Memorandum

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

Subject:	Envoy/Bravada Stalling General Motors ride and drive evaluation	Date:	June 22, 2004
From:	Cynthia Glass CAG Office of Defects Investigation	Reply to Attn of:	NVS-212 cag
To:	File for EA03-007		

The memo dated March 18, 2004, along with its attachments, were held until the closing resume was written. That is why the memo is dated 3 months before it was actually uploaded into the repository.

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Subject:	NCSA Weibull Warranty Analysis Report GM Envoy/Bravada Engine Stall	Date:	March 18, 2004
From:	Cynthia Glass Office of Defects Investigation	Reply to Attn of:	NVS-212 cag
To:	File for EA03-007		

NHTSA opened an investigation on engine stall on GM's Model Year 2002 Envoy with ECAS and Oldsmobile Bravada. GM provided warranty data as part of its December 18, 2003 response to ODI's information request letter supplement. ODI requested the National Center for Statistics and Analysis (NCSA) to analyze the data, and to specifically use Weibull analysis to determine if the results identify the stalling as early life failures or wear out failures. ODI provided the following data from GM to NCSA in electronic format:

- Vehicle Production data
- Vehicle Warranty start date
- Warranty repair records (including vehicle mileage, time in service and other warranty data)

Attached are NCSA's findings.

Survival Analysis of Warranty Data Associated with Stalling Due to ECAS and PCM Failure

Prepared by: National Center for Statistics and Analysis, NHTSA
For: Office of Defect Investigations, NHTSA
January 28, 2004

This report examines warranty claim data supplied by General Motors Corp. in response to a request for information from the National Highway Traffic Safety Administration's (NHTSA's) Office of Defect Investigations (ODI). The request for information concerned vehicles where voltage from the electronically controlled air suspension (ECAS) degrades the performance of the power train control module (PCM) resulting in engine stall. The vehicles involved were the 2002 GMC Envoy and Oldsmobile Bravada.

ODI requested that NHTSA's National Center for Statistics and Analysis (NCSA) conduct a Weibull survival analysis. ODI provided NCSA with production data at the VIN level including production date and warranty start date, as well as warranty claim data by VIN. NCSA merged the files and derived months-in-service variables. By ODI specification, any vehicle without a known warranty start date was deleted, and any vehicle with a claim occurring before the warranty start date was considered to have had its claim made at age zero, in effect removing it from the analysis. Fractional months-in-use values were rounded up to whole months, in keeping with traditional Weibull analysis convention. A summary of data steps is provided in Appendix A, and Appendix B shows a resulting table.

Analysis by Months-In-Use and Model

In consultation with ODI, the warranty data were subjected to analyses using both a 12-month and 18-month test period. Those vehicles not having at least the number of test period months between warranty start date and cutoff date were deleted, and only claims made within the test period were flagged as failures. Any vehicle attaining a lifespan equivalent to the test period without a claim became a "right-censored" or non-failure data point. The cutoff date used was December 16, 2003, the date of the information submission from GM. Additionally, the test was limited to vehicles produced before December 6, 2001, since vehicles produced after that date were fitted with modified ECAS wiring bundles and PCMs to address the stalling problem.

During discussions with ODI, GM asserted that Envoys and Bravadas manufactured between November 1 and December 6, 2001, had been provided with an "interim fix" to the stalling problem and should thus be excluded from the analyses. In response, we conducted 12- and 18-month analyses on three different vehicle populations: those manufactured from August 11, 2000 (Job 1) through October 31, 2001; those manufactured between November 1, 2001 and December 6, 2001; and both populations combined.

The data were analyzed by vehicle model using the SAS procedure RELIABILITY, fitting the data to a Weibull distribution. For each combination of vehicle model, test period, and manufacture date, shape parameters ("beta") were estimated via the method of maximum likelihood. Shape parameters less than one generally indicate an "infant mortality" lifetime distribution; shape parameters of one usually indicate "random failure" distributions; and shape parameters greater than one are generally considered indicative of the type of lifetime distribution known as "wearing out". Table 1 shows the estimates. The "n-Claim" column gives the number of vehicles with at least one relevant claim during the test period and the "n-No Claim" column gives the corresponding number of vehicles surviving the test period with no claim, or the "right-censored" data.

Manufacture Date	Test Period (months)	Make	Beta	Beta 95% Confidence Interval	"n" Claim	"n" No Claim
8/11/00–10/31/01	12	GMC	1.110	(1.0506, 1.1734)	1229	12999
		Olds	1.029	(0.9908, 1.0682)	2621	18647
	18	GMC	0.993	(0.9464, 1.0418)	1611	12422
		Olds	0.925	(0.8943, 0.9251)	3200	16600
11/01/01-12/06/01	12	GMC	1.296	(1.0463, 1.6059)	83	2432
		Olds	1.354	(1.0195, 1.7981)	47	807
	18	GMC	1.288	(1.0804, 1.5348)	123	2293
		Olds	1.254	(0.9353, 1.6805)	44	660
8/11/00–12/06/01	12	GMC	1.119	(1.0607, 1.1805)	1312	15431
		Olds	1.033	(0.9949, 1.0719)	2668	19454
	18	GMC	1.007	(0.9618, 1.0553)	1734	14715
		Olds	0.928	(0.8970, 0.9593)	3244	17260

Note that the combined groups are dominated by the first group since it had many more vehicles produced, and the parameters reflect that fact. The shape parameters close to 1 seen in the most relevant group, those manufactured 8/11/00–10/31/01, are close to 1 and in most cases are not statistically significantly different from 1 (as seen in the confidence intervals). Thus the lifetimes are modeled as "random failures", that is, knowing how long a component has survived does not give information on how long it is likely to continue to survive. It could be said that the component could go at any time. This unpredictability is reflected in the graph of the failure rate or hazard rate, which shows the likelihood of failure in the next moment, given that a component has survived up to a given time as shown on the x-axis. Figure 1 shows the Weibull-fit failure rates of the vehicles manufactured 8/11/00–10/31/01 under the twelve-month test, and shows that they are nearly straight lines. The shape parameters of the "interim fix" group are further from one, and although not extremely so, they show more of a "wearing out" life cycle where the likelihood of failure increases with time. The failure rates for the interim fix group are displayed in Figure 2. (Failure rates for the 18-month test are not shown but are similar.) Properties and behaviors of the Weibull distribution are summarized in Appendix C.

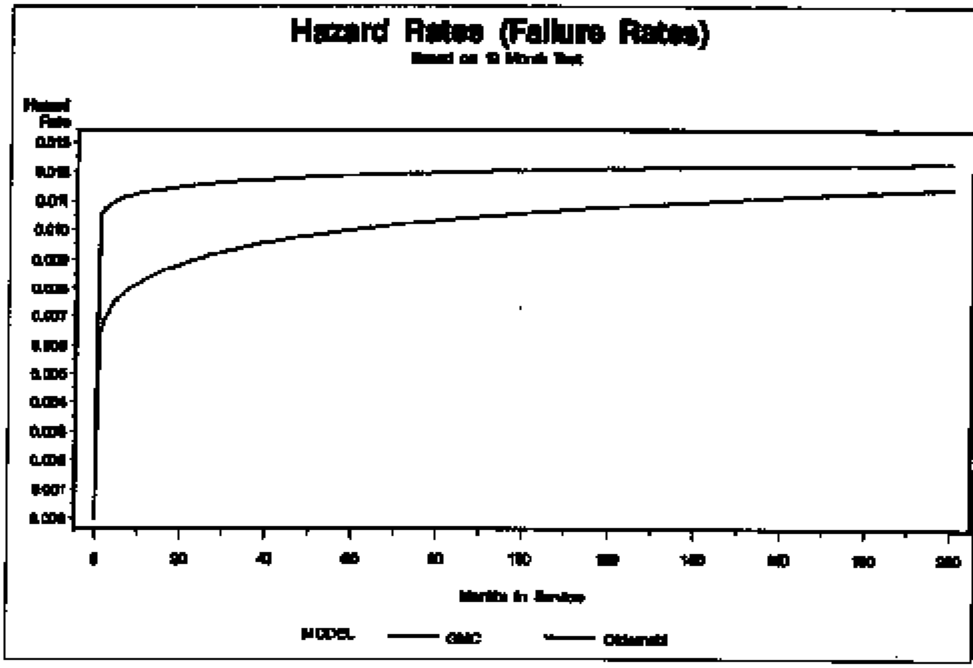


Figure 1

Vehicles Manufactured 8/11/00 - 10/31/01 12 Month Test Hazard Rate

GMC Beta=1.11
Olds Beta=1.029

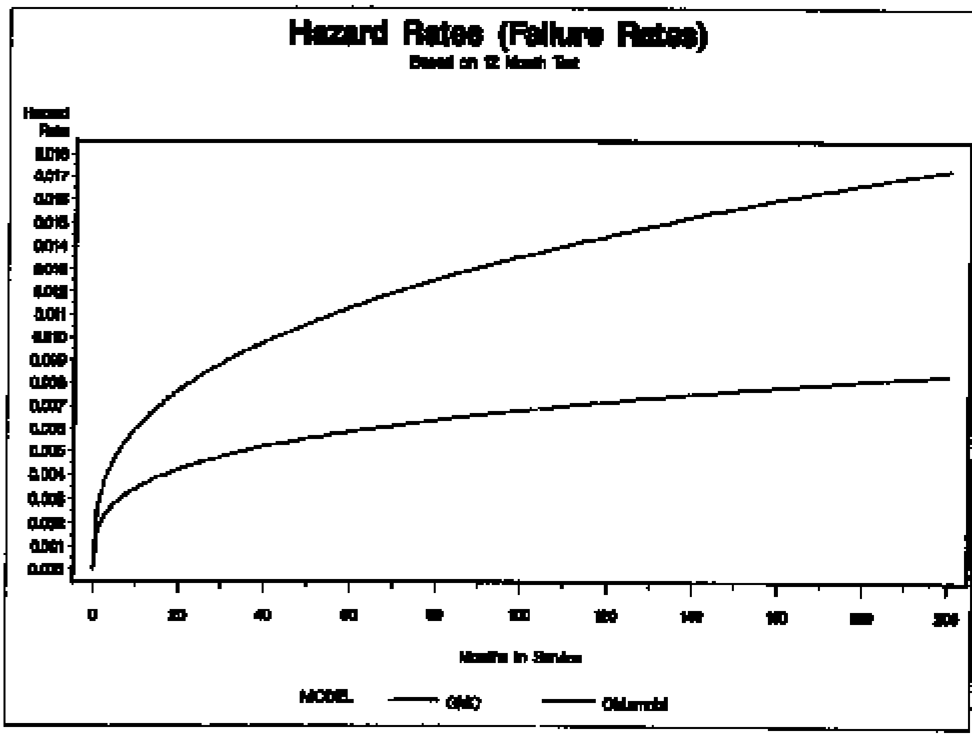


Figure 2

Vehicles Manufactured 11/01/01 – 12/06/01 (Interim Fix) 12 Month Test Hazard Rate

GMC Beta=1.296
Olds Beta=1.354

Conclusions

Various analyses were conducted on the GM Envoy and Bravada stalling claims. The production data and warranty data were merged and a Weibull analysis was performed on various combinations of make, test periods and vehicle manufacturing date groups. Noteworthy results included the following:

- For the vehicles with no fix (manufactured 8/11/00-10/31/01), each make-model fit to a Weibull distribution produced shape parameters close to 1.
- Shape parameters close to 1 are consistent with the type of lifetime distribution known as "random failure".
- For vehicles with an interim fix (manufactured 11/01/01-12/06/01), shape parameters were slightly higher than one and thus more indicative of the type of lifetime distribution known as "wearing out."

Thus the interpretation of these results would be that the components installed before November 1, 2001 are failing at random, meaning that prior life length does not give a good prediction of future life.

Appendix B shows the empirical frequency data in table and chart formats for the 12-month test applied to vehicles with and without the interim fix.

Appendices:

A. **Data Preparation**

B. **Months-In-Service Empirical Data - Tables and Charts**

C. **The Weibull Distribution in Survival Analysis**

Appendix A

Data Preparation

Certain steps were necessary to put the provided data into a form appropriate for analysis; the major steps are summarized below.

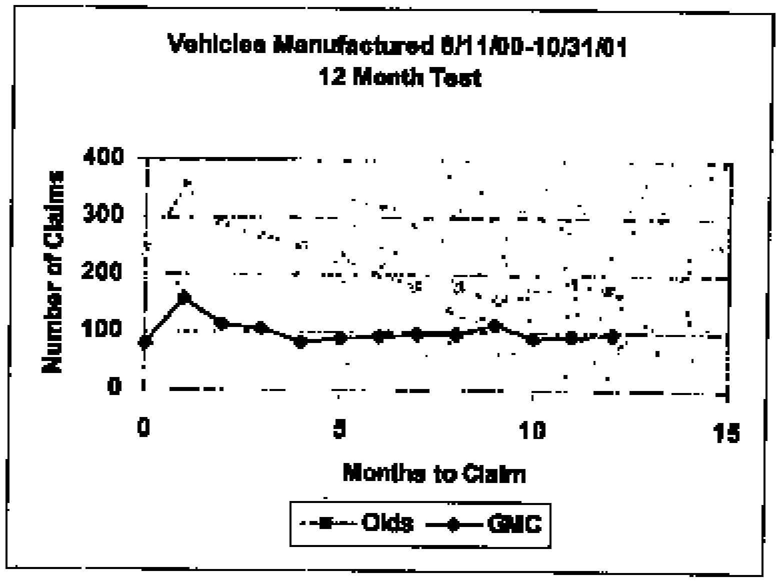
1. The warranty and production data sets were imported into SAS.
2. A variable for reference date was set as December 16, 2003.
3. A tally was made of how many times a vehicle had undergone a warranty claim.
4. Extra warranty claims were removed so that any vehicle having more than one claim was represented only by the initial claim.
5. The warranty and production data sets were merged by VIN.
6. Variables were constructed to represent days between warranty start date and claim date, and days between warranty start date and reference or cutoff date.
7. Days were converted to months by taking the largest integer in days/30.4 and adding 1, so that an event occurring during month t was recorded as a claim upon t months, in keeping with traditional Weibull analysis usage.
8. Variables for time at outcome were created based on months in field at repair (if claim) or at reference date (if no claim).
9. Vehicles were deleted if manufactured after December 6, 2001, or if warranty start date unknown.
10. If claim date precedes warranty start date, time in field at repair set to zero.
11. For months data, if claim in first (test period 12 or 18) months of life, censor variable set to 0 (uncensored), else set to 1 (right-censored).
12. Frequency data sets were constructed consisting of make-model, number of months to claim, number of claims, censor variable.

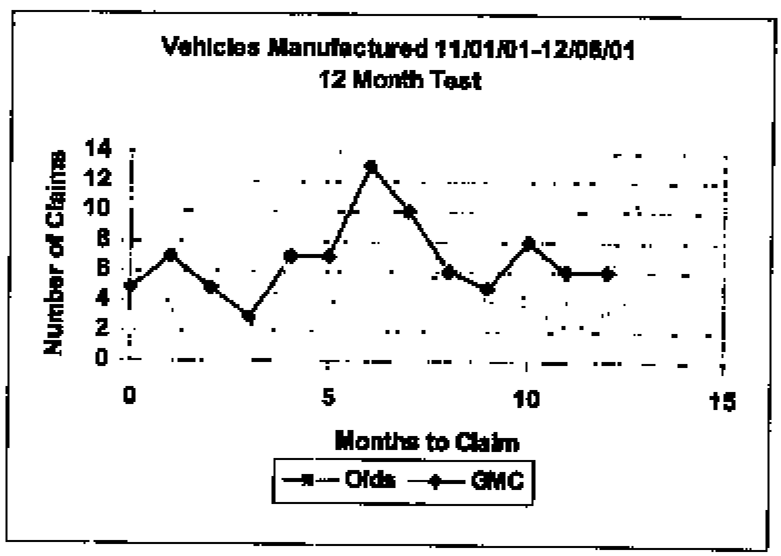
Appendix B

Months-In-Service Data Tables

The steps of Appendix A applied to the 12-month test periods for vehicles manufactured with the interim fix (8/11/00-10/31/01) and without it (11/01/01-12/06/01) resulted in the following table and corresponding charts. Note that the charts do not take into account the right-censored data, whereas the Weibull fit does take the right-censored data into account in estimating its parameters.

12-Month Test Number of Claims by Make, Months to Claim and Date of Manufacture			
Model	Months To Claim	Number of Claims Manu. Date 08/11/00-10/31/01	Number of Claims Manu. Date 11/01/01-12/06/01
GMC	0	79	5
GMC	1	159	7
GMC	2	114	5
GMC	3	108	3
GMC	4	82	7
GMC	5	91	7
GMC	6	94	13
GMC	7	95	10
GMC	8	97	6
GMC	9	113	5
GMC	10	89	8
GMC	11	92	6
GMC	12	95	6
Olds	0	238	2
Olds	1	352	3
Olds	2	289	2
Olds	3	266	2
Olds	4	254	6
Olds	5	229	4
Olds	6	203	6
Olds	7	175	5
Olds	8	179	6
Olds	9	155	4
Olds	10	165	4
Olds	11	185	2
Olds	12	172	3
GMC	No Claim	12999	2432
Olds	No Claim	18647	807





Appendix C

The Weibull Distribution in Survival Analysis

The theoretical population models used to describe unit lifetimes are known as lifetime distribution models. The population is generally considered to be all of the possible unit lifetimes for all of the units that could be manufactured based on a particular design and choice of materials and manufacturing process. A random sample of size *n* from this population is the collection of failure times observed for a randomly selected group of *n* units.

A lifetime distribution model can be any *probability density function* (or PDF) f(t) defined over the range of time from t = 0 to t = infinity. The corresponding *cumulative distribution function* (or CDF) F(t) is a very useful function, as it gives the probability that a randomly selected unit will fail by time t. The 2-parameter Weibull distribution is an example of a popular F(t). It has the CDF and PDF equations given by:

$$F(t) = 1 - e^{-\left(\frac{t}{\alpha}\right)^{\beta}} \quad \text{and} \quad f(t) = \frac{\beta}{\alpha}\left(\frac{t}{\alpha}\right)^{\beta-1} e^{-\left(\frac{t}{\alpha}\right)^{\beta}}$$

where β is the "shape" parameter and α is a scale parameter (the 63.2th lifetime percentile, generally denoted the "characteristic life").

The reliability function R(t), also known as the survival function S(t), is defined by:

R(t) = S(t) = the probability a unit survives beyond time *t*.

Since a unit either fails, or survives, and one of these two mutually exclusive alternatives must occur, we have

R(t) = 1 - F(t), F(t) = 1 - R(t)

Calculations using R(t) often occur when building up from single components to subsystems with many components.

The hazard rate is defined for non-repairable populations as the (instantaneous) rate of failure for the survivors to time *t* during the next instant of time. It is a rate per unit of time similar in meaning to reading a car speedometer at a particular instant and seeing 45 mph. The next instant the failure rate may change and the units that have already failed play no further role since only the survivors count.

The hazard rate (or instantaneous failure rate) is denoted by h(t) and calculated from

$$h(t) = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{R(t)} = \text{the hazard rate.}$$

The hazard rate is sometimes called a "conditional failure rate" since the denominator 1 - F(t) (i.e., the population survivors) converts the expression into a conditional rate, given survival past time *t*. For the Weibull distribution, the hazard rate is given by $\frac{\beta}{\alpha}\left(\frac{t}{\alpha}\right)^{\beta-1}$ and the Cumulative Hazard Function for the Weibull is the integral of the hazard rate or

$$H(t) = \left(\frac{t}{\alpha}\right)^{\beta}.$$