Bar Code Identification of SeverStal Slabs

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INTRODUCTION

Steel slab manufacturers are required to accurately identify their slabs both for internal record-keeping purposes, and to provide proper slab identification for their customers. This slab mark provides identity and traceability for each slab, thus enabling the manufacturer and the end-user to determine the manufacturing origin and process pedigree of the slab, typically starting at the Heat/Strand/Cut level.

Technology is now available that enables bar code identification to be created "on-site and on-demand" and to be automatically attached to cold or hot carbon steel slabs by laser marking a tag and MIG-welding the tag onto the slab face. The tag can be marked with text, graphic images and bar codes. The inherently high contrast nature of black laser marking on the smooth surface of the white tag background eliminates variations in slab torchcut surface appearance that would otherwise preclude bar code marking. This leads to reliable bar code reading that can be performed using low cost commercially available bar code scanners. The addition of this laser marked identification further enables the use of downstream bar code reading systems to scan the bar code for identification of the slabs at key manufacturing nodes, and also enables the ability to automatically update the database with manufacturing process results at these nodes on a slab-by-slab basis.

SeverStal North America, located in Dearborn, Michigan, USA, entered into discussions with InfoSight Corporation in 2006 to develop a specification for such an identification system. An order was placed for three (3) slab tagging systems in August, 2007 and the equipment was installed in early 2008.

This paper discusses the general evolution of laser-marked tag identification for slabs, and also discusses the equipment to automatically print and apply laser-marked tag identification to these slabs. Specific discussions of the SeverStal NA application are presented.

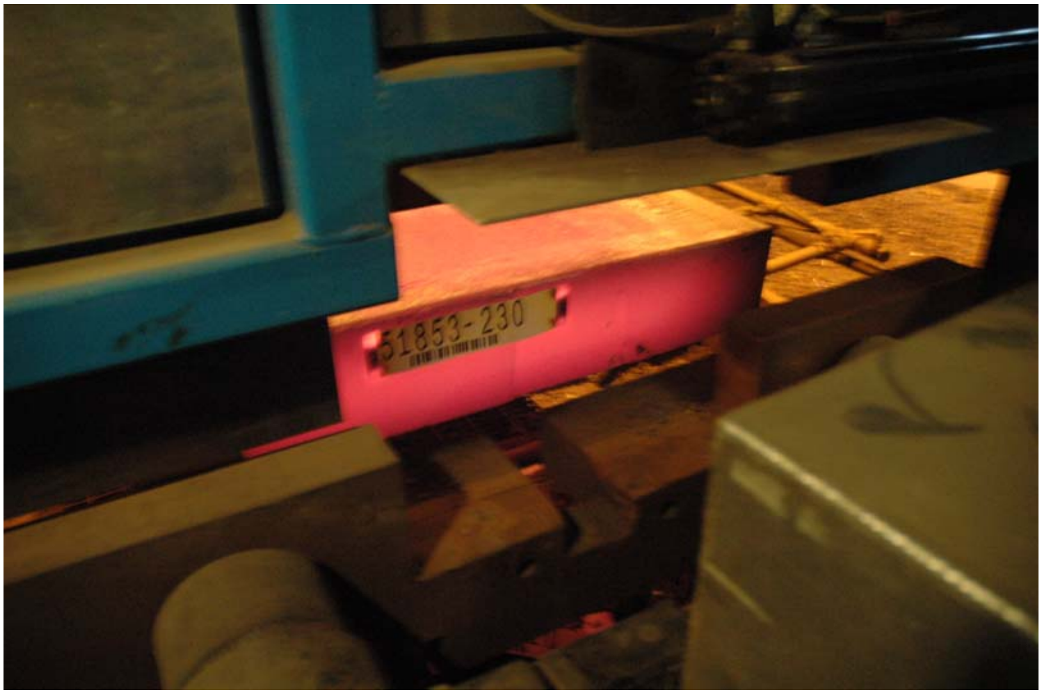

Figure 1 Typical Slab Tag after welding to the end of a torch-cut hot slab

HISTORY

Manual hand-marking of hot slabs can be a very hazardous and uncomfortable operation. Traditional methods include manual marking using a high-temperature crayon, or spray application of high temperature paint through a punched stencil board. The worker in high-temperature protective clothing typically marks hot slabs using a crayon on a stick, or prepares a punched high-temperature-compatible stencil and sprays high-temperature paint through the stencil to apply identification marking to the end or side of the slab. The punched stencil board may be punched manually by hand using a die punch machine, or in some cases, an automated punching device can automatically prepare the stencil board using a computer download. In more recent years, metal tag application by nail attachment has been used.

This manual marking job has accuracy, ergonomic and hazard issues. Due to the boring and repetitive nature of the work, human errors can occur when using these methods. Repetitive movements can result in repetitive workplace injuries. Frequent close-quarters exposure to high temperature steel and sprayed paint fumes are not desired by workers or by the employer.

In some cases, special high-temperature adhesive stick-on labels are applied. These labels can peel off in storage or shipment and result in lost identification.

Automatic marking methods for hot slabs traditionally have included systems to mark slabs using aluminum or bronze metal powder spray or paint spray to mark large crane-readable characters on the end or side of the slab. (SeverStal used automatic paint marking equipment prior to the installation of the automatic Slab Tagging Systems).

These traditional marking methods provide good man-readable identification of slabs, but typically do not provide good automatic machine-readability to facilitate automatic product tracking in the slab mill. Also, in the special case of metalized spray marking, contamination of the slab's metallurgy can be an issue.

In 1996, the first automatic Slab Tagging System was installed in North America. Several more automatic Slab Tagging Systems have been installed worldwide since then. The Slab Tagging System accepts downloaded information from the slab mill computer, automatically compiles and laser-marks a tag without requiring worker input or action, and automatically applies the tag to the end or side of the slab using MIG welds.

The laser mark is printed on the tag prior to attachment using a galvanometer-scanned CO_2 laser beam to quickly create the mark "on-site and on-demand". Much like an office laser printer, laser marking systems can print any combination of text, graphics and barcodes in relatively high resolution.

The Mill Computer can now download the entire variable mark data set to the Slab Tagging System to create the required slab mark on-demand; create a suitable slab identification number on-demand; and fill-in critical manufacturing data in the mark for each slab in real time as it arrives at the slab tagging station. The laser marker can also use the downloaded data to automatically parse out certain data to compose a slab identification bar code suitable for downstream bar code scanning. Occasional Operator action is still required for periodic maintenance and to replenish tag stock and weld wire, but accuracy, ergonomic and hazardous issues are greatly improved or eliminated when compared to past manual slab marking operations.

The advent of automated "on-site and on-demand" laser printing for hot slab mill products eliminates the requirement to manually crayon-mark slabs or to prepare punched stencils for manual spray mark application. It provides an alternative to automated metalized or paint spray marking. It provides a more robust attachment method than adhesive attached tags. It also provides enhanced automatic reading functionality because the automatically-marked bar code on the tag can now also be automatically scanned at various in-plant locations to identify the slab that is currently at that location.

SEVERSTAL EQUIPMENT LAYOUT

The figure below shows the layout of the Slab Tagging machines at SeverStal.

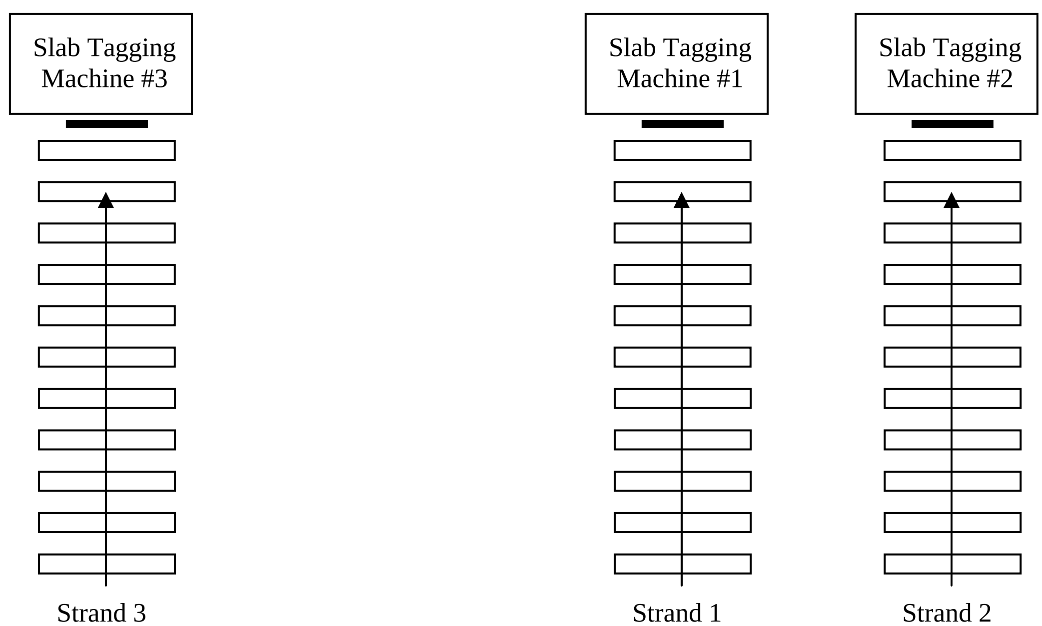

Figure 2 – SeverStal Slab Tagging Equipment Layout

Low carbon slabs are typically cast on Strands 1 and 2. High carbon slabs are cast on Strand 3. Slabs arrive at the end stop and the tag is applied through a cut-out in the end stop faceplate. Then the slab is retracted away from the end stop. All slabs are removed by crane for stacking on the floor beside the runout tables, and then slab haulers take the finished stacks to yard storage. A backup manual tag printer is provided so that identification tags can be nailed on with powder charge driven rivet nails in the event that one of the automatic machines is offline for maintenance or repair.

Figure 3 Slab Tagging Machines are located behind the end stops of Strand 2 (right) and Strand 1 (left)
Strand 3 is to the left – out of picture

TAG LOCATION AND MARKING CONTENT

The tags are typically applied to the leading torch-cut end of each slab, as it arrives at the end of the runout conveyor just after torchcut and deburring. This is the practice at SeverStal. Applying the tag to the end of the slab has the additional advantage that descaling is typically not required for good weld attachment, in instances where the tag is welded onto the hot slab immediately after torch-cut.

Alternately, tags can be welded to the side of a slab. However since scaling has usually started on the side for slabs reaching the end of runout, mechanical descale or high-pressure water descale is recommended just prior to welding. Mechanical descaling is performed using heavy duty rotary brushes localized at the weld point area.

For text marking of the tag, the typical hot slab mill wants the following minimum information applied to each slab:

- Heat (typically 5 or 6 digits)
- Strand Number (typically 1 or 2 digits)
- Cut Number (typically 2 digits)

The slab mill (or slab purchaser) may specify even more data to be marked in addition to the above, for example, purchaser name, purchase order number, weight, delivery location, etc. The printable tag area provides sufficient space for abundant text; multiple bar codes and multiple logos – limited only by marking resolution and what will "fit" in the available laser marking white tag area.

The bar code on the tag can encode the minimal information shown above (Heat, Strand Number, Cut Number), or it can encode a unique tracking number, typically referred to as a "PIN" or "Product Identification Number". The tracking number is also sometimes referred to as an LPN or "License Plate Number". Bar code parameters and limitations are discussed later in this paper.

SLAB TAG CONSTRUCTION

The slab tag backing material is 0.2mm (0.008 inch) thick stainless steel strip. The strip is coated with a white coating which can be easily darkened using 50 watt CO_2 laser energy. Both ends of the tag are reinforced with 19mm (3/4") wide "preform" reinforcing strips which are spot-welded to the backing material. These performs are punched with holes, called "weld sockets", thru which the MIG puddle welds are applied. Robust tag attachment is provided by four (4) corner MIG puddle welds, with one weld applied thru the weld socket at each corner of the tag. Weld socket holes are also provided for center-welding (still used today on some older Slab Tagging Systems) and also for four corner welding. Although four weld points are not required to attach the tag to the slab, the four point design adds attachment redundancy at minimal cost. Tags ship in a box of 250 tags per box weighing approximately 25 kg (55 lb.) per box.

It is very difficult to remove a MIG-welded tag from the slab, even with a prying tool. Failure to secure one or even two welds when using four weld attachment (due to a fouled weld nozzle, for example) typically does not result in loss of tag – the remaining welds are adequate to maintain tag attachment.

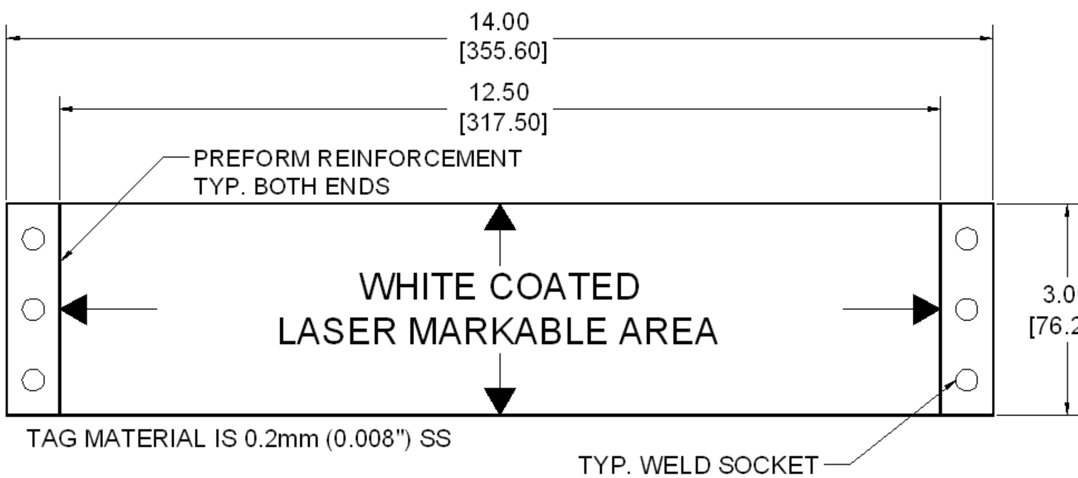

Figure 4 Standard Slab Tag geometry

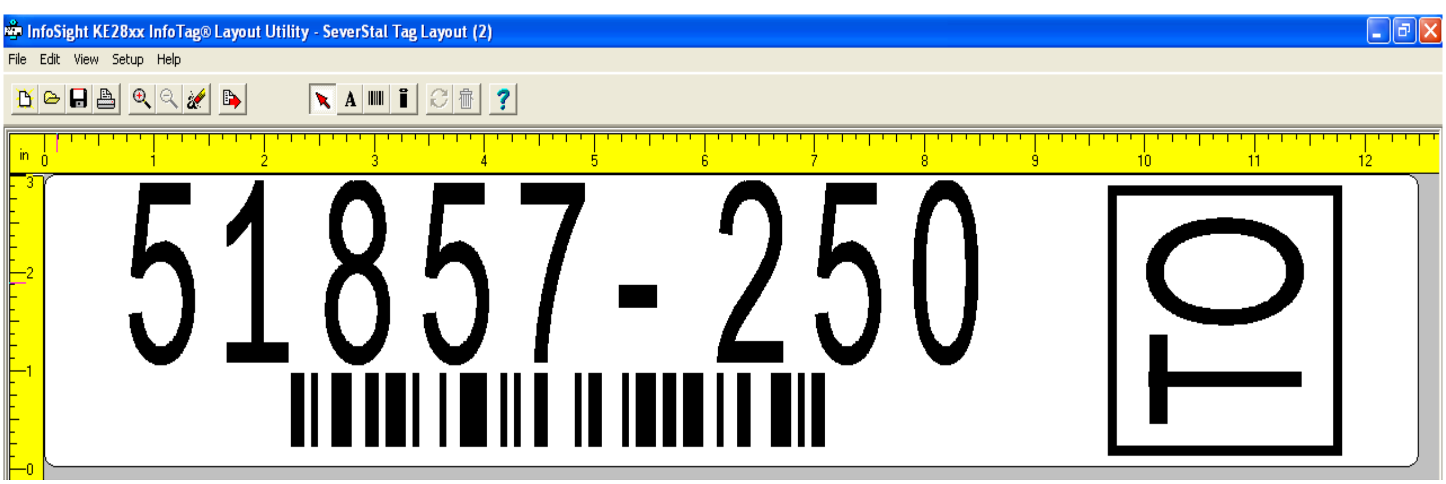

Figure 5 Example of a typical SeverStal Tag Layout shown in the Tag Layout Utility programming window
Note that the "TO" (turnover) logo (and other special logos) are used to indicate special processes to be performed downstream

Figure 6 Typical Slab Tag welded onto a slab end with four corner MIG welds

Figure 7 Typical stack of slabs in the storage yard

SLAB TAGGING MACHINE COMPONENTS

The Slab Tagging Machine is usually positioned to perform marking on the torch-cut end of an end-indexed slab, centered on conveyor rollers at the marking station. SeverStal requires the tag to be attached to the center front face for all of their slabs.

For the special case where manufacturers will sometimes slit slabs into 2 halves, it is possible to design the slab tagging machine to either (a) apply a center tag, or (b) shift laterally to apply one tag left of center and one tag right of center, on the end of the slab. When left and right tags are used, these tags remain attached to the left and right slab ends after the slab is slit into two pieces.

The machine design must be somewhat flexible so that it can be adapted to fit the geometry of the steel mill. It is difficult to design a "universal" machine because the geometry of nearly every steel mill is different. SeverStal's geometry was a unique challenge because of a low machine envelope height restriction (because two of the three machines had to "fit" under a heavy existing beam). Another challenge at SeverStal is created by limited floor space behind the end stops, resulting in a machine design that had to be compressed to "straddle" the end stop instead of residing entirely behind the stop. Ultimately, a quasi-common design was created to fit the geometry at all three end stops at SeverStal.

The Slab Tagging Machine consists of the following major mechanical assemblies – the <u>Tag Preparation Assembly</u> and the <u>Tag Applicator Assembly</u>, along with certain external controls.

1. Slab Tagging Machine Assembly
    a. The <u>Slab Tagging Machine Enclosure</u> contains the Tag Prep Assembly, the Tag Applicator Assembly, and other ancillary equipment
    b. <u>Tag Preparation Assembly</u> (also called the "Tag Prep Assembly")
        i. 50 watt CO_2 laser with power supply and control
        ii. Marking is performed using a focused non-visible CO2 laser beam
        iii. Laser enclosure
            1. The laser marker enclosure is air-purged to keep contamination out
            2. The optics chamber contains:
                a. Laser lenses as required for beam focus
                b. Galvanometer control and mirrors as required for laser beam aiming
        iv. Tag Magazine, with capacity to hold 250 tags (one entire box of tags)
        v. Tag Transfer Mechanism
            1. Stepper motor/ballscrew drive for tag movement during laser marking
            2. Tag Platen, used to hold tags for transfer using suction
            3. Air cylinder driven transfer slide to transfer the marked tag from the Tag Prep to the Tag Applicator
        vi. Laser Heat Exchanger – circulating system that routes ethylene glycol coolant through the laser, with a fan cooled heat exchanger for laser cooling
    c. <u>Tag Applicator Assembly</u>
        i. Long stroke air cylinder for the extend motion to "find" the end of the slab
        ii. Two (2) MIG welding nozzles with short stroke extend/retract and raise/lower cylinders for weld point positioning
        iii. Four ground tips contact the slab for weld grounding
    d. Weld Power Supplies X2
    e. Weld Wire Feeders X2
    f. Electrical takeover point boxes as required
    g. Air and Argon takeover point connections as required
2. Floor Control Panel, with pushbuttons/switches/lights for local machine control
3. Pulpit Control Panel, with pushbuttons/switches/lights for remote machine control
4. Electronics Enclosure – located remotely from the marking machine, provides microprocessor marking control and PLC machine control
5. Data Terminal – used for setup and diagnostics only

Figure 8 One of three SeverStal Slab Tagging Machines - shown in testing in the manufacturer's shop

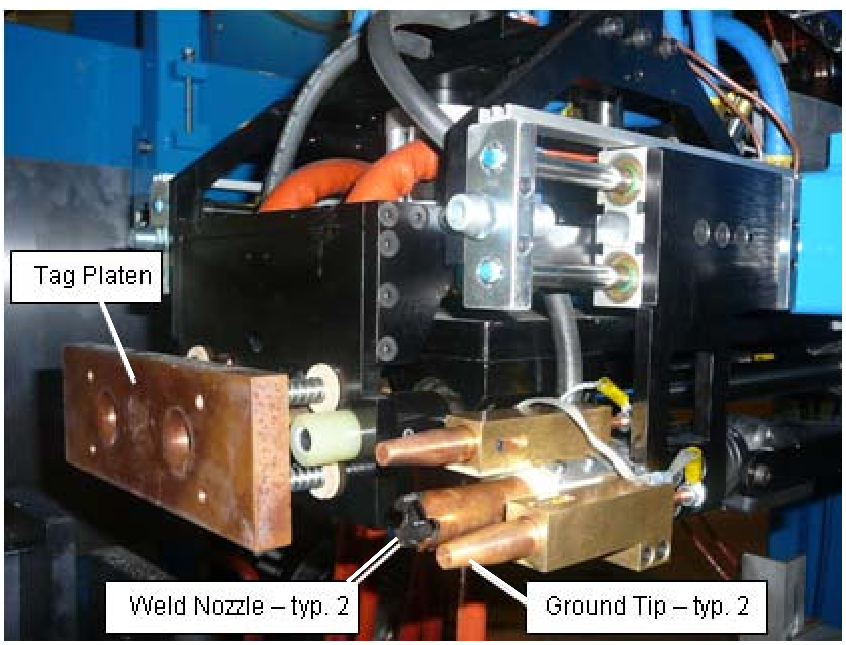

Figure 9 Close-up view of the Tag Applicator Assembly end tooling (heat shields removed)

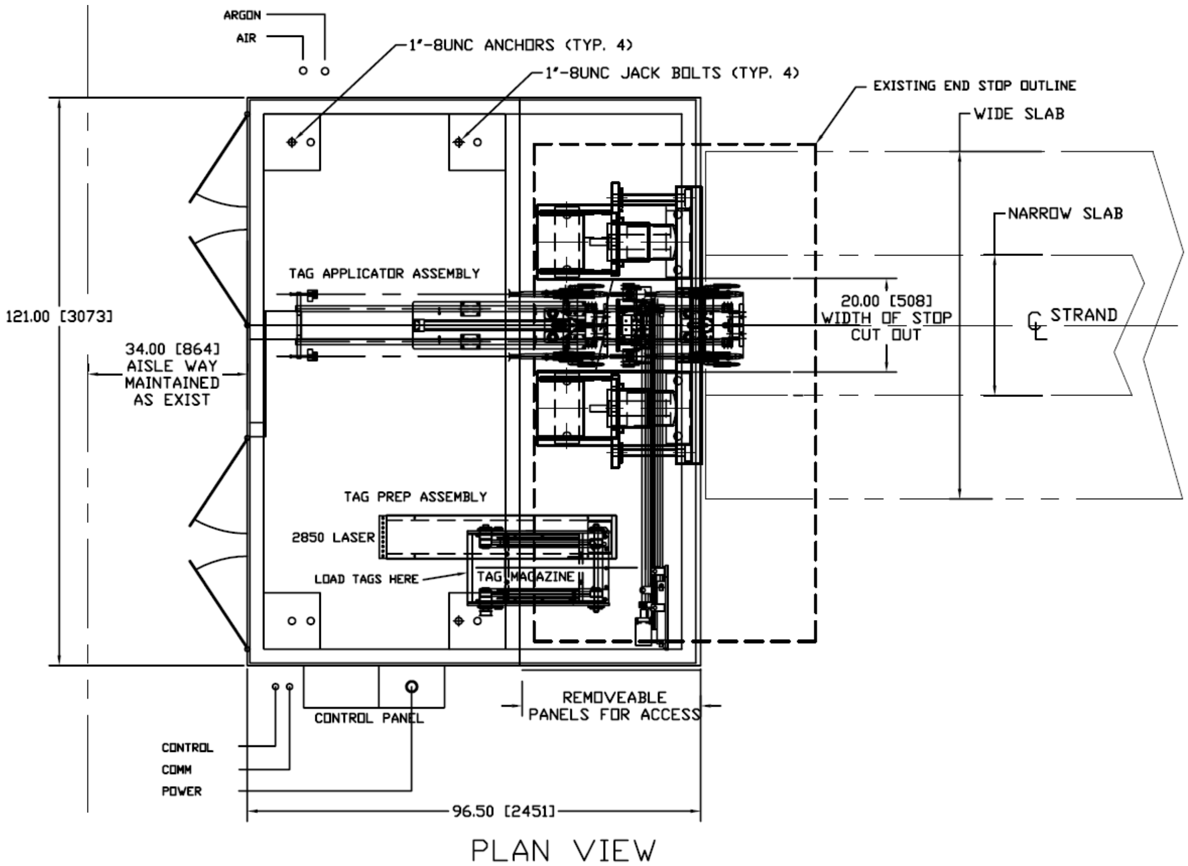

Figure 10 SeverStal Slab Tagging Machine Arrangement – plan view

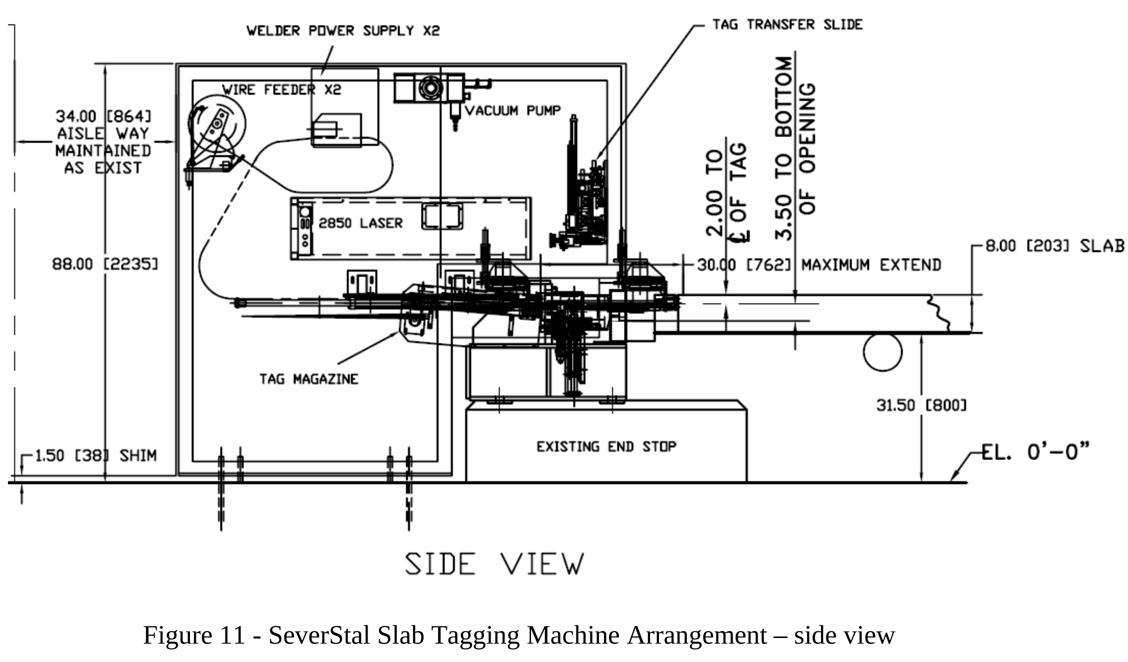

Figure 11 - SeverStal Slab Tagging Machine Arrangement – side view

SEQUENCE OF OPERATION

In general terms, the slab tagging machine will (a) receive the tag data from the mill computer, (b) prepare (laser-mark) a tag, and (c) apply (extend and MIG-weld) the tag onto a slab.

1. The Mill Computer downloads the marking data in advance of the next slab to arrive at the marking station, typically at completion of torch-cut.
    a. Usually only the “variable” data is downloaded – “label” data resides locally in the tag format in the Slab Tagging Machine.
    b. In some cases, there may be multiple tag formats or “layouts” resident in the slab tagging machine – in these cases, the correct tag format can be specified by download, or selected by the Operator.
        i. For example, one tag format may be “simple” – only HEAT, STRAND and CUT are marked.
        ii. Another tag format may include additional GRADE and WEIGHT fields
        iii. Another tag format may include additional fields for CUSTOMER INFORMATION
        iv. And so on, up to a typical maximum of ten (10) layouts – more are possible in special cases
    c. Certain “labels” on the tag may be programmed into each local tag format resident in the tagging machine, in order to minimize download data packet size
        i. For example, if “WEIGHT: 28540 LB” is to be marked on the tag, “28540” is the variable downloaded data that changes for each tag or slab, and “WEIGHT:” and “LB” are label fields resident in the local tag format.
        ii. Note that the format of all tag data, variable and fixed, is still editable, and can be changed at any time by the user.
2. The slab tagger compiles the marking “image” for laser marking, by:
    a. Using the currently-selected or downloaded tag format as the “template” for the tag
    b. Combining all variable (downloaded) data, all fixed (label) data, and all barcodes and logos, into one laser-markable bitmapped image for marking
3. The Tag Prep unit extracts a single tag from the tag magazine using a vacuum-powered Tag Prep platen. The Tag Prep platen then presents the tag at the laser marking position. Note that the Tag Prep platen grips the rear (uncoated) side of the tag, while leaving the coated side totally open for laser-marking.
4. The Tag Prep unit moves the tag laterally in a stepwise fashion, while scanning the laser beam vertically at each step position, in order to mark each column of “pixels” (or picture elements) making up the tag image.
5. When the entire tag has been marked, the Tag Prep Unit transfers the tag to the Tag Applicator centerline by air cylinder
6. The tag is then transferred the from the Tag Prep platen to the Tag Applicator platen.
    a. The Tag Applicator platen now grips the tag on the front (laser-marked) surface.
7. The mill controls issue the START MARKING CYCLE signal to the Slab Tagging System.
8. The Tag Applicator extends by air cylinder to contact the end of the slab.
    a. The tag platen presses the tag firmly against the slab to hold it in place during welding
    b. Two (2) MIG weld nozzles extend and weld the bottom corners of the tag in place with puddle welds, each approximately 12mm (1/2”) in diameter.
    c. The weld nozzles then retract, move to the upper corners of the tag, and again extend and weld the upper corners of the tag with puddle welds.
9. When all four corner welds are complete, the Tag Applicator retracts.
10. The MARKER CLEAR signal is issued to the mill controls by the Slab Tagging System. The slab is then retracted from the end stop to allow the crane to pick up the slab for stacking.
11. Slab tagging time is typically about 90 seconds from START MARKING CYCLE to MARKER CLEAR, depending on timing of the data download, laser-marked content and density, and the total size of the marked image.

Brief machine maintenance is typically required daily to:
1. Replenish tags
2. Perform a brief cleanup of the MIG weld nozzles by wire brushing and coating with anti-weld spatter spray

Machine maintenance is required less frequently to:
1. Replace weld wire - Two spools of welding wire must be replaced approximately every 2,750 slabs.
2. Clean laser optics - Approximately once per month, the laser optics (galvanometer mirrors and focusing lenses) are cleaned with cotton swabs and a cleaning solution.

LASER SAFETY

The Slab Tagging System utilizes an exposed (non-enclosed) laser beam, and therefore is defined as a Class 4 laser. However, the equipment design expands the laser beam internally and then focuses the laser beam externally in a fashion whereby the focused laser beam power per unit area is only considered hazardous in a very small focal length in close proximity to the tag marking surface. This zone is referred to in laser industry terminology as the “nominal hazard zone”. Unlike high-powered YAG lasers, this equipment does not require extensive safety enclosures or “block houses” to enclose the entire system. The user is required to adopt certain laser safety practices, and these practices are usually already in place by standard hot slab mill operating procedures - Normal safety glasses with side guards and long sleeve shirts are recommended for workers who work in close proximity to the equipment.

PITFALLS

The tag identification technology discussed herein is an excellent way to apply identification and bar codes to hot slabs, but it is also necessary to evaluate the metallurgy of the steel and also the downstream manufacturing processes and practices that the tag identification and the bar code must survive. Following is a list of potential slab mill pitfalls:

1. Tags are suitable for MIG welding to carbon and low alloy steel products. However, welding is not currently practical for high alloy steels with high Nickel or Chromium percentages. Welding technology for tag attachment is constantly improving, and automatic welding of higher alloys may someday be possible. Until then, other attachment methods for tags, such as automatic power nailing, can be provided for high alloy steel slabs exceeding these percentages.
2. Tags cannot be applied to dummy bar hooks if they are not cropped from the end of the leading slab prior to tagging
3. Shot blasting can remove tag markings by abrasion.
4. Scarfing can remove tag markings by torch burn abrasion, or can obscure tag markings with torch burn marks.
5. Stacking of slabs “end-to-end” (where the tag is “sandwiched” tightly between two hot slabs) will cause the laser marking to fade.
6. “Bumping” of slabs on conveyors (a typical practice where Operators “bump” slabs when conveyor roll drives are out of service) will damage the tag bar code. The man-readable information will remain somewhat readable.
7. Reheat typically consumes the tag completely.

For Item 1 above, tag nailing attachment methods can be provided for high alloy steels

For Item 2 above, a manually-applied tag is attached by nail to the side of the leading slab

For Items 3 and 4 above, downstream practices that can damage the tag must be evaluated on a case-by-case basis.

For Items 5 and 6 above – end-to-end stacking of slabs, and bumping of slabs, should be avoided.

For Item 7 above, the slab tag will generally survive application to carbon and low alloy slabs with temperatures from ambient up to 1000ºC (1832ºF). The tags will survive cool down to ambient temperature and subsequent storage and shipment conditions. The tags typically do not survive, and are completely consumed by, the reheat furnace.

BAR CODES

Successful bar code reading technologies and solutions are discussed.

The challenges related to successful bar code implementation in slab mills are:

1. How to select and use a suitable code symbology and content
2. How to apply a mark and bar code that will survive and remain readable throughout the process
3. How to “find” the bar code at the downstream reading stations

The user must be knowledgeable about bar code suitability and limitations. Many users initially assume that they can insert “unlimited” text and numerical data into a bar code. This is true only if you have enough space in the marking area for a very large code, and you have the proper bar code scanner to read such a code. Code 39 and Code 128 symbologies both provide the ability to encode both text and numerical data, but if alphanumeric characters are encoded within a Code 128 bar code, then the bar code length grows very quickly (e.g. – a Code 128 bar code encoding “51857250” will “fit” in a given available space on the tag at much lower resolution than a bar code encoding the same number of characters with mixed alphanumeric characters - “5A8B7C5D”).

If the resulting (higher density) bar code with alphanumeric characters is scaled down so that it will fit into the same available space as “all numbers”, the code resolution becomes much higher (both bar width and space width become more narrow) so that the code is unreadable in a practical sense in a slab mill environment.

Code 128 – “51857250”
All digits (numbers) - Note low resolution suitable for reading in slab mills

Code 39 – “51857250” – (compressed to fit in the same space)
Much higher resolution

2D Code – “51857250”

Code 128 – “5A8B7C5D” – (compressed to fit in the same space)
Same number of characters as the Code 128 above but now with mixed alphanumeric characters included
Much higher resolution

Figure 12 Bar Code Comparison

It is generally recommended to implement the Code 128 symbology encoding up to 12 digits (numbers only – no text – no punctuation characters) maximum. This will allow the laser printer to print a robust bar code at a large scale with relatively wide or “fat” bars and spaces, thus guaranteeing readability downstream.

Code 39 is acceptable for the automotive industry, for example, but is generally not recommended for slab mill use.

Reading technology is now readily available whereby two dimensional (2D) bar codes can be used to advantage by encoding a larger quantity of data in a smaller area, but the bar code readers for this code will be more expensive and may require shorter focal distances than for a one dimensional (1D) bar code.

Providing that (a) the pitfalls discussed above are avoided, and (b) the bar code symbology and content are correctly selected and implemented, then the potential for bar code survival and downstream readability is excellent.

Since slabs are typically always conveyed in the “flat” position on conveyors, the bar code orientation is well defined for bar code reading. Therefore, downstream automatic reading stations are feasible and are routinely implemented. Note that turning over a slab (i.e. – rotating the bar code 180 degrees) does not affect bar code readability. Also, less expensive handheld bar code scanners can be used for downstream bar code data acquisition when practical. Each reading station must be evaluated on a case-by-case basis to determine the best possible solution.

SUMMARY

The technology to automatically print and apply tag identification to hot slabs is routinely used today. A Slab Tagging Machine receives downloaded data from the Mill Computer, automatically compiles the data and laser-marks the tag, and automatically applies the tag to the end or side of the hot slab using four corner MIG welds. The laser mark on the tag can contain text, graphic images such as industry-standard or company logos, and bar codes. The tag and its attachment are designed to withstand long term outdoor storage and shipment and remain attached and legible. Automatic and/or manual downstream bar code readers can capture the identification of the slab from the tag at various manufacturing nodes, thus enabling automatic tracking of the slab throughout the process. The Slab Tagging Machine technology enables real-time bar code identification and tracking of hot slabs using bar codes, where none was available before when using manual or automatically-applied man-readable-only identification.

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