Hot Box Detector History

This document is an attempt to record the history of the development of Hot box Detectors and define the operation of HBD hardware and software systems and explain why some items are in the software requirement.

History

SERVO Origin

A gentleman by the name of Henry Blackstone, a Lieutenant in the U.S. Army left the military service in the late 1940s. His background in the military was in the prevailing heat sensing missile technology that was applied by the Army at that time. As a result, he formed a company later called the Servo Corporation of America. His background and experience led to the first application of infrared heat sensing technology to the Railroad Industry in the U.S.

In the mid 1950s, some of the first equipment was placed on consignment review on the Southern Railway in Atlanta, Ga. As the review period came to termination, Mr. Bill Brosdan, Chief Operating Officer for the Southern, offered to buy the two units under review. At the time, Mr. Blackstone's policy was to "lease equipment" as opposed to a "sale of equipment". A confrontation ensued between the parties. Mr. Brosdan immediately terminated the collaboration with the Servo Corp.

Original G.E. HBD

However, Mr. Brosdan, also, immediately invited the Executive VP of the G.E. Motor Controls Division in Salem, Virginia to inspect the Servo units while still installed in the field on the Southern Railway property. As a result, the first Hot Box Detectors built by G.E. were spawned. Which led to a lawsuit filed by the Servo Corp. against both the Southern Railway and the G. E. Corporation.

Servo Corp after first prevailing in the original lawsuit was reversed by an appellate court ruling, which invalidated the original patents held by the Servo Corp. on the original 7707 type scanners. Even so, G.E. modified the basic element from the bolometer sensor device to the newer pyrometer sensing element and continued production until the product atrophied from natural attrition. Which was the first introduction of the pyrometer device for Railroad Hot Box Detection use.

Origins of Southern Technology (STC)

Also, as a result of the Servo vs. Southern confrontation, the Southern Railway pioneered their own, in house design and adaptation of the HBD. The communications Research Group for the Southern, headed up for many years by Mr. R. A. Howell did the original adaptation for the Southern Railway in Chattanooga, Tn. The association of Mr. R.A. Howell, after his retirement from the Southern Railway, with Mr. Paul Mench of the Southern Technology Corporation has facilitated the development of this family of equipment. This branch of the Genisis tree has led to the current Southern Technology of Chattanooga, Tn. HBD equipment, whose units are currently in use by the CSXT.

Bill Poleni HBD

In the 1960s, a gentleman by the name of Mr. Bill Poleni split off from the Servo Corp. and developed an adaptation. He marketed approximately 15 units to the Atlantic Coast Line Railroad under an acquisition by Mr. R. D. Liggett, Chief Engr. Signals, ACL. The Servo Corp immediately filed suit and as a result the railroad market closed down on that product leading to Mr. Poleni's bankruptcy; even, though he eventually prevailed in the on-going litigation. This branch led to immediate extinction.

Roy DePriest Talking HBD

In 1965 Mr. Roy DePriest, Sr., on behalf of the old Seaboard Airline Railroad, received a U.S. patent on the first application of a "Talking Hot Box Detector" adaptation. Mr. Smith, President, Seaboard Airline Railroad authorized a waiver of patent protection rights that allowed Mr. DePriest to assign a proprietary license to the Servo Corporation. However, a contract of agreement between the Seaboard and Servo Corp. retained all shop rights, in perpetuity and for all successors and heirs thereof for the Seaboard Railroad.

Servo Overlay Systems

There were several suppliers of Servo Overlay detectors.
These systems used Servo rail mounted scanners and transducers. The signal processing was done with the supplier's specific hardware and software.

- **Devtronics Microprocessor Based Talking HBD**

Bob Douglas designed a Servo Overlay system. In 1978 the first microprocessor based Automated Voice Defect Detector was placed in service on the SCL Railroad at Newnan, Fl. in April of that year. Shortly thereafter, offers of merger from the Servo Corp. were extended, which subsequently failed.

A buy out of Devtronics, Inc. by Harmon Industries was formally executed in October 1997. However, Devtronics operations continued until January 1999.

- **Oregon Technical Products (OTP)**

Jim Heldorfer designed a Servo Overlay system. In the 1980's OTP offered a display board readout for HBD alarm data. They also had a microphone based dragging equipment detector and the overlay HBD system. Jim also worked for Harmon West Coast Operations (WCO) and was involved with the development of the WCO-24 talker.

- **CN Railway**

Canadian National developed a Servo Overlay system.

Harmon/G.E. HBD

Harmon Industries acquired the rights to the older, atrophied G.E. pyrometer HBD technology. This led to Harmon's entry into the HBD arena with some early WCO series HBD systems.

After Harmon's acquisition of Devtronics, Inc., it subsequently acquired Servo Corporation of America detector. This brought over the early versions of the ACS scanner family into Harmon's product line. Also, leading to subsequent improvements as the ACS scanner evolved to its current vintage.

G.E. Transportation/Harmon HBD

In about the year 2000, G.E. Transportation acquired Harmon Industries, which has led to the GETS MicroHBD family for Hot Box Detection.

Wes-Tek Origins

In 2001 an acquisition and agreement between Mr. Kenneth D. Swartzendruber and GETS for all intellectual and proprietary rights of the legacy line of Devtronics, Inc. equipment has resulted in the Wes-Tek evolution out of this genisis. Wes-Tek is dedicated to and continues to provide support for the Devtronics, Inc. line of equipment as well as Servo 9000 and OTP systems.

Summary

Most all original patents involving the application of IR technology to the Railroad Industry has either expired or been invalidated through the mutations of preceding litigation. Therefore, an unrestrained competition between vendors has led to an economic benefit for the Railroad Industry at

Hardware and Software Requirements

Transducers and gating:

Mounting:

My preference is for the rail to be drilled and transducers bolted to the rail.
There have been methods for clamping transducers to the rail for years and there are two problems with transducer clamps.

- There are too many parts to keep tight.
    - They are made to be adjustable for different size rail and transducer height. This makes them too complex with too many parts and too many places to come loose.
- You have to move ties to install them.
    - With the scanner in a tie crib the first transducer will be over a tie.

    - You will have to move the tie and end up removing two ties to get a transducer clamp installed.
- We may have to go to clamps.
    - With track connections now welded to the rail. Rail drills may not be available in the near future and we may have to go to a transducer clamp.
    - If I must clamp I would like to see this done with a single clamp that would secure both transducers and clamp between the ties with current tie spacing.
        - This could maintain proper spacing between transducer.
        - Must make sure we don't interfere with broken rail protection, i.e. must not span more than the width of a tie plate, 8" or less.

Gating:

It is preferred that the processor detect "0" crossing of the "sign" wave output of the transducer. This is the most accurate point and that can be critical for the speed calculations needed for digital sampling.

Minimum speed and Train Too Slow:

The minimum speed for a magnetic transducer is around 5 to 7 MPH. This will depend on the wheel flange height and width. From a scanner processing perspective the minimum gating speed is not a problem because there is a minimum speed that the preamp will respond to heat. If the train is moving too slowly then the preamp will reference up to the heat and not record the journal temperature. For this reason "Zero Speed" transducers don't add anything to the detector performance other than a more accurate axle count. You will still want an Integrity Failure when the speed is too slow to process heat.
The GETS-GS 2032 7.2 software has field control of the Train Too Slow speed and the default is set at 15 MPH. This was done to eliminate nuisance IF's from transducer mismatch. Tests indicate this will reduce those IF's by 52 %. If there are transducer mismatches above 15 MPH there are track or HBD hardware issues that need to be addressed. In the past the speeds recorded with the train data was the entering and leaving speeds. The slowest speed recorded was added to the display in 7.2 software. I wanted the slowest speed to be in the Warm Bearing data so the Tdata spec was changed so that instead and entering speed the slowest speed was sent in Tdata. This is part of the "TD" line in Tdata.

Wheel gates Forced Closed:

In a "two transducer" gating system the first transducer will open the gate and the second will close the gate. This is based on direction of travel. There can be a problem if, because of flat wheels or poor track conditions, you get an extra open or an extra close gate. With an extra gate on only one transducer the open-close sequence can get out of order and the detector will process the heat outside the bearing instead of on the bearing. To correct for this there should be a software functions that can detect when an extra gate has been processed and "force close" the gate to get it back in proper sequence. When this has happened there will be a warning message indicating “Wheel Gate Forced Closed” in the event log.

Total Axle Count for Train:

There are times when the “A” & “B” count will be accurate but “Total Axle Count” for the train will not be accurate. This is a function of the “Wheel Gate Forced Closed” event. In the 2032 system when the wheel gate is forced closed an axle count is added to the Total Axle count for the train. This will be noted in the “G” log each time it happens.

Speed calculations

Train speed should not be allowed to change on one wheel gate. This can give you a false speed if there were extra gates from flat wheels or bad transducers. To verify there is an accurate speed calculation the speed should be averaged over a minimum of 10 gates. There should be a maximum change that the speed is allowed to change from one sample to the next. Train acceleration and breaking can not occur at the performance of a “race car”. Therefore the speed can not change more than 1 MPH per gate.

Heat Processing and Calibration

Heat Processing:

One of the issues with heat processing is how does the HBD handle a negative output from the preamp.

Under trains you should not see a negative signal unless there is a “spine” car with no container on it. This can cause two problems:

- The detector can get a “sky” shot.
  - This will be cold
  - Could be “absolute zero”
  - It will at least be less than ambient.
- The detector can get a “sun” shot.
  - If the alignment of the detector is directly at the sun.
  - There will be a false alarm because the sun is extremely hot.
    - The detector lens on the preamp that will only pass light in the spectrum of 7 to 14 microns.
    - The sun has “unlimited energy” and produces energy in the full light spectrum.

There are two issues with a “sky shot”.

- How does the preamp respond
  - This can drive the preamp into negative or positive saturation.
  - It can take more than one time constant to recover.

    - This can hide the actual heat on a bearing, even an alarm, because the heat will be referenced as the "delta-T" above a "large" negative number and will never reach an alarm level.
- You can get a false alarm
    - If the car being scanned does not have a car bottom, to shield the sun, from the scanner.
    - The scanned area can include the bearing and sun outside the bearing but still inside the gate as defined by the transducers.
    - This will cause a 'false" alarm.

First Axle Processing:

Heat readings on axle "one" will not be accurate because of the following issues:

- No ambient reference prior to journal scan.
- Speed on first axle is set from activation of track circuit. On all other axles it is set by A to B timing for previous axle.
- With poor speed calculation the sampling rate will be off for the first axle.
- Because of these issues filtering is not applied to the first axle.

The HBD reports in the field do not report heat on the first axle and no values from the first axle are used in any of the field alarms.

Because of a hot journal failure on the Seligman sub in December of 2007 the mechanical department requested the Warm Bearing System be furnished the HBD readings for the first axle.

The 2032 software was modified so Tdata would include the unfiltered heat values for the first axle and the field alarms and displays would not include the unfiltered heat readings for axle one.

- This is included in 7.2 software.
- There is a setup option to disable the first axle heat from being sent in the Tdata report.

Calibration:

The Servo/Harmon/GETS preamp and processor has an issue with processing the output from the preamp when looking at the calibrated heat source.

As the reference wheel is rotating the preamp is referencing to the wheel. When the opening in the wheel is presented and the preamp is allowed to see the heat source. The output of the preamp goes negative until it sees the heat and then it will rise to a positive value. The problem is the total heat, process by the preamp, is from that negative starting point.
In any system with an A-to-D converter it can not process the negative values so only the positive heat is processed.

In the Servo 2000 system this was addressed in the hardware on the “A” board. The first thing the scanner input signal hits is a differential amp with 1 volt DC tied to the other side. This raises all the input values by that 1 volt and the signal will always be positive.

The 2032 input doesn’t have this differential amp input so the calibration is off. This was found early in the testing at Craig because I could not get the Servo 2000 and the 2032 levels to agree on the same train journal readings.

The calibration was corrected with a software adder during calibration. GETS tested several preamps and came up with an average “fudge factor” to use during calibration. This is a “big deal” because the fudge factor is 23 %.

Then for the 2032, during calibration, all scanner inputs are multiplied by 123%. The same 123% multiplier is applied to the “walk-a-round” test. That is so if you set the calibrated heat source on the scanner you will see the expected 130 readings when testing.

Calibration point:

It should be noted that the calibration point is not 130 degrees above ambient at all ambient temperatures. Servo had furnished a table showing the correct setting above ambient based on ambient temperature. This is built into the software in the Servo 2000 and Harmon 2032 systems. When you start the calibration procedure the detector tells you where to set the Function Simulator. This is true if you are using the “Red and silver” FS. The new GETS-GS Calibration Assistant (black case) and the STC universal Calibrated Heat Source (white case) have software in the calibrator that automatically controls the setting of the heat source. This is based on ambient temperature and they also have a delta-T controller to compensate for the heating of the reference wheel. The controller will keep the correct delta-T setting as the reference wheel heats up from radiant heating from the heat source.

Scanner Signal Filtering:

A negative side effect of using a pyro in the scanner is the noise they can respond to.

A pyro is a very sensitive device and prone to microphonic outputs. The microphonics can be carefully filtered by the software or hardware.

- **Hardware filtering:**

The STC pyro has Hardware filtering as well as software compensation.
The hardware filtering is a slower time constant on the coupling between the pyro cell and the amp. High speed changes in signal are just not passed by the amp. This helps with microphonics but there are trade-offs. The negative effect is high-speed roll-off. With the slower time constant the output of the pyro reduces as train speed exceeds 45 MPH. STC compensates for this in the processor with a speed compensation “fudge

factor". This is applied as a sliding multiplier value of the preamp output that is proportional to speed.

Note: At 90 MPH this multiplier is very aggressive and any heat seen can cause an alarm.

- **Software filtering:**

GETS-GS has a much faster time constant so there is no hardware filtering. Therefore there is no problem with "high-speed roll-off" but there are issues with microphonics.

The first filter applied was the **9 Point Median Filter** (Gen I Filter). Next filter is the **13 Point Median Filter** (Gen II Filter). These filters both work the same way the difference is the number of samples that are used in filtering each value.
First the system must have digital peak store so there are multiple samples of the journal scan to evaluate. The filter starts with the first sample in the journal scan. With the 13 point filter it then takes the next 12 samples and computes the median value for those 13 samples. That value replaces the value of sample 1. This process continues until you reach the last sample of the bearing scan. This limits the rate of change from one sample to the next to the median value of the next 12 samples and a microphonic will be averaged out.
This works well if there is only one false spike in the heat profile. If there are multiple spikes there can still be false alarms.

To correct for multiple spikes or all samples above alarm level the **Peak Detect Filter** (Gen III Filter) was designed.

This filter has three (3) software parameters to control the setting.

- Rising Threshold   Default setting 130
- Falling Threshold   Default setting 50
- Peak Counter   Default setting 1

This filter looks for the number of times a profile will transition above 130 and below 50. If this happens more that once the bearing is classed as "Atypical" and the train report will include an Integrity Failure instead of a false hot journal alarm.

The issue with this was with the 8 bit processor on the CPU-1 or CPU-2 this filter could not be applied in "real-time" but was applied at the end of the train in "post processing". This delay required that not all 2032 locations could have this filter enabled. The 5(A) locations and the location protecting concrete ties were required to be disabled.
The 16 bit processor in the CPU-3 was designed as a solution for this problem. It can apply the Gen III filter in real-time and the filter can therefore be enabled at all locations.

Scanner Design Issues:

- **Scanner spot size:**

There are differences in optics in the Servo/GE scanner and the Harmon or STC scanner.

With the Servo scanner the optics produce a focused scan volume that is projected as a “point” source beyond the bearing. This produces an approximately 1” spot on the bearing cup that is scanned for heat.

With the Harmon and STC scanners the focal point is in the pyro cell in the preamp. This produces a scan volume that is not focused to a point beyond the journal but is increasing in volume the farther it is from the scanner.

In the Harmon Model 38 preamp this produced a spot 3 ½” to 4” at the bearing. This has two problems:

- Heat from the bearing is “surface averaged” across the spot size.
    - The spot may include truck frame that is at ambient and bearing that is at an alarm point.
    - The heat processed will be an average of the volume of the spot.
    - There may be only one time constant worth of full heat reading on the bearing cup.
- The system is difficult to test because a “point source” with heat will not alarm the system.

In the STC Sentry or NG system the spot was modified with the “cat eye” pyro.
The original “outboard” scanner used a “flake”, in the pyro, that was 4mm X 4mm. This produced a spot approximately 4” at the bearing. To reduce the surface averaging for an “inboard” scan the flake was changed to be 1mm X 4mm (cat eye). This produces a spot 1” by 4” at the bearing. The pyro is oriented so it is 1” wide and 4” tall and is in the edge of the grease seal 7 ½” from gage. This does keep the scan from surface averaging heat from the sides but the profiles do look more like a “sine” wave than flat topped. STC did test a 1” X 1” flake but the signal to noise ratio was too high and they were concerned about false alarms.
The STC **Type I** rail mount scanner appeared to have shading issues. This is an indication that the scanner baffles were in the scan volume. Calibration of this scanner was done with the adjustment at 210 degrees and the heat source at 180 degrees to compensate for this shading. The **Type II** rail mount scanner does not have this shading issue and the calibration adjustment is at 180 with the heat source set at 180 degrees.

- **Focus:**

Because of the scanner spot size and optics the Harmon and STC scanners are “bench” focused and there is no field adjustment for focus. The Servo scanner must be focused. This is done in manufacturing but focus can be changed in the field. The problem is the focus can be moved inadvertently when the alignment mirror is set in front of the scanner lens. Symptoms of a field focus problem are unbalance of channel 1 and 2 average levels. If channel averages are consistently not balanced and cleaning lens and calibration doesn’t correct then focus is the problem. Without a scope there is not an accurate way to currently field focus the scanner. You can verify the problem is focus with the following procedure.

- Calibrate the scanner, with the heat source on the scanner lid as normally done.
  - Record the gain setting that the system detector assigned.
- Set the heat source on the alignment fixture and again calibrate.
  - The heat source must be at the alignment point. To find that point:
    - Remove the scanner lid.
    - Install the alignment mirror.
    - Put the alignment fixture on the track and move the “flag” until the “dot” is centered on the flag.
    - Remove the alignment mirror from the scanner.
    - Remove the alignment flag from the fixture.
    - Install the “angle block”, for the heat source, on the alignment fixture and secure the heat source to the block with the mounting screw.
  - Again calibrate the scanner.
    - Compare the gain setting calculated with what was recorded with the heat source on the scanner.
    - If these gain settings are not “close”, within 2 to 3 points of each other then this is proof of a focus problem.
- Without a scope the scanner can’t be field focused.
  - Scanners, where the above procedures indicate a focus issue, should be removed from service.
  - Return the scanner to GETS for a bench focus adjustment.
  - **NOTE:** The replacement scanner will require calibration after installation.

- **Mirrors or Reflectors:**

When mirror or reflector is used in the IR scan view make sure they are a “front surface” mirror.

HBD systems work by detecting the amount of Infrared light emitted from the bearing surface. This light is proportional to the bearing temperature and the emissivity of the bearing surface. The issue is the HBD is detecting IR light not heat. IR light has all the same caricaturists as visible light. It can be focused, reflected, refracted, and attenuated. A “normal” mirror has the reflective surface on the back of the glass. If a back surfaced mirror is used for a HBD the IR light detected will be attenuated by passing through the glass. That is why a “front” surfaced mirror must be used. This can be glass with the reflector on top of the glass or a polished “mirror reflective” metal surface.

  - **Note:** If a heater is used on a polished metal surface. The heat of the mirror can be additive to the IR light processed by the HBD.

- **Reference Shutter or under car reference for ambient:**

The Harmon Model 38 and IRIS preamp used a reference shutter.

With a reference shutter the “heat” the HBD can see is the difference between the temperature of the reference shutter and the bearing. The reference shutter will not be at ambient temperature.

- In the summer time the track ballast absorbs heat and this heat is radiated into the scanner. The reference shutter will be heated to this ambient. The HBD will only be able to record the difference between this heated reference shutter and the bearing.
- In the winter the case heaters in the scanners will heat the reference shutter above ambient. The HBD will only be able to record the difference between this heated reference shutter and the bearing.
- In both of these cases the HBD readings will be reduced because to the heated reference shutter.

The Servo/GE and STC system use “under car” reference.
This reference eliminates the issues with the reference shutter being heated. The only issue is if there is not a car bottom to reference on. See the discussion of “sky and sun” shots above.

- **Case Heater:**

Case heaters are provided in the scanners to help with ice, snow, and fogging of lens or mirror.
Note: In all HBD systems the case heaters are disabled during train passage.
This is done because the AC in the scanner cable can cause false alarms in the HBD system.

Scanner drainage, ventilation, and heat all have to be managed to avoid fogging of the lens and/or mirror.

Scanner heaters are also critical to avoid ice or snow buildup on top and underneath the scanner. Ice can build up under the scanner because of the scanner being warm and cause rain or snow to melt on the scanner and run off and build up an ice block under the scanner.
This ice block can be addressed in two ways:

- Add a blanket to the scanner.
- Put a “crib heater” under the scanner

In addition, in some locations, cold air blowers are added to the scanners to control snow buildup.

- **Scanner aerodynamics:**

The aerodynamics of the scanner can be critical to managing drainage and ventilation. There was always antidotal reports that the Phase I scanner had fewer water spotting problems than the Phase II scanner. In 2004 GETS agreed to run tests to verify the design of the scanner. They were able to find a wind tunnel they could use that would allow water spray to be used in the testing. It was shown that the top plate of the scanner was an airfoil and created negative pressure in the scanner. This negative pressure could pull water from under the scanner into the scanner cavity and cause water spotting. In addition water in the scanner was not allowed to drain because of the negative pressure. The top plate for the scanner was redesigned to eliminate the airfoil and the negative pressure was eliminated. Retro fit kits were available in 2005 to upgrade the scanners.

This shows the importance of the scanner design and the effect it can have on maintenance and the reliability of the system.