GE Transportation Systems
Repair Specification

May 20, 2009 | Guidelines for Ductile Iron Repair by Metal Locking
GEVO SERIES MAIN FRAME | Rev. 0

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**Issue Date:**
**Rev Date:** 8/31/2009

**Check One:**
**New** [ x ]
**Change** [ ]
**Supplement** [ ]
**Proposition** [ ]

**Device ID:** GEVO12, GEVO16
**Device Name:** Diesel Engine – Main Frame
**Quantity:**

**Charge No.:**
**Customer:** Various

**Revision History:**

| Revision | CO | Date | Author | Revision Description |
|---|---|---|---|---|
| 0 | 0 | 8/31/09 | K. Massing | Created to document Metal Lock Repairs |
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## 1 SCOPE

This specification defines requirements for ductile iron repair by the process known as metal locking or metal stitching that is being applied on the GEVO series diesel engine mainframe.

The repair classification of this product is not relevant. This document specifies the actual repair that may be performed either in situation, at the assembly facility or at a vendor location.

### 1.1 Symbols

| | |
|---|---|
| GETS | General Electric Transportation Systems, Erie, PA |
| RMSH | Reliability, Maintainability, Safety, and Human Factors |
| CTQ | Critical-to-Quality Characteristic (see section 13.2) |
| DRS | GETS drawing retrieval system |



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### 1.2 Definitions

| | |
|---|---|
| Locomotive Year | 8328 hours |
| MW-Hrs | Mega Watt Hours |
| CTQ | Critical to Quality |
| Overhaul | Removal of the Engine from the locomotive for Remanufacture |
| ACO Cost | Total part/service cost including material, labor and overhead |
| MF/LY | Mission Failure per Locomotive Year |
| UX | Unit Exchange |
| Dasher | Component failure and removal tracking system |
| RU | Replaceable Unit |
| MF/LY | Mission Failures per Locomotive Year |
| RM/LY | Component Removals per Locomotive Year |

### 1.3 Change Instructions and Authorization

Only technical requirements are contained in this specification.

Once this specification is released as revision 0, changes shall be controlled by a CO (Change Order - GETS internal change document). Revision letters (A, B, C, etc.) and a date shall be used to identify the latest revision of this specification.

## 2 PART NUMBER AND ITEM DESCRIPTION

The part numbers in this document refer to a single type of repair, regardless of the extent of the defect. The diesel engine organization (GETS Diesel Engine COE) must be contacted if the damage exceeds the scope of repairs as defined in this document. Contact parties include diesel engine product engineering personnel and UX Inspection personnel.

### 2.1 Part Number & Description

This specification number plus the given part or group number shall be the GETS part or group number for this product.

Quantities for ordering or invoicing purposes are defined by the number of individual repairs performed on the casting. One casting may require multiple repairs of the same type. The repair should be invoiced by quantity of repairs noted by location or position in the casting. The casting identification such as engine SN, locomotive Road Number, or mainframe casting number should also be noted on the invoice.



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| P.N. | Title | Description |
|---|---|---|
| 84A225810P1 | Crankcase Window Repair | GEVO series mainframe repair of damage to the area adjacent to the crankcase door. |
| 84A225810P2 | Fore & Aft Cylinder Bore Walls | Repair of defects or damage to the areas inside of the cylinder bore. |
| 84A225810P3 | Water Passage Repair | Repair of defects in the exterior wall of the water passage containing the core plug bosses. |
| 84A225810P4 | Pan Rail Repairs | Repair of the pan rail. |
| 84A225810P5 | Interior Wall & Water Passage | Repair of damage or defects to the bulkheads repairs between crank throws. |
| 84A225810P6 | Interior Bulkhead Repair | Repair of damage or defects to the interior bulkheads between crank throws. |
| 84A225810P7 | Alternator Mounting Foot Repair | Crack or defect repair of alternator mounting feet. |
| 84A225810P8 | Rear Exterior Bulkhead Repair | Repair of damage or defects to the exterior bulkhead at the rear of the engine. |
| 84A225810P9 | Cam Window Corner Repair | Repair of the corners of the cam windows. |
| 84A225810P10 | Core Fin At Back Of Cam Cavity | Repair of core fins at the interior vertical bulkhead. |
| 84A225810P11 | Special Repair | This group number is to be referenced for all other repairs provided with permission from the Diesel Engine COE |

## 2.2 Summary of Requirements

**Product type** Ductile iron structural repair without the use of welding

**Outline Drawings** Main Frame Pre-Machined - 84E902044/84E902047
Final Machining – 84E902045/84E902048

**Supplier & Cat. No** Approved source is MLS (Metal Locking Systems), Buffalo, NY

**Construction type** Steel locking plates and Steel threaded stitch pins.



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| | |
|---|---|
| **Cooling required** | Not Applicable |
| **Temperature range** | -40 F to 300 F |
| **Rating / Capacity** | Meets requirements of un-repaired casting. May be applied to all EVO mainframes regardless of rated horsepower of original frame. |
| **Other Features** | Repair should not be easily detectable by naked eye without close inspection. Inserted material should blend to original material without steps or sharp edges. |

## 3 APPLICABLE DOCUMENTS

The following documents form a part of this specification to the extent specified herein. The revision in effect when the Purchase Order is issued to the Supplier shall apply. Documents are listed in the order of precedence. Referenced documents are available from GETS or are available as an industry standard.

| Title of referenced document | Document Number | Location |
|---|---|---|
| Purchase Order | | Sourcing |
| This specification | 84A225810 | DRS |
| GETS Environmental Requirements Spec | 84A200750CB | DRS |
| GETS Quality Standards Specification | 41A296300AC | DRS |
| GETS Reliability Standards Specification | 41A296300AD | DRS |
| Mainframe Drawings (12cyc) | 84E902045 | DRS |
| Mainframe Drawings (16cyc) | 84E902047 | DRS |
| Mainframe Ductile Iron Material Spec | C50E80 | DRS |
| Mainframe Assembly Drawings (12cyc) | 84E902046 | DRS |
| Mainframe Assembly Drawings (16cyc) | 84E902048 | DRS |
| Mainframe Inspection Criteria | 84A216888CA | DRS |
| Mainframe Repair Drawing | 84E902044/047 | DRS |

Locations:

| | |
|---|---|
| Sourcing | GETS Sourcing organization |
| DRS | GETS Drawing Retrieval System |
| Industry | Available as an Industry Standard |

## 4 FUNCTIONAL, PERFORMANCE, & SYSTEM REQUIREMENTS



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The repair shall comply with all stated requirements.

## 5 SCOPE OF REPAIR

There are currently eleven different types of repair that are commonly applied to the GEVO mainframe. A description of each repair and the regional limits of the repair are described below. Damage that extends beyond the limits described should be reviewed and approved the repair vendor and by GETS personnel on a case by case basis.

The repairs may be classified as damage repair, defect repair, or crack repair. In the case of damage or defect repair, the affected region is removed from the casting and a replacement casting is locked in place. The replacement material must meet or exceed the requirements of C50E80 or be taken from a donor (scrap) casting. A crack repair does not involve significant material replacement. Each repair may include some combination of material replacement and crack repair.

The damage repairs are typically associated with a major engine failure such as a connecting rod failure. Crack repairs may be associated with locomotive wreck repair. The repairs may also be applied to casting defects on used frames and on new frames with GETS engineering approval.



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## 6 GENERAL REQUIREMENTS

- If the frame was used in service, before considering a metal lock repair, it should be determined if the frame has been additionally damaged. Specifically, whether or not the alignment of the crank and cam bore alignments have been affected.
- Metal lock repairs may never be welded.
- Repairable damage to the cylinder banks is very unlikely.
- Metal lock type repairs will extend slightly beyond the area of the damage. This must be recognized when considering repairs.
- Metal lock repairs to areas that will be later machined are prohibited. The subsequent machining will affect the appearance and integrity of the metal lock.
- Repairs should not extend into multiple surfaces and through transitions between bulkheads and support ribs or gussets.
- Frame drawings should be consulted before considering metal locking repairs to determine if another repair option is available.



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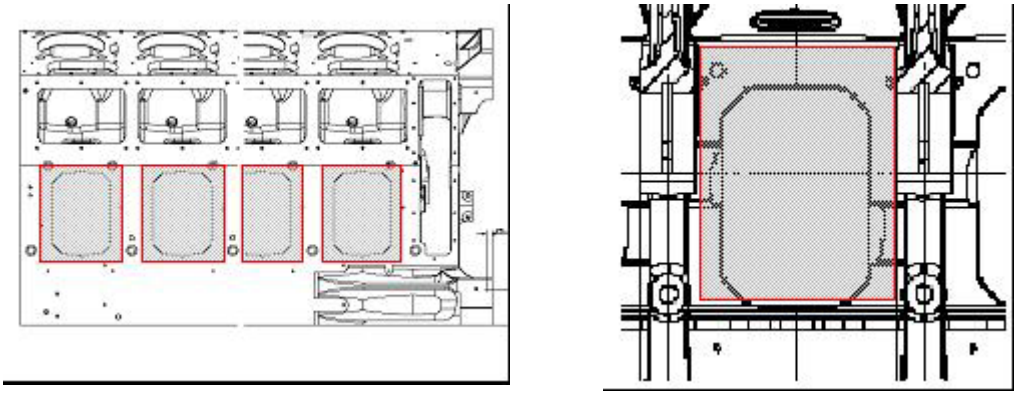
## 7 APPROVED REPAIRS

### 7.1 Crankcase Window Repair - 84A225810G1

Repair of damage to the area adjacent to the crankcase access door.

Damage and subsequent repairs may not extend to the interior bulkheads or interior gussets. Laterally, the damaged region must be confined to the exterior wall of the mainframe as shown in Figure 1 and not extend to the within 2.5cm of the side bolt bosses or engine mounting foot holes. In the vertical direction, the repair should not extend to the 10degree banks.

Grove City Engineering or UX inspection personnel should review mainframes that require crankcase window repair and pan rail repair at the same position.



a) b)

FIGURE 1: a) Mainframe window repair area as viewed from the outside of the frame. b) Interior view of frame repair shows the exterior wall and bulkhead walls.



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### 7.2 Fore and Aft Cylinder Bore Walls - 84A225810G2

Repair of defects or damage to the areas inside of the cylinder bore.

The upper and lower cylinder bores are repairable using sleeve repairs described in the frame drawings and should not be repaired using metal locking. The contour of the bore that describes the bottom of the water passage is not an acceptable area for repair. The areas between the upper and lower cylinder bores and bottom of the water passage may be considered for metal locking. In the lateral direction, the damage, defects, or subsequent repair should not extend to within 2.5cm of the cylinder hold down stud bosses. In the vertical direction, damage, defects, or subsequent repairs may not extend to the upper or lower cylinder bores or water passage contour as shown in Figure 2.

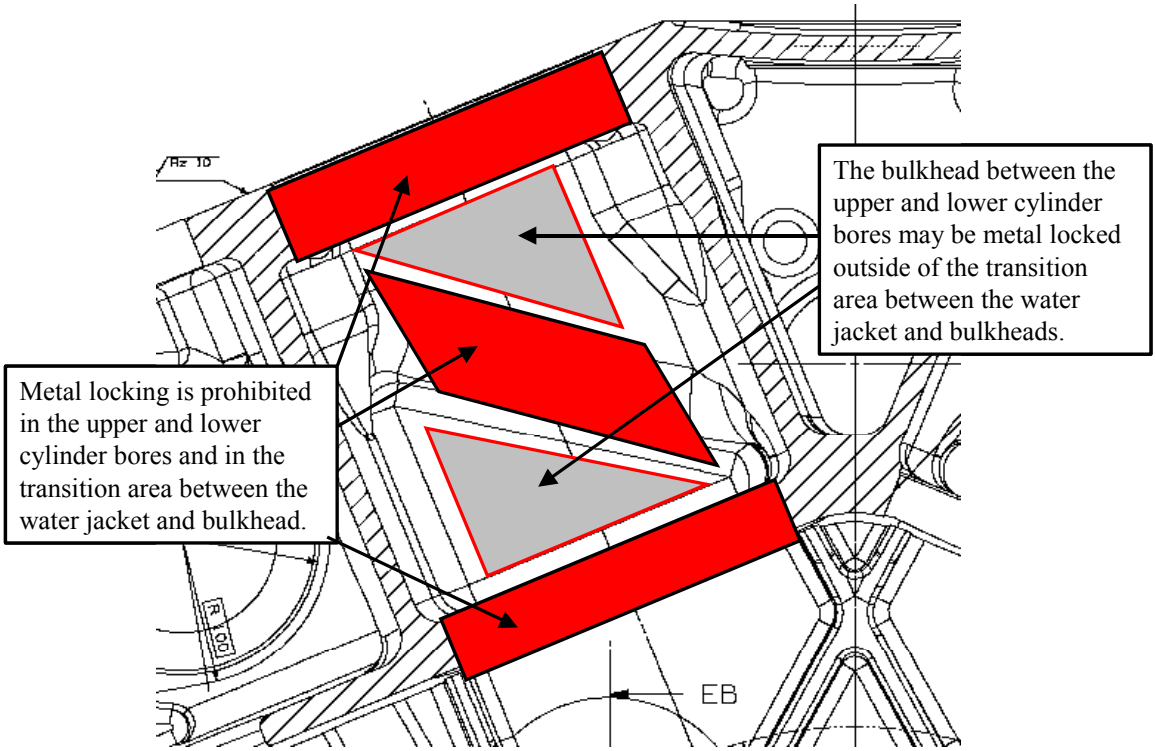


FIGURE 2: Cylinder bore repair viewed from the inside of the cylinder bore.



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### 7.3 Water Passage Upper Wall Repair - 84a225810G3

Repair of defects in the exterior wall of the water passage containing the core plug bosses.

Metal lock repairs have been successfully performed in the top of the frame in the surface containing the core plugs. It should be noted that the material in this area is thin and not as conducive to metal locking as thicker areas. Repairs may not involve the bosses for the core plugs or extend to within 2.5cm of the radii at the edges of the water passages.

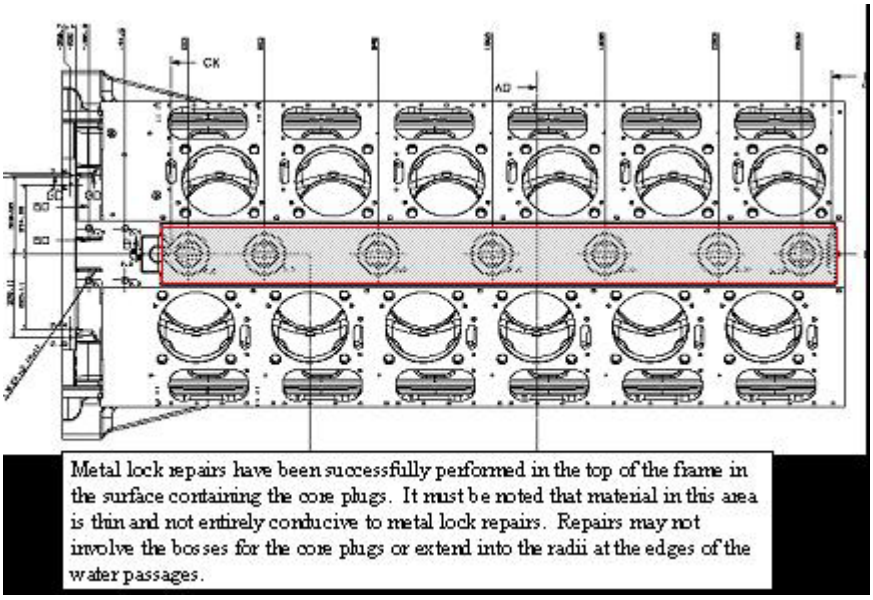


Figure 3: Water Passage Upper Wall Repair



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### 7.4 Pan Rail Repairs - 84a225810G4

Repair of pan rails.

Pan rail repairs are permissible provided the defect, damage, or subsequent repair does not extend into the interior bulkheads and gussets. The repairs may not extend beyond the inside face of the exterior wall.

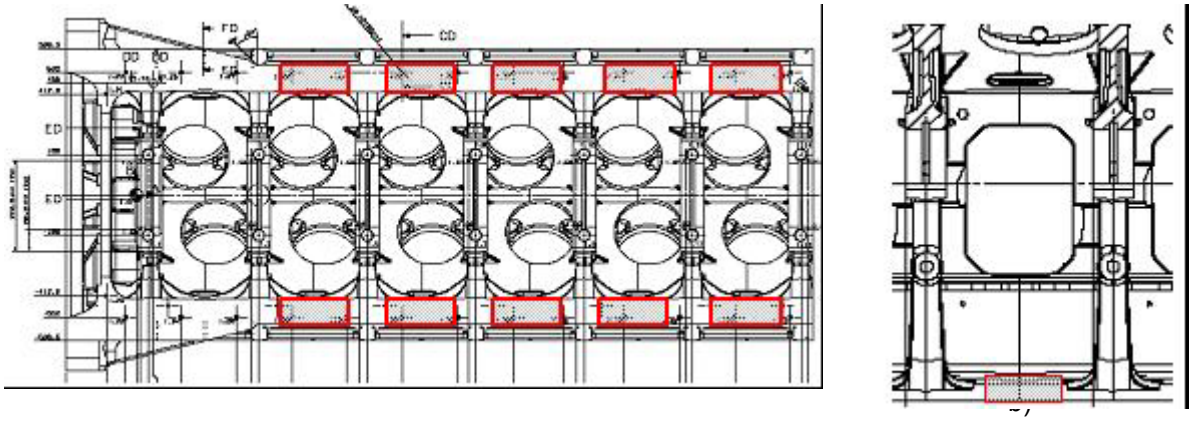

FIGURE 4: a) Bottom view of mainframe showing pan rail repair region b) Interior view of Section view of mainframe showing pan rail web depth (see also figure 5a).



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## 7.5 Lower Interior/Exterior Wall and Interior Water Passage Repair - 84a225810G5

Repair of damage or defects to the bulkheads between crank throws.

The wall of the water passage between the cylinder hold down studs has been successfully repaired. The wall is relatively thin, a water passage, and subject to some loading from the cylinder hold down studs therefore repairs in this area should be undertaken with careful consideration of these factors. The bottom of the water passage running the length of the frame contains several interior radii and areas that are not accessible and should not be considered for repair. The area below the crankcase door is unlikely to sustain damage but should be considered for repair provided the damage, defect and subsequent repairs do not extend to any of the interior gussets or bulkheads.

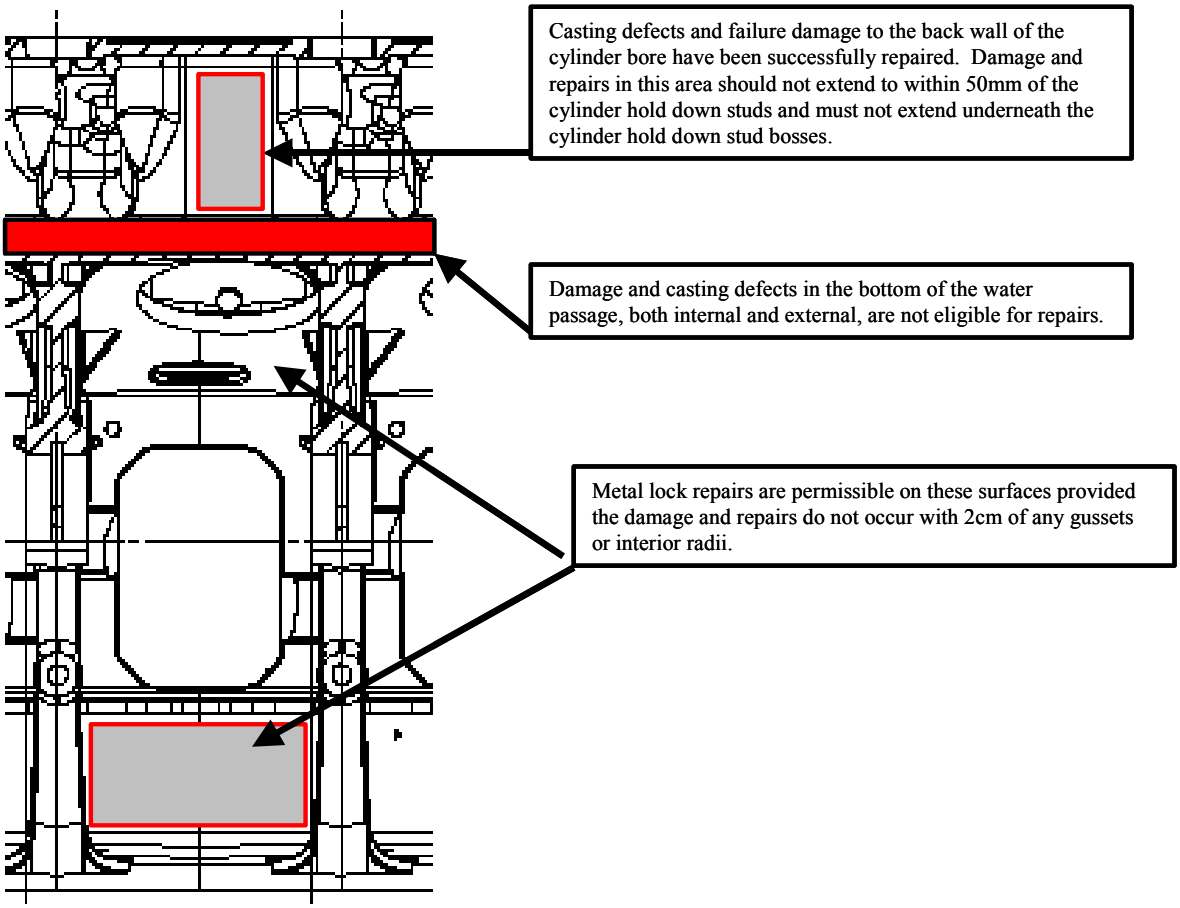


Figure 5: Lower Interior/Exterior Wall and Interior Water Passage



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### 7.6 Interior Bulkhead Repair - 84a225810G6

Repair of damage or defects to the interior bulkhead walls between crank throws.

The region between the cylinder bores and the main bearing cap mounting surface is not eligible to be repaired. The forces from the combustion process are transferred through this area and the oil passages between the camshafts and crankshaft pass through this area as well. The areas of the bulkheads outside of this area may be considered for repair. The repair may not include the side bolt boss or drilled region. The repair may include the "T" section of the bulkhead archway below the side bolt, however it is common to blend out the missing half of the "T" flange. The repairs, defects, or damage may not include the gussets or extend into any interior radii.

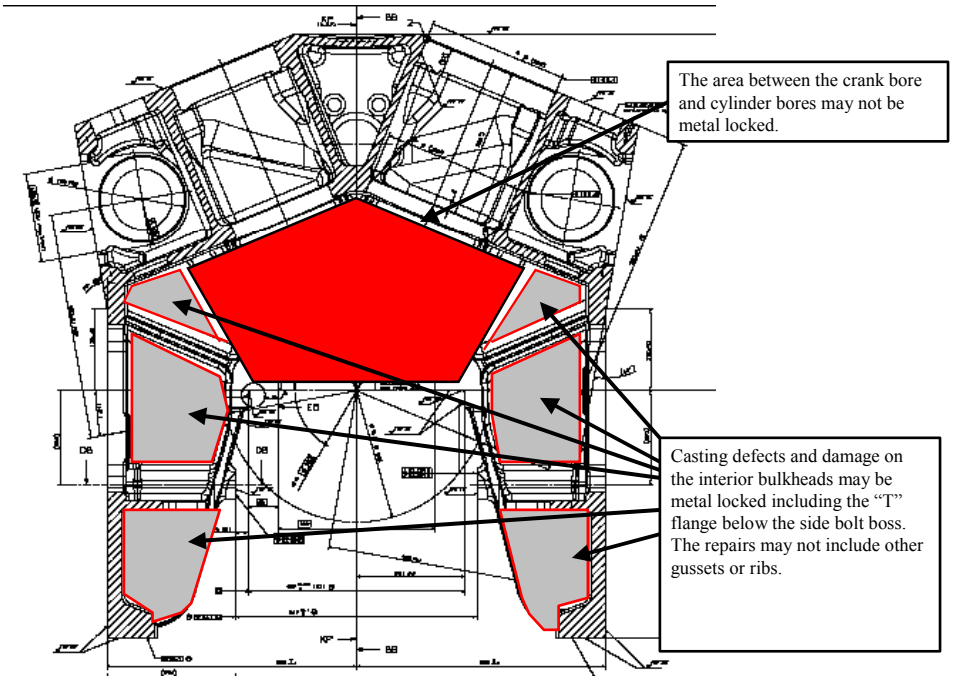


FIGURE 6: Section view of mainframe showing interior wall (bulkhead) repair.



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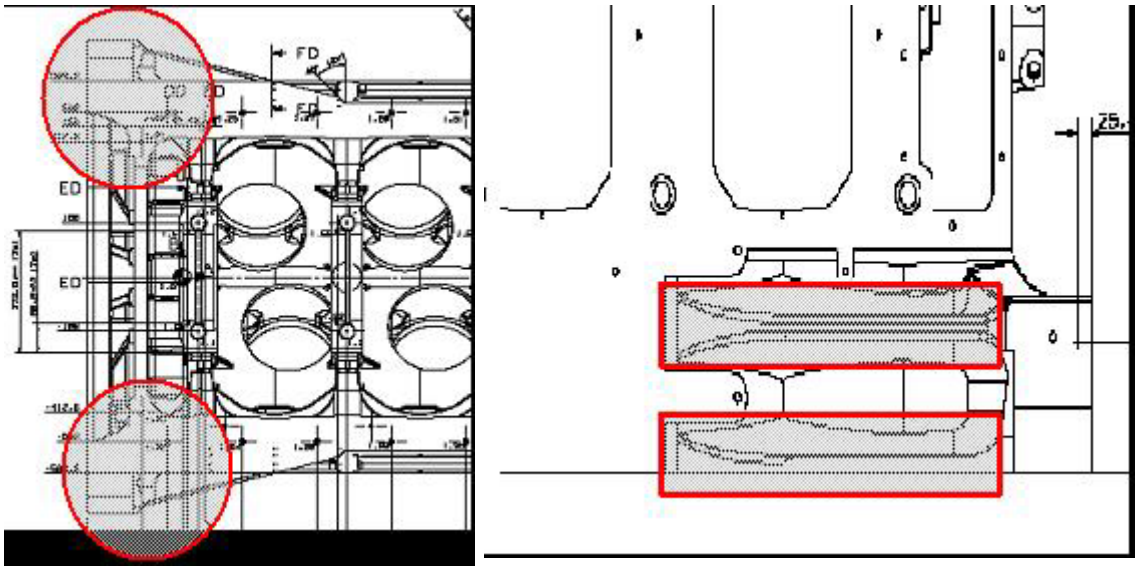
### 7.7 Alternator Mounting Foot Repair - 84a225810G7

Crack or defect repair of the alternator mounting feet.

The mounting foot repair may include repairs to the pan rails near, and exterior gussets connected to, the alternator mounting feet. These are typically simple crack repairs, not usually associated with replacement of damaged material. Defects in the support gussets must be minor in nature and away from the exterior edges of the ribs. Alternator feet have not typically sustained damage similar to that seen on FDL series engine mounting feet and due to their design and material are unlikely to. The success of FDL foot repairs suggests that GEVO foot repairs should be considered with engineering review.




a) b)

FIGURE 7: Mainframe alternator mounting feet repair regions a) foot, b) gusset



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### 7.8 Rear Exterior Bulkhead Repair - 84a225810G8

Repair of damage or defects to the exterior bulkhead at the rear of the engine.

Repairs to the rear exterior bulkhead below the alternator mounting ears and above the alternator mounting feet is permissible. Damage to this area other than casting defects is unlikely. Repairs may be considered provided that the damage and subsequent repair does not extend to the support gussets. The block for the crankshaft position sensor has been successfully repaired by metal locking previously and may be considered for repair.

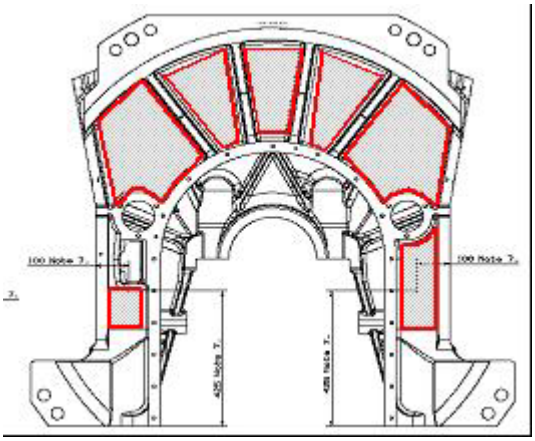

FIGURE 8: Rear Exterior Bulkhead Repair



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### 7.9 Cam Window Corner Repair - 84a225810G9

Repair of the corners of the cam windows.

Cracks in the corners of the cam windows are acceptable to be metal locked provided the crack does not extend into the cam bore.

The bottom of the camshaft cavity may be repaired by metal lock provided the damage or subsequent repair does not extend to the vertical walls of the cavity.

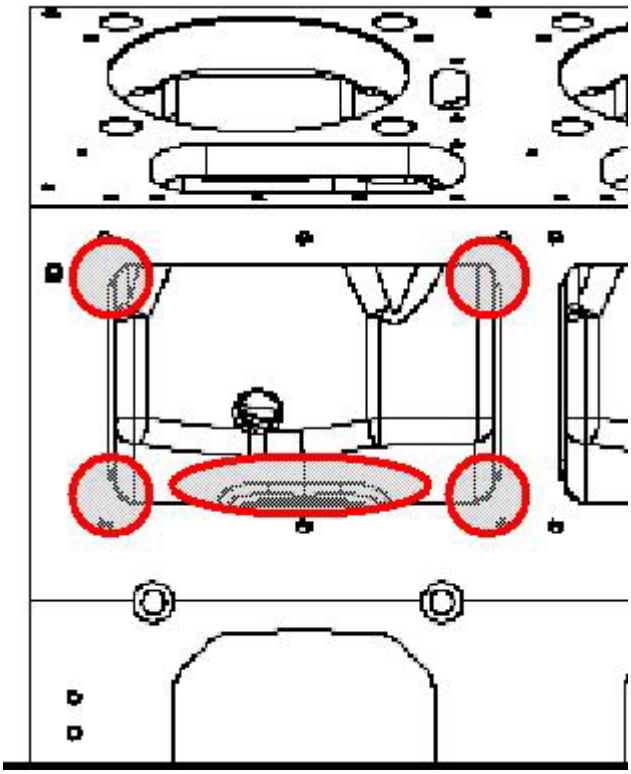

FIGURE 9: Cam window corner and cam cavity repairs.



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### 7.10 Core Fin At Back Of Cam Cavity - 84a225810G10

Repair of core fins at interior vertical bulkhead.

Core fins at the interior vertical bulkhead of the camshaft cavity may be repaired using metal locking provided the core fin does not extend to the area beneath the cylinder hold down stud bosses.

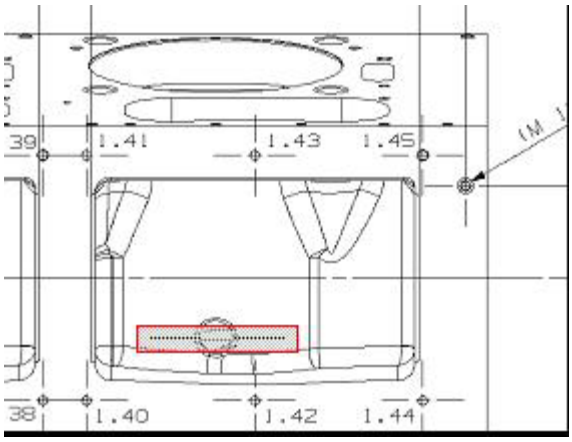


FIGURE 10: Cam Cavity Core Fin Repairs.

### 7.11 Special Repair - 84a225810G11

This group number is to be referenced for all other “special” repairs provided with permission from the Diesel Engine COE.

## 8 STRUCTURAL STRENGTH REQUIREMENTS

The repaired region must maintain the same tensile strength and fatigue properties of the un-repaired material. Stress concentrations or excessive residual stresses must not be imparted on the casting as a result of the repair.

## 9 USER / CUSTOMER REQUIREMENTS

Repair surface should be peened completely and should not be visually different from an un-repaired casting without close inspection.



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## 10 ENGINE OVERHAUL REQUIREMENTS

The repaired casting must be able to flow through the standard UX process at Grove City and at other rebuild facilities without special consideration. Standard cleaning, inspection and machining process associated with reconditioning and component rework will be applied at approximately 6-year intervals.

## 11 SOFTWARE REQUIREMENTS

Not Applicable

## 12 MECHANICAL REQUIREMENTS

The repair shall comply with all stated requirements. The repaired casting shall perform no differently than a new or un-repaired UX casting

**General –** Replacement material to meet the minimum requirements specified in C50E80.

**Size, shape, weight –** Size limitations specified in Section 4 of this document. The repair should attempt to maintain the same shape and surface contour as the original casting. The repaired casting must pass all inspection criteria (84A216888CA, 84E902044, 84E902045, 84E902047, 84E902048) after all finish work and associated machining have been applied.

**Envelope –** The repaired frame should meet the requirements applied to a UX frame 84A216888CA, 84E902044, 84E902045, 84E902047, 84E902048.

**Finishes –** The repaired surface should be peened completely and should not be visually different from an un-repaired casting without close inspection

## 13 ELECTRICAL REQUIREMENTS

Not Applicable

## 14 MATERIALS & WORKMANSHIP

The repair shall comply with all stated requirements. Repair components may be purchased or custom machined by the vendor

**Fasteners** – Stitch pins to be of high quality steel (MINIMUM YIELD STRENGTH)

**Locks** – Locks should be precision machined and of high quality steel. (MIN YIELD STR)

**Cast Material** – Replacement material to meet the minimum requirements specified in C50E80



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**Tools** – Drills, Grinders, Taps shall be maintained

**Sharp edges and burrs –** No sharp edges or burrs allowed on completed repair

**Welds** – No welding shall be applied to any of the repaired regions specified in this document.

## 15 ENVIRONMENTAL REQUIREMENTS

The product shall be designed to meet or exceed the environmental design requirements specified in the Environmental Requirements Specification; GETS document 84A205544.

The engine mainframe is the primary structural component of the diesel engine. The repair will be subject to the high temperature, high vibration environment typically associated with engine operation.

## 16 RELIABILITY REQUIREMENTS

This repair will not compromise the reliability of the casting. The repaired casting shall meet or exceed the reliability requirements of an un-repaired casting.

The allocated reliability of the mainframe assembly is 0.0001 MF/LY and 0.0012 RM/LY

### 16.1 Reliability Plan

A Reliability Plan and a corresponding Implementation Schedule shall be defined by the Supplier and approved by the Purchaser. These materials shall accompany the Supplier's proposal in response to this purchase specification and related solicitation.

Current approved suppliers may waive this step if they meet the grandfathering conditions associated with QSW xxx.

### 16.2 Mission Reliability

The repaired casting shall have a 99.94% probability of successfully performing its intended mission function (as defined in 10.6) over the specified useful life under the operational and environmental conditions outlined herein. Mission failures are those primary failures, which result in the inability of component to perform its functional CTQs.

99.94% success rate is equivalent to 0.0001 MF/LY and applies to the entire mainframe assembly. The repair cannot not compromise mission reliability.

### 16.3 Removals Reliability



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The product shall have a 99.28% probability of successfully performing all defined functions over the specified useful life under the operational and environmental conditions outlined herein without removal.

99.28% success rate is equivalent to 0.0012 RM/LY and applies to the entire mainframe assembly. The repair cannot not compromise mission reliability.

### 16.4 Mission Reliability Demonstration

It is required that the supplier demonstrate before full production launch, a minimum mission reliability of 99% over the useful life (10.3) of the supplied component or system. It must be made with a statistical confidence of at least 95%. The qualifying tests must include at least all mission and safety critical failure modes identified by FMEA.

An example of an approved validation matrix and a detailed test plan are included in the attachments to this document (attachments I and II). New vendors must be approved through the new component introduction (NCI) process.

### 16.5 Useful Life

The useful life of the repaired mainframe shall be no less than an un-repaired mainframe. Currently 20 years under any combination of storage or service life.

### 16.6 Mission Critical Function

The mission critical functions for the repaired mainframe are defined as follows:

- Structural support of engine operating components, both internal and external
- Transmission of lubricating oil to engine bearings without loss of pressure or external leak
- Secure engine and attached components to the locomotive platform

## 17 MAINTAINABILITY REQUIREMENTS

Not Applicable

## 18 PACKAGING AND MARKING REQUIREMENTS

Not Applicable

## 19 QUALITY ASSURANCE REQUIREMENTS



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This success of this repair is based strongly on the craftsmanship of the repair technician. Any device, tool or fixture that may improve the ergonomic conditions of the repair should be applied.

Each craftsperson should be trained in the repair procedure. The vendor shall keep updated qualification and certification records of approved craft personnel.

## 20 DOCUMENTATION REQUIREMENTS

Each repair will be documented and records of the repair shall be kept at the vendor. These records are to include the engine serial number (if applicable), the frame casting number, the location of each repair by engine position, the date of repair, the physical location where the repair was performed, and the name of the craftsperson performing the repair.

Documented work instructions and standards for acceptance will be created and controlled by the vendor.

## 21 RESPONSIBILITIES

### 21.1 Supplier Responsibilities

The Supplier is responsible for meeting all requirements of this specification and other referenced specifications and standards. The Supplier shall submit a list of exceptions with the proposal offer. All exceptions must be approved in writing by the Purchaser prior to final acceptance and shipment of the product.

### 21.2 Communication

The sole channel of communication between the Purchaser and the Supplier in all matters related to the establishment or alteration of contractual requirements to be fulfilled by the Supplier shall be through the GETS Sourcing Agent.

A formal documentation system shall be used to track the exchange of technical data and information between the Purchaser and the Supplier.

The exchange of technical data and information not affecting change control, cost, or delivery may be communicated directly between Supplier and Purchaser engineering organizations and followed up by memos through the Sourcing Agent of the Purchaser.

### 21.3 Design Reviews

The Supplier shall conduct design reviews for major development phases of the product, as applicable. The Purchaser and Supplier shall agree to the quantity, scope, and schedule of the planned design reviews. The Purchaser shall be notified at least one month in advance of the review and will participate in all reviews.



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### 21.4 Technical Support Availability

Technical support shall be agreed upon between the Purchaser and Supplier. As part of the response to this specification, the Supplier shall provide a description of the type of technical support available to GETS.

Technical support considerations shall include on-site training, on-site product integration, maintenance manual documentation, phone support, and post delivery field services.

Maintenance manual documentation shall be provided by the Supplier, with periodic updates, covering the design and implementation of the product modifications.

## 22 WARRANTY

The warranty shall be defined in the purchase contract and administered by GETS Sourcing.

## 23 OTHER

**Special or unique requirements**

**Specification Revision History**

**This document was reviewed:**

- **for CTQ characteristics by: _____(name) _____(date)**
- **for Reliability requirements by: _____(name) _____(date)**
- **for Specification Release by: _____(sponsoring mgr.) _____(date)**



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## ATTACHMENT I: TEST PLAN FOR DUCTILE IRON REPAIR FATIGUE TEST

OBJECTIVE:

The purpose of this test is to demonstrate the relative fatigue strength of material repaired by the metal locking or metal stitching process. The repaired and as-cast material will be evaluated in the form of a test bar that is loaded in the axial direction. The loading will by applied cyclically and the load will increase in a step fashion.

BACKGROUND:

Cast iron repairs have been applied to the 7FDL main frame for many years. These repairs have demonstrated good reliability (zero known failures) in the areas that they have been applied.

The proposed test will be used as part of the approval requirements for Purchase Specification 84a225810.

TEST PLAN:

Test Pieces (to be supplied by GETS engineering):

See proposed test bar drawings shown in Figure 1.

| | | |
|---|---|---|
| Qty 6 | 84A213xxxP1 | - Test bar – Not Repaired |
| Qty 7 | 84A213xxxP2 | - Test bar – Repaired |

Parts will be identified with 2-digit designation as follows:
B1 to B6 – Un-repaired sample
R0 to R6 – Sample repaired bars (R0 is for trial run)

Test Equipment:

A) Dynamic loading axial test machine and monitor/control/reporting equipment capable of sinusoidal or pulse loading to 80,000 lbs.
B) Fixtures for holding the test bars in both tests. (the bars will be designed to minimize the amount of fixture creation)

Relevant Documents:

| | |
|---|---|
| 84a225810 | GETS Specification: Ductile Iron Repair by Metal Locking |
| 41A222348 | GETS Drawing: Engine Rebuild Instructions |
| 41E914464 | GETS Drawing: Main Frame Repair |
| C50E80 | GETS Specification: Materials Specification For The Cast 7HDL Engine Crankcase (61ksi UTS in heavy wall sections) |



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Test Conditions:
The applied loads should be axial with static or dynamic bending loads minimized. A strain gage may be applied to the part to monitor the part stress (to be discussed with the test lab).

Test Details:

1. Perform dynamic fatigue test per Table 1 on sample R0 (this is the trail part, see Figure 1 and 2 for details).
2. Adjust the start point of the testing based on the failure point of R0 after review with GETS engineering.
3. Perform step fatigue test per Table 1. Test 12 samples in randomized order (three samples of each type)
4. Record the total number of cycles to failure, the load or load step at failure and the number of cycles at the failure load.
5. Return failed samples and data to GETS Engineering contacts:

   1503 West Main Street, Ext.
   Grove City, PA 16127



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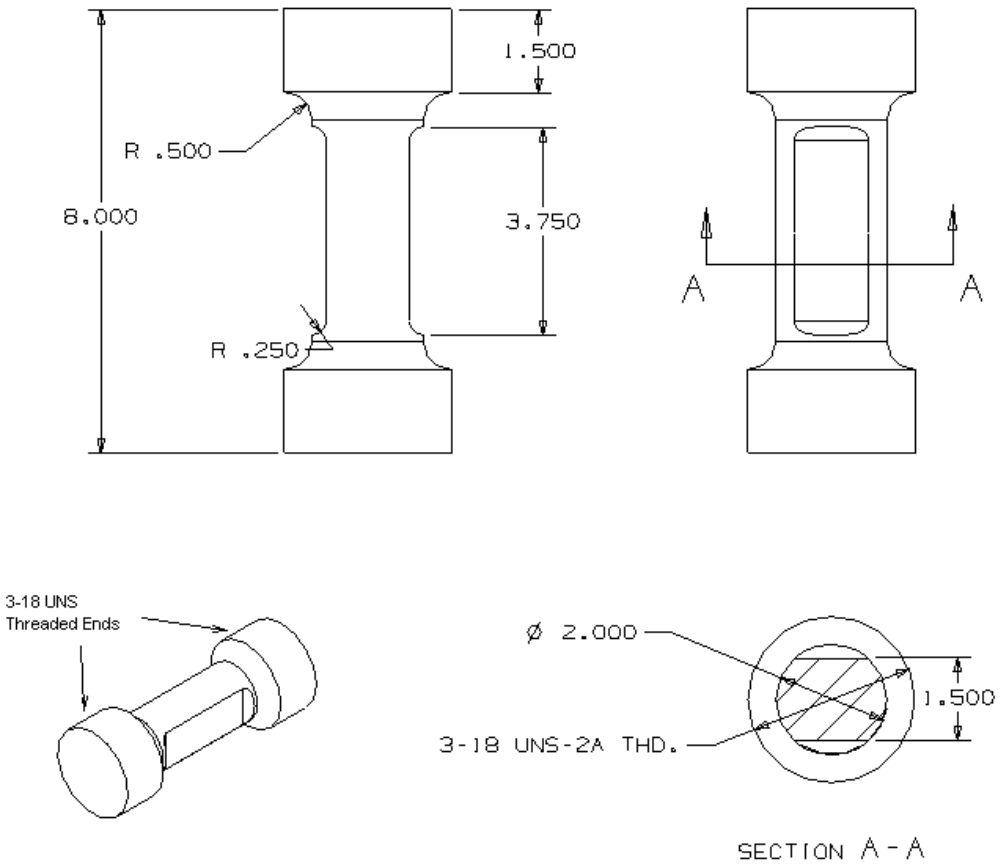


Figure 1: Test bar geometry. Bar is to be cut into 2 symmetric pieces and repaired.



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TABLE 1: Planned Load Steps for Ductile Iron Bar Fatigue Test

| | | |
|---|---|---|
| Test Cross Sectional Area = | 3.75 | in2 |
| Ductile Iron UTS = | 61,000 | psi |
| Ductile Iron Endurance Limit = | 28,000 | psi |
| Start Stress = | 21,000 | psi |
| Stress Step = | 2,100 | psi |

| Load Step | # cycles at step | Stress Amplitude (peak) | Force Amplitude (peak) |
|---|---|---|---|
| 1 | 1.00E+06 | 21,000 | 78,750 |
| 2 | 1.00E+06 | 23,100 | 86,625 |
| 3 | 1.00E+06 | 25,200 | 94,500 |
| 4 | 1.00E+06 | 27,300 | 102,375 |
| 5 | 1.00E+06 | 29,400 | 110,250 |
| 6 | 1.00E+06 | 31,500 | 118,125 |



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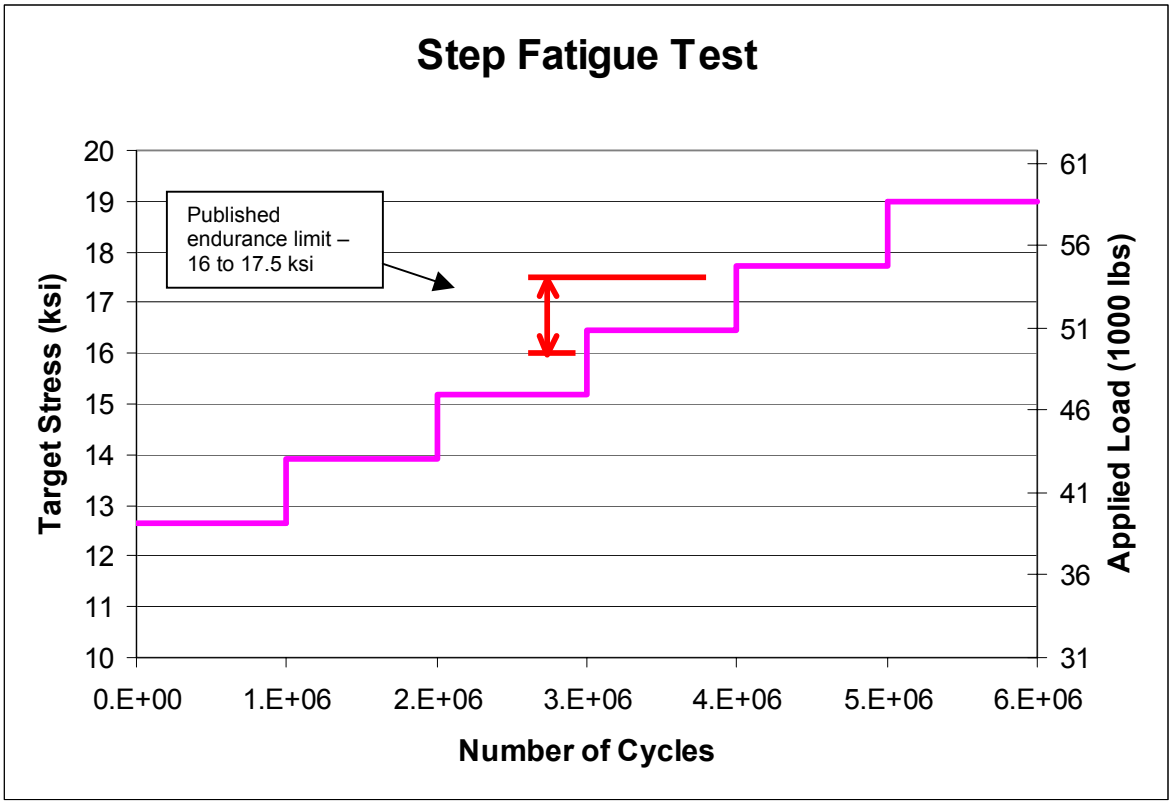


Figure 1: Example of step fatigue test showing published endurance limit range for material



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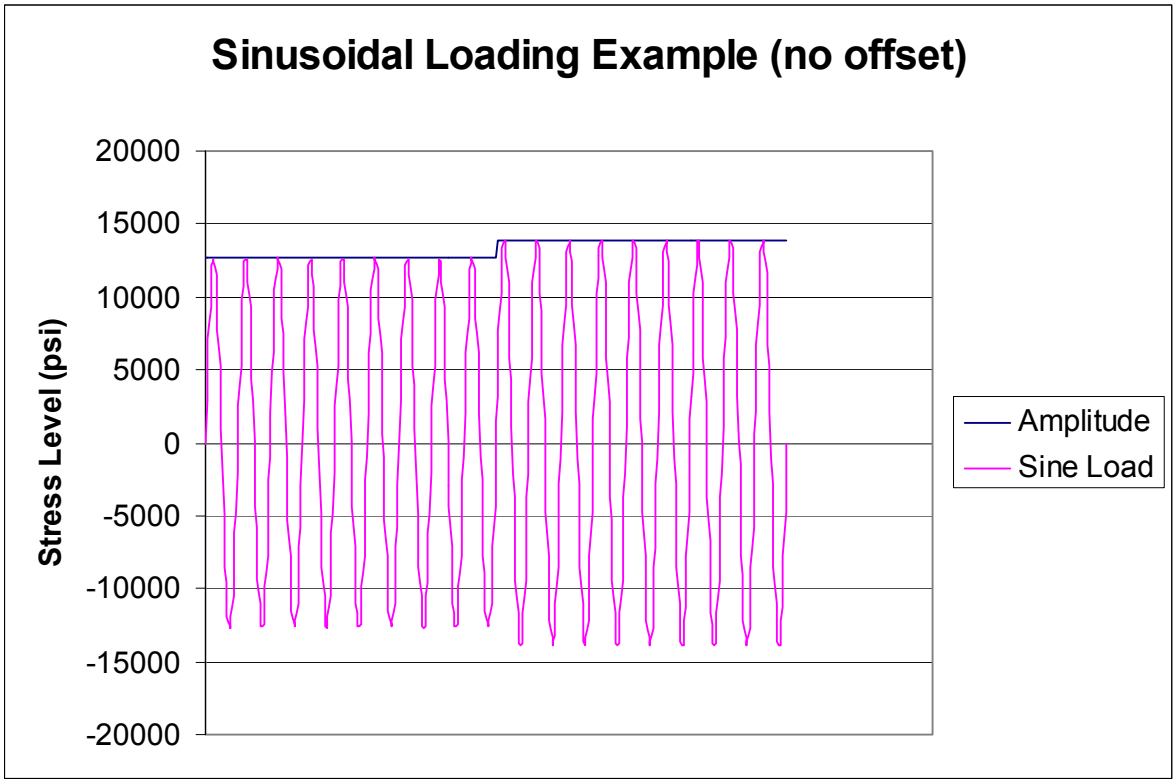


Figure 2: Example of loading with zero offset



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## ATTACHMENT II: EXAMPLE VALIDATION MATRIX FOR NEW REPAIR VENDORS

**Component: GEVO Mainframe Repair** **Dwg. Nos.: Repair Spec. 84a225810**

**Change Description: New Vendor** **NCI #: TBD** **Design Folder: TBD**

| **Ref. Component Design Spec. No. _None_** | | | **Verification** | | | **Validation** | | |
|---|---|---|---|---|---|---|---|---|
| ***Requirements*** | ***Criteria*** | ***Design Control*** | ***Resp.*** | ***Plan*** | ***Results*** | ***Resp.*** | ***Plan*** | ***Results*** |
| Material | Meet design intent | Drawings<br>Material Spec | DE, Vendor | Review repair material and BOM with vendor | | DE | Simple material checks of repair hardware (Hardness test)<br>Visual review of general quality | |
| Form | No errors on drawings and specs. Parts made to print. | Drawings<br>Material Specs | DE, Vendor | Drawing / Spec review | | DE | Visual inspection of repaired area | |
| Fit | Assembles into next assembly. | Assembly drawing | DE, Vendor | Establish fit requirements and checking process for replacement material | | DE, QE | Visual Inspection of repaired area | |
| Function | Meets design intent. | Drawings<br>Material Specs | DE | Visual inspection of vendor demonstration trials<br>Evaluation of ultrasonic testing for process control | | DE, QE | Visual Inspection of repaired area<br>Die penitrant inspection of repair<br>Acceptance test at GC test cell (no leaks) | |
| Performance / Emissions | Meets required emissions and performance targets. | ECC list<br>SDS<br>SFS | | None | | | None – This is not an ECC. This change will not affect engine performance or emissions. | |



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May 20, 2009 Guidelines for Ductile Iron Repair by Metal Locking Rev. 0

GEVO SERIES MAIN FRAME

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Reliability | R≥0.99 @ T=12 mos (with 95% confidence) before >50% cut-in | Drawings Material Specs | DE, Test lab. | 1) Fatigue test of repaired bars 2) Calculate reliability of other metal lock repairs from current vendor | | DE, QE | *Expect failure away from repair… use reliability of un-repaired frame for cut-in*<br><br>Repair 10 engines. Reviewed by UX frame inspection (GC) for repair quality and repeatability | |
| Durability / Life | ≥ 6 years or ≥26,000 MWH to overhaul (16cyl) ≥ 2 overhauls | Drawings Material Specs | | Same as above | | | Same as above | |
| Maintainability | TTR ≤ current and operator access OK | Drawings Material Specs | | None | | | None | |
| Manufacturability | Dimension 4 sig or better | Drawings Material Specs | | None | | | None | |
| Weight | No significant weight change | Drawings Material Specs | | None | | | None | |
| Cost | $ ACO < 0.9 x current | Quotes / P.O.s | CA | Compare quote to current | | CA | Compare P.O. to current after 12 mos | |

**Engineer: C. Atz_____** **SQE: Mike Schleigh___** **Prod Owner: D. Rihel / J. Rihel___**

**Revision Date: 3/7/02**

**Eng. Manager: R.J. McGowan_____** **Emission Compliance Manager: N/R_____** **Principal**

**Eng.: J. Dowell_____**

| | | | |
|---|---|---|---|
| Author: K. Massing | Approval: R. C. Peoples | | 84A225810 |
| Issued: GETS Engineering 5/30/2009 | BUS. AREA: DGC | DIST: N/A | Sheet 30 of 30 |

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