 | 0.034 | 0.063 | 0.0077 |

were purchased from ARMCO by VAI, and these coils were cold rolled at VOEST-ALPINE Stahl in Linz, Austria. Deep drawing trials were also carried out.

The production parameters that were desired for casting and hot rolling of the purchased coils were provided by VAI giving special consideration to the features of a scrap based electric arc furnace steel production route. The parameters were selected to obtain a deep drawing steel FePO4 according to EN 10130 after cold rolling.

### 2.1. Production of Hot Rolled Coils at ARMCO, Mansfield

VAI purchased 3 hot rolled coils of steel grade AISI 1005 from ARMCO that were produced from direct charged 132 mm medium thickness slabs cast at a speed of 1.8 m/min. A comparison between targeted and actual chemical composition of the hot rolled coils is shown in Table I. It can be seen from Table I that the contents of carbon, manganese and nitrogen are near their upper limits. Aluminium is below it's lower limit and copper and chromium exceed the upper limits for steel FePO4. The deviations between target and actual compositions of the steel have a strong influence on the mechanical properties of the cold rolled steel, which will be shown later.

At Mansfield, slab samples are taken on a routine basis to inspect internal quality. The stiff segments and the compact roller geometry of the casting machine ensure sound and crack-free internal slab conditions, which can be concluded from macro etches and sulfur prints of a low carbon 100 mm slab cast at 3 m/min, **Fig. 4**. The correct choice of mold powder in combination with the inverse mold oscillation ensure uniform solidification in the plane parallel mold. During the commissioning phase the surface of the thin slabs were inspected very carefully before rolling, all cast slabs were free of corner cracks, longitudinal and transversal cracks.

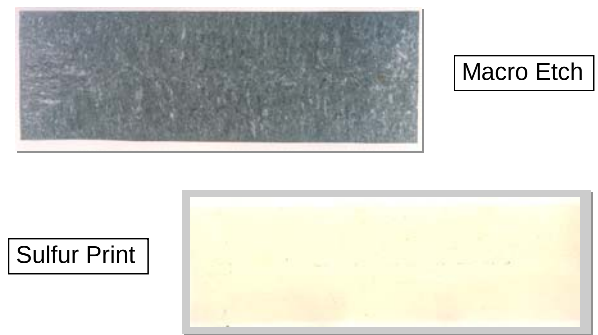



**Fig.4**: Slab quality of low carbon thin slab

The slabs were directly charged into the walking beam furnace at a charging temperature of 850 °C. After equalization and heating to rolling temperature the slabs were discharged at a temperature of 1260 °C.

At ARMCO the rolling process is split into roughing, using a reversing roughing stand, and finishing, using a 6 stand finishing train. The following hot rolling practice was used for the production of the low carbon steel hot rolled coils:

- Descaling at the main descaler,
- 5 roughing passes at the reversing roughing mill, transfer bar thickness 27 mm,
- Descaling of the transfer bar at the finishing mill descaler, transfer bar temperature in front of the finishing mill 1000 - 1100 °C,

- Rolling in the 6 stand finishing mill to a final strip thickness of 2.5 mm and 3.3 mm respectively, final rolling temperature 850 - 900 °C,
- Strip cooling in the laminar cooling line,
- Coiling at a temperature of 550 - 600 °C.

After rolling, the coils were transported to Linz for cold rolling and deep drawing trials. **Fig. 5** shows the trial coils in the coil yard of the pickling line in Linz.

**Fig. 5**: ARMCO coils for cold rolling and deep drawing trials next to the pickling line at VOEST-ALPINE Stahl works, Linz.

Strip thickness and strip temperatures for one of the trial coils are shown in **Figs. 6 and 7**.

The mechanical properties of the hot rolled ARMCO coils were investigated. Hot rolled samples were taken from each coil at the head end, strip middle and tail end. The mechanical properties were determined for each sample at the strip edge and at the strip center in a longitudinal, right angle and at an angle of 45° to the rolling direction. Also the micro-structure of the longitudinal specimen from strip edge and center at head, middle and tail end of each coil was investigated.

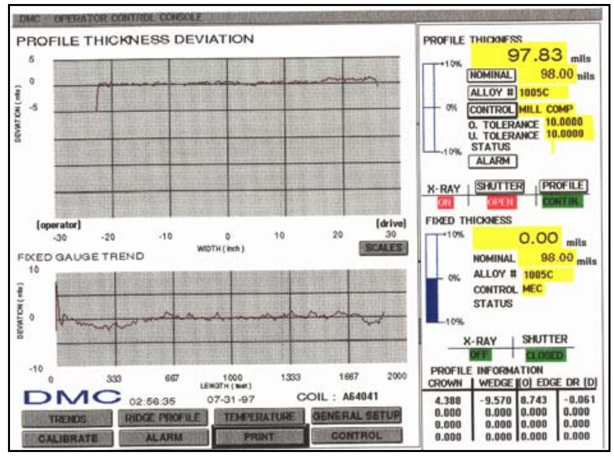



**Fig. 6**: Strip thickness chart.

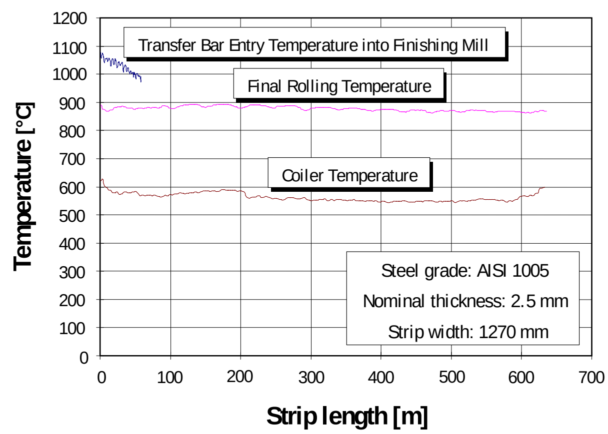



**Fig.7**: Strip temperatures

The investigation showed that there was a slight increase in the yield point and tensile strength from the head end towards the tail end of each strip. The material was slightly softer at the strip edge, compared to the strip center, for each specimen relative to the angle of rolling direction. The tensile strength of the ARMCO hot rolled material was approx. 30 to 60 MPa higher than that for a typical material used for the production of deep drawing quality FePO4.

A comparison between mechanical properties for the trial material, for the typical HRC of AISI 1005 from ARMCO and a typical hot rolled material used for the production of deep drawing quality FePO4 at an integrated steel works is shown in **Fig. 8**.

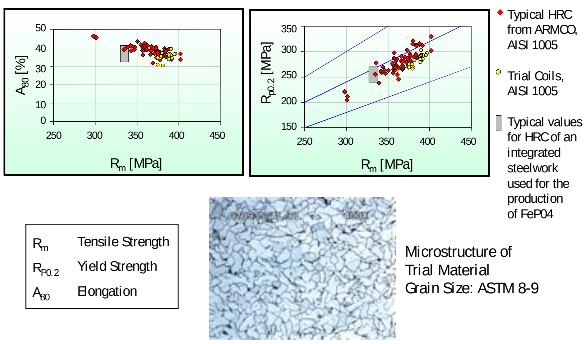



**Fig. 8**: Mechanical properties of the hot rolled coils.

The surface quality of the hot rolled coils was evaluated in Linz after pickling at the pickling line. The coils did not show any surface defects over their entire length. This confirmed the excellent surface quality of the ARMCO hot rolled coils, produced by the CONROLL®–Technology. The results of this investigation reinforced the results obtained in previous evaluations in 1996 and 1997, which also demonstrated excellent surface quality, **Fig. 9**.

Metallurgical Defects of Low Carbon Strips (AISI 1005, 1006)

| | |
|---|---|
| April 1996 | 47 coils inspected (22.8 km total strip length)<br>41 coils defect-free<br>13 single light defects[1)] on 6 coils (99.52 % prime yield[2)])<br>no heavy + medium defects |
| June 1997 | 25 coils inspected (11.5 km total strip length)<br>23 coils defect-free<br>3 single light defects[1)] on 2 coils (99.66 % prime yield[2)])<br>no heavy + medium defects |

1) Definition of light metallurgical defect:
* light lines (< 0.1 m) related to small inclusion or blow-holes
* light shells (< 0.5 m) related to small cracks or conglomeration of small blow-holes

2) One defect corresponds to 1 m defective length

**Fig. 9**: Surface quality investigation and results from ARMCO hot rolled coils.

## 2.2 Cold Rolling of ARMCO Coils at VOEST-ALPINE, Linz

After pickling, the ARMCO coils were cold rolled using a standard practice for the production of a deep drawing FePO4 steel. A summary of the production steps, including those for hot rolling and cold rolling, is given in **Fig. 10**.

AISI 1005C, Heat No. at ARMCO 971326, Slab 132 x 1270 mm, Casting Speed 1.8 m/min

| Main Production Parameters | Coil No. | | |
|---|---|---|---|
| | A64038 (ARMCO) 070935 (VASL) | A64040 (ARMCO) 070936 (VASL) | A64041 (ARMCO) 070937 (VASL) |
| WBF Charging Temperature [°C] | - | 838 | 819 |
| WBF Discharging Temperature [°C] | - | 1266 | 1263 |
| Final Rolling Temperature [°C] | 855 - 905 | 857 - 909 | 862 - 893 |
| Coiling Temperature [°C] | 536 - 655 | 567 - 647 | 543 - 627 |
| Hot Strip Thickness, [mm] | 3.31 | 2.49 | 2.48 |
| Target Finished Steel Grade (acc. to DIN EN 10130) | FeP04 (St14) | FeP04 (St14) | FeP04 (St14) |
| Cold Rolling Reduction Ratio [%] | 69.8 | 69.9 | 69.8 |
| Cold Strip Thickness [mm] | 1.00 | 0.75 | 0.75 |
| Annealing Temperature [°C] | 650 | 650 | 650 |
| Temper Rolling Reduction Ratio [%] | 0.6 | 0.6 | 0.6 |

**Fig. 10**: Production steps of cold rolled steel.

The following figure, **Fig. 11,** shows a thickness chart of one of the cold rolled coils.

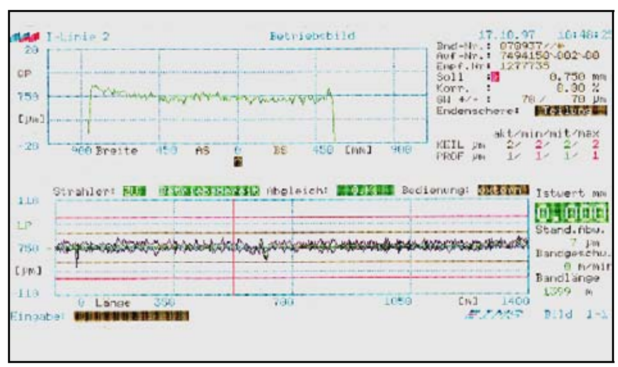


**Fig. 11**: Cold rolled coil thickness chart.

The cold rolled coil samples were taken at the same locations relative to the rolling direction as described previously for the hot rolled coil samples. The mechanical properties were determined and the microstructure of the cold rolled material was investigated.

The mechanical properties of cold rolled coils are shown in **Fig. 12**.

The cold rolled strip showed the following mechanical properties, evaluated at VASL:

| Parameter | Requirements for FeP04 (St14), acc. to DIN EN 10130 | Actual values for 3 trial Coils (AISI1005) | | |
|---|---|---|---|---|
| | | Average | Min. | Max. |
| $R_{p0.2}$ [ N/mm$^2$] | ≤ 210 | 231 | 215 | 261 |
| $R_m$ [N/mm$^2$] | 270 - 350 | 356 | 341 | 375 |
| $A_{80}$ [%] | ≥ 38 | 36.6 | 32.0 | 43.0 |
| $r_{90}$ | ≥ 1.6 | 2.08 | 1.98 | 2.20 |
| $r_m$ | - | 1.54 | 1.46 | 1.87 |
| $n_{90}$ | ≥ 0.180 | 0.191 | 0.185 | 0.201 |
| $n_m$ | - | 0.192 | 0.187 | 0.202 |

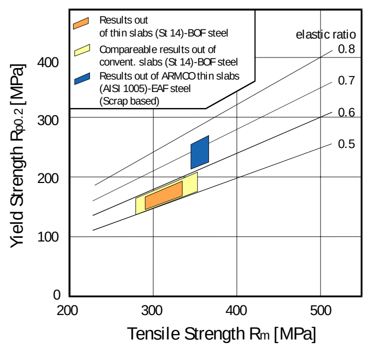
**Fig. 12**: Mechanical properties of the cold rolled trial material.

A comparison of the actual mechanical properties and the standard requirements for FePO4 shows the following results: For specimens taken at right angles to the rolling direction the R $_{p0,2}$ yield point ranges between 228 and 256 MPa. The tensile strength for the same specimen shows values between 350 and 375 MPa.

Thus, the yield point and tensile strength values exceed the required values for steel FePO4 according to standard EN 10130. The values for the elongation after fracture range between 32 and 43%. Thus the required minimum value of 38% is not reached consistently. The r–values in the transverse direction lie between 2.0 and 2.2 and, therefore, meet the requirements of the standard. The n–values between 0.185 and 0.200 meet the standard requirements as well.

The high yield and tensile strength values are caused by the scrap based steel production in the electric arc furnace resulting in higher contents of residual elements, especially Cu, Cr and N. Considering the chemical analysis of the steel with relatively high contents of C, Mn and residuals, the mechanical properties of the ARMCO material seem to be a logical result.

Using low residual BOF steel in a thin/medium slab direct casting and rolling process will lead to mechanical properties, which will satisfy all standard requirements for deep drawing steels. This was proven in several thin slab casting and rolling campaigns at VOEST-ALPINE Stahl, Linz, which were carried out in the early 1990-s. A comparison of the mechanical properties of cold rolled strip produced during these campaigns in Linz, and those at ARMCO is shown in **Fig.13.**




| Chemical composition (in %): | | |
|---|---|---|
| | Target Values for St 14 | ARMCO trial material (AISI 1005) (hot band specimens) |
| C | 0.035 - 0.065 | 0.056 |
| Mn | 0.17 - 0.25 | 0.25 |
| Si | < 0.05 | 0.026 |
| P | < 0.015 | 0.0055 |
| S | < 0.015 | 0.0011 |
| Al | 0.040 - 0.070 | 0.032 |
| Cr | < 0.05 | 0.067 |
| Ni | < 0.08 | 0.033 |
| Cu | < 0.06 | 0.062 |
| N | < 0.0080 | 0.0077 |

**Fig. 13**: Comparison of mechanical properties of different low carbon steels.

The microstructure of cold rolled coils can be seen in **Fig.14**. The typical pan cake structure with cementite bands, which is required for this steel, can be seen.

The surface quality of the cold rolled coils was evaluated at an inspection line at VOEST-ALPINE Stahl works, Linz, **Fig. 15**. All coils showed an excellent surface quality, corresponding to the B (O5) standard for automotive exposed parts according to EN 10130.

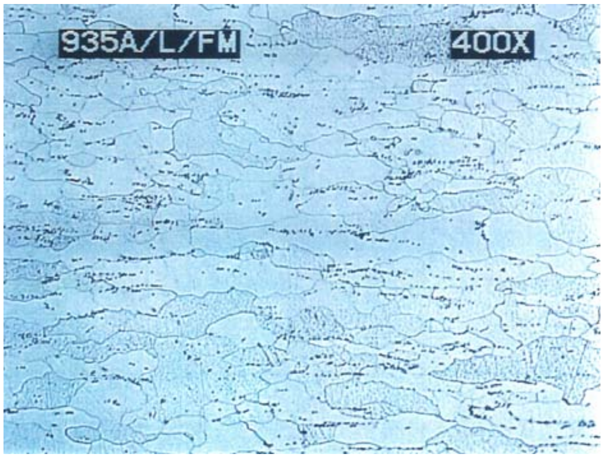



**Fig. 14**: Microstructure of ARMCO cold rolled coil.

**Fig. 15**: Surface quality inspection of cold rolled steel.

### 2.3 Deep Drawing Trials with ARMCO Material at STEYER Nutzfahrzeuge

The cold rolled material was used for deep drawing trials. During these deep drawing trials, exposed parts for a door of a medium size truck were produced in a 3-step deep drawing process. The doors produced showed excellent surface quality and sufficient deep drawing quality for the production of this part of a truck door, **Fig. 16.**

**Fig. 16**: Exposed part for a medium size truck.

## 3. STAINLESS DEVELOPMENT AND PERFORMANCE AT MANSFIELD

The initial efforts to develop a direct hot charge production practice for stainless at Mansfield began less than six weeks after the first successful carbon steel heat, with casting trials on 409 stainless. By December, 1997, some two and one half years after this first 409 stainless casting trial, all carbon steel production had been suspended and a 100% stainless product mix was ultimately realized at Mansfield. The startup curve along with the transition to 100% stainless production is shown in **Fig. 17**.

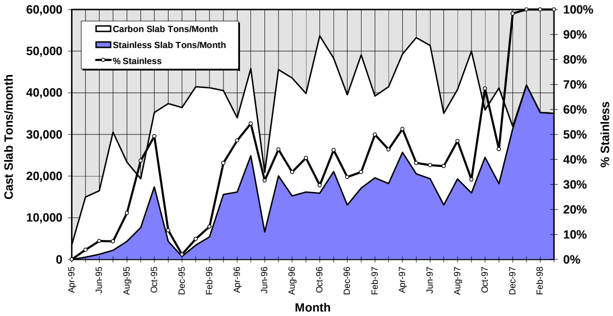



**Fig. 17**: Mansfield Startup Curve and Transition to 100% Stainless Production.

The ability to move to a 100% stainless product mix at Mansfield was made possible by the development of successful direct hot charge practices for two principal ferritic stainless grades: 409 stainless and 430 stainless. Today, Mansfield's production consists of twelve sub-grades of 409 stainless and four sub-grades of 430 stainless that have been tailored for use in a variety of automotive and commercial applications. A growing amount of 434, 439, 400, 181, 410, and 420 stainless is also currently being produced at Mansfield by the direct charge, no-grind process.

### 3.1. 409 Stainless Development

Despite the fact that ARMCO had developed a great deal of experience in producing 409 stainless without slab grinding by the thick slab production route at its Butler, PA facility, several unanticipated quality problems were encountered during the Mansfield 409 development that had to be overcome before commercial quality 409 could be produced there. The principal quality problems on these initial production trials of 409 stainless at Mansfield were scale streaks, short line defects, and ridging.
These defects were all successively overcome during an intensive development effort that ultimately involved modifications to the steelmaking, casting, and hot rolling practices. The flexibility of the Mansfield direct hot charge configuration and advanced technologies incorporated into the VAI caster, such as hydraulic mold oscillation, air mist cooling, and dynamic spray control were crucial to the success in overcoming these initial quality problems on 409 stainless[3].

The progress made in eliminating one of the principal caster related quality problems at the Mansfield facility, the short line or black line defect, is shown in the composite quality index plot shown in **Fig. 18**. Similar progress was also made on the scale streak and ridging during this period of 409 practice development.

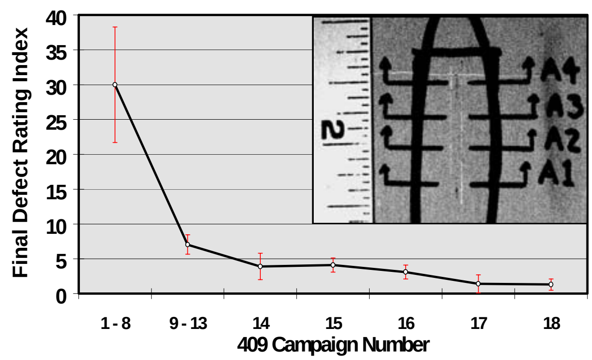



**Fig. 18**. Progress in Reducing the Incidence of Short Line Defects at Mansfield.

Upon completion of the 409 practice development effort, the process of shifting ARMCO's commercial 409 production to Mansfield was initiated. This process, which involved re-qualifying the new 409 production routing with ARMCO's 409 customers, required that the surface quality of the direct rolled 409 supplied from Mansfield be comparable to the traditional thick slab routing and also that mechanical properties of the 409 stainless produced by thick and thin slab routings be comparable so that the supply routings through ARMCO were transparent to the customer.

The melt/cast and hot mill related quality performance that has been achieved for the 409 stainless produced at Mansfield and finish processed at Zainesville (one of several finishing facilities for 409 within ARMCO) in 1997 is shown in **Fig. 19**. By the second half of 1997, an impressive internal coil diversion rate of 0.63% was achieved using Mansfield supplied 409 at Zainesville, all without slab conditioning.

The ability to produce direct rolled 409 at Mansfield with mechanical properties that are comparable to ARMCO's traditional thick slab process routing was also demonstrated. The mechanical properties of the 409 produced by the Mansfield direct hot charge routing are compared to these obtained by the traditional Butler thick slab routing in **Table II**. The mechanical properties are comparable, with the exception that the Mansfield material exhibits a slightly higher elongation and lower yield strength due to a lower level of residuals that result from operating the Mansfield facility as a dedicated ferritic stainless facility (i.e., no austenitic stainless production).

With the goals of achieving surface quality and mechanical properties comparable to conventionally produced 409 finally achieved, the objective of qualifying Mansfield produced 409 with ARMCO's customers was ultimately realized and, today, the majority of ARMCO's 409 stainless is produced at the Mansfield facility and applied to a wide range of automotive applications, such as those shown in **Fig. 20**.

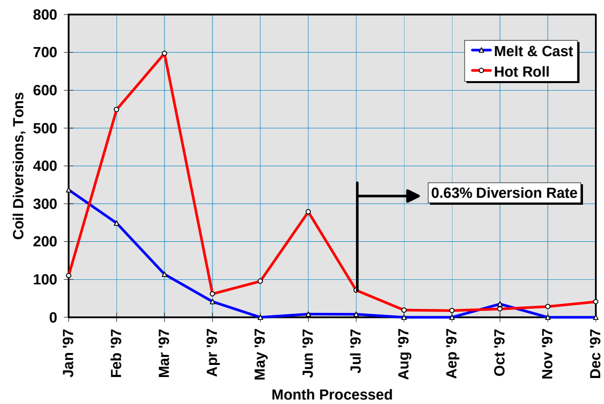



**Fig. 19**: Summary of Cast/Melt and Hot Rolling Related Coil Diversions on 409 Stainless Produced in Mansfield and Processed on #1AP in Zainesville in 1997.

**Table II**
Comparison of ARMCO 409 Stainless Mechanical Properties by Production Facility (0.040" to 0.060" Gauge - 10/1/97 through 1/29/98)

**Mansfield Thin Slab**

| | Cold Work (%) | Gauge (inches*1000) | YS (psi) | UTS (psi) | Elong (%) | Hardness (B) |
|---|---|---|---|---|---|---|
| Average | 61.9% | 51.2 | 34,961 | 61,670 | 35.7 | 65.6 |
| Standard Deviation | 1.0% | 5 | 1,269 | 1,547 | 2.0 | 1.4 |
| Number of Samples | 268 | 268 | 210 | 210 | 210 | 210 |

**Butler Thick Slab**

| | Cold Work (%) | Gauge (inches*1000) | YS (psi) | UTS (psi) | EL (%) | Hardness (B) |
|---|---|---|---|---|---|---|
| Average | 62.9% | 51.8 | 36,919 | 63,846 | 33.7 | 68.2 |
| Standard Deviation | 1.3% | 6 | 2,532 | 2,498 | 2.1 | 2.0 |
| Number of Samples | 326 | 326 | 241 | 241 | 241 | 241 |

### 3.2. 430 Stainless Development

The efforts to develop practices to produce 430 stainless by the direct hot charge process at Mansfield began in March of 1996 with attempts to employ the practices that were developed for 409 stainless. These initial trials demonstrated that the development of a direct rolling practice for 430 stainless would require significant additional development to meet the demanding surface quality requirements

**Fig. 20**: Typical automotive products manufactured from Mansfield produced 409 and 439 stainless steel.

for this grade. The principal quality problems encountered on these initial 430 stainless trials were the short line defect that had been observed previously on 409, and a line defect that had not been observed previously on carbon steel or 409 stainless produced at Mansfield, the caster fold defect shown in **Fig. 21**.

The 430 stainless grade proved to be much more susceptible to the short line defect than 409 stainless, and also proved to be very susceptible to mold stickers during casting. The breakout pre-detection system that was incorporated into the caster and the instrumented mold that was developed jointly with VAI were particularly useful in the development of casting practices for this grade[2].

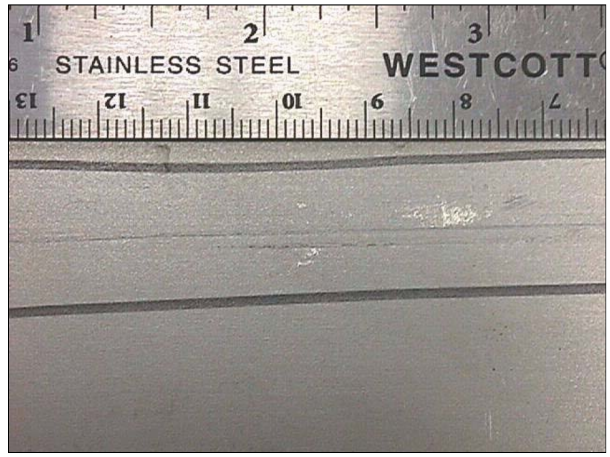



**Fig. 21**: Typical Caster Fold Defect Observed Initially on Annealed and Pickled 430 Hot Band.

The progress that was made in eliminating the two principal defects on 430 stainless, the short line defect and the caster fold defect, is shown in **Figs. 22 and 23**. Ultimately the developments required to overcome these defects, to develop a casting practice that was not susceptible to mold stickers, and to produce mechanical properties that were comparable to those produced by a conventional thick slab routing, **Table III**, took almost 18 months to complete.

Today, the Mansfield facility is producing all of the 430 stainless for Coshocton Operations (ARMCO's primary 430 finishing facility) by a direct hot charge routing. This 430 stainless is being applied to a wide range of automotive and consumer applications, such as those shown in **Fig. 24**. These applications include exposed automotive trim and a range of mirror finish 430 bright anneal applications, which are among some of ARMCO's most surface critical applications.

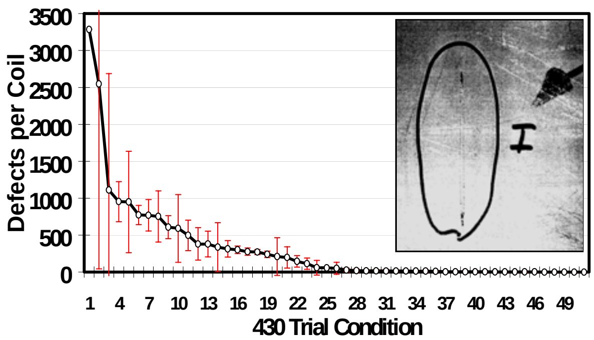



**Fig. 22**: Progress in Reducing Short Line Defects on 430 Stainless at Mansfield.

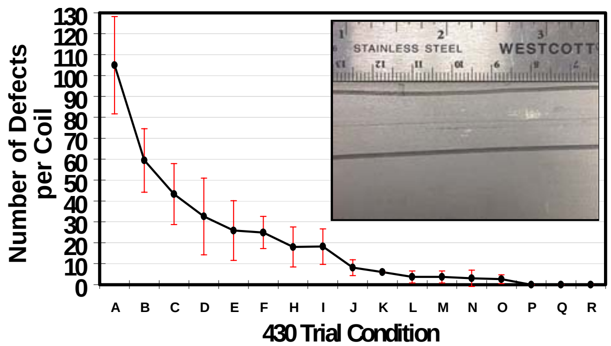



**Fig. 23**: Progress in Reducing Fold Defects on 430 Stainless at Mansfield.

## Table III

Mansfield Produced - Coshocton Processed 430 Bright Anneal Mechanical Properties

Average Mechanical Properties for 7/97 through 6/98

| Gauge Range (inches)*1000 | | Number of Tests | Hardness (B) | Yield (psi) | Tensile (psi) | Elong (%) |
|---|---|---|---|---|---|---|
| 1 | 12 | 129 | 80.5 | 45,996 | 73,659 | 29.0 |
| 12 | 19 | 307 | 71.8 | 45,805 | 72,023 | 29.3 |
| 19 | 40 | 561 | 75.4 | 46,347 | 71,630 | 29.7 |
| 40 | 150 | 73 | 80.8 | 47,297 | 69,911 | 30.0 |

Corresponding Standard Deviations

| Gauge Range (inches)*1000 | | Number of Tests | Hardness (B) | Yield (psi) | Tensile (psi) | Elong (%) |
|---|---|---|---|---|---|---|
| 1 | 12 | 129 | 2.7 | 2,344 | 2,882 | 1.9 |
| 12 | 19 | 307 | 3.1 | 2,418 | 2,601 | 1.9 |
| 19 | 40 | 561 | 2.6 | 2,905 | 2,225 | 1.7 |
| 40 | 150 | 73 | 2.2 | 3,392 | 1,686 | 1.4 |

**Fig. 24**: Typical Automotive and Consumer Products Manufactured from Mansfield Produced 430 and 434 Stainless Steel.

### 3.3. Ongoing and Future Stainless Developments

ARMCO is continuing to work to expand the range of stainless grades being produced at Mansfield by the direct rolling process. The ability to produce ferritic AISI 439 stainless at Mansfield has already been demonstrated, and work is ongoing to qualify other high chrome ferritics, such as 434, 435, 436, and 181 for production at Mansfield. Significant progress has also been made in the development of practices for producing martensitic stainless grades, such as 410S, 410, 420, and 440 at Mansfield. Ultimately, the long term goal for the Mansfield facility is to continue to expand production of the specialty flat rolled ferritic and martensitic stainless grades to produce a quality stainless product while taking advantage of the efficiencies of the direct hot charge routing.

**Table III**
Future Plans for Direct Hot Charge Stainless Practice Development at Mansfield Operations

| Martensitic Stainless Grades | High Chrome Stainless Grades |
|---|---|
| • 410S | • 434 |
| • 410 | • 439 |
| • 420 | • 181 |
| • 440 | • 435 |
| | • 436 |

## 4. SUMMARY

The common goal for both ARMCO and VAI at Mansfield was to demonstrate that a high quality level could be achieved with a direct linked casting rolling process for a wide range of flat rolled steel grades, including exposed automotive carbon steels and stainless steels.

An investigation program was carried out to demonstrate the level of quality achievable on direct rolled carbon steels. The surface quality of ARMCO cold rolled strip meets all requirements for automotive exposed parts (O5-Quality). This material shows sufficient deep drawing for the production of exposed truck doors, although the tensile strength and the yield point of the EAF-based trial material were somewhat higher than the corresponding standard values for deep drawing quality.

The efforts involved in the transition of Armco's Mansfield operations to a 100% direct charge flat rolled stainless production facility were reviewed. The performance of Mansfield produced 409 stainless for automotive applications and 430 stainless for automotive and consumer applications has been demonstrated through documentation of surface quality, mechanical properties, and the achievement of a successful migration of the major portion of Armco's production of these two grades to the Mansfield facility. Plans for future expansion of Mansfield's stainless production were also presented.

## 5. REFERENCES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3. "Thin Slab Casting Practice Development at Armco's Mansfield Operations", R. J. O'Malley, A. J. Flick, and G. Hohenbichler: Proc., CCC'96, Linz, Austria, May 1996, Slab Session - Paper 16.