
Celebrate
PUBLIC WORKS!
APWA WA
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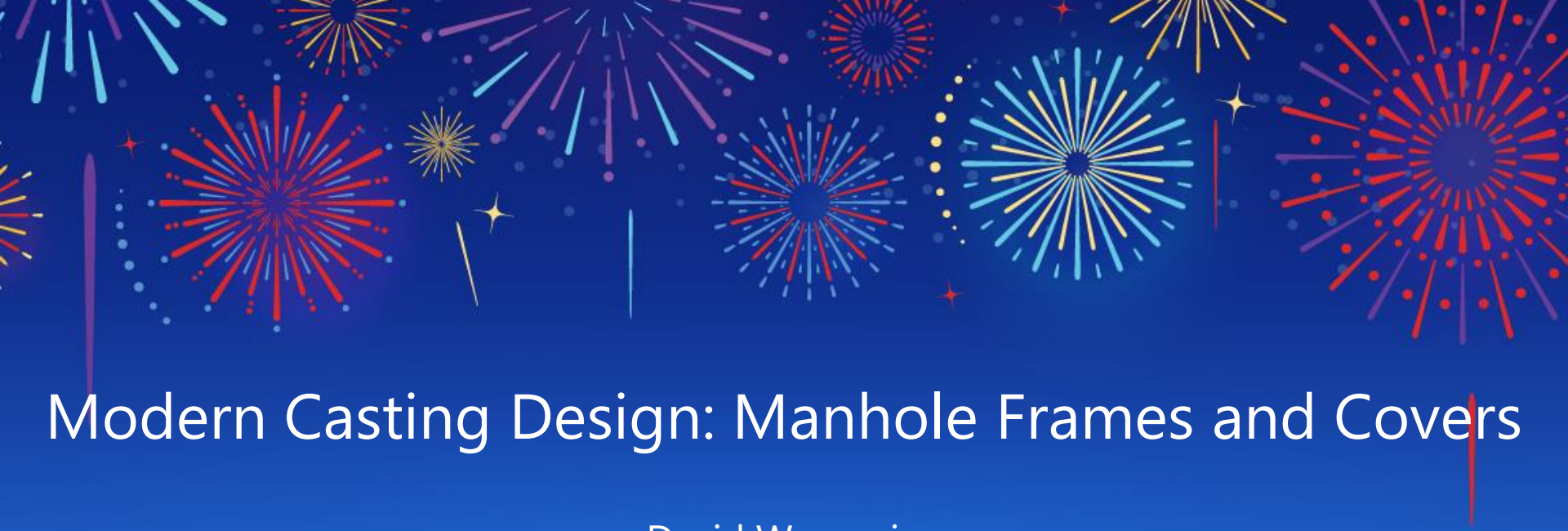
2024 FALL CONFERENCE



Modern Casting Design: Manhole Frames and Covers

David Wangerin

LEARNING OBJECTIVES

Objective 1

- Review current manhole frame and cover designs and specifications.

Objective 2

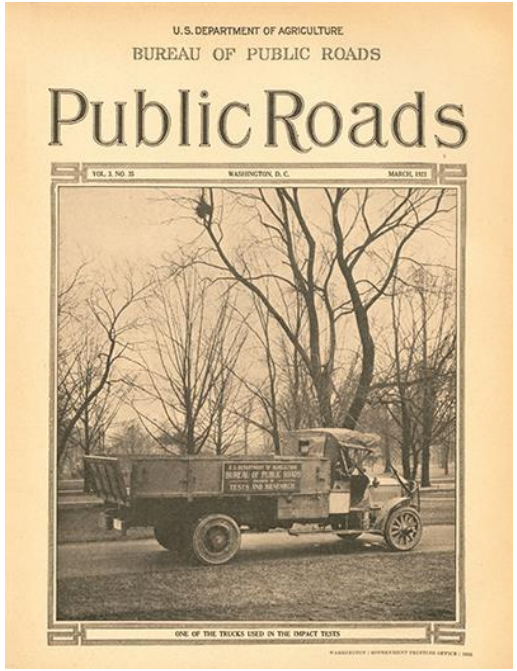
- Compare existing standards to modern casting design standards.

Objective 3

- Identify manhole frame and cover installations that require innovative or unique solutions.

History

- Like today, cast iron manhole frame and cover designs were based on:
  - Why the cover and frame was needed.
  - Where the cover and frame was installed.
  - How the cover and frame was installed.
  - What the cover and frame was installed over.
  - Who designed the cover and frame.
- Cast iron manhole frame and cover designs are still being used that predate “modern” road construction and design standards.
- Public Roads Vol. 3 Issue 35 March 1921
  - "When roads were built to carry the traffic of a few years ago they were built according to 'experience' and empirical rules, and the actual weight or speed of the load was only generally considered... . The transition from horse-drawn to automobile and truck traffic has changed the surface and strength requirements of a road."



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- 1845 - First Known Iron Manhole Covers installed in Brooklyn Heights, NY
  - Hyatt Cover, " Vault Light"
- 1870 – First recorded use of liquid asphalt or bitumen in US roadway construction – Newark
- 1871 – Asphalt Patent – Nathan Abbott
- 1880 – League of American Wheelmen founded.
- 1891 – First concrete road "test strip" installed in Bellefontaine, OH
  - George Bartholomew, Buckeye Portland Cement Co.
- 1893 – US Office of Road Inquiry Launched
  - First incarnation of the Federal Highway Administration (FHWA)
- 1904 – Survey of American Roads
  - 2 million miles of rural roads
  - 154,000 miles gravel, stones, or other paving materials
- 1908 – Model T Production

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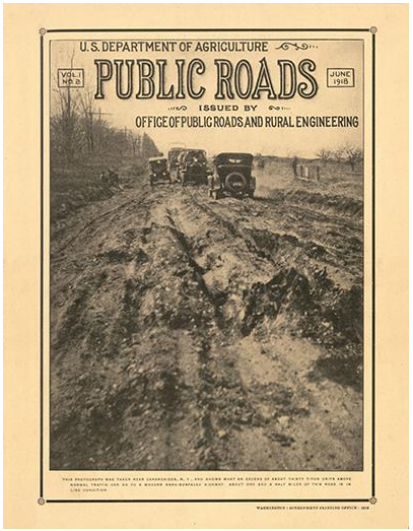
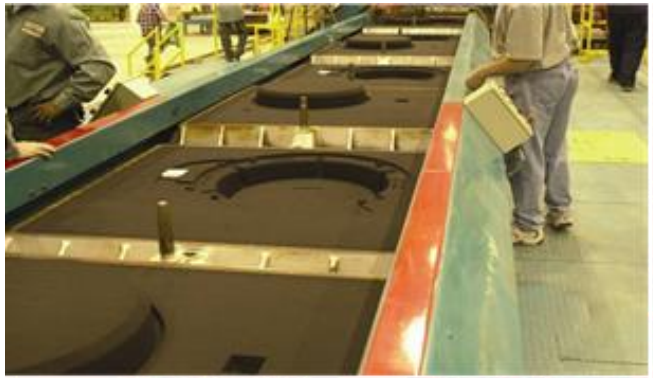
Photo courtesy of AASHTO



- 1914 – 1918 – First World War
- 1914, December 12 – AASHO Formed
  - 16 States, American Association of State Highway Officials
- 1916 – President Woodrow Wilson created Federal Aid Highway Program
- 1918 Induction Furnace Patent
- 1921 – Federal Highway Act
  - Primary and Secondary Systems for funding
- 1930 – First Modern Computer
- 1939 – 1945 – World War II
- 1943 – Keith Dwight Millis invents ductile iron
- 1944 – AASHO H20 Loading defined
- 1956 – President Dwight D. Eisenhower – Federal-Aid Highway Act of 1956
- 1961 – Computer Aided Design (CAD) invented
- 1973 – AASHO renamed to AASHTO

Modern Foundry – EJ, Ardmore, OK



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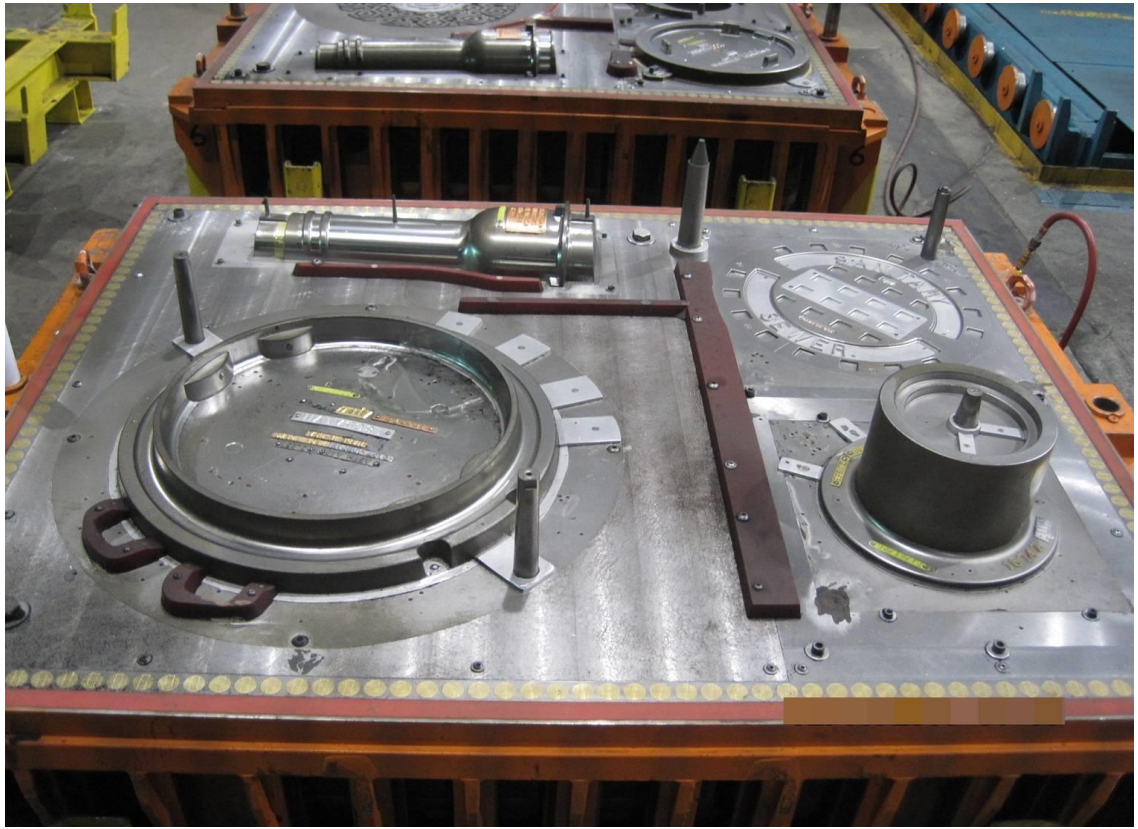
Pattern Setup

Cope and Drag



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Product Molding

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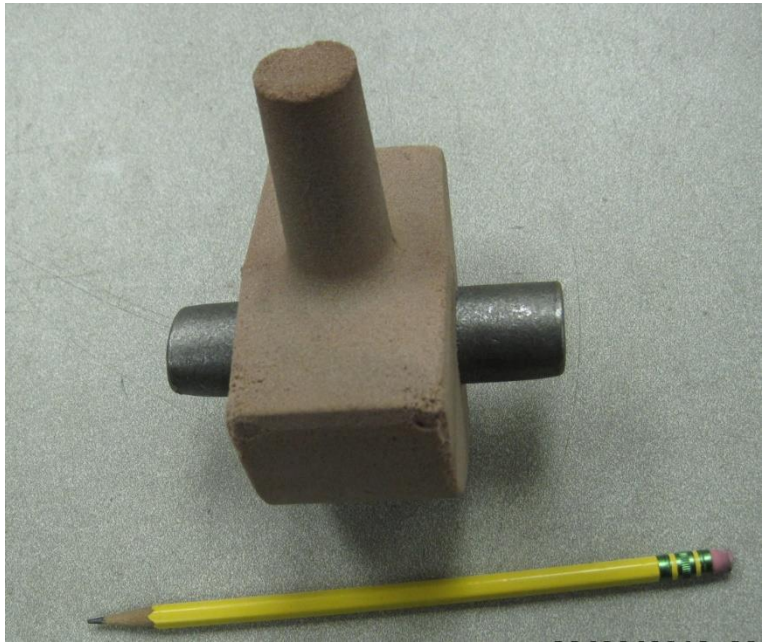
Cores

- Cores form parts of a casting that cannot be made with green sand.
- Manufacturing of cores is required prior to making green sand molds.

These cores are made using a Shell Core Process also known as a “Hot Box.”

Cores

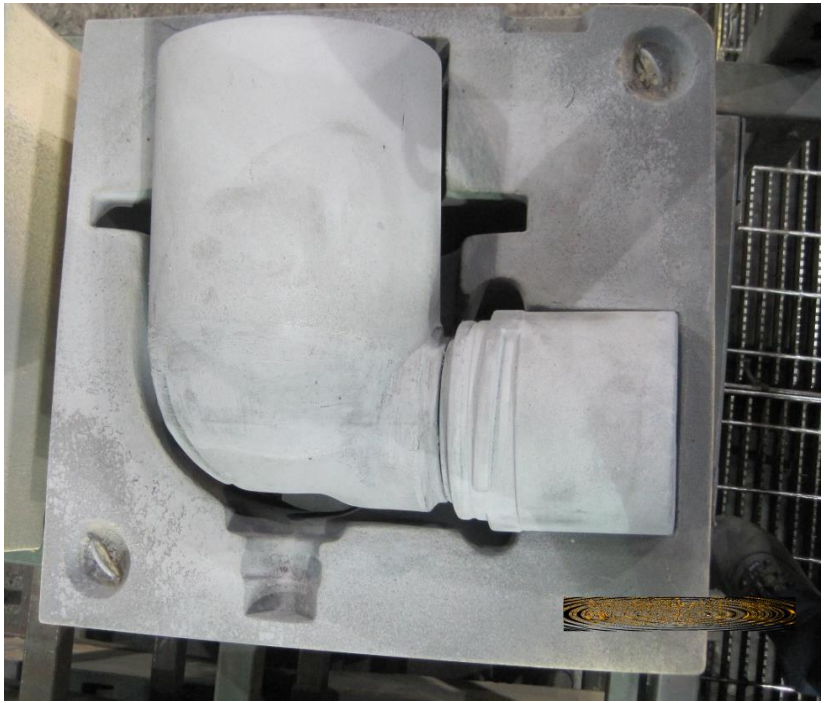
- Pick Bar Core – Forms a recess while also holding a steel bar that is cast into covers.
- Cores are typically purchased from manufacturers that specialize in the core forming processes.



These cores are made using a “Cold Box” also known as Isocure, No-Bake or Air-Set.

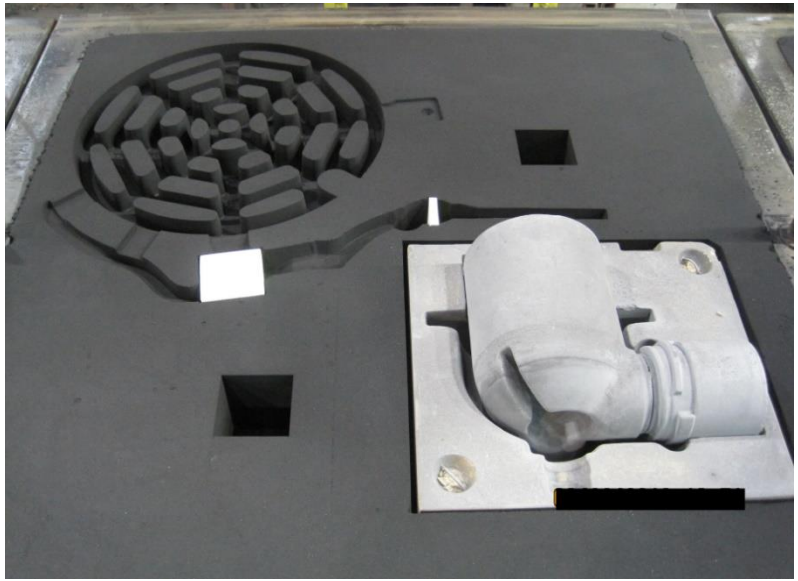
Cores

- All cores use specific types of sand and a resin binder to hold the sand grains together.



Cores

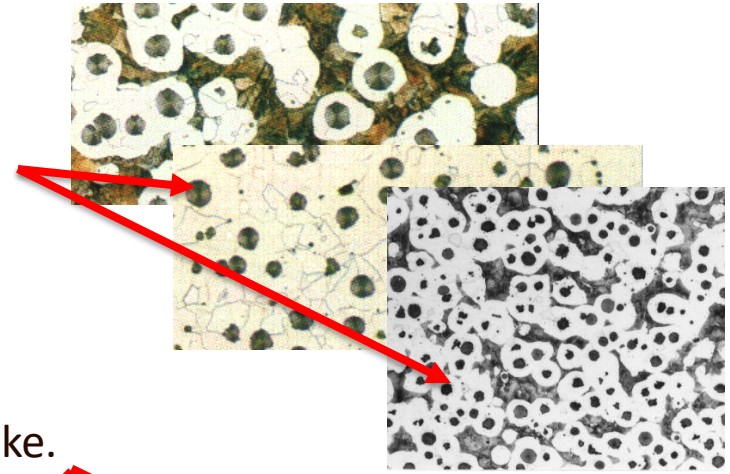
Cores are added to certain molds to create internal voids or areas of negative draft (overhang) in the casting.



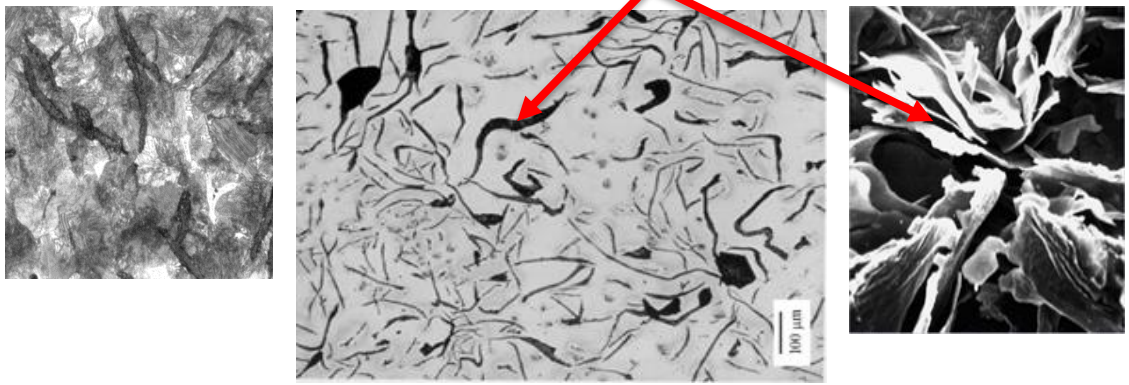
Written Specification Considerations

Gray and Ductile Iron

Ductile (nodular) Iron
During solidification graphite solidifies in a ball or sphere within the iron matrix. Low Sulfur plus Magnesium changes the iron's surface tension as it cools, thus allowing for the graphite to ball up.



Gray (flake) Iron
During solidification graphite solidifies as a flake.



ASTM A48 Class 35B

Component Elements Properties	Metric	English
Carbon, C	3.25 - 3.5 %	3.25 - 3.5 %
Chromium, Cr	0.050 - 0.45 %	0.050 - 0.45 %
Copper, Cu	0.15 - 0.40 %	0.15 - 0.40 %
Iron, Fe	91.9 - 94.2 %	91.9 - 94.2 %
Manganese, Mn	0.50 - 0.90 %	0.50 - 0.90 %
Molybdenum, Mo	0.050 - 0.10 %	0.050 - 0.10 %
Nickel, Ni	0.050 - 0.20 %	0.050 - 0.20 %
Phosphorus, P	<= 0.12 %	<= 0.12 %
Silicon, Si	1.8 - 2.3 %	1.8 - 2.3 %
Sulfur, S	<= 0.15 %	<= 0.15 %

ASTM A536 80-55-06

Component Elements Properties	Metric	English
Carbon, C	3.6 - 3.8 %	3.6 - 3.8 %
Cerium, Ce	0.0050 - 0.20 %	0.0050 - 0.20 %
Chromium, Cr	0.030 - 0.070 %	0.030 - 0.070 %
Copper, Cu	0.15 - 1.0 %	0.15 - 1.0 %
Iron, Fe	90.738 - 94.175 %	90.738 - 94.175 %
Magnesium, Mg	0.030 - 0.060 %	0.030 - 0.060 %
Manganese, Mn	0.15 - 1.0 %	0.15 - 1.0 %
Molybdenum, Mo	0.010 - 0.10 %	0.010 - 0.10 %
Nickel, Ni	0.050 - 0.20 %	0.050 - 0.20 %
Phosphorus, P	<= 0.030 %	<= 0.030 %
Silicon, Si	1.8 - 2.8 %	1.8 - 2.8 %
Sulfur, S	<= 0.0020 %	<= 0.0020 %

What does 80-55-06 mean?

- 80 - Minimum Ultimate Tensile Strength
  - In this case 80 means 80,0000 lbs
- 55 - Yield
  - This is when the material will start to deform, in this case 55,000 lbs.
- 06 - Elongation
  - This is the percentage, in this case 6% that the material will deform/stretch before breaking

- This is different when compared against gray iron which has one number of 35 which is the Minimum Ultimate Tensile Strength of 35,000 lbs. Gray iron doesn't like to bend/deform.

AASHTO H20 vs. AASHTO M306 H20

- Design Load vs. Proof Load
- H20 or H20-44 was published in 1944.
  - 16,000 lb load applied on a 10″ x 20″ contact area.
- M306 H20 was originally published in 1989.
  - Applies a 2.5x safety factor to design load for final 40,000 lb proof load.
  - Load is applied on a 9″ x 9″ contact area.

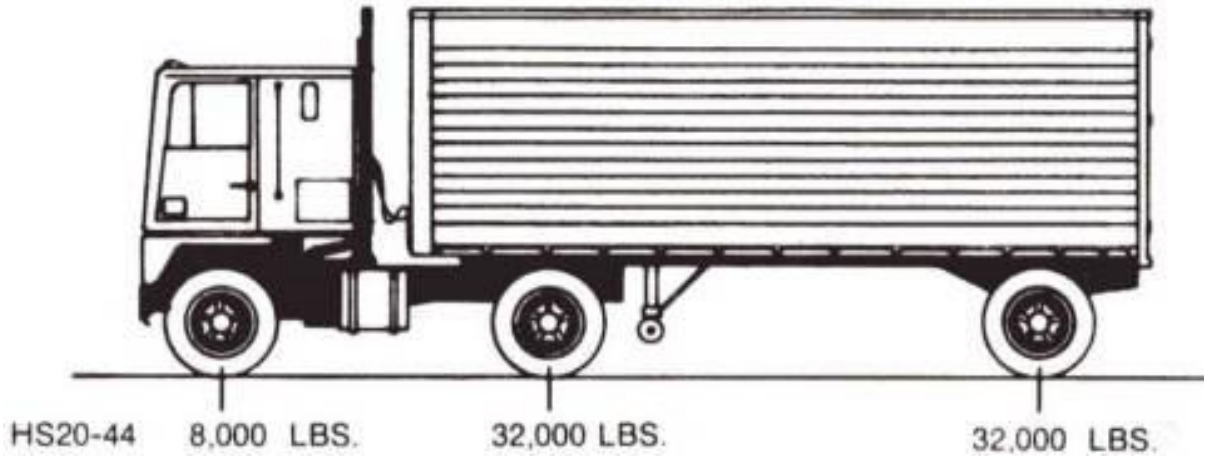
H-20

HS-20

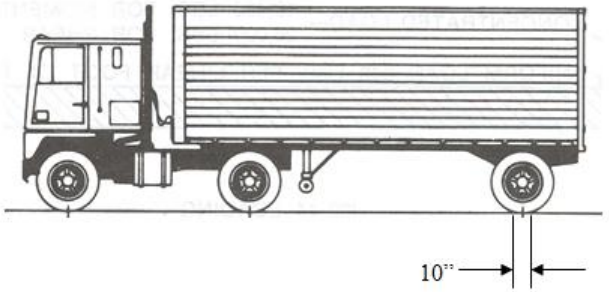
These sketches illustrate the AASHTO-approved live loading specifications for standard H20 and HS20 trucks.

Source: AASHTO Standard Specifications for Highway Bridges.

Standard HS Truck (Tractor Trailer)

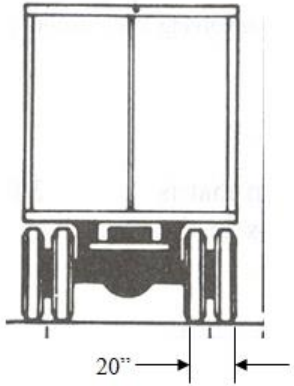


10” x 20” Contact Area



3.30 TIRE CONTACT AREA

The tire contact area for the Alternate Military Loading or HS 20-44 shall be assumed as a rectangle with a length in the direction of traffic of 10 inches, and a width of tire of 20 inches. For other design vehicles, the tire contact should be determined by the engineer.



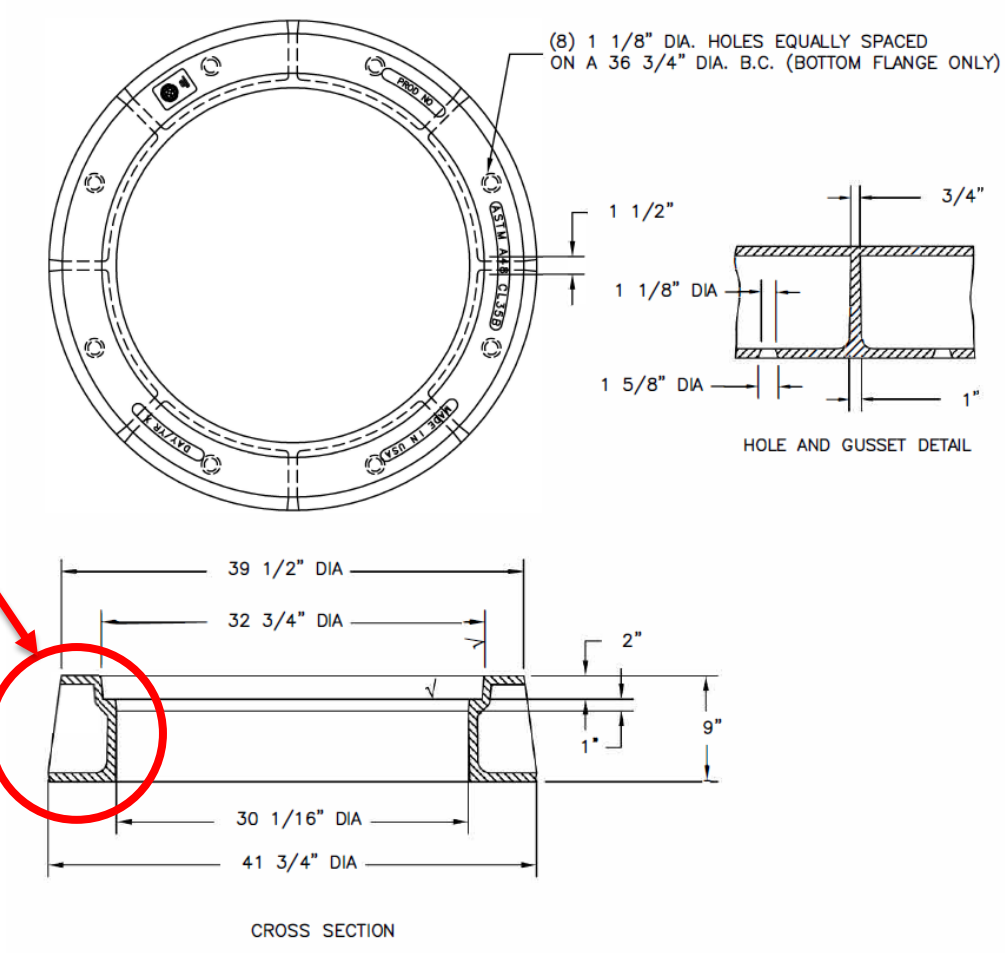
AASHTO M306 specification summary

- AASHTO M306 is published by The American Association of State Highway and Transportation Officials (AASHTO). It is one of the most trusted and respected specification bodies in the United States.
- AASHTO M306 originally published in 1989, important revisions in 2004, 2007, 2010 and latest revision 2016.
- It is the most up to date specification currently published, with all aspects of casting quality addressed.

Examples of Current Casting Standards

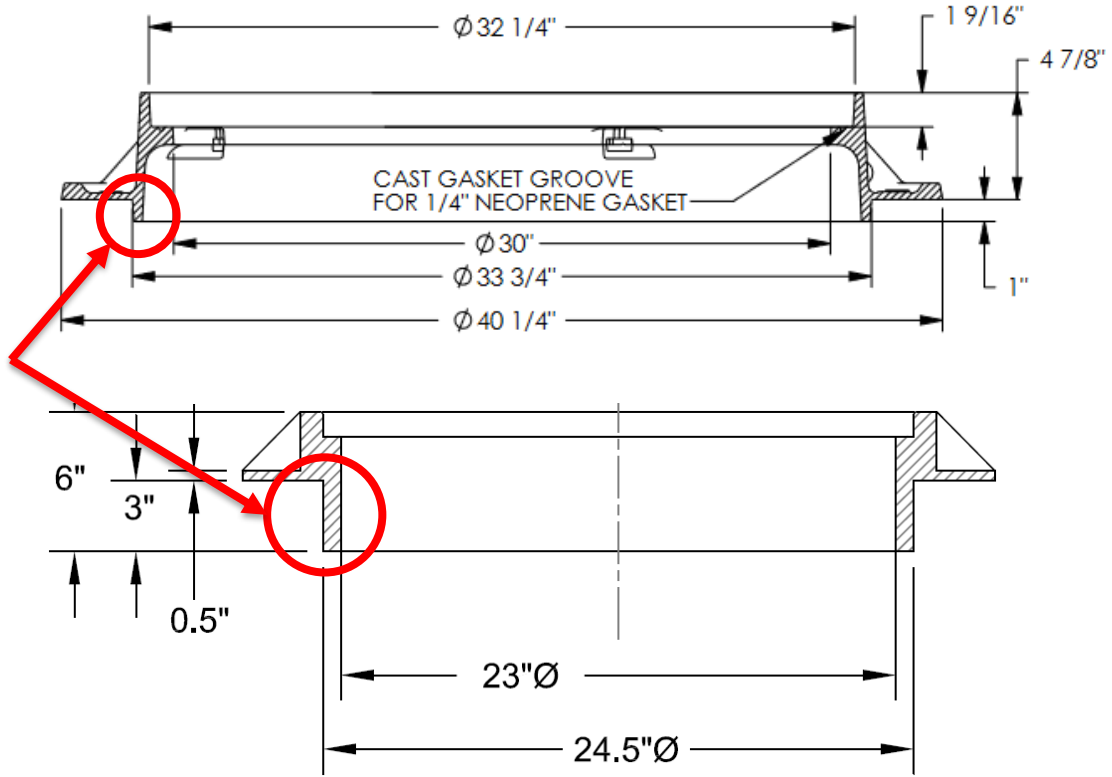
Double Flange or “C” Channel

- Includes any frame with outside diameter negative draft.
- Initially used with loose or semi-rigid materials.
- One of the oldest cast-iron frame designs.
- Requires the use of radial “ring” cores during molding.



Mud Ring

- Name comes from the excessive amount of mortar/grout used at the top of the brick manhole.
- Originally designed for centering on brick manhole structures.
- Functioned as a “keystone” for tapered brick structures.
- One of the oldest cast-iron frame features.



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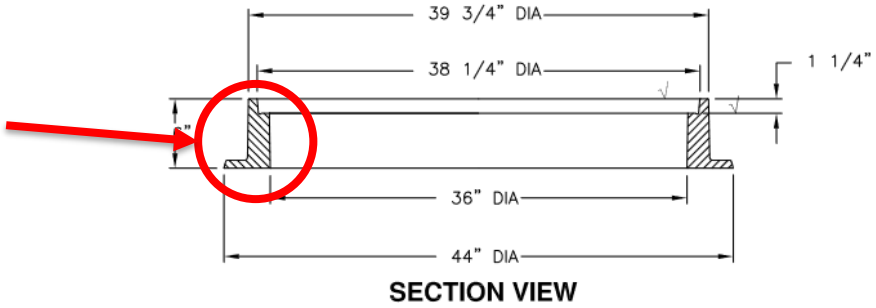
Straight Wall or Flat Face

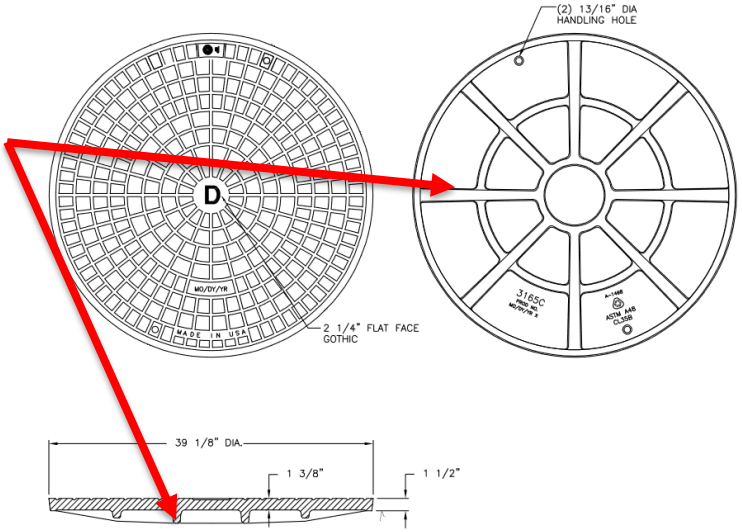
- Cover Seat does not have a ledge and is supported by solid iron below the seat.

Radial Rib

- Benefits Ductile Iron cover design.
- Unstable when resting on the underside of the cover.
- Based on historical construction design rather than an analysis of material properties.



SECTION VIEW

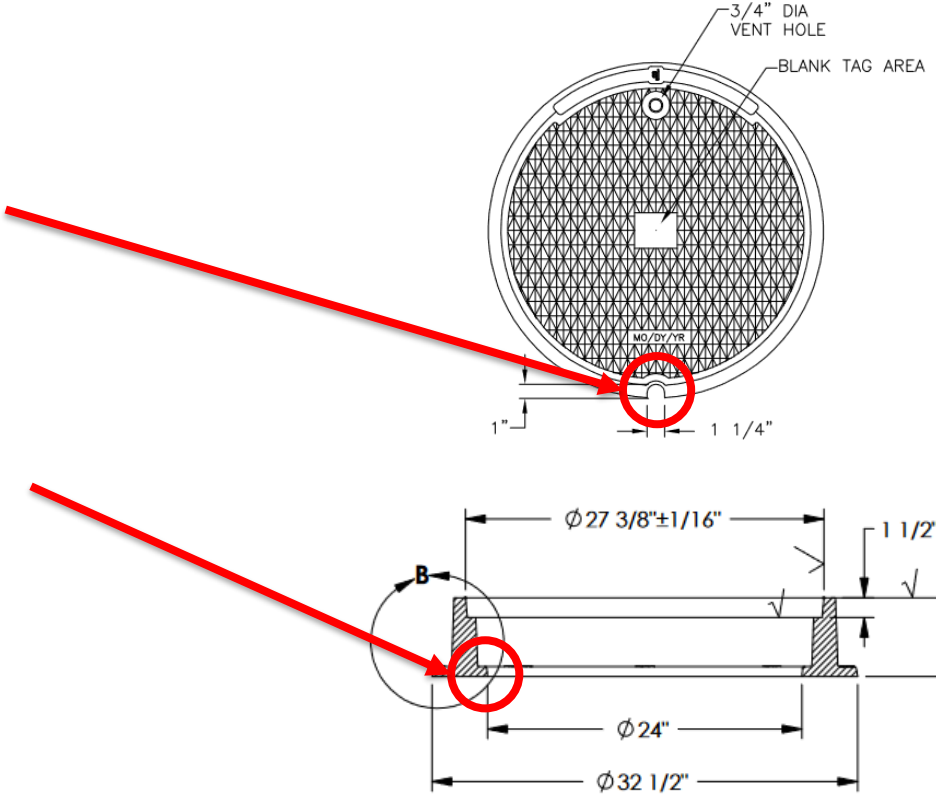


Open Pick Slot

- Requires placing hands between cover and frame during removal.

Inner Flange or Secondary Seat

- Used for catch pans or pressure plates.

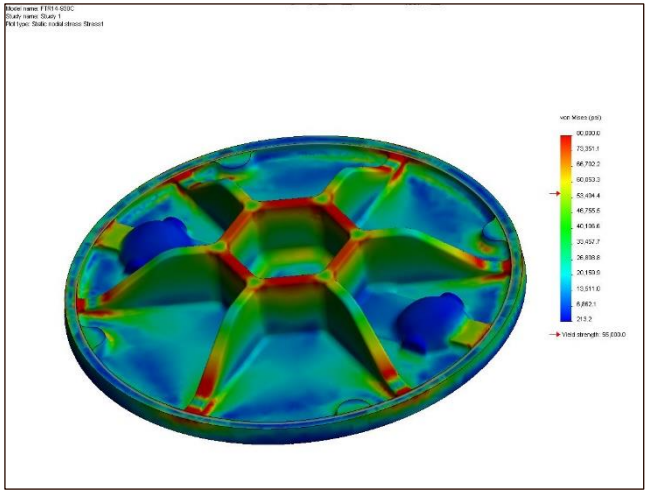


Modern Casting Designs

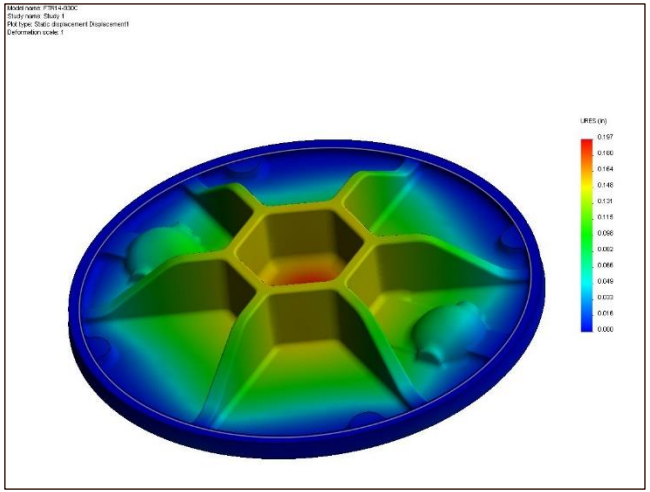
Standards and Specifications

- Modern Design and/or Innovative products must perform as well or better than the products being replaced

Finite Element Analysis (FEA)



Model FTR14-930C
Static nodal stress



Model FTR14-930C
Static displacement

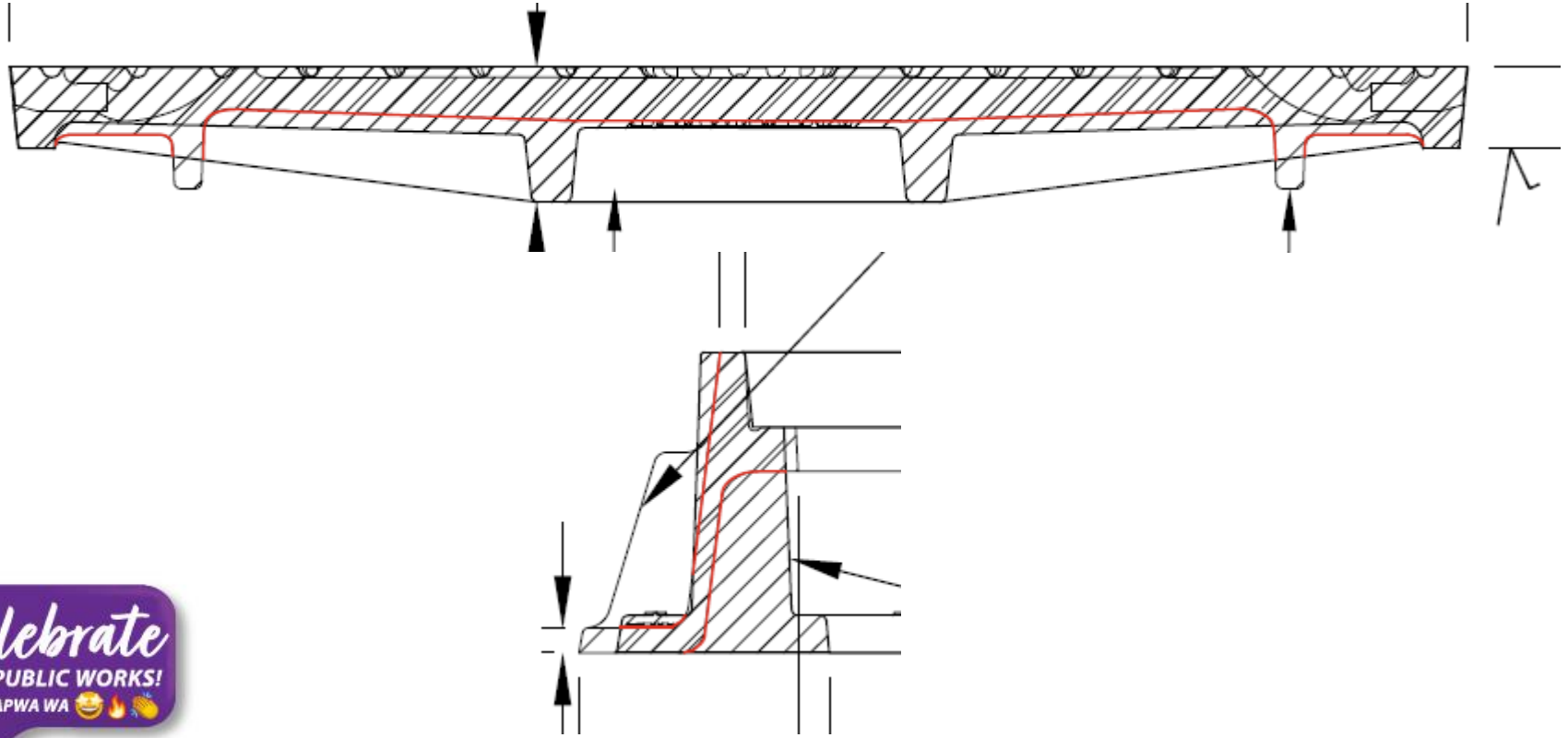
Modern Design

MODERN COVER DESIGNS

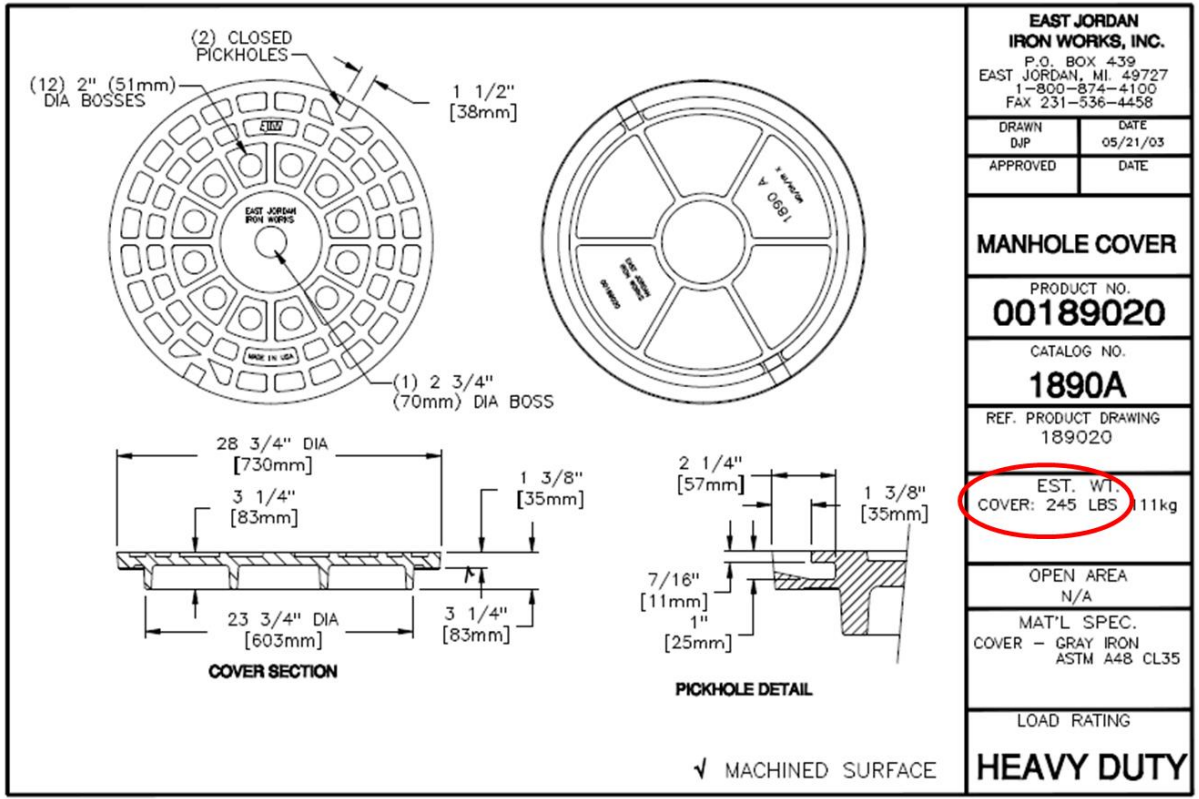
Platen design for Gray Iron.

Ribbed design for Ductile Iron.

Modern Design Profile Comparison



Historical Version Design



Historical Design Loading

Standard Proof Load Test - Data Entry Screen

Date of test: 08/20/92

Tested by: TRI

Distribution:

Cover or Grate being tested :	
Product#	00189020
Description	1890A SOLID COVER W/ CPHO
Material	Gray Iron
Production Location	EAST JORDAN
Cover/Grate Weight	230
Cast Date	

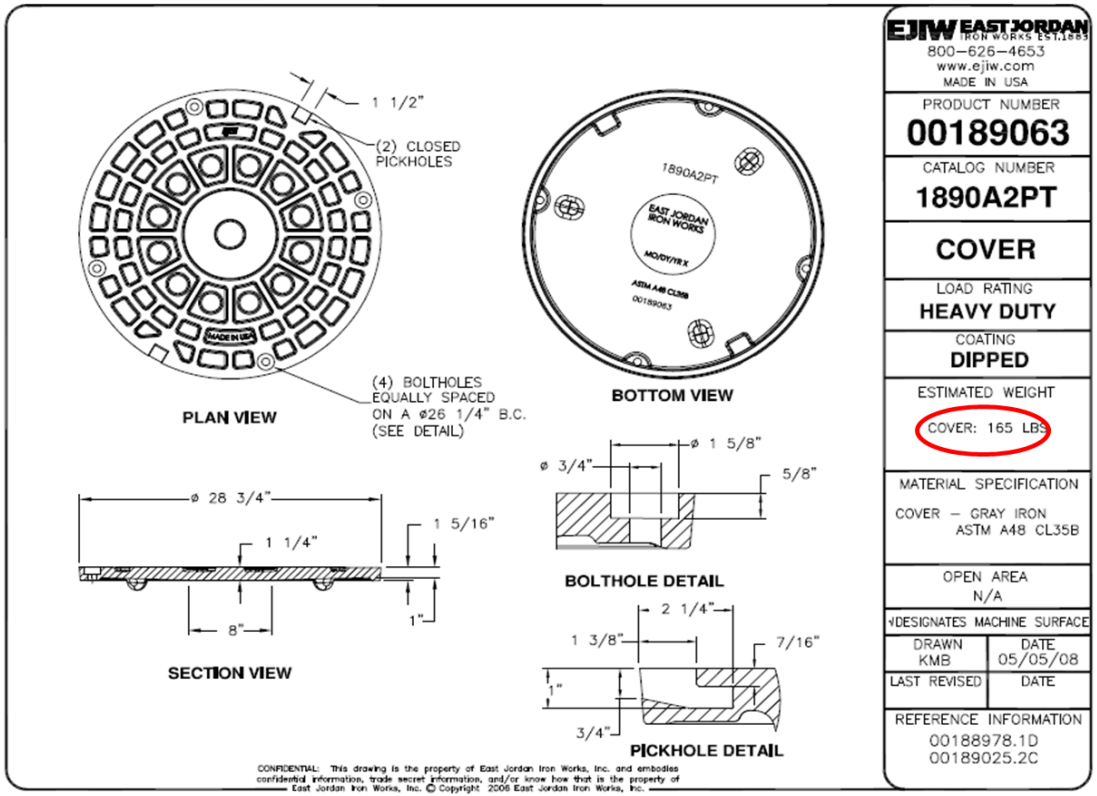
Frame used for test :	
Product#	1890Z
Material	
Production Location	
Frame Weight	
Cast Date	
Number of Bars Supporting Load if No Frame	

Amount of Load Applied Without Failure for 1 minute	510	PSI	40,055 Lbs
Unit Cracked or failed at	800	PSI	62,832 Lbs
1/8" Permanent Deformation		PSI	Lbs
1/4" Permanent Deformation		PSI	Lbs
Unit Destructed at		PSI	Lbs
Load Rating for this test :	HEAVY DUTY		

Comments:

Picture:

Modern Design



Modern Design Loading

Standard Proof Load Test - Data Entry Screen

Date of test: 02/02/2010

Tested by: DAL

Distribution:

Cover or Grate being tested :	
Product#	00189063
Description	1890A2PT CV
Material	Gray Iron
Production Location	ARDMORE
Cover/Grate Weight	170
Cast Date	05/22/2008

Frame used for test :	
Product#	00189014
Material	Gray Iron
Production Location	ARDMORE
Frame Weight	174
Cast Date	01/25/2010
Number of Bars Supporting Load if No Frame	

Amount of Load Applied Without Failure for 1 minute	**PSI**	40,000 **Lbs**
Unit Cracked or failed at	**PSI**	103,220 **Lbs**
1/8" Permanent Deformation	**PSI**	**Lbs**
1/4" Permanent Deformation	**PSI**	**Lbs**
Unit Destructed at	**PSI**	**Lbs**
Load Rating for this test :	EXTRA HEAVY DUTY	

Comments: 00189063.pdf

City of Houston Casting Designs

Traditional Design Frame & Cover		**Modern Design Frame & Cover**	
	Heavy ribs were removed, and the end result was the modern design, weighing 78 pounds less and withstanding higher traffic load ratings.		
275 lbs.		197 lbs.	
			
245 lbs.		125 lbs.	
	The traditional mud ring added unnecessary weight to the manhole frame, and has been removed in the modern design.		
Assembled weight = 520 lbs.		Assembled weight = 322 lbs.	
Proof Load Exceeds H-20 / H-25		Proof Load Exceeds AASHTO M 306	

Modern Design

	Weight (lbs.)							
Clear Open	24"		27"		30"		36"	
Design	Std.	Mod.	Std.	Mod.	Std.	Mod.	Std.	Mod.
Cover	175	138	230	183	305	234	440	340
Frame	260	126	280	135	320	145	370	165
Assembly	435	264	510	318	625	379	810	505
% Reduction	39.3%		37.6%		39.4%		37.7%	

Modern Design – Ductile Iron

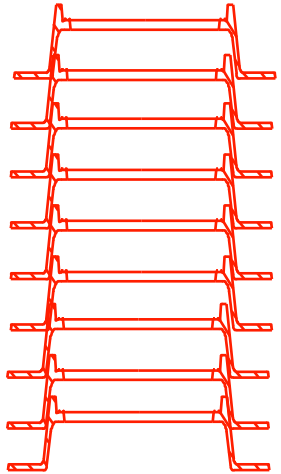
	Weight (lbs.)										
Clear Open	24"		27"			30"			36"		
Design	Std.	Mod.	Std.	Mod.	DI	Std.	Mod.	DI	Std.	Mod.	DI
Cover	175	138	230	183	142	305	234	161	440	340	241
Frame	260	126	280	135	N/A	320	145	N/A	370	165	N/A
Assembly	435	264	510	318	277	625	379	306	810	505	406
% Reduction	39.3%		37.6% →	46%		39.4% →	51%		37.7% →	50%	

Modern Design - Performance

	Loading (lbs.) (in accordance to AASHTO M306 H20)			
Clear Open	24"	27"	30"	36"
Standard	69,912	70,486	77,853	75,006
Modern	66,759	82,467	90,321	113,430

Additional Benefits – Safety, Handling and Logistics

- Transportation Example
  - Standard Design – 64 Assemblies = 13 Pallets
  - Optimized Design – 105 Assemblies = 13 Pallets
- Stackability (Nesting)
  - Reduces area required for storage at facilities and job sites
  - Improved stability during shipping and handling
    - Reduced damage from shipping and handling
    - Improved safety from accidental shifting or collapse



Additional Benefits – Safety, Handling and Logistics

- Reduction in weight improves ergonomics
  - Reduction in workplace/lost time injuries
    - Private Contractors
    - Maintenance
    - Inspectors
- Opportunity to improve design elements
  - Size, shape and type of pick slots
  - Infiltration
  - Locking options

Additional Benefits – Opportunity

- Modernization of existing designs requires interchangeability with existing infrastructure
- Opportunity to improve design elements
  - Size, shape and type of pick slots
  - Infiltration
  - Locking options

Application Specific Solutions

Elevated Structures

- Pivoting Manhole Covers
  - Ease of operation
  - Heavy equipment not required
  - Can be installed in difficult to access areas
- Composite Manhole Covers and Frames
  - Lightweight
  - Resistant to H2S derived corrosion

Patented solution

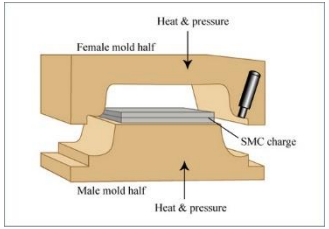
Composite Manhole Covers and Frames

- Understanding Methods of Manufacturing
  - BMC/SMC/RIM or RTM
- Resistant to H2S derived corrosion
- Same Loading requirements as Iron Covers and Frames
- Additional requirements:
  - First published Regional Standard
    - Greenbook Standard Specifications for Public Works Construction 2024 Section 206.7

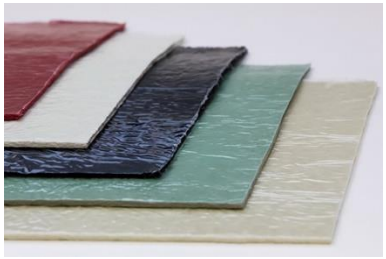
Composite Methods of Manufacture

Compression Molding

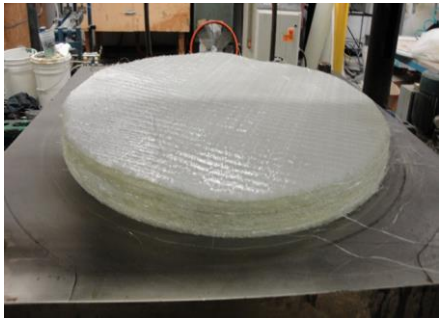
BMC



SMC

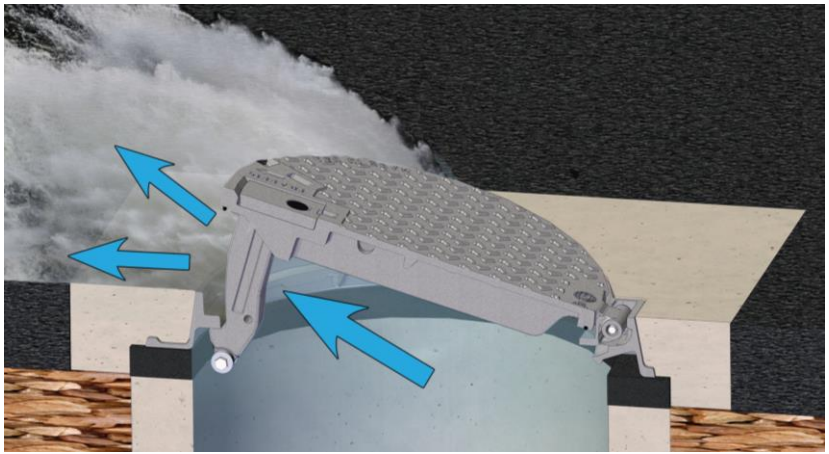


Injection Molding



Cover Displacement

- Internal pressure controlled release
- Explosion mitigation



Locking Options

- Standard Bolting
- Security Bolting
- Cam Locks
  - Improved security
  - Eliminates loose and missing fasteners
  - Captive Wrench

Rehabilitation and Multi-Stage Projects

- Adjustable Manhole Covers and Frames
  - Designed to allow upper frame to move with the environment (frost or hydraulic upheaval)
  - Installation up to 5° slopes
  - Wide range of installation heights, easy installation

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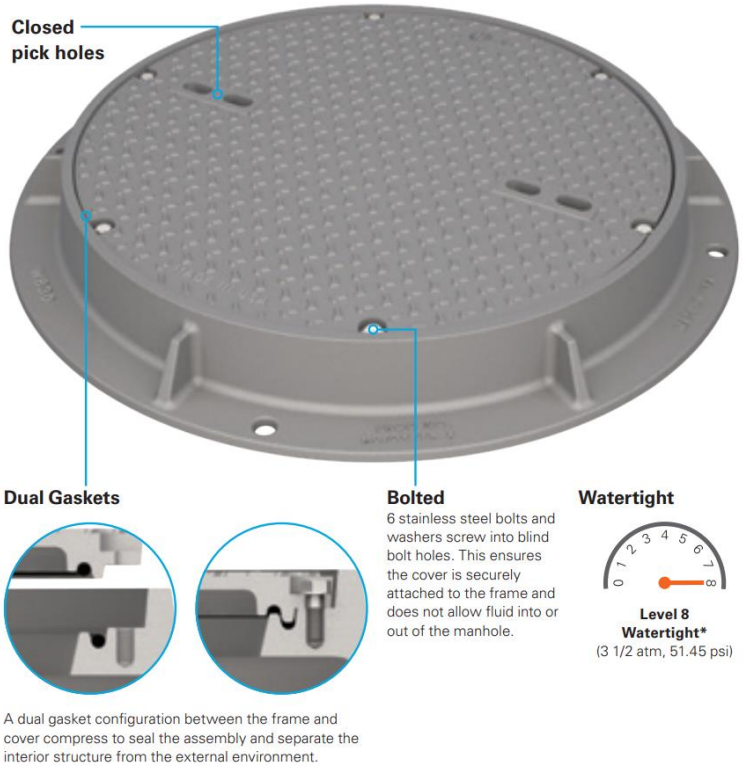
Hinged Units

- Captive vs Removable
- Hinge pocket
- Infiltration
- Lift Assist

Infiltration

- Installation Location
- Water Resistant Covers
  - Why not "Waterproof?"
- Cushion/Sealing Materials
  - Structure degradation



Celebrate PUBLIC WORKS! APWA WA

Thank You

Thank you for attending.

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