TEAM 5
TUNDISH SPARK SHIELD AUTOMATION

SDI Steel Dynamics, Inc.®

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INTRODUCTION

In this document the project that included the design and implementation of an automated spark shield prototype for a tundish will be discussed beginning with the background of the project, followed by the design and solution and finishing with a cost analysis with a projected timeline.

OVERVIEW

Above is an image of molten steel being poured into a tundish taken by group member Kyle Tew. The white-hot liquid metal can be seen splashing as it makes contact with the tundish, throwing sparks to the surrounding area. Our project was to design and implement an automated lift for the caster spark shield (seen above) that will protect operators from sparks, slag, and molten metal that escapes the tundish while steel is being poured. This will ensure the safety of the operators and thus decrease the amount of down time due to injuries. There is a great need for such a device that will protect the operators due to the large amount of injuries that have occurred during operation, and decrease the time needed to operate the shield. In 2013 there were thirteen injuries on this particular operation. This project is concerned with safety and time, and thus is of up most importance. Its implementation will:

- Increase safety for operators
- Decrease down time due to injuries
- Create a cost effective, simple, and interchangeable safety mechanism
- Decrease time and effort needed to operate the shield; it will be automatic

BACKGROUND INFORMATION

At Steel Dynamics Inc. Structural and Rail Division, structural beams for buildings are manufactured, as well as railway rails that are shipped and installed throughout the continental U.S. To manufacture the rails scrap steel is melted into molten steel by means of an electric furnace. Once the steel is in a liquid state it is then poured into a tundish which holds the liquid steel and then drained from the bottom of the tundish into a mold where it cools slowly. Though it might be a simple process, the risk of injury is still greatly prevalent. While the steel is in the tundish it must be stirred, have the temperature read, and have samples taken for quality analysis, and it is during these processes that the operators are put at risk of injuries.

For those that do not know, a tundish is a funnel that is used to direct molten steel from a large bucket into the mold that forms the steel into the desired shape. It is made from a refractory brick, which is a ceramic material that has a very high resistance to heat thus allowing it to withstand the 2000+ degrees Fahrenheit that the steel is poured at. The image below shows all components of a tundish, however for the purposes of this project it is only necessary to define the three major components that all tundishes have.

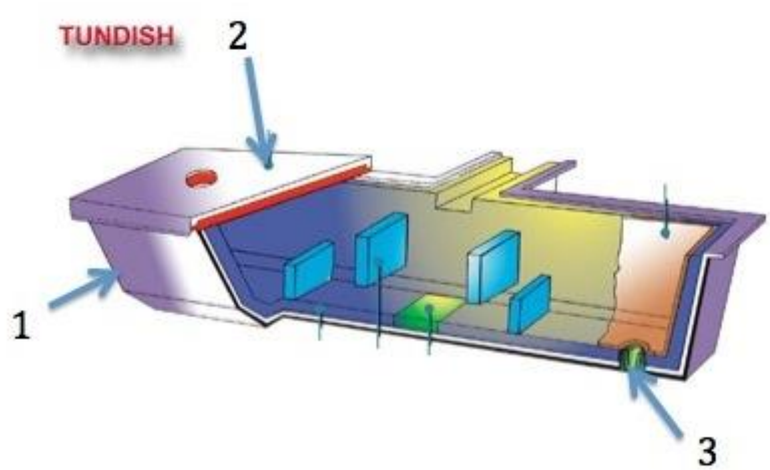


Image from http://calderys-indoporlen.com

Technical Definition

A Tundish is composed of 3 main parts

1) **Housing**

This is the body of the tundish which funnels the molten steel into the mold.

2) **Cover**

The cover acts as a lid on top of the tundish to trap heat it, thus helping the steel remain in a molten state.

3) **Stopper mechanism**

The stopper mechanism is the means by which operators control how fast or slow the molten steel is flowing out of the tundish. This control is done by a rod with a piston on the end that opens or closes the hole through which the steel is flowing out of the tundish.

The majority of the injuries is exactly what one would expect—severe burns. These burns occur when the molten metal splashes out of the tundish and onto the operator. Though the operators are wearing protective equipment, they are not covered completely. Even if they were covered from head to toe, the molten steel is 2,000 degrees Fahrenheit and thus there are very few wearable protective measures that can withstand such a high temperature.

PROBLEM STATEMENT

Currently there are few safety measures that shield the steel from splashing on to the operators. The majority of the safety measures are simply chains that hang from the ceiling in a way that forms a wall that the operators stand behind while the steel is being poured. This is not sufficient to protect them, however, because the metal slag still splashes through the gaps in the chain shield and onto the operators. Once burned, due to the severity of the injury many complications including but not limited to infection. This project was to implement an automated lift system for a spark shield to help create a safer work environment for employees, and in doing so also reduce the injuries and safety risks associated with the tundish. Reduced injuries means reduced downtime due to injuries and thus more money is made for the company.

Tasks

- Research the problem to include all details
- Gather information such as measurements to begin the designing process
- Ask for operator input (i.e. their thoughts, concerns, and comments)
- Design prototype
- Develop prototype in CAD software
- Have CAD drawing quoted for manufacture
- Design automation control
- Install prototype
- Modifications if necessary
- Observation and prove out prototype
- Design automation control

RESEARCH PROCESS

The drawing below depicts the spark shield design with the winch and 2 safety cables. For the purpose of winch selection we as a group chose to base the winch load capabilities on a dead-weight hoist of the spark shield by a single cable wound to the cable winch. For the cables themselves we calculated the force exerted on a single cable while winding to determine the necessary cable size. This ensures there is a built-in safety factor by way of only one single cable is needed to support the load whereas the actual design includes three separate.

Execution Strategy

Our execution strategy incorporates proven methodologies, extremely qualified personnel, and a highly responsive approach to managing deliverables. Following is a description of our project methods, including how the project will be developed, a proposed timeline of events, and reasons for why we suggest developing the project as described.

EXPECTED RESULTS

We expect the proposed solution to Steel Dynamics Inc.’s requirements to provide the following results:

Financial Benefits

- Decrease in downtime due to injuries
- Decrease insurance claims
- Decrease in healthcare costs

Morale Benefits

- Safety for operators
- Peace of mind for operators
- Backing up the core value of “Safety First”

EQUIPMENT SELECTIONS

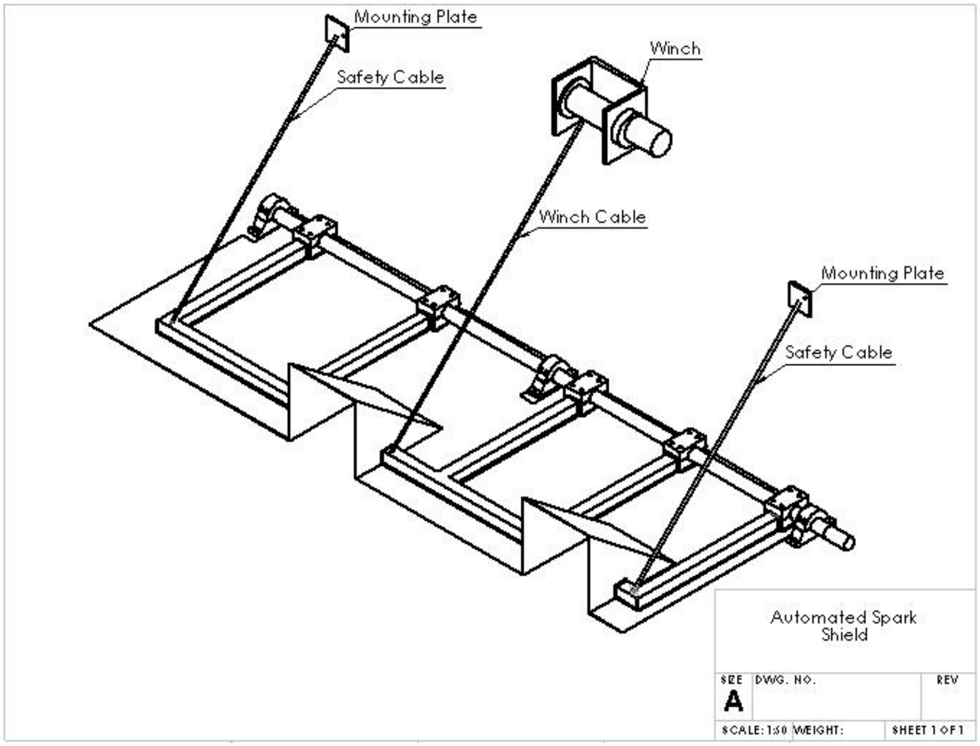
As previously stated we chose to approach the project as if the winch were doing a “dead pick” from the ground. Therefore, the chosen winch would need to be able to lift only the weight of the shield itself. The shield has a weight of 718 pounds and the winch has a load rating of 2,000 pounds. This means the winch will be successful in lifting the shield by a factor of 2.79, meaning the winch is capable of lifting 2.79 times the weight of the shield in a dead pick. Safety chains have been chosen to act as a mechanical fail safe device.

In the event the winch cable would break the shield will free fall for 5 feet, a distant which we ascertained from on-site measurements of the spark shield in relation to the tundish. At the end of 5 feet of travel the safety chains would have to engage and stop the shield from crashing onto the tundish causing possible damage. For the load generated by the shield free-falling we chose to once again approach the load calculations by treating the shield as dead-weight for the maximum potential load. Based on our calculations (seen in Appendix A) the max load during freefall would be 3590 lb-ft. The chains selected based on these calculations are ½” stainless steel proof coiled welded chains. Each chain has a load capacity of 4,500 pounds; therefore, with two chains the maximum load capacity is 9,000 pounds. Because the shield is supported by the shaft linking it to the bearings, realistically this force will never be generated by the shield itself.

Materials and System components chosen
We have chosen a Thern Electric Power winch model 4WP2-A-P, which includes the following characteristics:

- Double worm gear
- Internal brake
- 1.3 HP motor
- Pressure plate
- 5/16” galvanized aircraft cable 28 ft. length
- Emergency hand crank
- Rotary limit switch
- Epoxy finish
- Electronic overload control
- NEMA 4 enclosure for motor control

These materials were all supplied to us by Contractors & Industrial Supply Co., Inc. Wire Rope & Rigging. They also helped us determine the correct winch for our application based on the load and environment the winch would be operating in. For more on the specifications of the winch, see Appendix B.



RESULTS AND IMPLICATIONS

Because of our project, there is now a functioning automation system for the spark shield at Steel Dynamics, Inc. With the system being automated, we predict the number of injuries and time lost will be reduced by the ease of which the spark shield can now be raised and lowered. The ease of use also further incentivizes workers to use it on a regular basis. Because of time restrictions, we are unable to do further data analysis of the effectiveness of the spark shield.

COST ANALYSIS

Material Cost	Estimate	Actual	Difference
Raw Materials (Beams, fasteners,	$1,200	$600	**-$600**
High Temperature Paint	$100.00	$0	**-$100**
Wench & Cable	$2,500	$6,100	**+$4400**
Services Cost			
Assembly and Installation (Contracted out)	$1,000	$2,000	**+$1,000**
Total	**$4,800**	**$8,700**	**+$3,900**

As can be seen by the table above, our original estimates for the work to be done were almost only half what the total costs of the project at its completion.

CONCLUSION

Our team value safety and my solution will solve this problem permanently, efficiently, and with little cost to the company. This will create decreased downtime, increased productivity, and increase morale within the organization. This spark shield automation will give the operators a sense of safety and security. It also reiterates the fact that SDI cares about its employees, and safety is the core value. SDI continues to set industry standards in production rates, efficiency, and safety. Thank you for your time and consideration.

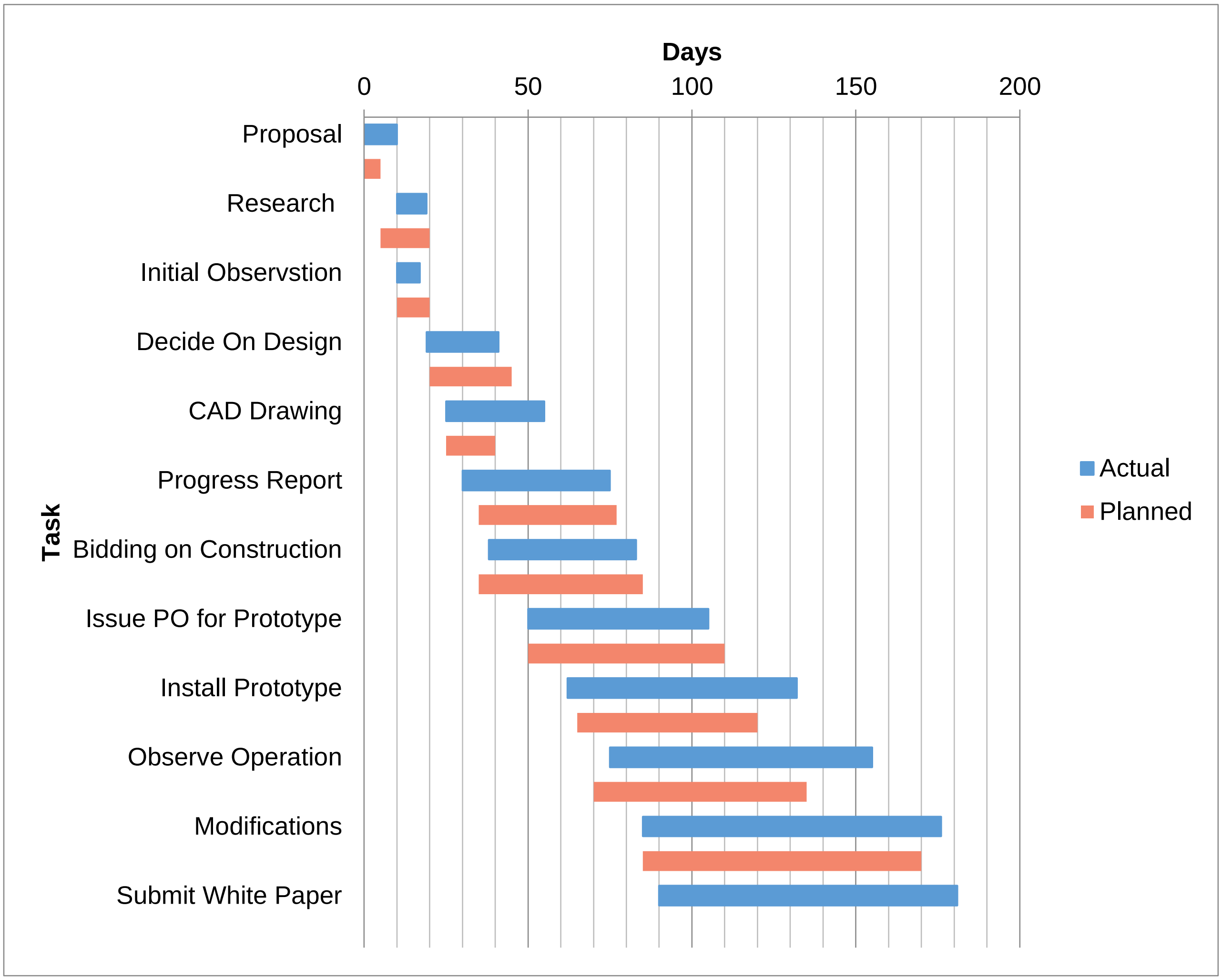
Upon the completion of the beta testing it was determined that the automation of the shield was too slow and needed to be sped up.

We also learned that the lead time for this winch in particular took longer than expected. We waited almost four weeks for the winch to arrive on site. It was also hard to find time to install the winch, test it, and make necessary modifications. This was due to the fact that the machine was constantly running, and did not allow us to install the winch and supporting frame work.

Additionally, the contractors took longer and were more expensive than originally quoted. This was another delay to the process. In all the project was competed in a timely manner and the operators are happy with the current design. SDI plans to install a similar device on the other caster. It was nice getting to hear the input from the production staff, as they often feel that no one listens to their concerns.

In all this is a great start to the innovation of necessary tundish safety devices. This project has laid the ground work for future developments and revisions.

GANTT CHART


Days
0
50
100
150
200
Task
Proposal
Research
Initial Observstion
Decide On Design
CAD Drawing
Progress Report
Bidding on Construction
Issue PO for Prototype
Install Prototype
Observe Operation
Modifications
Submit White Paper
Actual
Planned

APPENDIX A

Dynamic Load During Freefall

$$KE = \frac{1}{2}mv^2$$

$$X = \frac{at^2}{2} \rightarrow t = \sqrt{\frac{2X}{a}}$$

$$t = \sqrt{\frac{2 * 5\cancel{ft}\, s^2}{32.2\cancel{ft}}} = \sqrt{\frac{10\, s^2}{32.2}} = \sqrt{.310559s^2} = .557s$$

$$v = a \times t = \frac{32.2\, ft}{\cancel{s^2}} \left| \frac{.557\, \cancel{s}}{} \right. = 17.944\, {}^{ft}/_{s}$$

$$KE = \frac{1}{2}\left|\frac{22.298lbs\, \cancel{s^2}}{\cancel{ft}}\right|\frac{17.944^2\, ft^{\cancel{2}}}{\cancel{s^2}} = \frac{1}{2} \times 22.298lbs \times 321.987ft = 3589.83\, lb \cdot ft$$

Dynamic Load During Operation

$$KE = \frac{1}{2}mv^2$$

$$v = \frac{8ft}{\cancel{min}} \left| \frac{\cancel{min}}{60s} \right. = .133\, {}^{ft}/_{s}$$

$$KE = \frac{1}{2} \times \frac{22.298\, lb\, \cancel{s^2}}{\cancel{ft}} \left| \frac{.133^2\, ft^{\cancel{2}}}{\cancel{s^2}} \right. = .197\, lb \cdot ft$$

APPENDIX B

Series 4WP2 and 4WP2T – Performance Characteristics – Section 2

series	description	motor hp	load rating (lb) 1st layer	load rating (lb) mid drum	load rating (lb) full drum	wire rope dia. (in)[1]	line speed (fpm) 1st layer	line speed (fpm) full drum	drum capacity (ft)[2] 1st layer	drum capacity (ft)[2] mid drum	drum capacity (ft)[2] full drum	approx. ship wt. (lb)
4WP2[3]	includes controls	1.3	2000	1500	1200	1/4	8	13	11	35	77	85
4WP2T8-2000-8[4]	includes controls	1.3	2000	1200	800	1/4	8	19	19	130	280	101
	ATLAS winch – 8" drum – for pulling or lifting					5/16	8	19	15	85	190	
4WP2TC-2000-8[4]	includes controls	1.3	2000	1200	800	1/4	8	19	12	87	190	106
	clutch model – 5.5" drum – **for horizontal pulling only**											

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Power Winches Section 2

Series 4WP2 and 4WP2T Worm Gear Power Winches

Up to 2000 lb capacity

Model 4WP2T8-2000-8 shown with wire rope

Wire rope assemblies sold separately

- **115 Volt Single Phase Electric Motor** includes power cord with grounded plug and a momentary contact-type push button pendant control on a control cord.
- **Machine Cut Worm Gears** provide accurate operation and long lasting service.
- **Enclosed Oil Bath** provides continuous lubrication of gears to minimize wear. Oil seals keep oil in and dirt out.
- **Internal Mechanical Brake** provides positive load control for lifting and lowering operations.
- **Ball Bearings** and self-aligning bronze bearings provide smooth and efficient operation.
- **Pressure Plate** on series 4WP2T8 only, applies pressure to drum and wire rope to help maintain uniform winding.
- **Dual Function Cable Anchor** for quick disconnect of wire rope with swaged ball fitting, or recessed cable anchor with set screw for wire rope with unfinished end.
- **Mounting Options** include floor, wall, or ceiling.
- **Two-year Limited Warranty**
- **Cast Aluminum** construction, for lightweight strength.
- **Corrosion Resistant** durable paint finish protects against corrosion in harsh environments.
- **Large Diameter Drums** minimize wear to the wire rope and help extend its life.
- **Clutch Model** allows operator to manually disengage the drum to rapidly unwind wire rope. **Clutch models do not include pressure plates.**

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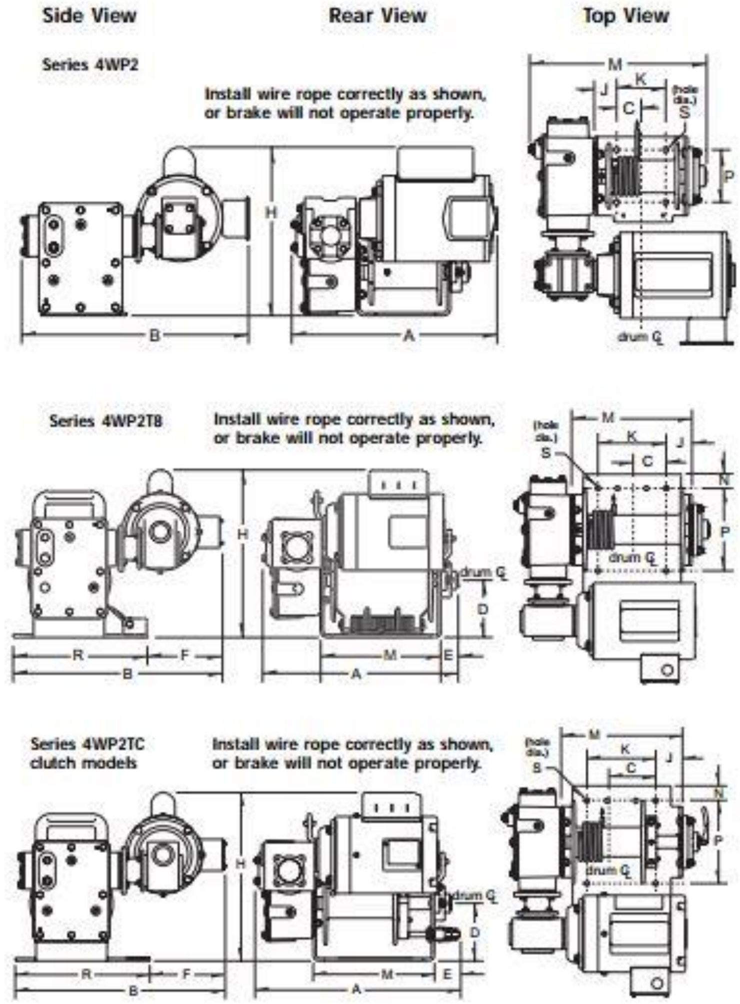
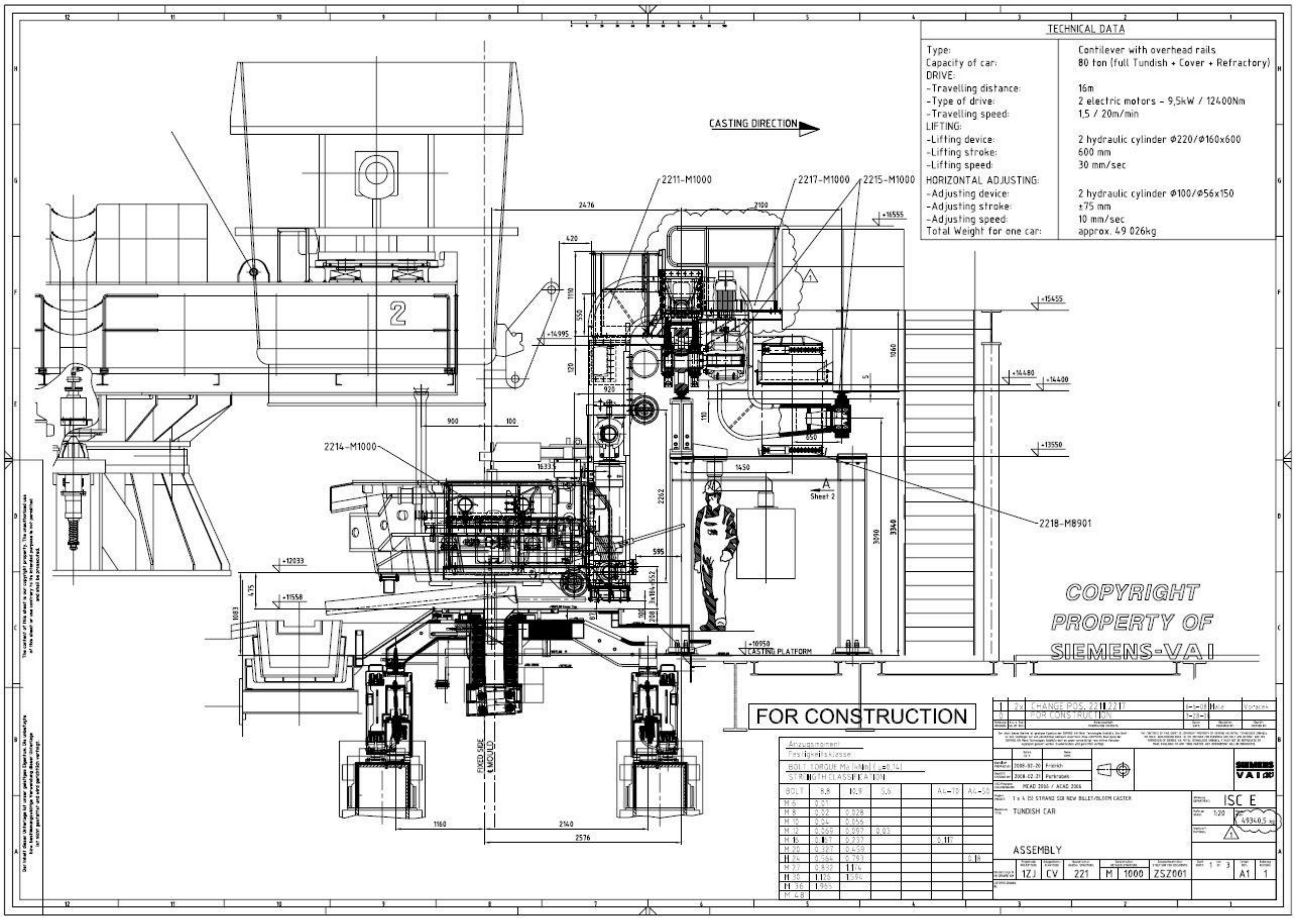
Options and Accessories

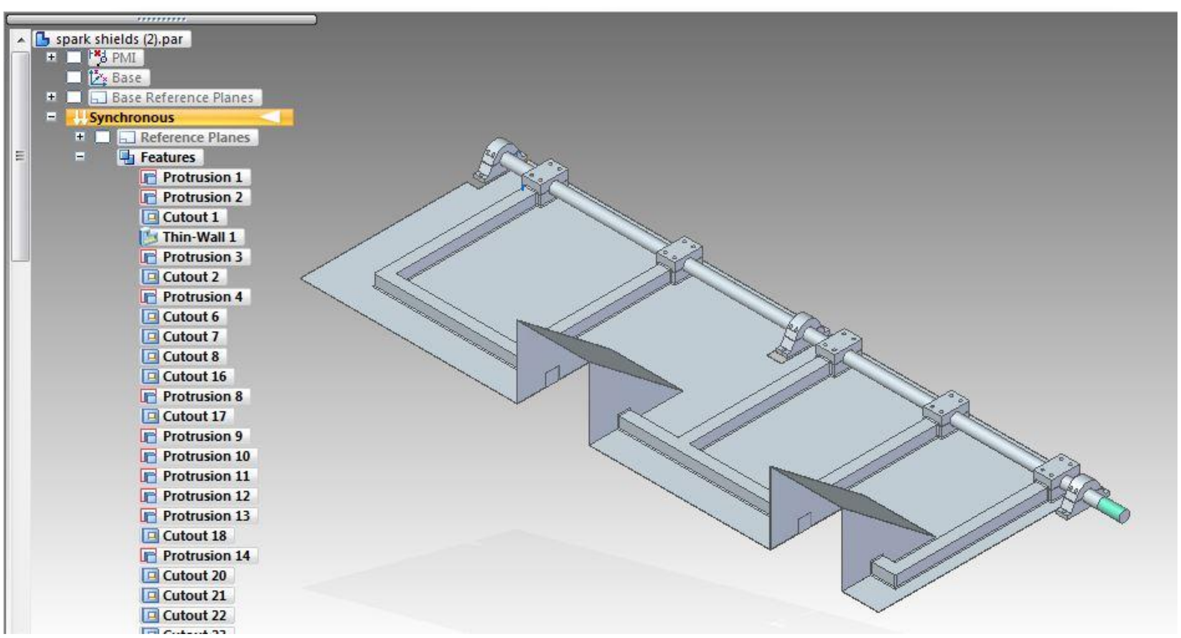
- **Emergency Hand Crank** for manual operation in case of power failure. Does not include handle.
- **Two Part Line Kit** to convert to double line rigging. **Not available for 4WP2 Series.**
- **Rotary Limit Switches** for secondary shut-off to limit load travel in one or two directions. **Not available on clutch models.**
- **Special Motors and Controls** including severe duty and explosion proof.
- **Special Finishes** for hazardous environments.
- **Torque Limiters** as part of the motor controls on electric models.



Important:
It is the owner's or operator's responsibility to determine the suitability of the equipment to its intended use. Study all applicable codes, manuals, and regulations. Be sure to read the Owner's Manual supplied with the equipment before operating it.

Power Winches Section 2


TECHNICAL DATA
Type: Cantilever with overhead rails
Capacity of car: 80 ton (full Tundish + Cover + Refractory)
DRIVE:
-Travelling distance: 16m
-Type of drive: 2 electric motors - 9,5kW / 12400Nm
-Travelling speed: 1,5 / 20m/min
LIFTING:
-Lifting device: 2 hydraulic cylinder Ø220/Ø160x600
-Lifting stroke: 600 mm
-Lifting speed: 30 mm/sec
HORIZONTAL ADJUSTING:
-Adjusting device: 2 hydraulic cylinder Ø100/Ø56x150
-Adjusting stroke: ±75 mm
-Adjusting speed: 10 mm/sec
Total Weight for one car: approx. 49 026kg
CASTING DIRECTION
2211-M1000
2217-M1000
2215-M1000
2214-M1000
2218-M8901
CASTING PLATFORM
FOR CONSTRUCTION
COPYRIGHT
PROPERTY OF
SIEMENS-VAI
TUNDISH CAR
ASSEMBLY
ISC E


spark shields (2).par
PMI
Base
Base Reference Planes
Synchronous
Reference Planes
Features
Protrusion 1
Protrusion 2
Cutout 1
Thin-Wall 1
Protrusion 3
Cutout 2
Protrusion 4
Cutout 6
Cutout 7
Cutout 8
Cutout 16
Protrusion 8
Cutout 17
Protrusion 9
Protrusion 10
Protrusion 11
Protrusion 12
Protrusion 13
Cutout 18
Protrusion 14
Cutout 20
Cutout 21
Cutout 22

RESOURCES

[1] Jiangyin Dongchen Machinery Manufacturing Co.,Ltd , "Tundish Carl" steelmakingmachince.com http://www.steelmakingmachine.com/pdf/Tundish-Car.pdf

[2] Bill Bennett. Melt Shop Mechanical Engineer. Personal interview 9/10/14. SDI Columbia City.

[3] Thern.com http://www.thern.com/portable-power-winches/4wp2t-atlas-portable-power-winch/

[4] Machine Elements in Machanical Deisgn 5th edition.