Improving Hot Box Detector Performance Through Technology
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Fred Meeks
Engineer Systems – Detectors
4515 Kansas Ave
Kansas City, KS 66106-1199
Phone: 913.551.4606
Fax: 913.551.4647
Email: fred.meeks@bnsf.com

Ben Church
Principal Engineer
31003 East Argo Road
Grain Valley, MO 64029
Phone: 816.650.4664
Fax: 866.420.0425
Email: Ben.Church@ge.com

ABSTRACT:

To meet the demands of a growing market, **BNSF** targeted **"Improving Velocity"** as a key imperative for 2006. Reducing Hot Box System "Nothing Found" stops mapped directly into this imperative. This presentation describes the implementation of Hot Box Detector algorithms that have led to a significant reduction in the Nothing Found stops on **BNSF**. This presentation will then describe the collaborative process used by **BNSF** and **GETS** to achieve these improved results.

INTRODUCTION

The performance of Hot Box Detector systems has always been a priority for railroads.

On **BNSF,** the 2006 goal for improved velocity, focused on the four areas shown to have highest impact.

They were failures from:

- Movable Bridges
- Nothing Found stops at Hot Box Detectors
- Frog or Turnouts
- Insulated Joints

Because Hot Box Detector “Nothing Found” stops had such a major impact on velocity we needed to see what we could do to improve our performance.

We had a benchmark for our existing performance. We were at 6.5 Sigma for Nothing Found stops per million axles scanned. We thought being better than 6 Sigma should be good enough. We had been reducing our stops for several years what more could we do ? What didn’t look so good was when we stopped a train we found a defect only a little more than 31 % of the time. This was definitely an area that needed improvement.

THE PLAN

We needed to know what was causing these Nothing Found stops. GE provided a 6 Sigma “Black Belt” to assist BNSF with finding and eliminating the cause of Nothing Found stops. Data was collected for every Nothing Found stop on BNSF for two months. This data would include:

- Time
- Date

- Direction
- Speed
- Detector Type
- Type Alarm
- Car Type
- Train Type
- Profile Analysis of the Alarm

With this information the analysis of the data would determine if the problem was with the detector systems or the inspection process. This analysis concluded that no factor was significant other than the bearing profiles.

For the last six years BNSF has had a very aggressive plan to replace the old “analog” systems with “digital” systems. These new systems capture the profile of the heat on any journal that has alarmed. This allowed us to study the validity of each alarm. It was found that when the train crew didn’t find a failed journal, on inspection, the profile would show it wasn’t valid journal heat.

The causes for these Nothing Found alarms were:

- Microphonic
- Sun
- Brakes
- Loose connection on power supply, Pyro, or scanner cable
- Multiple alarms before it was corrected

Preliminary conclusion:

The existing filter algorithm used to filter noise in the bearing profiles, referred to as the 9-Point Median filter, was not providing complete correction for Nothing Found alarms.

Constraints for 2006 Improvements

Recognizing the urgency to find a practical solution, the following constraints were placed on the project:

- *Focus only on the MicroHBD* - Even though other HBDs exhibited worse performance, the MicroHBD was selected due to large installed base and BNSF has plans to replace older HBDs in the future. From an investment perspective, this was a Win-Win decision for both customer and supplier.
- *Focus on a software-only solution* - leverage the installed base of MicroHBD.
- *Improvement must be verifiable before deployment* **–** Must have confidence in the fix before BSNF-wide rollout of new MicroHBD software.
- *Improvement must be ready before "Peak Season"* **–** November 2006

STOP DATA ANALYSIS

BNSF provided GE with 2004 and 2005 stop data in a spreadsheet format. This data contained the date, site, detector type, stop reason, and subdivision for each stop that occurred within this 2-year period. The data was sorted and reduced to only MicroHBD and Nothing Found stops and the following analyses were performed.

Frequency of Occurrence of Nothing Found Stops by Subdivision

Figure 1 shows the frequency distribution of Nothing Found stops by subdivision.

Key observations:

- 25 of the 91 BNSF's subdivisions account for 75% of all Nothing Found stops
- The highest Nothing Found subdivision was the Gallup subdivision.
- The Panhandle subdivision (6th highest) had 50% fewer Nothing Found stops than the Gallup subdivision
- Most subdivisions had fewer Nothing Found stops in 2005 as compared to 2004

Based on the stacked bar analysis, a decision was made to look for seasonal dependencies on the 5 subdivisions with the most Nothing Found stops.

Nothing Found Monthly Analysis by Subdivision

Figure 2 shows the monthly distribution of Nothing Found stops by subdivision over the 2-year period for the five subdivisions with the most Nothing Found stops over that period.

Key observations:

- November 2004 to March 2005 was the peak season for Nothing Found stops.
- There were significantly lower Nothing Found stops in 2004 as compared to 2005
- The Slaton division had three cyclical peaks on 3-month cycles (see June'04, September'04 and December'04). However, this cycle did not continue through 2005.

Based upon this analysis, a decision was made to analyze Nothing Found stops by detector site on the Gallup Subdivision.

Nothing Found Monthly Analysis by MicroHBD site

The line chart in *Figure 3* shows the monthly distribution for the top 4 Nothing Found MicroHBD sites on the Gallup Subdivision over the 2-year period.

Due to the random and low frequency of Nothing Found stops, the decision was made to postpone additional focus on the stop data. Instead, we began analyzing the actual Nothing Found bearing profiles.

Background on Previous Work to Reduce HBD Nothing Found Stops

Before describing the analysis of the Nothing Found bearing profiles, it is important to explain the background of the Nothing Found analysis that GE conducted in previous years.

In 2002, GE's Global Research Center (GRC) in Schenectady, NY conducted a study to reduce Nothing Found stops using filtering techniques. A physics based model was developed to estimate the sensor response to a hot bearing considering the geometry of the installation, size of wheel and bearing, as well as train speed. Also, this effort resulted in the invention of the median filter concept to reduce Nothing Found stops (Patent No. 6,911,914 B2).

The first implementation of the median filter was tailored to the existing MicroHBD software architecture at that time. A 9-point median filter was implemented by GE and deployed on BNSF resulting in an improvement in performance, as compared to the 12-month period without the filter.

However, in 2002 it was recognized that more Nothing Found stops could potentially be filtered with a 13-point median filter if some of the existing software architecture was changed. These changes would be necessary to reduce the risk of missing a true hot bearing due to the potential of truncated bearing profiles on 28 inch wheels.

Some of the enabling features required for deploying a 13-pt median filter were:

- Continuous digital sampling of Bearing Scanners

- Bearing Sampling Window Offset
- Larger Bearing Profile Sampling Window

Since 2002, the MicroHBD software architecture has been re-designed to overcome some of these limitations. A review of the GRC study and an analysis of the 2006 software architecture revealed that the new architecture could be modified to support a 13-point median filter.

NOTHING FOUND BEARING PROFILE ANALYSIS

Before investing labor in modifying the MicroHBD software and deploying the new software at all the MicroHBD field locations, a desk verification of the 13-point algorithm was conducted. A sample size of 34 Nothing Found bearing profiles where provided by BNSF to GE in the form of P-data files. This bearing profile sample data was imported into a spreadsheet for analysis. Using spreadsheet formulas a median filter algorithm was developed. The results showed that 27 of the 34 Nothing Found bearing profiles were reduced below the alarming threshold. This is a 79% reduction. *Table 1* shows the summary results from the spreadsheet analysis. Based upon this analysis, we had confidence that the 13-point median filter would significantly reduce Nothing Found stops and should be incorporated in the MicroHBD.

Implementation

BNSF wanted to be cautious in changing the alarm properties of the HBD systems. To make sure there were no unforeseen consequences from the implementation of the 13-point filter, an extended field test was needed. From previous data we knew that the Gallup Subdivision had the highest frequency of Nothing Found stops. We installed the new software in the 28 systems on the Gallup Subdivision. After operation on the Gallup

Subdivision the filter had not adversely affected the HBD system operation and had been shown to reduce Nothing Found stops. We were ready to go forward with implementation on all MicroHBD systems.

BNSF RESULTS WITH 13-POINT MEDIAN FILTER:

GE developed the 13-Point Median Filter and BNSF field tested and approved it for installation in all systems in October of 2006. The goal was to have the new software installed on the "Southern Transcon" and as much of he remaining BNSF system prior to "Peak Season". BNSF has 738 of the GE MicroHBD (2032) systems in-service!! This was no small task!

We met that goal. The performance results were …

- With 67% of the 2032 system operating the 13-point median Filter
- Hot Journal Nothing Found stops were **reduced 55%** - Based on per Million Axles Scanned

This was a tremendous improvement!

WE WANT MORE:

Looking at our Nothing Found stops now we see we still have room to improve. We still have Nothing Found alarms that the 13-Point Median Filter can't eliminate. GE has committed to further software development for additional filtering in "post-processing". This will take more processing than can be applied in "real time" to every axle. This filter will only be applied to the axles that would have alarmed with the 13-point Median Filter. The goals of the post-processing would be:

- Filtered alarms to become an **Integrity Failure** not an alarm.

- Report sufficient information for us to correct a problem before we have unnecessarily reduced train velocity.

CONCLUSION

There can be new solutions to old problems if railroads and suppliers are committed to working together on common problems.

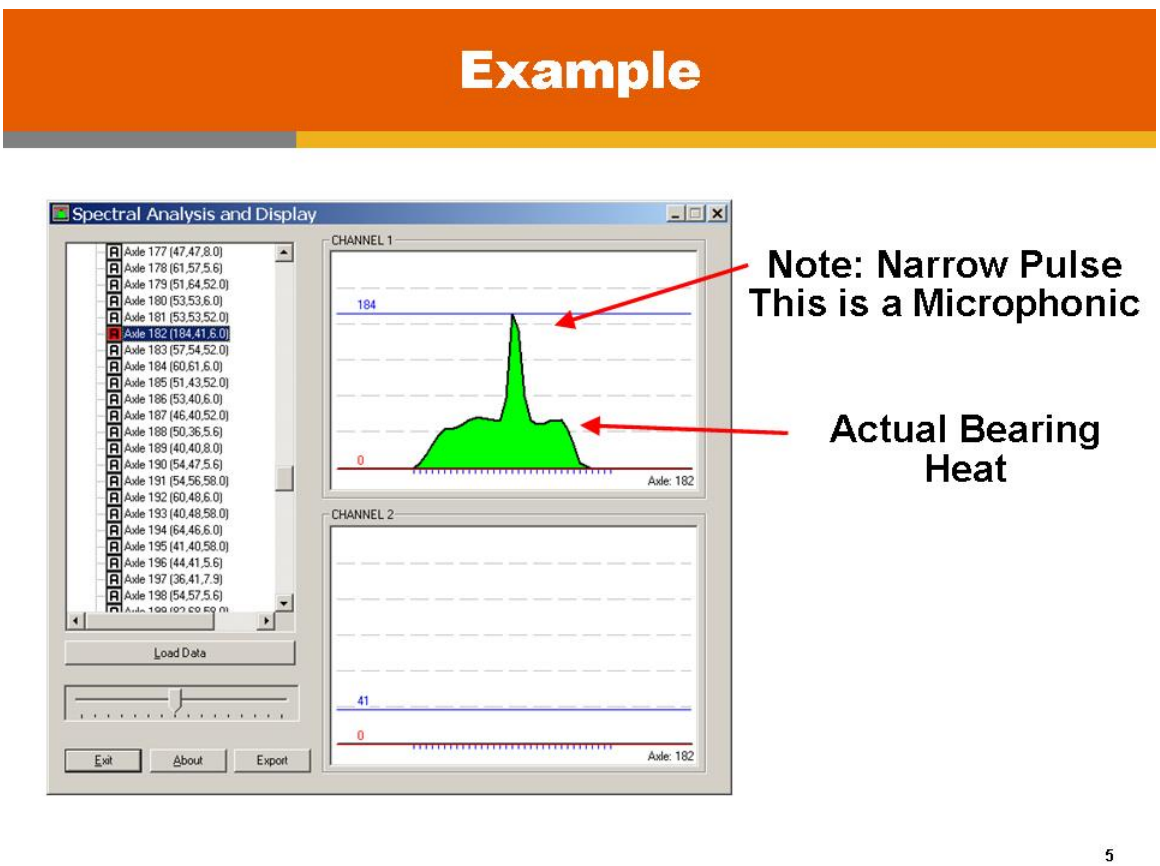
- All of us, on both sides of the industry, have limited resources.
- We must work together to leverage those resources.
- Railroads must be willing to participate in development costs.

The results can be dramatic!!

DEFINITIONS

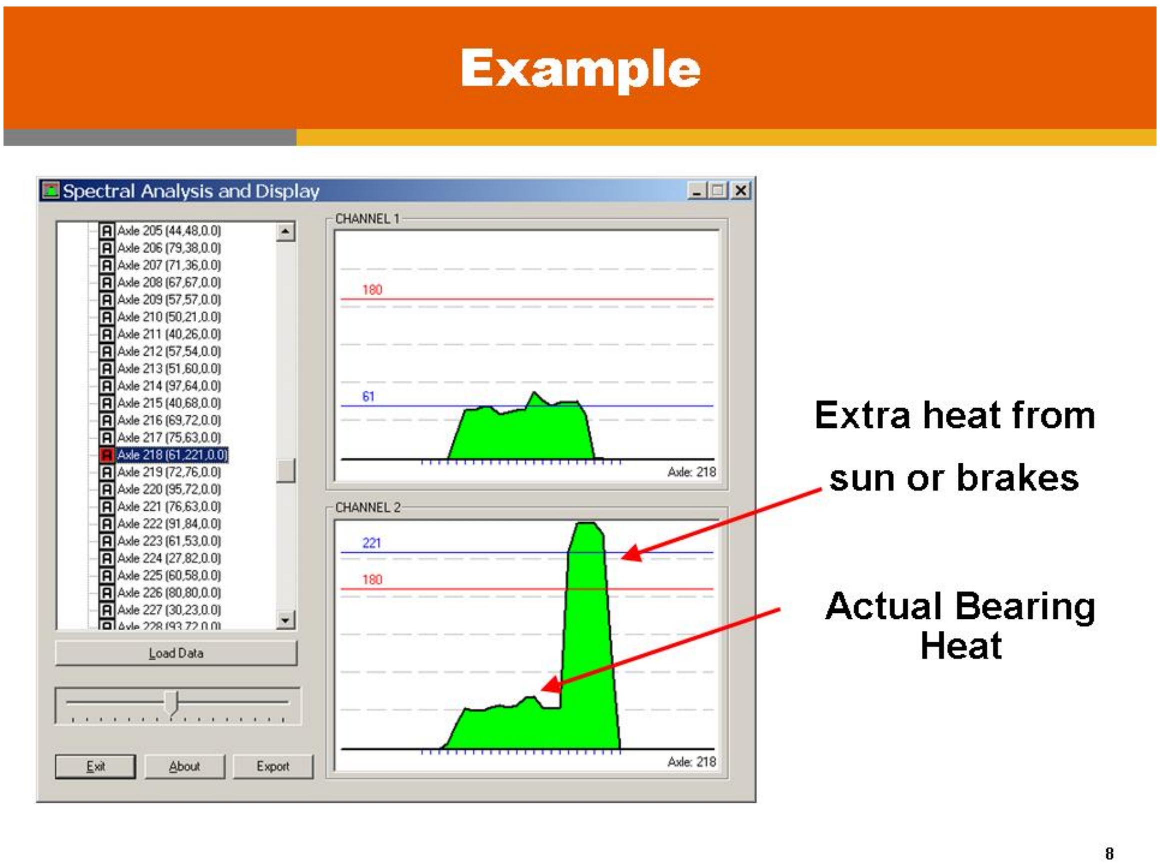
Microphonic

The normal fail mode of a Pyro is to become “noisy”. This noise can be caused by loose components in the Pyro or by extreme track forces from flat wheel or poor track conditions. In these conditions, the Pyro acts like a microphone and will give an output proportional to these forces. This output is a “Microphonic” output. A microphonic output is a transient response and is of short duration in respect to the total gate width.



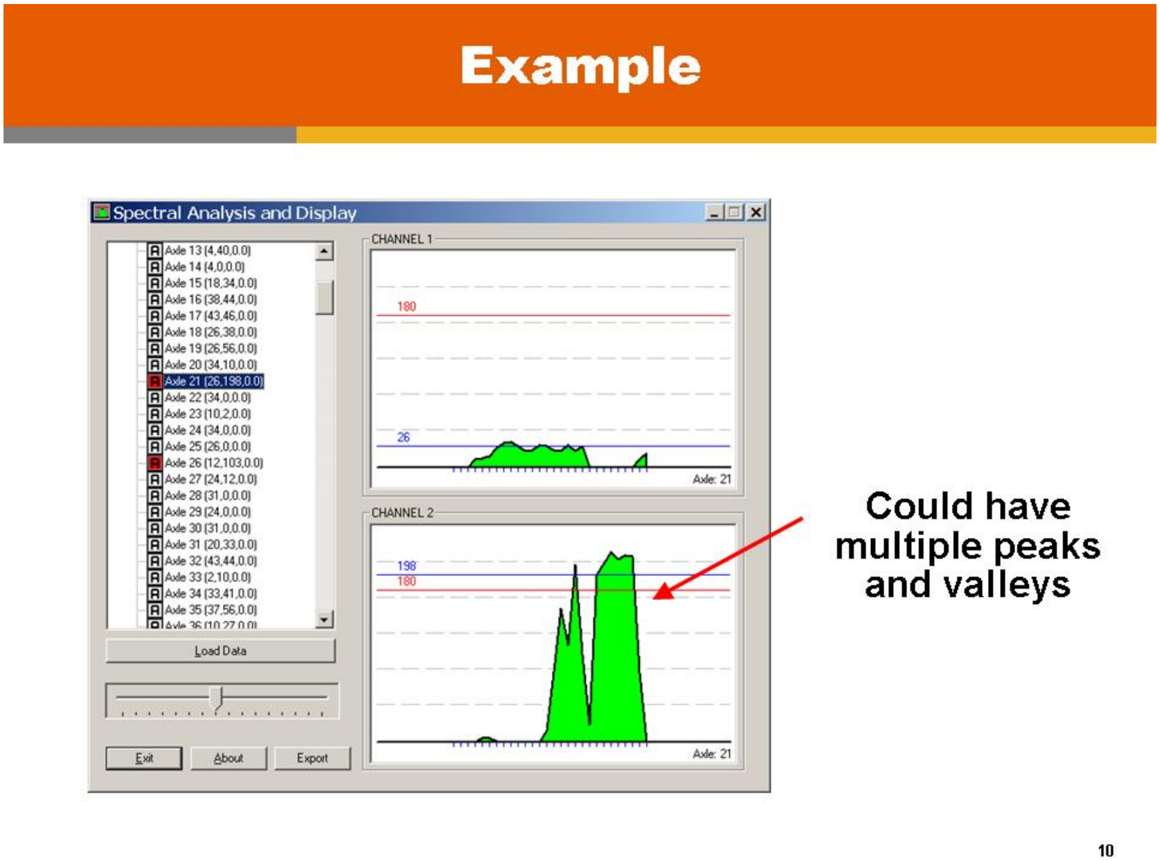
Sun Shot

The sun has unlimited energy and produces energy in the full light spectrum. The HBD systems are filtered to accept only energy in the 7 to 14 microns wave length. There are times when the sun is in direct line with the HBD scan angle. At these times, if the rail car does not shield the sun from the scanner, the sun will cause a false alarm. This false alarm is called a “Sun Shot”.

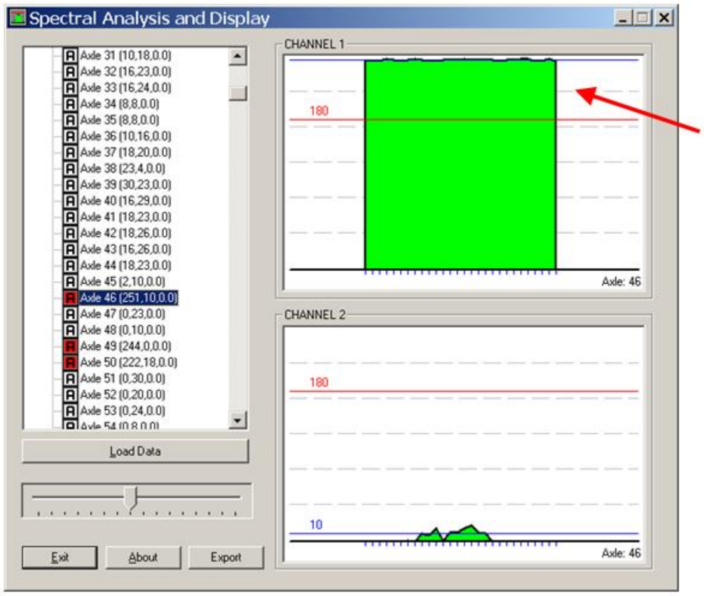


Loose Connection

A loose connection can cause a transient response in the Pyro. This loose connection could be any place in the Pyro output or power circuits including Pyro Scanner cable connector loose at the Field end or the House end.



Example



Could be max reading for all samples

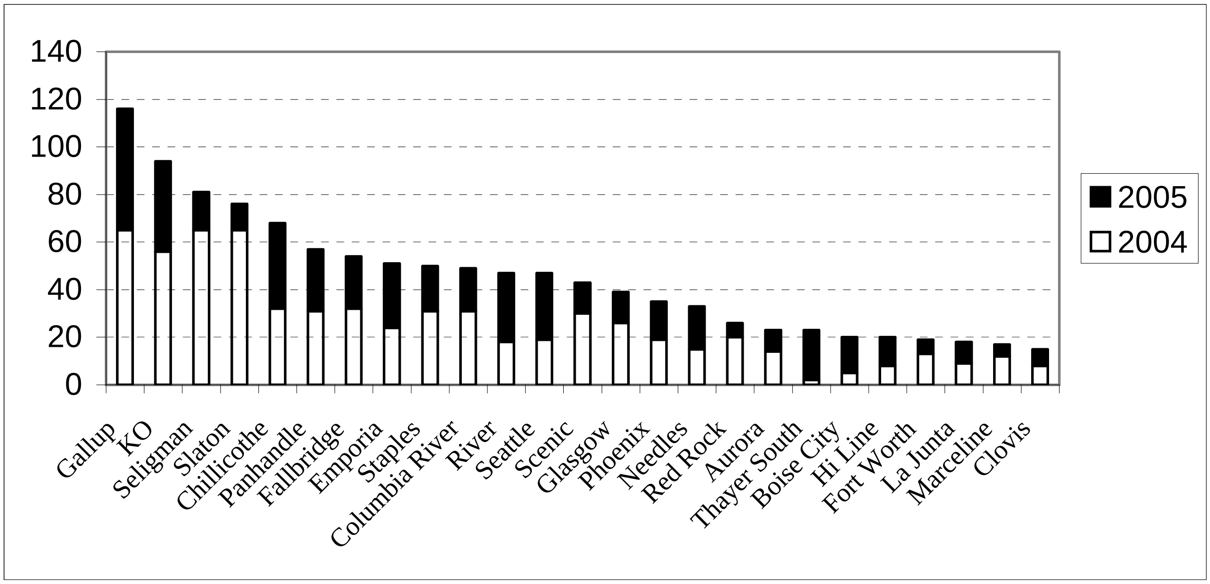


Figure 1: Frequency of Nothing Found Stops for Top 25 Subdivisions

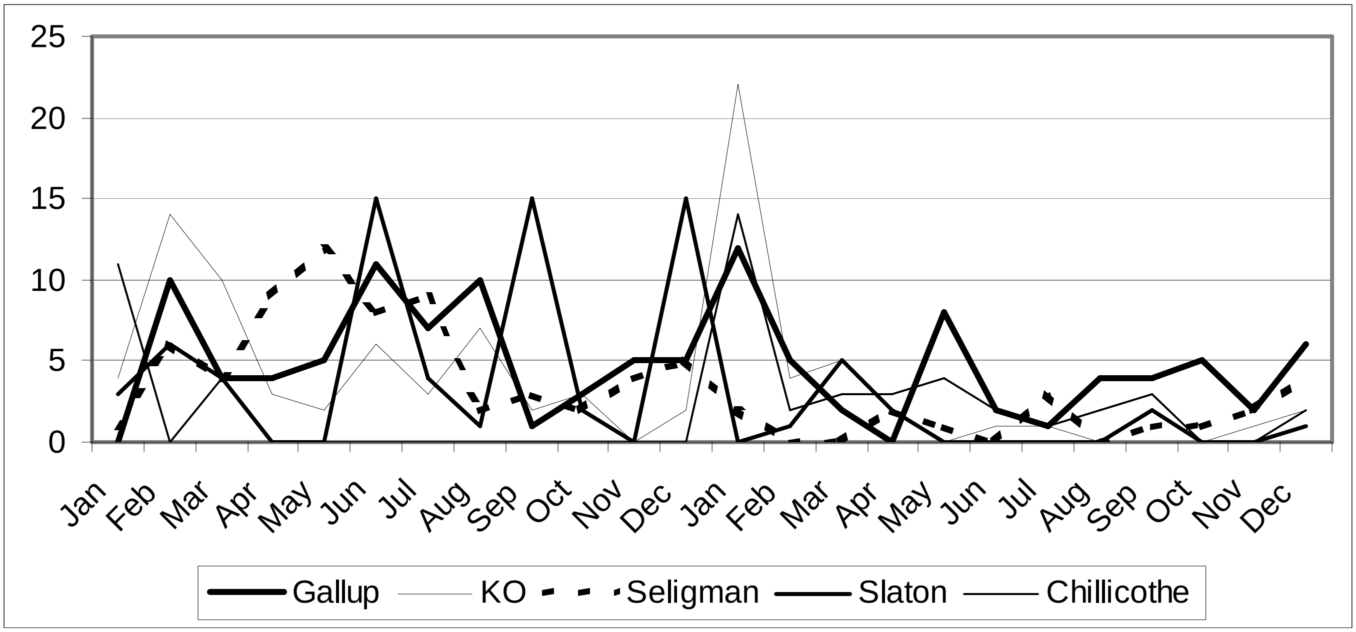


Figure 2: Frequency of Nothing Found Stops by Month for Top 5 Subdivisions

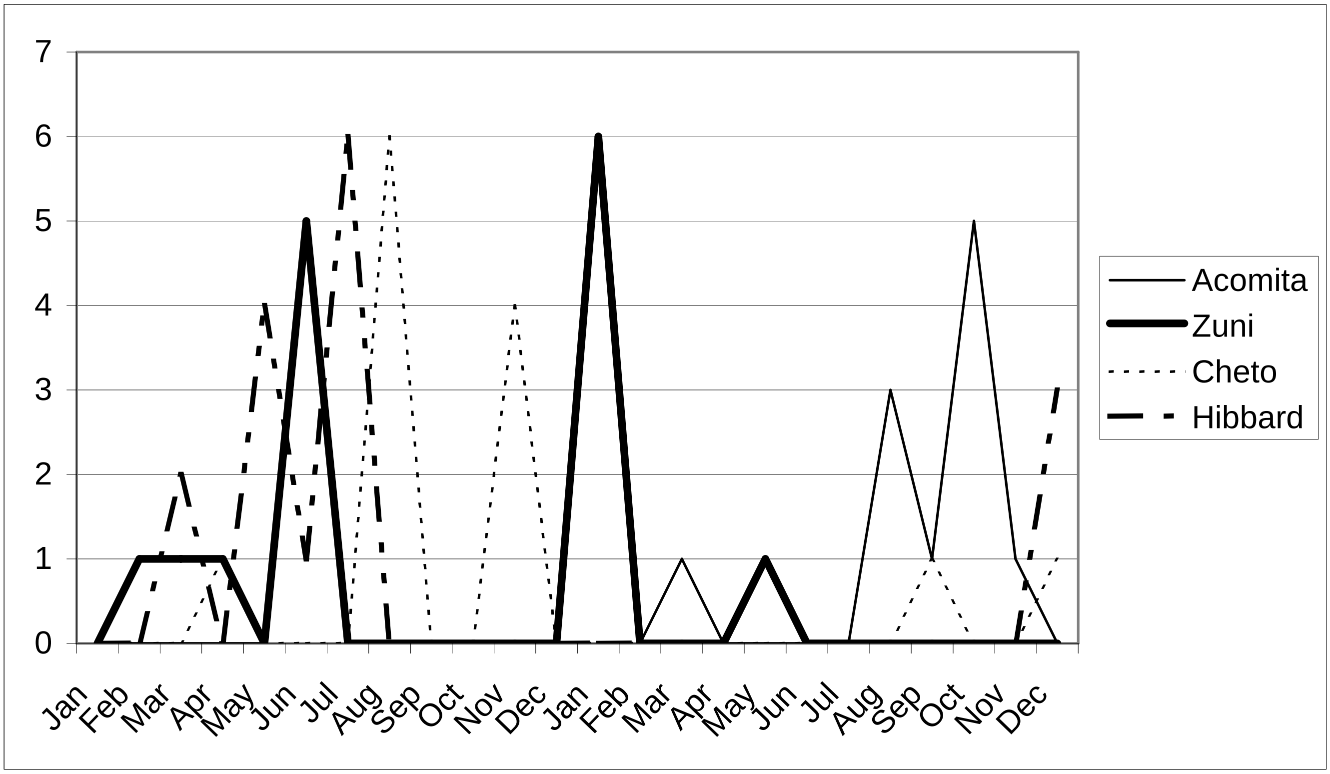


Figure 3: Top 4 Nothing Found HBD Sites on Gallup Subdivision

Table 1: 13-Point Filter Analysis using Nothing Found profiles

Date	Time	Location	ST	Axle	Reading	calculated 13 pt median result	13 pt eliminated alarm?
04/27/06	2:00	Wittenberg	MO	44	209	126	Y
04/28/06	10:30	Odessa	WA	200	207	57	Y
4/29/2006	19:40	Wayne	OK	97	252	253	N
4/29/2006	19:40	Wayne	OK	207	252	56	Y
4/30/2006	10:00	Acomita	NM	252	252	111	Y
04/30/06	17:20	Lakeside	NE	58 - 1	208	138	Y
04/30/06	17:20	Lakeside	NE	58 - 2	182	104	Y
05/01/06	9:10	Benkelman	NE	10	222	0	Y
05/04/06	16:50	Electra	TX	26	185	24	Y
05/05/06	0:30	Electra	TX	186	214	60	Y
5/5/2006	12:15	Wayne	OK	311	221	157	Y
5/6/2006	19:25	Wayne	OK	42	207	76	Y
5/7/2006	1:00	Wayne	OK	146	252	0	Y
5/7/2006	21:55	Winslow	AZ	132	221	223	N
5/7/2006	21:55	Winslow	AZ	133	251	253	N
5/7/2006	21:55	Winslow	AZ	134	251	253	N
5/7/2006	21:55	Winslow	AZ	135	208	210	N
5/7/2006	21:55	Winslow	AZ	136	194	196	N
05/11/06	22:38	Benkelman	NE	18	197	38	Y
05/11/06	10:14	Bellemont	AZ	27	252	253	N
05/11/06	10:14	Bellemont	AZ	29	191	0	Y
05/11/06	10:14	Bellemont	AZ	41	252	0	Y
05/12/06	4:03	Benkelman	NE	34	204	99	Y
05/17/06	16:45	Roland	KS	302	252	102	Y
5/20/2006	10:04	Angel	AZ	129	252	58	Y
5/20/2006	10:04	Angel	AZ	131	199	51	Y
05/21/06	5:40	Electra	TX	142	191	102	Y
5/22/2006	10:10	Angel	AZ	166?	201	71	Y
5/25/2006	10:08	Angel	AZ	162	182	0	Y
5/25/2006	10:08	Angel	AZ	191	233	0	Y
05/30/06	0:37	Ottawa	KS	308	187	102	Y
06/01/06	11:40	Miami	TX	302	251	84	Y
06/03/06	0:15	Chillicothe	TX	42	222	0	Y
06/15/06	15:14	Amory	MS	40	206	16	Y
						Y	**27**
						N	**7**

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