

### INDUSTRY SURVEY OF FROG WELD REPAIR BEST PRACTICES

by David Davis, Jian Sun,  
Vin Terrill\* and Bill Hansen\*

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#### Summary

Based upon a survey of railroad best practices, the Association of American Railroads (AAR) has developed guidelines for the most effective methods of making weld repairs to frogs. In short, the area to be repaired should be thoroughly prepared, and all defects and work-hardened metal should be removed. A weld material with lower carbon content than the base metal should be used. And the welder should minimize and control heat input to avoid frog distortion.

The need to make weld repairs can be delayed and sometimes avoided by proper and frequent profile grinding. Grinding helps to extend the lives of frogs by keeping impacts to a minimum and by removing flowed, damaged metal from the frog before it can start a crack.

While several frog weld repair maintenance practices — both in-track and out-of-track — have been identified as “best practices” for mainline turnouts and crossing diamonds, shop repair of frogs becomes the only reasonable option in railroads under heavy traffic. These practices were selected after evaluating those used by the participating AAR member railroads. Several of these offer significant savings in frog life-cycle cost over typical practices. Several heavily used lines in North America have reached the point where in-track weld repairs cannot be done practically by the identified best practices due to the lack of track time.

These findings are from an extensive series of interviews and field visits to AAR member railroads. Both maintenance supervision and front-line personnel were interviewed about weld-repair practices currently used on heavy-haul track. This work was conducted under the AAR’s Special Track Work Research Program.

\* Rail & Track Consultants



Association of American Railroads  
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## INTRODUCTION AND CONCLUSIONS

Maintenance of special track work is of great importance and concern to North American railroads. About 6,800 frogs are replaced at a cost of \$120 million annually. Additionally, another \$120 million is spent on turnout and crossing-diamond maintenance per year. The load environment on these components is quite severe, making them the shortest-lived track segments in the system. The effects of increased axle loads on frog life is of great concern. High-angle crossing diamonds tested at the Transportation Technology Center's Facility for Accelerated Service Testing (FAST) had lives of 30 million gross tons (MGT) or less under a 39-kip wheel load train, as compared to lives of 150 to 300 MGT under 33-kip wheel loads in revenue service.

A literature review, survey of practices and field visits were conducted to gather the information presented here. The currently used frog weld repair best practices for heavy-haul operations identified from our study are presented in Exhibit 1. A brief description of each practice and its advantages are listed.

Conclusions drawn from this study include:

- The average life of rail bound (i.e. turnout) austenitic manganese steel (AMS) frogs, until first repair, is 60 MGT.
- The average life of AMS inserts (i.e crossing diamond frogs) until first repair is 50 MGT.
- The life of rail-constructed frogs is similar to AMS frogs.
- Grinding should be the primary frog-maintenance technique.
- An effective maintenance grinding program can delay the need for repair welding and reduce the amount required.
- Most weld repairs are for breakouts, not wear.
- Approximately 75 percent of frog repairs are for cracks and broken-out surface pieces.
- On high-tonnage lines there is often insufficient track time to do weld repairs by best practice methods. In such cases, out-of-track repair is the best alternative. Shop repaired frogs have performance characteristics equal to new castings.

## RECOMMENDED BEST PRACTICES

The practices that show the most improvement over previous standard practices are welder train-

ing and periodic requalification, use of combined power source equipment, a program of routine frog-surface grinding, weld-repair criteria that permit welding only when truly needed, proper frog preparation for welding, minimization of heat input, positive control of frog temperature and frog distortion, and stress relief of weld layers.

Methods and materials which minimize required track time are, by necessity, gaining wide acceptance as available track time diminishes. This is especially true for large blocks of track time on many lines. Such items as air-arc gouging for damaged metal removal, a flux-cored or solid-wire feeder and use of the flux-cored arc-welding method offer the potential of doing a weld repair faster than with previous methods.

Implementation of these best practices for any given line should be preceded by an economic analysis. The design of the turnout or crossing diamond, the type and quantity of traffic, and the resources available to the track maintenance forces are key factors in such an analysis. A systems approach should be taken.

## WELD REPAIR LIFE

The life of the original frog as manufactured and the life of subsequent weld repairs has been estimated from survey data. Exhibit 2 shows these estimates for the original frog and the first four repairs. It is interesting to note that the original frog and weld-repair lives of rail-constructed frogs compare favorably to those of AMS castings. It is likely that the AMS casting frogs are in more severe service environments, however. The casting and weld repair life values also agree with data collected from a heavy axle load revenue-service test site and reported in TDs 95-002 and 96-012.

Exhibit 3 lists the composite recommended frog-grinding policies for the surveyed railroads. It appears, however, that these policies are seldom fully implemented due to lack of track time and available welders. The welders are often too busy making weld repairs to keep up with grinding.

## RESEARCH NEEDS

In some areas there is clearly a best practice and in others, there is a lack of evidence that one practice is truly better than another. In these cases more research and testing needs to be done. Listed below are some areas of maintenance and design that we suggest should be developed.



Exhibit 1 — Weld Repair Best Practices

Activity	In Track Best Practice	Shop Best Practice	Comments
Qualification of Welders	Formal training: 4-13 weeks. Written testing follows AWS D15.2. Periodic requalification.	Same	Some require additional testing beyond AWS.
Track Welding Equipment	Combined power source for welding current, electric power and compressed air. Flexible-shaft electric grinders or hydraulic hand grinders are preferred.	Automatic welders — Gas Metal Arc Welding (GMAW) or Flux Cored Arc Welding (FCAW) — used to build up entire running surface.	Wire feeders for FCAW are preferred on high-traffic lines.
Maintenance Grinding	Considered the most important maintenance technique; it can extend the life of any frog type. Should be done on a regular schedule. Use flangeway contour gage.	N/A	
Weld Repair Criteria	Wear/Batter: typically 3/8" Breakouts: 3" x 3/4" x 1/2" transverse cracks in wheel transfer section always warrant repair	Same.	Cracks in flangeway floor do not necessarily warrant repair.
Frog Preparation for Welding	Remove all defective and work hardened metal. Dye penetrant and hardness testing should be used. Grinding is the preferred removal method. Cracks should be penetrated 100% with a "U" shaped groove.	Same. All cracks and flaws removed. All cavities filled. Surface is machined off to a depth of at least 3/16".	Air carbon arc gouging and Oxy arc slicing are also used when track time is limited. Heat input must be controlled.
Control of Heat Distortion	Control of maximum inter-pass temperature to 500 F. Use of skip welding, reverse beads, etc. to minimize heat input.	Frog restrained when removing damaged metal and when welding.	Crowning and use of opposing heat are used to a lesser extent.
Preheat	AMS (cold weather): 100 F Rail constructed frogs: 700 F	N/A Same	Preheat extends 2-10" past weld zone.
Welding Process	Flux Cored Arc Welding (FCAW) method is gaining popularity over Shielded Metal Arc Welding (SMAW) or "stick" method.	FCAW for filling cavities: GMAW for the weld overlay.	It is faster, more efficient and inputs less heat.
Heat Buildup Control	Skip welding, bead size (5/8" wide) and pattern (stringer), heat input (current & voltage), polarity, and quench-cooling	Water cooling is also used.	Use of temperature measurement, (i.e. pyrometer), is essential.
Stress Relief of Weld	Peening each weld bead. Some do not peen the first and last layers.	GMAW welds are not peened.	Four blows per inch puts weld into compression.



Exhibit 2 — Average Life of In-Track Weld Repairs

Frog Type	Steel Casting	First Repair	Second Repair	Third Repair	Fourth Repair
Rail-Bound Manganese	57	37	33	37	32
Manganese Insert	47	33	30	23	35
Rail Constructed	58	55	52	52	52

- Shop frog repair — Develop a rapid-change-out frog and economic analysis.
- Partial weld frog — Study the effect of leaving cracks under weld repairs.
- Weld consumable — Identify consumables that minimize deformation and maintain toughness.
- Weld repair shape — Optimize weld repair shape to produce desired deformed profile and minimize tensile stresses at weld-fusion line.
- Maraging steel (Vario) frogs — Develop a performance database and in-track maintenance procedures.

Maintenance practice is highly dependent on the turnout and crossing-diamond design and materials. Improved designs and materials will reduce the total amount of required maintenance and can alter the types of maintenance needed.

The operations requirements will also affect the amount and type of maintenance applied to the frog. Many lines are at or near train capacity. Track time, as measured by train-delay costs, is prohibitively expensive. In these cases an absolute minimum of frog maintenance is performed. In essence, operating costs are minimized at the expense of track-capital costs.

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**Note: Contact Dave Davis at (719) 584-0754 with questions or comments about this document. E-mail: dave\_davis@aar.com**

Exhibit 3 — Recommended Frog-Grinding Intervals

Frog Type	First Grinding	Second Grinding	Third Grinding	Steady-State Grinding Interval
Pre-Hardened AMS	5 MGT	20 MGT		20 MGT
Weld-Repaired AMS	1 Day	1 week	1 month	20 MGT
Rail Constructed	5 MGT	20 MGT		20 MGT
Maraging Steel	n/a	n/a	n/a	n/a

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