

qualification tests and a comparison of results between used and unused fasteners. BART's conclusion was

...the useful life of a BART fastener will in all likelihood not be a factor of the loads on the rail system under normal services conditions and may well depend on other conditions, such as environmental deterioration, heat, ozone, sunlight, or some unknown type of failure. However, from visual inspection and from the electrical tests, none of these factors has caused significant harm to these fasteners to date.

In conclusion, the BART challenge to install CWR on aerial structures was successfully met by a practical design that has been confirmed by 13 years of experience.

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Publication of this paper sponsored by Task Force on Rail Transit System Design.

Manufacturing, Reclamation, and Explosive Depth Hardening of Rail-Bound and Self-Guarded Manganese Frogs on the Chessie System

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ABSTRACT

Rail-bound and self-guarded manganese frogs have been used on the Chessie System for many years. For the past half-century, they have been manufactured or reclaimed at shops operated by the railroad. In May 1961, explosive depth hardening was initiated and the policy established whereby this process was applied to all rail-bound manganese frogs, self-guarded frogs, and one-piece manganese guard rails manufactured or reclaimed by the railroad. This amounts to approximately 90 percent of the systems requirements. In addition, any of these components purchased complete from outside suppliers are sent to the Chessie System and are explosive depth hardened before being put into service. Tests indicate that this process extends the service life of products manufactured from austenitic manganese steel and also acts as a quality control check on the integrity of the products exposed to this process.

In the case of rail-bound manganese frogs, the components are acquired from various sources and the finished products put together at the Chessie System plants in Martinsburg and Barboursville, West Virginia. Although the word "manufacturing" is more commonly used to describe the activity, "assembling" would be a more accurate term.

MANUFACTURING FROGS

Rail-bound manganese frogs are used primarily on heavy density lines where traffic is approximately equal on both sides of the frog. Figure 1 shows the names of detail parts of a rail-bound manganese frog per American Railway Engineering Association (AREA) Plan 690-52 in the Portfolio of Trackwork Plans. The major components are the manganese insert, wing rails, leg rails, filler blocks, and necessary high-grade bolts of sundry lengths. The inserts are purchased from various sources. Head and toe filler blocks and necessary bolts are likewise obtained

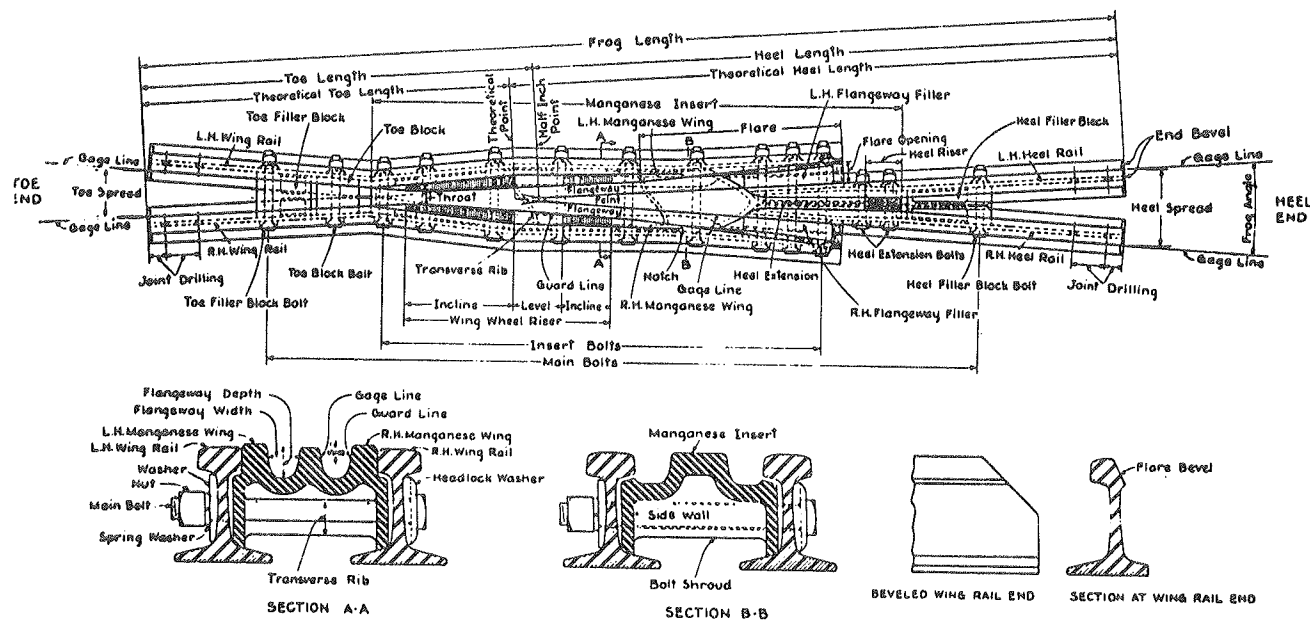


FIGURE 1 Preferred names of parts for rail-bound manganese steel frogs.

from outside sources. Wing and leg rails are manufactured from standard stock rail received from various rail rolling mills. They are cut to length, planed, drilled, heated, and bent at the shops to conform to the type of frog being made. The necessary components are brought together and assembled to form a finished frog. Tests are being conducted concerning the use of various types of fasteners. Also, epoxy glues have been used to bond the wing rails to the casting. These tests are being analyzed to determine whether the service life of the frog is extended sufficiently to justify the additional cost involved. To date, the data assembled are inconclusive. To demonstrate the magnitude of this operation, the two plants manufactured 462 new frogs in 1985.

RECLAIMED FROGS AND GUARD RAIL

As with many metallic trackwork materials, certain portions of a rail-bound manganese frog experience considerable wear while others are only slightly affected. Because of this fact, many parts of a scrapped frog are salvaged and used to produce a secondhand frog that is as good as a new one, with no limitations regarding where it may be installed.

Used frogs are shipped to the plants and inspected to ascertain their condition. Those found to have usable parts are moved into the shop for disassembly. Castings are inspected for wear and cracks. Those found sound and worthy of reuse are welded to conform to a preestablished acceptable profile. Either new or reclaimed components are used to assemble a secondhand frog. The criteria used to determine whether new or repair components are used depend on the availability of salvageable parts. Should there be a sufficient quantity of repaired or repairable parts, then reclaimed frogs will be built using such items. However, if used parts are not available, new and used components are intermingled. After assembly, the frogs are moved to a finishing location in the shops where they are ground to final tolerances and inspected for conformance with specifications.

Approximately 350 rail-bound manganese frogs are reclaimed annually. Recent economic studies indicate that this practice results in the production of a frog that has unrestricted usage for about 42 per-

cent of the cost of a new one. (Note that there is no significant difference in service life between reclaimed and new frogs.)

Manganese Self-Guarded Frogs

Self-guarded frogs are not manufactured at the Chessie System plants. They are, however, explosive depth hardened and reconditioned. All new self-guarded frogs are given a one-shot explosive-hardening treatment before installation in the track. When a frog becomes worn beyond acceptable limits, it is removed from the track and shipped to one of the plants where its condition is inspected and a determination is made as to whether it is repairable. Usually, the worn areas are built up by welding and the missing components are replaced.

Various welding electrodes with a variety of chemical compositions are used for rebuilding. It has been determined that an electrode with an alloy content of approximately 40 percent (consisting of chromium, manganese, nickel, silicone, and carbon) will provide the best welding properties with minimum plastic deformation. Such an electrode produces tensile properties of about 130,000 psi with a 2-in. elongation of approximately 33 percent.

Surface preparation using air carbon arc or grinding, or both, is employed. When actually welding, care should be taken to minimize overheating the manganese casting. Good practice calls for applying a 500° to 600°F tempelstik to the casting adjacent to the area to be welded. When the tempelstik begins to melt, it indicates that the casting has absorbed excessive heat and the welding should be stopped until the metal cools off at that location. To continue welding the casting when the temperature exceeds these limits will result in an inferior weld that will not fuse with the parent metal and will result in premature failure.

Each used frog is evaluated and if the estimates indicate that repairing it would require in excess of 60 lb of electrode, the casting is scrapped. This is based on the fact that the cost involved exceeds the benefits. Any usable components are salvaged for use in other frogs. This is only a guideline and not a rule because other extenuating factors are given consideration.

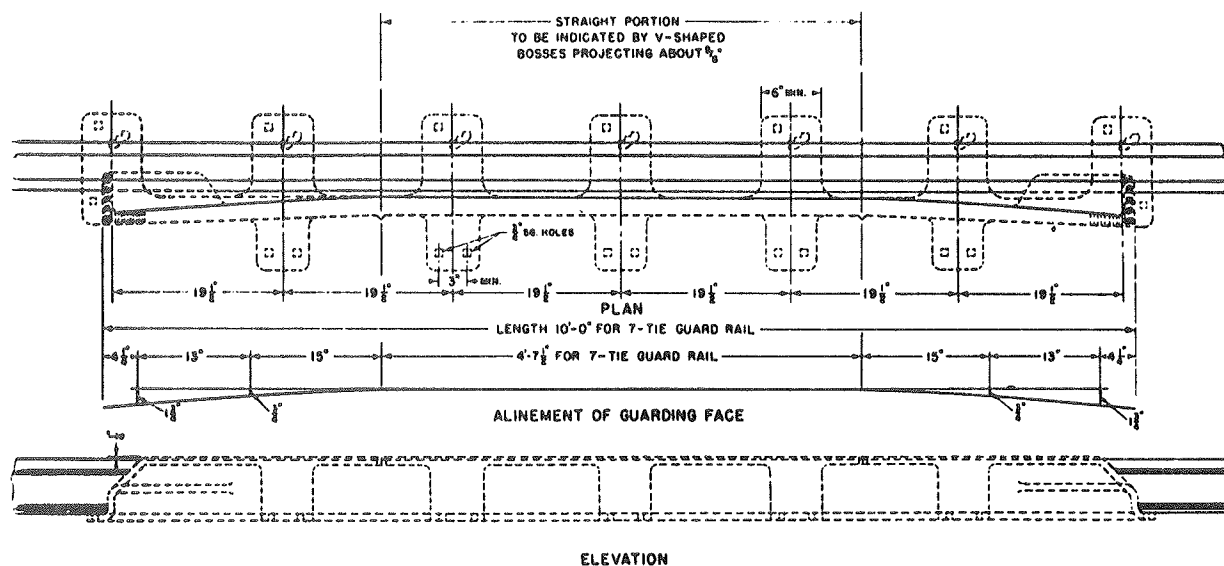


FIGURE 2 Manganese steel one-piece guard rail in accordance with AREA Plan 510-40.

Manganese One-Piece Guard Rail

Manganese one-piece guard rails are standard on the Chessie System. They are purchased from various suppliers on the basis of plans and specifications that accord with AREA Plan 510-40 (see Figure 2). The guard rail is exactly 10 ft overall and incorporates fixed tie plates, which requires spiking seven ties. As was the case with frogs, the primary wear on these components is on the guarding face. Chessie System standards dictate that new guard rail be installed with a 1 7/8-in. flange-way opening. The Guard Check Gage and Guard Face Gage allowable limits are based on the class of track involved. When the wear on the guarding face reaches the point at which it is impossible to maintain the permissible tolerances, the guard rail is removed from the track and shipped to a reclamation shop. Each item is inspected with regard to structural integrity and measurements are taken regarding physical wear. If an item is determined to be sound, the guard rail is checked for alignment and straightened if necessary and the guard face and rail seats are built up by welding. They are then ground to approximate an original "new" contour. Reclaimed guard rails are not restricted with regard to future installation. Service life is equal to that of the original product. Cost comparisons indicate that a one-piece manganese guard rail can be reconditioned to as-good-as-new condition for less than 10 percent of the initial new cost.

Manganese Crossings

Except in emergency situations, the Chessie System purchases all railroad crossings from outside sources. The corners are explosive depth hardened (two shots) at Martinsburg before installation. When rail crossings wear beyond the economical point of field welding, they are replaced and the various segments are inspected to determine if reclamation is feasible. Several factors determine whether a crossing will be repaired. The extent of wear and the characteristics of the traffic passing over the crossing are the primary factors used in making this decision. Because of the customized features of each individual crossing, few are interchangeable. Heavy-tonnage high-speed crossings are seldom reclaimed. Those in minor traffic territories are rebuilt if conditions warrant it.

Manganese steel is an extremely tough nonmagnetic alloy in which the usual hardening transformation has been suppressed by a combination of high manganese content and rapid cooling from a high temperature. The resultant steel is characterized by high tensile strength, high ductility, and superior wear resistance. It is particularly suited to railway track work components, such as frogs and crossings that are subjected to severe service of combined abrasion and heavy impact loading. Manganese steel is produced in various chemical combinations varying from 1.0 to 1.4 percent carbon and 10 to 14 percent manganese; however, Chessie System castings are purchased according to AREA specifications for special track work that conform to ASTM A-128, Standard Specification for Austenitic Manganese Steel Castings, except that the chemical properties may be modified to satisfy special situations. Manganese steel's unique ability to "work-harden" under impact loading is an extreme advantage to railway users. Hardnesses in the 550 Brinell Hardness Number range have been achieved, but because of the low yield strength of manganese steel, plastic deformation or flow will occur in isolated areas as a result of impact before surface hardening. To minimize metal flow and the resulting problems, however, it is necessary to preharden manganese steel castings before their installation. Such prehardening will retard the plastic deformation and thus provide increased service life.

EXPLOSIVE DEPTH HARDENING

Prehardening can be accomplished by hammering, pressing, or explosive depth hardening (EDH). The Chessie System has used EDH since 1961 and is convinced that it is a beneficial process. In 1956, a new type of detonating explosive was developed in the form of a flexible sheet of uniform thickness. It was safe to handle, easy to cut to any pattern to fit complex shapes, and could be attached to castings using an adhesive, thus making it adaptable to track work components.

The high-velocity hardening technique is based on an entirely different principle than the plastic deformation of cold metal using the hammering or pressing concept. The manganese steel is subjected to shock waves with extremely thin interfaces that travel through the casting at high velocities. The pressure waves set up the slip or strain lines within

the manganese steel that characterize the cold working process. Velocity impact-hardening can be carried out on practically all of the casting surfaces providing that the explosive sheet can be cut to, and shaped to fit, irregular and nonflat surfaces such as fillets and radii.

After numerous tests, it was determined that the most practical and economical procedure to follow in using this process is as follows:

One shot using a flexible plastic explosive having 0.083-in. uniform thickness and 2.0-g/in.² weight. This increased the hardness of the areas subjected to the hardening to approximately 325 Brinell Hardness Number (BHN).

Others have experimented with two and three applications, which increases the hardness of the parent metal to between 350 and 390 BHN. Laboratory and field tests have shown that no more than three shots should be made on a casting. Additional attempts to further increase the hardness could result in surface fatigue in the form of microcracks and thereby defeat the benefits of the process.

An additional benefit of EDH is that as well as extending the surface life of manganese castings, it aids in locating casting defects and, as such, acts as a quality control measure.

EDH on the Chessie System is performed at Martinsburg, West Virginia. The shooting bed was fashioned from a retired building foundation in a remote location about 7 mi from the city. The pit is 15 by 40 by 8 ft deep. A 39-in. frame sits on top of the wall and supports a curtain of 1-in. rubber belting, which dampens the shock waves. The bottom of the pit has a 24-in. bed of river sand. Frogs to be shot are placed into the shooting bed using a 5-ton capacity crane mounted on a truck. The frogs are positioned on the floor of the bed so that the rail ends are free and not resting on the sand. This helps to prevent bending of the frog when detonation occurs. Next, each frog is cleaned to remove oil, grease, protective coatings, and so forth. This is accomplished by using a solvent and wire-brushing the areas involved. Moisture is removed from the frog using a propane torch. When the frog is thoroughly clean and dry, an adhesive is applied with a paintbrush.

Flexible-sheet explosives 0.083 in. thick and weighing 2.0 g/in.² come in 20-in., 20-lb rolls. They are precut using templates that conform to the frog areas to be shot. The precut explosive pieces are placed on the adhesive and smoothed out so that no air bubbles exist. Also, the explosive material is extended below the top of the wear surface by at least 1 in. The entire surface to be hardened is covered with explosive material. A blasting cap is affixed in the vicinity of the point and connected to underground wires that terminate at the shooting building approximately 350 ft from the blast site. After detonation, each item that was explosive-hardened is inspected for defects, checked for hardness, and stamped to indicate the month and year the item was hardened before it is shipped and used. Extreme care is taken to ensure that all of the shooting operations are performed safely. The sheet explosive is stored in an approved magazine and a daily perpetual inventory is maintained. Detonating caps are kept separate from the explosives and stored in a bunker away from the blasting pit and explosives. Only qualified persons are permitted to perform the EDH process. They must be familiar and comply with the rules and regulations of the state of West Virginia and U.S. Bureau of Explosives.

fice have applied pressure to force relocation of the Chessie System's shooting facilities. It is a "no-win" situation. Anyone planning an explosive-hardening operation should conduct an extensive environmental impact study and obtain the necessary permits to carry out the operation before investing the required funds. The environmental aspects of the operation are becoming critical. Although seismographic measurements taken at distances of 1,500 to 3,000 ft from the shooting site indicate that the resulting vibrations and noise levels are well within safe ranges, the nuisance factor exists and must be given consideration.

TEST RESULTS

Based on previous studies, the average vertical wear in the vicinity of the point of a frog is 0.0006 ft/million gross tons (MGT) for EDH frogs and 0.002 in./MGT for nonhardened frogs. Chessie System Engineering Department Maintenance Rule 1429 requires that a slow order be placed on main-track frogs with vertical wear at the point in excess of 3/8 in. The frog should be built up by welding before the slow order is lifted. When the wear exceeds 0.5 in., the frog is taken out of service and replaced or repaired, whichever is the most practical and economical. Using the preceding figure as a basis, EDH frogs should accommodate 625 MGT before reaching the slow-order status and 833 MGT before removal. Nonhardened frogs will only sustain 187 MGT before reaching slow-order limits and 250 MGT before removal. These are only average figures and could vary considerably depending on the physical characteristics of the turn-out and maintenance practices.

CONCLUSIONS

EDH costs an average of \$410 per frog. Based on an average cost of \$3,000 per frog, the process increases the cost of the item by 12 percent while extending the service life from 2 to 3 times that of nonhardened frogs. It can be proven beyond a doubt that EDH is a justifiable process. For a 12 percent increase in the cost of a frog, the service life is extended 2 to 3 times, producing a 44 to 63 percent annual savings in frogs only. Other maintenance functions such as welding, surfacing, adjustment to bolts, and so forth, are likewise minimized. A reduction in the cost enhances the justification of the process, but, for this paper, it has been quantified.

There is some controversy regarding the number of shots a manganese casting should receive. Tests on the Chessie System indicate that one shot produces the desired results. Each shot adds approximately \$400 to the cost of the end product. As can be seen from Figure 3, the relationship between the number of explosive applications and the wear hardness is not a straight line function. Wear occurs rapidly during the first 3 to 4 MGT. Beyond this point, the rate of wear is much less. A series of tests indicates that after 20 MGT, one-shot frogs have reached approximately 350 BHN hardness.

These results are a combination of EDH and work hardening of the wheels over the frog. Wheel work hardening is a noncost process. If manganese castings are artificially hardened to 350 BHN or greater, the work-hardening process is less efficient and the additional cost questionable.

GLOSSARY (1)

Frog--A track structure used at the intersection of two running rails to provide support for wheels and

A WORD OF CAUTION

For the past 5 years, local residents, the news media, county commissioners, and the Governor's Of-

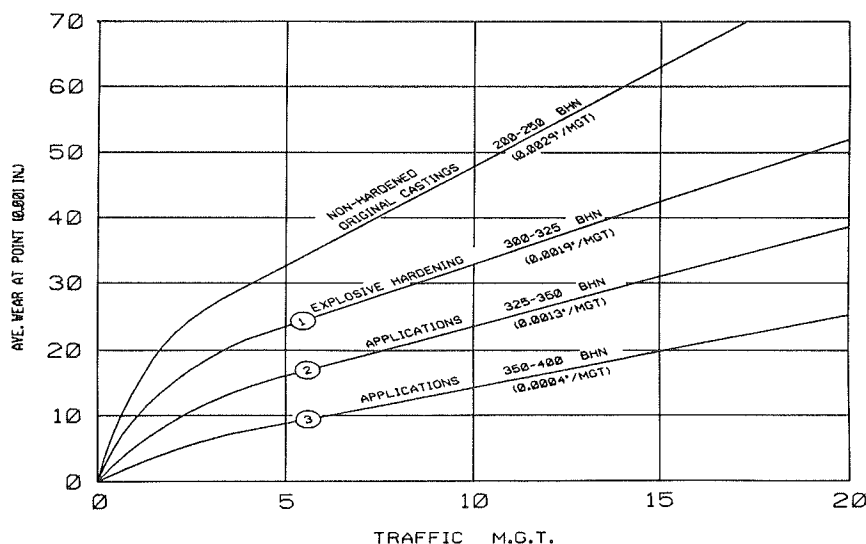


FIGURE 3 EDH/work hardening versus wear/service life.

passageways for their flanges, thus permitting the transfer of wheels from one rail to the other.

Rail-Bound Manganese Frog--A frog consisting of a cast manganese insert that is fitted into and between properly bent rolled rails and held together with bolts.

Self-Guarded Frog--A single manganese steel casting frog with guides or flanges above its running surface that contact the thread or rims of wheels for the purpose of guiding their flanges correctly past the point of the frog.

Heel End (Frog)--That end of a frog that is the farthest from the switch; or the end that has both point rails or other running surfaces between the gage lines.

Toe end (Frog)--That end of a frog that is nearer the switch or the end that has both gage lines between the wing rails or other running surfaces.

Frog Point (Frog)--That part of a frog lying between the gage lines extending from their intersection toward the toe end.

Half Inch--A point located at a distance from the theoretical point toward the heel.

Guard Check Gage--The distance between the gage line of a frog to the guard line of its guard rail or guarding face, measured across the track at right

angles to the gage line at a point 5/8 in. below the top of the head of the running rail.

Guard Face Gage--The distance between guard lines measured across the track at right angles to the gage line.

Guard Rail--A rail or other structure laid parallel with the running rails of a track to hold wheels in correct alignment to prevent their flanges from striking the points of turnouts, or crossing frogs, or the points of switches.

Alloy Steel--Steel containing more than 1.65 percent manganese or more than 0.60 percent silicon or other elements added for the purpose of modifying or improving the mechanical or physical properties normally possessed by plain carbon steel.

REFERENCE

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Publication of this paper sponsored by Committee on Railroad Track Structure System Design.