Statistical In-Service Safety Performance Evaluation of Guardrail End Treatments

Research Report

For
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March 2017

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INTRODUCTION

Several guardrail end treatments have been used in Wisconsin in the past twenty years. The last statistical in-service safety performance evaluation of guardrail end treatments in Wisconsin was conducted by the Traffic Operations and Safety Lab (TOPS Lab) in 2008 and found that turn down guardrail ends provide the least effective safety record of all guardrail end treatments used in Wisconsin at that time (*1*). ET Plus is one of several crash test approved guardrail end treatments that has been used in Wisconsin. Recently, fifteen states, including Wisconsin, have taken ET Plus end treatment off their approved product lists following concerns about its safety performance due to a design change in 2005. American Association of State Highway and Transportation Officials' (AASHTO) Manual for Assessing Safety Hardware (MASH) (*2*) and the Federal Highway Administration (FHWA) encourage in-service performance evaluation of roadside safety hardware (*3*). The objective of this research is to statistically evaluate in-service safety performance of guardrail end treatments that are approved and available for installation in Wisconsin. Specifically, this research will compare ET Plus and SKT.

GUADRAIL END CRASH IDENTIFICATION

Crashes that involved collision with guardrail end treatments on the entire State Trunk Network (STN) from 2005 through 2013 are pertinent to this research. In 2005, the design of ET Plus was modified and hence the choice of 2005 as the beginning year for this analysis.

The most straightforward way to identify these crashes is to use the "First Harmful Event" and "Most Harmful Event" fields that indicate Guardrail End in the Wisconsin police crash report forms. Crash report forms were obtained from the WisTransPortal (*4*). Past research has shown miscoding of crash report forms (*5*). In order to ensure that as many of the guardrail end crashes are captured as possible, crashes with Guardrail Face, Impact Attenuator, Bridge Parapet End, Bridge Rail and Median Barrier as the "First Harmful Event" or the "Most Harmful Event" were examined.

A manual review of crash report forms was done to ensure that the crashes included in analysis did involve collisions with guardrail end treatments. During the manual review of crash reports, the following additional information was obtained from the narrative and/or the crash diagram:

1. Sequence of events (both before and after the crash)
2. Point of impact: initial impact point of vehicle with guardrail based on Model Minimum Uniform Crash Criteria Guideline (MMUCC) numbers (1-12)
3. Collision before or after impacting the guardrail end with other vehicles or fixed objects
4. Rollover before or after the crash with the guardrail end
5. Possible intrusion of guardrail end into vehicle occupant space

Research team made efforts to obtain photographs from law enforcement agencies, if the crash reports indicated that photographs were taken. However, due to the lack of a repository of photographs, they could not be obtained.

GUARDRAIL END TREATMENT IDENTIFICATION

After identifying guardrail end crashes, to identify the type of end treatment at the time of crash, a two-step process was followed:

1. Identify the end: Multiple guardrail ends could be in the vicinity of the crash as mapped in the STN crash map. In this step, the end involved in the crash is identified. A spatial matching of crashes and end types was performed using ArcGIS to identify all guardrail ends within 1,000 feet of a crash. The inventory developed by the TOPS Lab was used for this purpose. Research team developed a software to use Google Earth™ to display the crash location, the locations of all the guardrail ends within 1,000 feet of the crash and the crash report. Figure 1 below illustrates the process followed to identify the end.

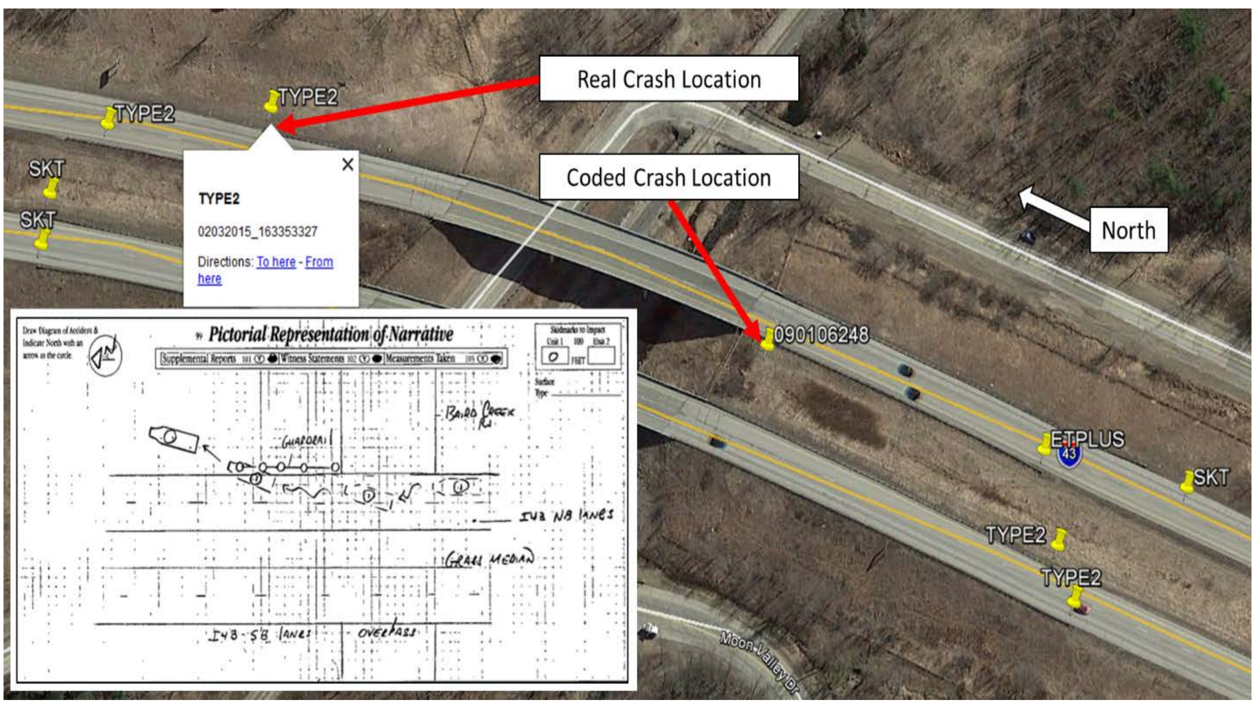

Figure 1. Identification of Guardrail End Involved in Each Crash.

2. Identify the end type: For each crash, the end type at the time of crash is required. Therefore, Photolog data since 2005 was obtained from WisDOT. As part of their business processes, WisDOT operates a data collection vehicle, known as the Photolog van, that travels the state taking photographs along highways every 1/100th mile. The data collection process is known as “photologging”. WisDOT photologging efforts started in 1974 by the

Engineering Services group of the WisDOT and continue to this date (*6*). The current version of the WisDOT photolog system includes two photographs linked to differentially-corrected GPS observations and cumulative distance measurements. The goal of the photolog program is to travel and photograph all Wisconsin STH highways every 3 years (in each direction) while traveling on the rightmost lane. The research team developed a software to extract Photolog images prior to the crash using the location information of the guardrail end. Manual review of the extracted Photolog images was performed to identify the end type for each crash as illustrated in Figure 2.

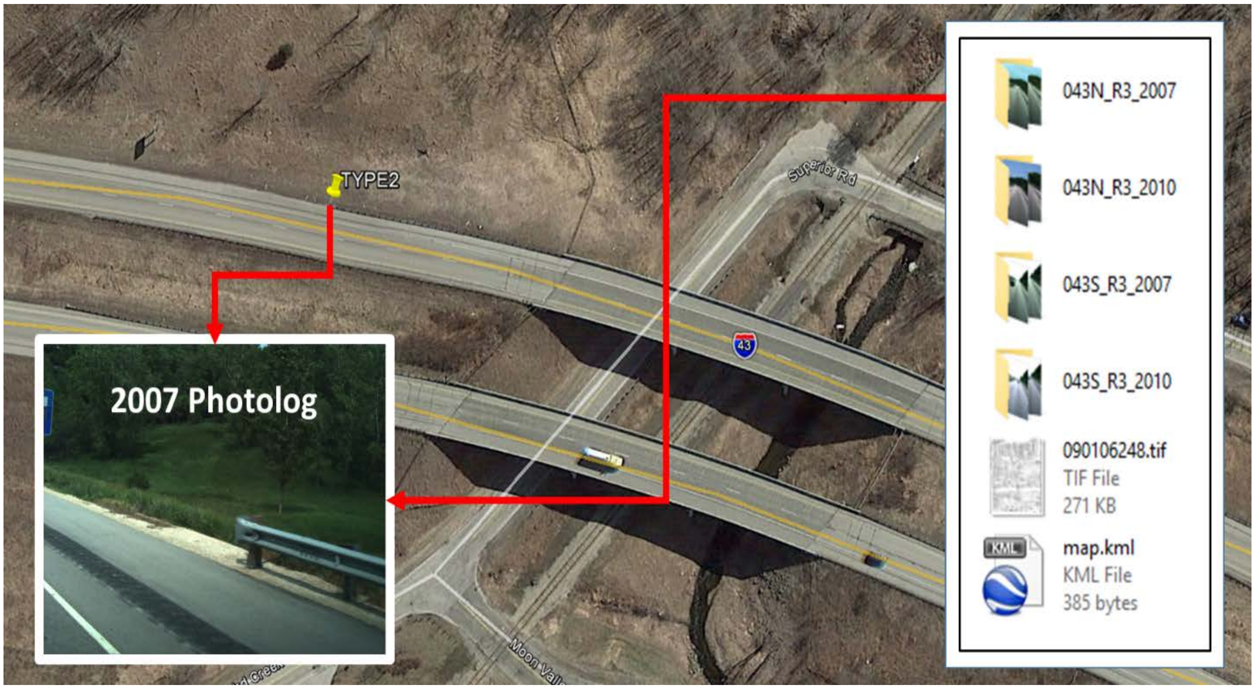

Figure 2. Identification of the Type of Guardrail End Involved in Each Crash.

Several challenges were encountered in this process to ensure guardrail end treatments were correctly identified including:

1. crash reports with missing WisDOT Reference Point (RP) coding,
2. insufficient information in the crash report to understand the location of the crash,
3. incorrect crash location,
4. ramps not covered by Photolog and
5. Photolog data not available for some crashes in 2005.

If the guardrail end treatment could not be identified, then those crashes were eliminated from the study as they could not be used in the safety performance evaluation. Owing to these challenges the type of guardrail end treatment involved could not be identified for all the crashes that involved collision with a guardrail end treatment. The actual number of crashes for which the end type could not be identified and/or classified is described in "Guardrail End Crash Data" section.

CRASH TEST PROTOCOLS FOR EVALUATING GUARD RAIL END TREATMENTS

Crash testing of vehicles to evaluate roadside safety hardware performance under controlled conditions has been on-going for over 75 years. Standardizing the test protocols to allow roadside hardware comparison began in 1962 and has evolved ever since. In 1993, the National Cooperative Highway Research Program (NCHRP) published Report 350 established six performance test levels (TL), with levels 1-3 for passenger vehicles based on vehicle speed, with TL-3 using a top speed of 62 mph (*7*). Levels 4-6 are done with various large truck classifications, starting at 18,000-pound single unit van trucks for TL-4. The FHWA determined for practical worst case impact conditions, TL-3 would be the minimum standard for funding eligibility of guardrail end treatments on high-speed National Highway System roads (*7*).

In 2009, revised crash test protocols were established by AASHTO and were endorsed by the FHWA, and are contained in the AASHTO MASH (*2*). The crash test protocols were modified primarily, to account for changes in the passenger vehicle sizes driven in the United States, as well as for advances in the science of crash testing, and adding more tests and changes to evaluation criteria. However, the practical worst-case impact conditions for evaluating crashworthiness of guardrail end treatments remains at TL-3. It is important to note that there are no side impact conditions for passenger vehicles in NCHRP 350 or MASH. In 2015, MASH testing protocols were updated for cable barrier testing and large trucks (TL-4), but no changes were made to crash test design criteria for TL-3 or guardrail end treatments.

For in-service safety evaluation studies, crashes involving vehicles that are not in the test level design criteria are removed. Specifically, non-passenger vehicles such as motorcycles, large trucks and buses are commonly excluded when comparing TL-3 guardrail end treatments. Therefore, crashes involving these vehicle types were excluded from the analysis.

GUARDRAIL END CRASH DATA

Following the identification of guardrail end crashes and guardrail end types, and excluding crashes involving motorcycles, large trucks and buses, 955 crashes are in the crash dataset for analysis. The process that resulted in the set of 955 crashes was achieved as follows and is also illustrated in Figure 3.

In order to ensure that as many of the guardrail end crashes are captured as possible, crashes with Guardrail Face, Impact Attenuator, Bridge Parapet End, Bridge Rail and Median Barrier as the "First Harmful Event" or the "Most Harmful Event" were examined. About 29,000 crashes satisfied the "First Harmful Event" or "Most Harmful Event" criteria. These 28,831 crash reports were manually reviewed and 2,844 crashes were identified as guardrail end crashes. Of these 2,844 crashes, the guardrail end type was identified for 1,300 crashes. After excluding Type 2 (downstream ends used on divided roadways) and bullnose end types, 1,012 crashes resulted. After excluding motorcycles, large trucks and bus crashes, 955 crashes are in the dataset for analysis. Table 1 shows the crash severity distribution for the guardrail end crashes. About 65% of the crashes resulted in property damage only. Less than 2% were fatal crashes.

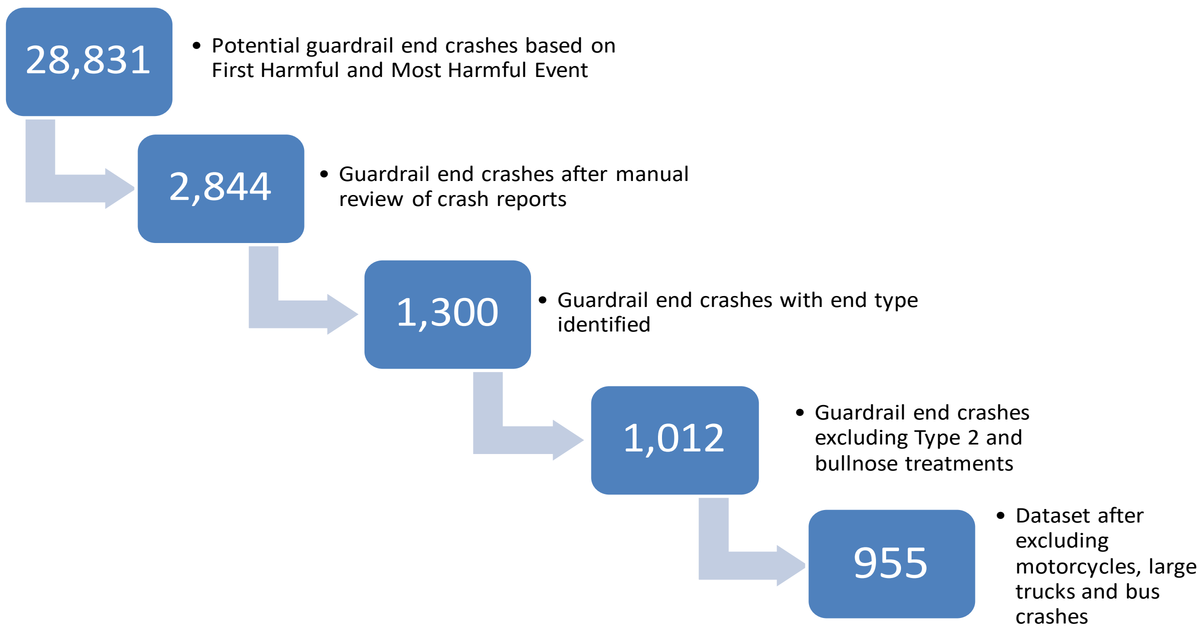

Figure 3. Guardrail End Crash Dataset Derivation

Table 1. Crash Severity Distribution for Guardrail End Crashes

Crash Severity	# of Crashes	% of Crashes
K: Fatal	13	1.4%
A: Incapacitating Injury	87	9.1%
B: Non-Incapacitating Injury	121	12.7%
C: Possible injury	106	11.1%
PDO: Property Damage Only	628	65.8%
Total	955	

Table 2 shows the crash severity distribution by guardrail end type. The highest number of guardrail ends on the STN (based on the "best estimate" inventory completed by the TOPS Lab in

2015 for state-maintained roads) are SKT's followed by turndown ends, as shown in Table 3. Therefore, there were more SKT and Turndown crashes than the other types of end treatments. From the Photolog and/or Google Streetview ™ images it was not always possible to distinguish between similar looking end types. When these situations occurred, the following similar units were combined:

1. ET2000 and SKT, and
2. SRT, BCT and MELT.

Table 2. Crash Severity Distribution by Guardrail End Type.

	ET2000	ET Plus	MELT	SKT	TURNDOWN	BCT	SKT/ ET2000*	SRT/BCT/ MELT*
K	2	4	0	3	2	0	0	2
A	3	3	1	36	25	7	2	10
B	13	5	2	52	26	4	3	16
C	11	4	1	40	29	5	2	14
PDO	47	28	19	276	121	29	33	75
Total	76	44	23	407	203	45	40	117

*: Not included in the statistical analysis

Table 3. Guardrail End Type "Best Estimate" Inventory for State Maintained Roads as of 2015.

End Type	Number
SKT	11406
Turndown	3953
Type 2	2690
ET2000	1466
BCT	1347
ET Plus	1076
MELT	857
SRT	559

DATASETS FOR ANALYSIS

During the manual review of crash reports, additional information was collected from the narrative and/or the crash diagram. A collision with another vehicle before or after and/or a rollover before or after the impact with the guardrail end has a high probability of contributing to the crash severity outcome. The objective of this study is to evaluate the safety performance of guardrail end treatments. Hence, in order to minimize confounding effects of these factors on crash severity outcome, four different datasets were created. The four datasets are as follows:

1. Dataset 1: This is the dataset of 955 guardrail end crashes for which the guardrail end types were identified.
2. Dataset 2: No other collision before and no rollover before impacting the guardrail end.
3. Dataset 3: No other collision before or after and no rollover before impacting the guardrail end.
4. Dataset 4: No other collision or rollover before or after impacting the guardrail end.
5. Dataset 5: Frontal or near-frontal impacts of guardrail ends.

The rationale for examining Dataset 2 is the crash severity outcome is not affected by a collision with another vehicle or object and rollover of vehicle prior to impacting end treatment. The Dataset 3 eliminates the crashes that may have severity increases that were the result of a collision with another vehicle or object after impacting the guardrail end. The Dataset 4 also eliminates rollover crashes after impacting the guardrail end. A terminal may be the cause of a rollover; however, other features could also be causing the rollover. Therefore, these crashes are removed. Past literature has already shown that turndown ends contribute to rollover crashes so caution should be given in examining the results of Dataset 4 for turndown end treatments.

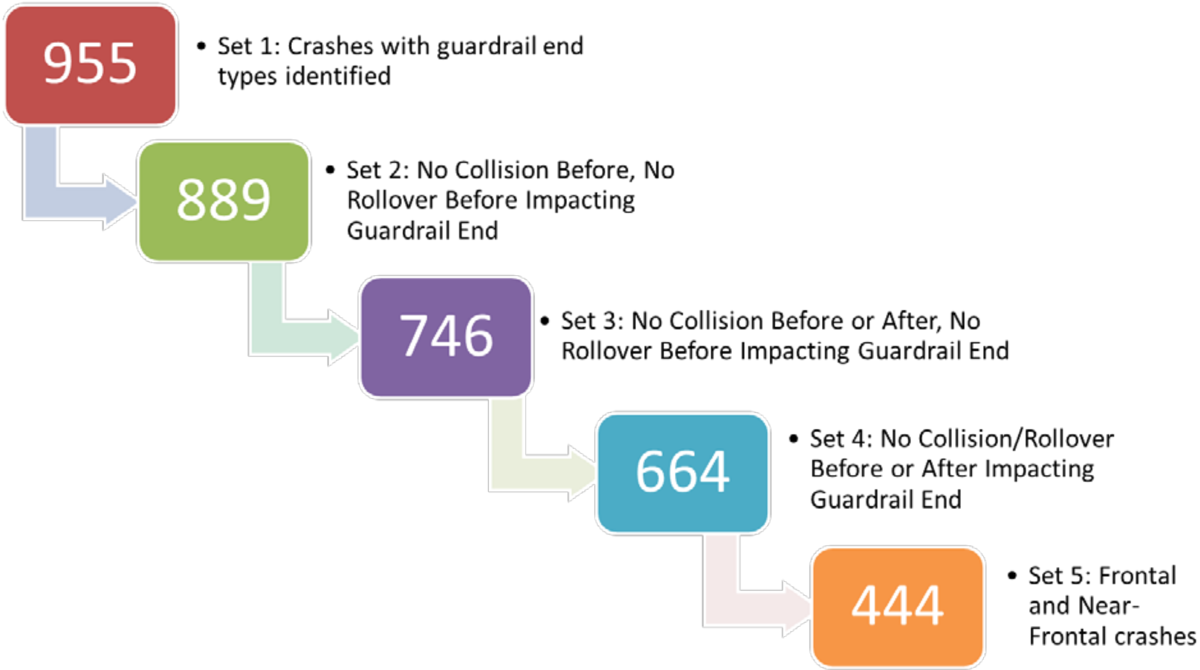

Figure 4. Four Analysis Datasets.

An additional filter was applied to Dataset 4 to create another data set called Dataset 5. This data set removed crashes involving side impact (yawing or off-track crashes) since these conditions are not in the current design protocol for TL-3. Dataset 5 was created by limiting it to crashes in which the vehicles impacted the guardrail end in head-on or near head-on position. This was determined by looking at the point of impact in the crash report diagram and/or narrative. The crash results from this data set allows the hardware to be compared closer to the conditions used in the NCHRP-350 and MASH TL-3 protocols.

While side impact (yawing) vehicles are not currently part of the test protocol for TL-3, the MASH estimates that half of all run-off-the road crashes involve non-tracking or yawing (8). Therefore, using all passenger vehicle impact conditions (Dataset 3 and 4) may be a useful comparison for measuring total in-service safety performance. This comparison would enable one to determine if a product has the capability of performing better under all impact conditions.

CRASH SEVERITY ANALYSIS

The datasets of guardrail terminals were collected from police crash reports for the period from 2005 through 2013. The data were collected, categorized, and analyzed from all the types of guardrail terminals that existed on State highways during this time period. However, over this nine-year time period, WisDOT updated their guardrail standard terminals so that new improvement projects only used terminals that complied with NCHRP-350 crash test criteria. As a result, only three proprietary terminals were used on WisDOT FDM design standards during this time period for new projects. The three terminals were the ET-2000, manufactured by the Trinity Corporation; the ET Plus also manufactured by the Trinity Highway Products LLC; and the Sequential Kinking Terminal (SKT) manufactured by the Road Systems Inc. Shortly after the ET Plus was approved for Federal Highway Administration funding on Federal-aid projects (determined to comply with NCHRP-350 crash test criteria), the Trinity Corporation ceased offering the ET-2000 for sale. This resulted in two terminals, the ET Plus and the SKT, available for new installations during the latter data collection time period. Therefore, this study focused on comparing the ET Plus and the SKT terminals to each other, since these are the only two terminals that satisfy the NCHRP-350 test criteria that were used in Wisconsin. Table 4 shows the crash severity distribution for ET Plus and SKT for all the five datasets. As shown in Table 2, for 40 crashes, it could not be ascertained if the end type was SKT or ET2000. These forty crashes were not included in the analyses.

Data such as those depicted in Table 4 are often analyzed statistically using Pearson's Chi-squared test to compare the two crash severity distributions (9). The null hypothesis is that the two populations have the same distribution with respect to crash severity. One of the assumptions underlying the Chi-squared test is that the expected frequency in each cell is at least five. When this assumption is violated, Chi-squared test results may not be reliable. The Fisher's exact test is a more conservative test which does not require this assumption and is widely used in such circumstances (9). For this analysis Fisher's exact test was used to compare the severity distributions.

Table 4 shows the results of Fisher's exact tests. (The assumptions for the Chi-squared test are not met due to the very small expected values for fatality (K)). The p-values are less than 0.05 for all the five datasets indicating that there is a significant difference in the severity distribution between SKT and ET Plus. The most common threshold for declaring "statistically significant results" is 0.05. Thus, using this threshold, the differences in the distributions are statistically significant for all the five datasets. The major factor leading to the statistical significance is that number of fatality with ET Plus is considerably higher than with SKT. However, given all of the issues with data collection, uncertainty of installations being according to standards and considering that the total sample of ET Plus crashes is only 44, these results should be considered suggestive only.

Table 4. Crash Severity Distribution of ET Plus and SKT for the Five Datasets

Filters applied (Yes/No)	Dataset 1		Dataset 2		Dataset 3		Dataset 4		Dataset 5	
No collision before impacting guardrail end	No		Yes		Yes		Yes		Yes	
No Rollover before impacting guardrail end	No		Yes		Yes		Yes		Yes	
No Collision after impacting guardrail end	No		No		Yes		Yes		Yes	
No Rollover after impacting guardrail end	No		No		No		Yes		Yes	
Frontal or near frontal impact	No		No		No		No		Yes	
Crash sample size	955		889		746		664		444	
	ET Plus	SKT	ET Plus	SKT	ET Plus	SKT	ET Plus	SKT	ET Plus	SKT
K: Fatal crashes	4	3	4	2	3	0	2	0	2	0
A: Incapacitating injury crashes	3	36	3	32	2	28	1	17	0	15
B: Non-incapacitating injury crashes	5	52	5	45	2	33	2	29	1	19
C: Possible injury crashes	4	40	4	37	4	32	3	28	2	22
PDO: Property damage only crashes	28	276	27	265	22	232	21	223	11	145
Total crashes	44	407	43	381	33	325	29	297	16	201
Fisher’s exact test: p-value	0.02046		0.01031		0.003466		0.03168		0.0161	

In order to not over emphasize the few fatal crashes, past research has recommended grouping the severe crashes for analyses. Also, past studies including the most recent TOPS comparison of KABCO and CODES data from Wisconsin crashes have revealed that severe injuries can be overestimated by relying exclusively on KABCO rating (*10, 11*). Furthermore, it was found that incapacitating injury (injury severity A) as classified by law enforcement is overestimated. In other words, less serious injuries are sometimes classified as A. Therefore, several researchers have started grouping crash severities in order to avoid biasing the analysis. In this research, data for fatality (K), incapacitating injury (A) and non-incapacitating injury (B) were grouped together while the other two categories were grouped together. Fisher's exact tests were performed and the results are shown in Table 5. The p-values are not significant for any of the five datasets, indicating that there is no statistically significant difference between SKT and ET Plus when K-A-B crashes are compared with C-PDO crashes.

Table 5. Results of Fisher's Exact Test for K-A-B Vs C-PDO.

ET Plus vs SKT K-A-B Vs. C-PDO	P-value(Fisher's exact)
Dataset 1	0.4532
Dataset 2	0.3260
Dataset 3	0.8155
Dataset 4	0.7899
Dataset 5	0.7400

OTHER ANALYSES

Other secondary analyses were performed in the course of this research. These are briefly summarized here and details are presented in Appendices, as relevant.

1. Crash severity analyses were also performed using CODES data. CODES records were found only for 170 of the 955 crashes and did not reveal any new findings. The details of the analysis and results are presented in the Appendix A.
2. During the manual review of crash reports (MV 4000) to confirm guardrail end involvement, possible intrusion of guardrail end into vehicle occupant space, was also noted based on officer's narrative and/or crash diagram. Three crashes were found which described intrusion into vehicle occupant space. The end types involved in those three crashes were one each of SKT, MELT, BCT or MELT (could not be distinguished). Narratives and diagrams from the crash reports for the three crashes are shown in Appendix B.
3. Crashes involving non-passenger vehicles such as motorcycles, large trucks and buses were excluded before performing the statistical analysis. Appendix C presents the characteristics of those crashes compared to passenger vehicles.
4. Appendix D lists the Document numbers of all the 955 crashes included in this analysis.

LIMITATIONS OF IN-SERVICE PERFORMANCE EVALUATIONS

When conducting in-service performance evaluations of roadside safety hardware, it is important to understand the role real-world crash environment has on evaluating the performance and comparing safety hardware to ideal conditions that exist during crash tests in a laboratory setting. The FHWA has previously identified and reported on several performance limitations for all types of guardrail end treatments, and summarized the limiting conditions into two general categories: vehicle impact conditions, and guardrail end installation/maintenance conditions (*12*). The impact conditions include initial point on the vehicle that struck the guardrail end, speed of the vehicle at moment of impact, angle of collision, and type of vehicle. The end treatment installation/maintenance conditions include failure to follow the installation instructions, guidelines, maintenance of snow and ice removal near the guardrail end at the time of the collision, and perhaps most notably grading and site issues outside of design standards. These impact and installation/maintenance conditions can separately or in combination adversely affect the safety performance and are difficult to identify and control when evaluating in-service performance. Data sets created for this study attempted to eliminate certain initial impact vehicle points and type of vehicles to better account for some of the impact conditions, but the ability to account for other impact conditions and installation/maintenance conditions are beyond this study.

CONCLUSIONS

The objective of this research was to perform a statistical in-service safety performance of ET Plus and SKT end treatments. These are approved and available for use in Wisconsin. The "Most Harmful Event" and "First Harmful Event" fields in crash reports were used to obtain crashes that potentially involved collision with guardrail ends. Almost 29,000 crash reports were manually reviewed to confirm collision with guardrail ends. Software was developed and used in conjunction with WisDOT Photolog data and Google Earth maps to enable the process of identifying the guardrail end involved in each crash as well as to identify the end type. At the end of this process guardrail end types were identified for 955 crashes.

Based on collision before or after and rollover before or after impacting guardrail end, four datasets were obtained. A fifth dataset was a subset limited to frontal and near-frontal impacts on the guardrail ends. KABCO based severity comparison was performed for all the five datasets. When all the five severity levels (K, A, B, C, and O) were included in the analysis, there was statistically significant difference (at the 5% level) between the severity outcomes of SKT and ET Plus, regardless of the dataset. The major factor leading to the statistical significance is that number of fatalities with ET Plus is higher than with SKT. Comparison was also done by combining KAB as one group and CO as another group of severity outcomes. This resulted in no statistically significant difference when these combinations were applied in any of the five datasets.

Even given this detailed analysis, it is difficult to judge conclusively end terminal performance. There are a number of missing variables that can significantly influence performance. Given the limitations in data collection, uncertainty with installation and maintenance site conditions at the time of the crash, and the effect of vehicle variables such as speed at moment of contact and angle of collision, the results of the statistical analysis can only be considered suggestive. Therefore, guardrail end treatment in-service performance evaluations should be continued to reach more conclusive results. Development of a maintenance database that catalogs all guardrail end treatment replacements (including photographs of the guardrail end hit) would increase the dataset, reduce the uncertainty associated with some of the factors that contribute to crash severity outcome and enable a more conclusive evaluation.

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APPENDIX A: CODES ANALYSIS

The Crash Outcome Data Evaluation System (CODES) facilitated by the National Highway Traffic Safety Administration uses probabilistic methodology to link crash records to injury outcome records. The records include those collected at the scene, by emergency medical services in route, by hospital personnel after arrival at the emergency department or admission as an inpatient and/or, at the time of death, or on the death certificate. CODES data are determined for each individual participant in a crash. CODES data were joined with the crash data. For 170 crashes, 194 CODES records were found. CODES uses Maximum Abbreviated Injury Score (MAIS) which classifies the severity of the outcome for each individual participant into 6 categories: Maximum, Critical, Severe, Serious, Moderate and Minor. Table 6 shows the MAIS distribution for the 194 CODES records as well as the KABCO equivalent for each of the MAIS designations.

Table 6. MAIS Distribution and KABCO Equivalents

MAIS Score	No. of Records	KABCO equivalent
Maximum	0	K
Critical	3	A
Severe	4	A
Serious	7	A
Moderate	22	B
Minor	119	C
Unknown	39	

Table 7 and Table 8 show the MAIS and KABCO distribution for the 170 crashes which had CODES records. Based on CODES data 14 crashes should have been classified as A, but KABCO data suggests that 46 crashes have a severity of A. In other words, 32 of the crashes (about 70% percent) marked as severity A are not of severity A, according to medical opinion. This data reinforces the fact that severity A crashes are overestimated based on KABCO scale. The six fatalities do not show up in MAIS most likely because there were no hospital records for the killed occupants.

Table 7. MAIS Distribution of Crashes.

Maximum MAIS Score	No. of Crashes	KABCO equivalent
Maximum	0	K
Critical	3	A
Severe	4	A
Serious	7	A
Moderate	21	B
Minor	101	C
Unknown	34	

Table 8. KABCO Distribution of Crashes.

KABCO	No. of Crashes
K	6
A	46
B	62
C	42
PDO	14

Any intrusion of guardrail end into vehicle occupant space is expected to result in injuries to the extremities or pelvic girdle. Hence CODES data was used to examine body region of maximum injury by guardrail end type. Table 9 shows the AIS body region of maximum injury for the 194 CODES records. Thirteen records had lower extremity as the body region of maximum injury. Table 10 shows the distribution of these 13 records by guardrail end type. The sample sizes are too small to perform any statistical analysis. Of specific interest, is the ET Plus and none of the records involved ET Plus.

Table 9. AIS Body Region of Maximum Injury.

Body Region	No. of Records
ABDOMEN & PELVIC	3
EXTERNAL/BURNS/OTHER	2
FACE	30
HEAD	23
LOWER EXTREMITY	13
SPINE	27
THORAX	6
UNKNOWN	65
UPPER EXTREMITY	24
MISSING	1
Total	194

Table 10. Distribution of Lower Extremity AIS Body Region of Injury by End Type.

MAIS Score	BCT	ET2000	SKT	SRT/BCT/MELT	No. of Records
MINOR	0	2	4	3	9
MODERATE	1	0	1	0	2
SERIOUS	1	0	1	0	2
Total	2	2	6	3	13

Table 11 shows the AIS body region of maximum injury for the 194 CODES records. Twelve records had extremities or pelvic girdle as the body region of maximum injury. Table 12 shows the distribution of these 12 records by guardrail end type. The sample sizes are too small to perform any statistical analysis. Of specific interest, is the ET Plus and only one of the records involved ET Plus.

Table 11. ISS Body Region of Maximum Injury.

Body Region	No. of Records
ABDOMEN & PELVIC GIRDLE	5
CHEST	2
EXTERNAL	77
EXTREMITIES OR PELVIC GIRDLE	12
FACE	2
HEAD/NECK	36
UNKNOWN	59
Total	194

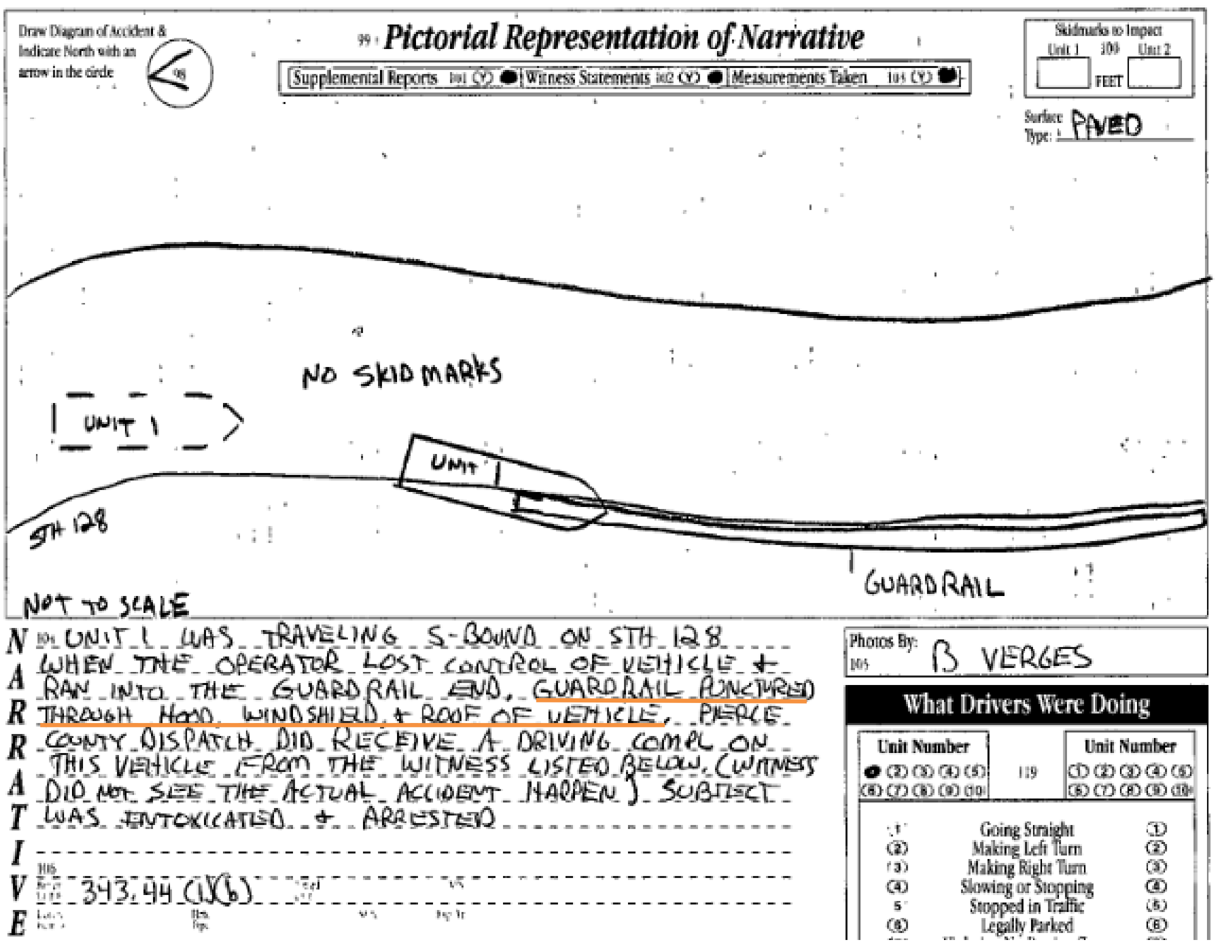
Table 12. Distribution of Extremities or Pelvic Girdle ISS Body Region of Injury by End Type.

MAIS Score	BCT	ET2000	ET Plus	SKT	SRT/BCT/ MELT	No. of Records
MINOR	0	1	0	0	1	2
MODERATE	1	1	0	3	0	5
SERIOUS	1	0	1	1	0	3
UNKNOWN	1	0	0	1	0	2
Total	3	2	1	5	1	12

APPENDIX B: INTRUSION INTO VEHICLE OCCUPANT SPACE

Crash reports in which intrusion of guardrail end into vehicle occupant space is described are shown below.

1. Accident number: 061004347
   End Type: Either BCT or /MELT
   Injury Severity: A



Pictorial Representation of Narrative

Draw Diagram of Accident & Indicate North with an arrow in the circle

Supplemental Reports (Y) | Witness Statements (Y) | Measurements Taken (Y)

Skidmarks to Impact: Unit 1 — FEET — Unit 2

Surface Type: PAVED

NO SKID MARKS

UNIT 1

UNIT 1

STH 128

GUARDRAIL

NOT TO SCALE

NARRATIVE: UNIT 1 WAS TRAVELING S-BOUND ON STH 128 WHEN THE OPERATOR LOST CONTROL OF VEHICLE + RAN INTO THE GUARDRAIL END. GUARDRAIL PUNCTURED THROUGH HOOD, WINDSHIELD, + ROOF OF VEHICLE. PIERCE COUNTY DISPATCH DID RECEIVE A DRIVING COMPL ON THIS VEHICLE FROM THE WITNESS LISTED BELOW. (WITNESS DID NOT SEE THE ACTUAL ACCIDENT HAPPEN) SUBJECT WAS INTOXICATED + ARRESTED

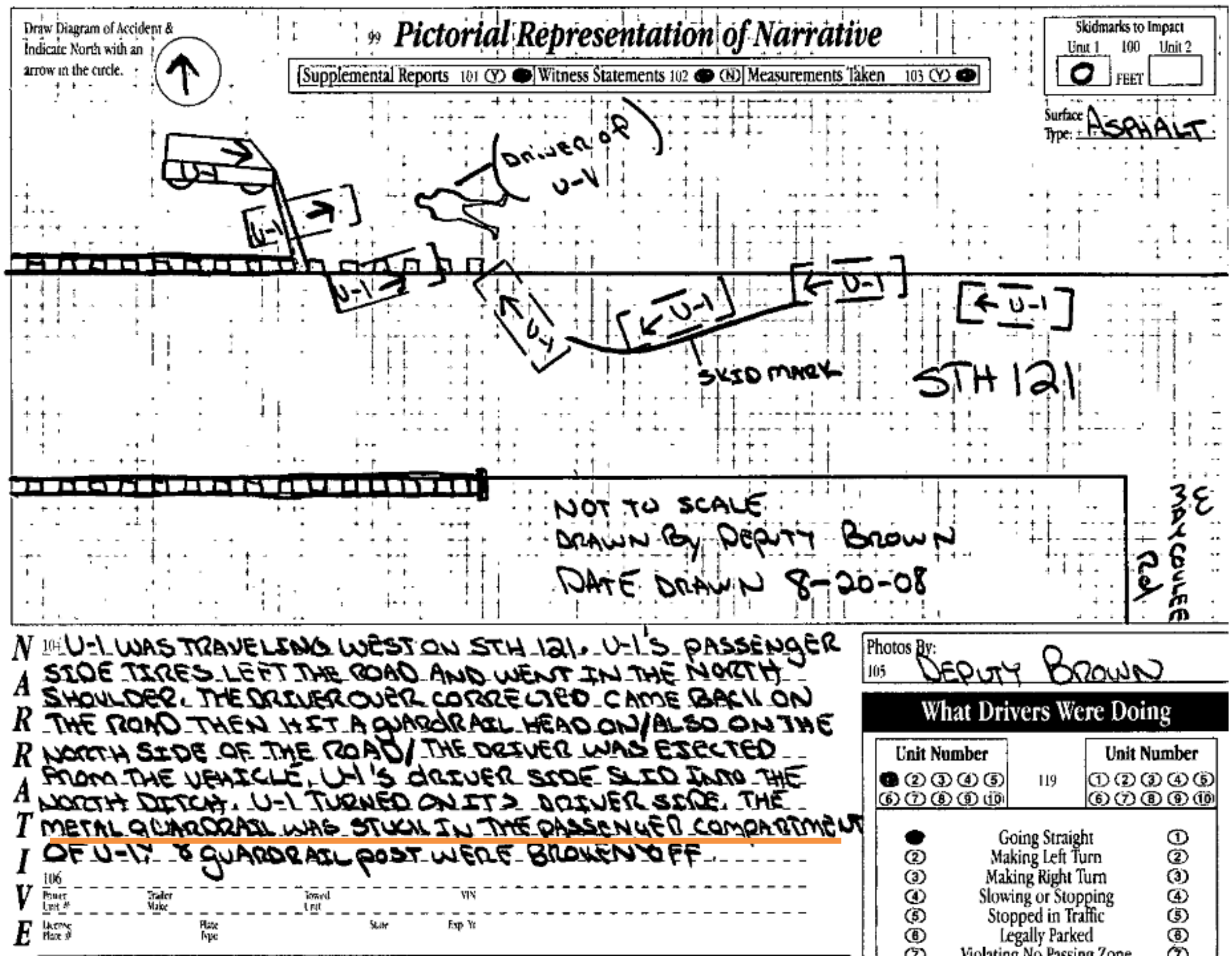
343.44 (1)(b)

Photos By: B VERGES

What Drivers Were Doing

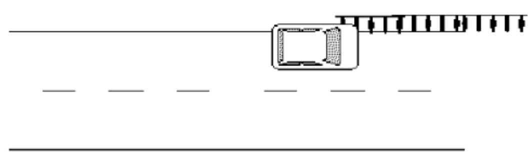
Unit Number		Unit Number
1	Going Straight	1
2	Making Left Turn	2
3	Making Right Turn	3
4	Slowing or Stopping	4
5	Stopped in Traffic	5
6	Legally Parked	6

2. Accident number: 080805727
   End Type: SKT
   Injury Severity: A



3. Accident number: 110801458
   End Type: MELT
   Injury Severity: B

DIAGRAM AND NARRATIVE



DRIVER STATED HE WAS TRAVELING SOUTHBOUND ON US HWY 51 AND LOST CONTROL OF HIS VEHICLE. THE VEHICLE SLID SIDEWAYS THROUGH THE MEDIAN AND STRUCK THE END OF A GUARD RAIL ON THE DRIVERS SIDE. THE GUARD RAIL CAME THROUGH THE VEHICLE AND THE DRIVER WAS PINNED IN THE VEHICLE. DRIVER STATED HE WAS GOING ABOUT 70MPH. THE ROAD WAS WET FROM RAIN.

APPENDIX C: CRASHES INVOLVING NON-PASSENGER VEHICLES

Non-passenger vehicles impacted guardrail ends in fifty-four crashes. Forty-five crashes were single-vehicle crashes and the rest were multi-vehicle crashes. One crash involved a motorcycle and the rest were all trucks. Crash severity distribution of these crashes are compared to crash severity distribution of passenger vehicle guardrail end crashes in Table 13. Guardrail ends are designed for passenger vehicles and hence one might expect poorer safety outcomes when other vehicles impact them. The proportion of fatal (K), incapacitating injury (A) and non-incapacitating injury (B) crashes is higher for non-passenger vehicle crashes than for passenger vehicles crashes.

Table 13. Crash Severity Distribution of Non-Passenger Vehicle and Passenger Vehicle Guardrail End Crashes.

Crash Severity	Non-Passenger Vehicle Crashes		Passenger Vehicle Crashes	
	# of Crashes	% of Crashes	# of Crashes	% of Crashes
K	3	5.6%	13	1.4%
A	7	13.0%	87	9.1%
B	8	14.8%	121	12.7%
C	5	9.3%	106	11.1%
PDO	37	57.4%	628	65.8%
Total	60		955	

APPENDIX D: DOCUMENT NUMBERS OF GUARDRAIL END CRASHES INLCUDED IN ANALYSIS

070801580
051109808
051115358
051201059
051203750
051209974
060108060
060204134
060204315
060204898
080105951
080116006
081008330
081100114
081207165
090504728
090605395
090900608
060400278
060404607
060407963
060807153
061200506
071002816
071200171
071205604
071207174
071208717
071209230
071212723
080102070
080202974
080204064
080204694
080205057
080205209
080301725
080302383
080307815
080403732
080505661
080509631
080607214
081212436
081213645
081214679
081217376
090105259
090206177
090407277
090502219
090908827
091103086
100109610
100204940
100403272
100406626
100605930
100802328
100802715
100900462
101005914
101006837
101012085
101108311
101111389
101207548
101214319
110100125
110105747
110107205
110109454
110209870
110211885
110300485
110309771
110403323
110407188
110407746
110505295
110605287
110705387
110802112
110802837
110805786
110805963
110901885
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111108623
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120105030
120105926
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120108463
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120403507
121108897
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121200661
121201442
121201496
121206311
130106369
130106426
130110454
130200678
130206168
130208716
130210748
130211981
130301033
130309801
130507415
130510395
130602781
130606124
130705159
130800247
130806106
131006372
131102509
131104794
131107324
131201070
131202233
131203772
051100178
061010589
070100574
080103363
080103374
080109184
080109396
080207728
080607733
080905422
081001334
081104158
081105066
081105609
081200508
081207534
081208730
081208740
081214261
081214551
090103852
090201388
090303421
090801229
090900341
090900425
091111150
091204309
091211960
101003658
101210982
110807392
131009831
131201536
131201564
131202260
050304430
050509564
050800227
050801990
051000691
051004737
051008943
051101166
051101962

070800239	080706134	090807966	070807948
070801096	080800081	090901328	070807982
050903866	080803989	090902323	070900851
050904255	080805727	090902630	070905256
051102289	080807931	090905286	071000626
051107798	080808176	090905507	071002093
051107917	080809601	090906604	071003037
051107989	080900804	060304293	071006372
051108175	080901400	060306756	071008059
051109097	080907447	060307068	071102954
051110902	081004428	060308928	071105580
051113678	081007027	060309828	071106085
051114372	081011330	060401005	071113278
051200026	081102041	060401447	071200265
051200546	081103126	060402757	071201139
051202512	081204115	060403614	071202218
051207119	081204801	060406176	071203088
051209217	081204954	091205022	071204224
051209969	081205269	091205369	071206935
051212025	081207228	091206218	071208050
051214497	081207817	091207284	071208310
060104590	081208978	050100425	071208940
060105807	081210660	050101605	071209476
060106069	060207463	060409379	071210190
060106414	060209518	060500243	071210627
060108057	060300033	060500460	071211302
060109400	060300079	060503172	071212307
060109887	060300534	060504857	071213118
060111002	060301257	060505055	071215493
060200155	060302038	060509468	071215556
060200281	060302290	060510326	071215988
060204443	060303718	060510902	071217394
060205002	090506765	060600061	080100251
060205263	090507056	060610349	080100794
060205635	090601825	060700414	080101379
080105148	090604193	060700993	080102310
080111948	090606252	060704122	080102394
080112015	090606256	060705144	080203166
080112592	090700330	061004347	080203269
080113804	090701826	061102174	080204411
080114474	090701838	070300936	080204658
080115306	090706632	070500590	080206165
080200462	090707858	070508586	080206219
080200979	090707890	070603584	080208487
080202606	090800620	070801895	080210671
080705533	090800957	070807382	080300496

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080303528	090301809	100202073	100905040
080304109	090301841	100202688	100905798
080304630	090303266	100203535	100909346
080304979	090303298	100207454	101004328
080401329	090303705	100207567	101006233
080404685	090307263	100207604	101006619
080405940	090307553	100208182	101007391
080505950	090308342	100303496	101010287
080508155	090402441	100304343	101103434
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110302836	111202407	121202176	130301841
110306231	111206078	121202730	130301844
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110607183	120300037	130201357	130507389
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