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THE COMPOUND GROWTH OF DOLLAR ENTROPY ON A NEW DESIGN IN THE FIELD DUE TO A DEVASTATING EVENT

INTRODUCTION

In the world of industrial design there are many examples of designs which should have never been adopted because of possible devastating disasters waiting to happen. The most prominent example for the whole world to see is the Chernobyl nuclear power plant.

In the automotive world we have seen many an example of a design without which the manufacturer would have been better off because one devastating event triggered **false assumptions** by the news media about the unreliability of the design.

In this bulletin we shall discuss the concept of **Dollar Entropy** and how it can be used to show in advance that certain types of designs should never be attempted due to the fact that the **Dollar Loss per Item Sold** can mushroom beyond any possible profitable expectations which may have been imagined for the design. Such a mushrooming of losses can be triggered by one disastrous experience by a customer using the design when it becomes obvious that the design, by its very nature, is vulnerable to being blamed falsely.

THE FIRST RULE IN DEVELOPING A RELIABLE PRODUCT

Back in 1981 Detroit Research Institute published a bulletin entitled **The Five Rules For An Effective Reliability Program.** This was Volume 11, Bulletin 2, May, 1981. In that bulletin it was pointed out that the **First (and most important) Rule was:**

Rule #1 : To build adequate reliability, you must count the cost of failures, as well as the profits of success.

The whole purpose of this rule is to avoid situations in which losses due to unreliability in a product would wipe out all profits from sales of the product, or even exceed all profits.

As far as profits from sales of reliable items are concerned, there is no great difficulty in determining them, once we know the cost of research, development, and production involved, as compared to the selling price.

The tricky part of the design evaluation process is the prediction of losses which could be experienced due to various troublesome factors which might be involved in the product's usage by customers. Generally speaking, there are two main types of bad factors causing failure losses. These are:

(a) Non-Catastrophic Factors
(b) Catastrophic Factors

Non-catastrophic factors are what might be called inconvenience or nuisance factors, such a short times between needed corrections or repairs, or failures which violate warranty promises by failing too early. Non-catastrophic factors which occur too frequently are a source of loss to the manufacturer in various ways, such as:

1. Losses requiring the producer to pay for failures occurring before warranty has expired.

2. Losses due to a drop in customer loyalty due to dissatisfaction caused by having more failures than a competitor's similar product.

Catastrophic factors present much more difficult situations to be coped with. This is because litigation might be involved in cases of serious injury or death, or disastrous environmental effects on human health or property. Furthermore, special situations could involve allergic reactions from medical supplies or pharmaceuticals. Critical machine parts which pass ordinary usage tests might not pass in rare cases of certain extraneous factors which might cause a malfunctioning of the machine and thus make it to appear that the machine is not reliable enough to prevent the serious injuries or deaths which might result when, for example, a drunken operator is involved. More than once it has turned out the news media have convinced the public that machinery should be designed so as to automatically give protection against all types of carelessness and cases of violated safety rules. For such reasons it is necessary to imagine worst case scenarios and their resulting catastrophic effects before ever approving any design which might be vulnerable to such extreme situations. As the well known saying goes, "Make your product idiot-proof!" This is all a reminder that Murphy's Law still holds, and
LET THE SELLER BEWARE !

AN EXAMPLE OF PLOTTING DOLLAR ENTROPY CALCULATIONS

Suppose a certain machine produced and sold has the following history over the first 150 days since deliveries to customers began:

TABLE 1 (With Catastrophic Failure)

PROBLEM TITLE: AN EXAMPLE OF PLOTTING DOLLAR ENTROPY
WITH SAMPLE SIZE = 8473

AGE IN DAYS SINCE DELIVERY WHEN IN THE INTERVAL	NO. OF MACHINES IN INTERVAL	TOTAL FAILURE EXPENSE ON ALL SOLD MACHINES
15.00	1,014.00	$ 15,600.00
30.00	1,255.00	$ 12,109.00
45.00	970.00	$ 10,254.00
60.00	1,339.00	$ 8,408.00
75.00	892.00	$ 6,751.00
90.00	1,127.00	$1,450,011.00
105.00	655.00	$ 2,756.00
120.00	542.00	$ 1,765.00
135.00	460.00	$ 852.00
150.00	219.00	$ 294.00

TABLE 1A (Without Catastrophic Failure)

PROBLEM TITLE: AN EXAMPLE OF PLOTTING DOLLAR ENTROPY
WITH SAMPLE SIZE = 8472

AGE IN DAYS SINCE DELIVERY WHEN IN THE INTERVAL	NO. OF MACHINES IN INTERVAL	TOTAL FAILURE EXPENSE ON ALL SOLD MACHINES
15.00	1,014.00	$ 15,600.00
30.00	1,255.00	$ 12,109.00
45.00	970.00	$ 10,254.00
60.00	1,339.00	$ 8,408.00
75.00	892.00	$ 6,751.00
90.00	1,126.00	$ 4,812.00
105.00	655.00	$ 2,756.00
120.00	542.00	$ 1,765.00
135.00	460.00	$ 852.00
150.00	219.00	$ 294.00

DOLLAR ENTROPY ANALYSIS OF THE DATA

We analyze the dollar loss data in the example by employing the **Dollar Entropy Method,** as explained in DRI's Statistical Bulletin #3 of Volume 18, published in July of 1988. This procedure produces the following table:

TABLE 2

PROBLEM TITLE: AN EXAMPLE OF PLOTTING DOLLAR ENTROPY
WITH SAMPLE SIZE = 8473

DOLLAR HAZARD = DOLLAR LOSS PER MACHINE IN INTERVAL
DOLLAR ENTROPY = CUMULATIVE LOSS PER MACHINE

END PT.	NO. ACTIVE	DOLLAR HAZARD	DOLLAR ENTROPY
15.00	7,966.00	1.9583	1.9583
30.00	6,831.50	1.7725	3.7308
45.00	5,719.00	1.7930	5.5238
60.00	4,564.50	1.8420	7.3659
75.00	3,449.00	1.9574	9.3232
90.00	2,439.50	594.3886	603.7119
105.00	1,548.50	1.7798	605.4916
120.00	950.00	1.8579	607.3496
135.00	449.00	1.8976	609.2471
150.00	109.50	2.6849	611.9320

The above data includes the Catastrophic Failure.

NOTE: Detroit Research Institute has a Computer Program (GRPENT) which automatically calculates the Number Active, the Dollar Loss in each interval, and the Dollar Entropy. This program is part of the software package given to all those who attend the seminars on Statistical Methods for the Study of Field Failures.

If the one machine with the catastrophic failure is omitted, and we take the 1,126 other machines in the 76 to 90 day day interval, we find that the losses in that interval total only to $4,812. Our loss table becomes modified as follows (Without Catastrophic Event):

TABLE 3

PROBLEM TITLE: AN EXAMPLE OF PLOTTING DOLLAR ENTROPY
WITH SAMPLE SIZE = 8472

DOLLAR HAZARD = DOLLAR LOSS PER MACHINE IN INTERVAL
DOLLAR ENTROPY = CUMULATIVE LOSS PER MACHINE

END PT.	NO. ACTIVE	DOLLAR HAZARD	DOLLAR ENTROPY
15.00	7,965.00	1.9586	1.9586
30.00	6,830.50	1.7728	3.7314
45.00	5,718.00	1.7933	5.5246
60.00	4,563.50	1.8424	7.3671
75.00	3,448.00	1.9579	9.3250
90.00	2,439.00	1.9729	11.2980
105.00	1,548.50	1.7798	13.0778
120.00	950.00	1.8579	14.9357
135.00	449.00	1.8976	16.8332
150.00	109.50	2.6849	19.5181

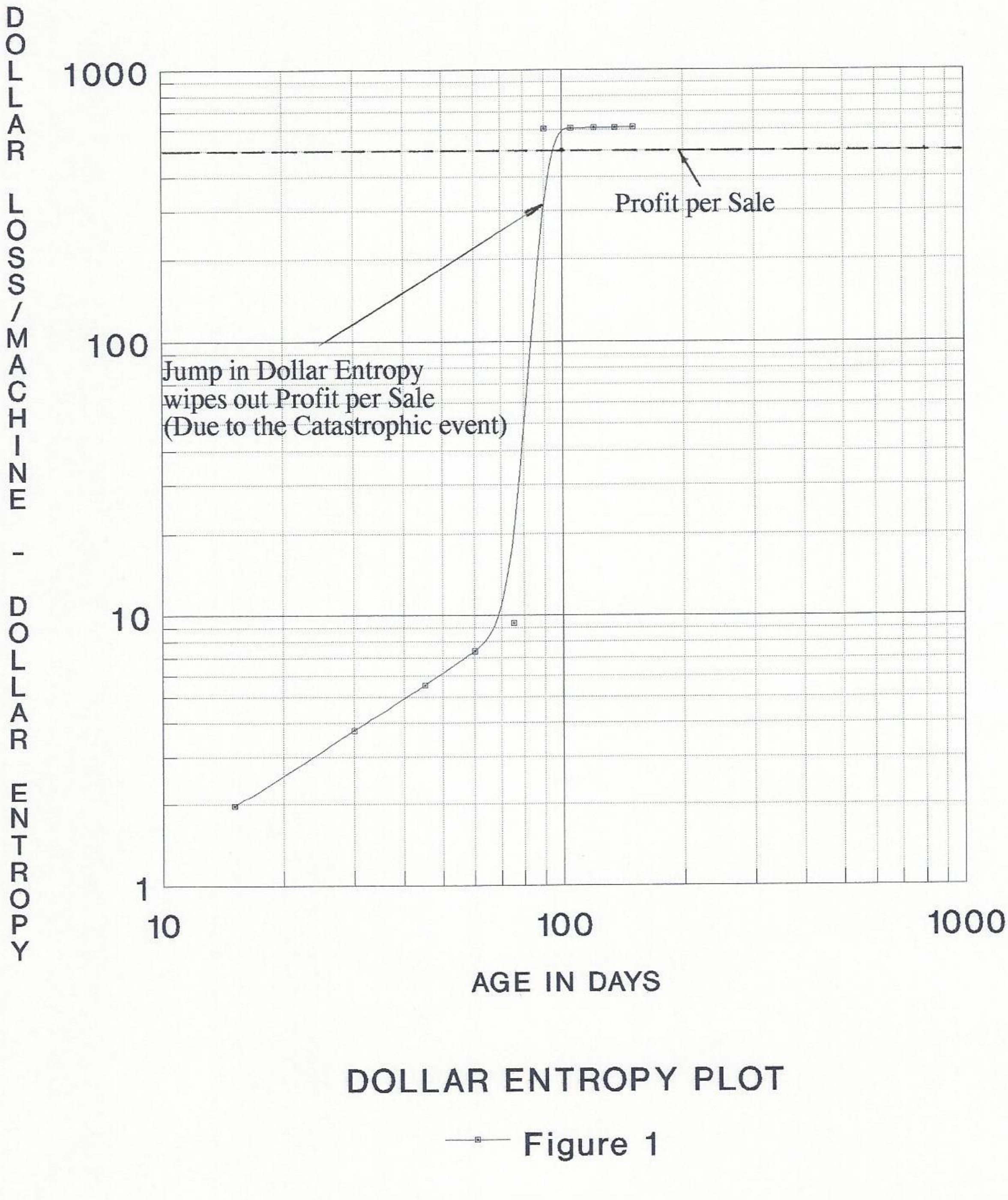
The above data does not include the Catastrophic Failure.

We plot the **Dollar Entropy** as ordinate versus **Ages in Days** as abscissa on Entropy Paper for both Tables 2 and 3. The plots are shown in Figures 1 and 2, respectively. It can be seen that the one catastrophic event increases the **Loss per Machine** by $592.41 after the event takes place. Without the catastrophic event, we end up with a **Loss per Machine** of $19.52 after 150 days of usage by customers.

CONCLUSION

It can be seen that without the catastrophic event the **Loss per Machine** after the 150 days of service is only $19.52. If these machines are sold at a profit of $500 per machine, the seller would still have a profitable business, as long as there is no catastrophic failure as the one which occurred in the 76 to 90 day interval. However, the one catastrophic failure, which added an additional **Loss per Machine of $592.41** after it happened, has caused this particular machine model to become unprofitable.

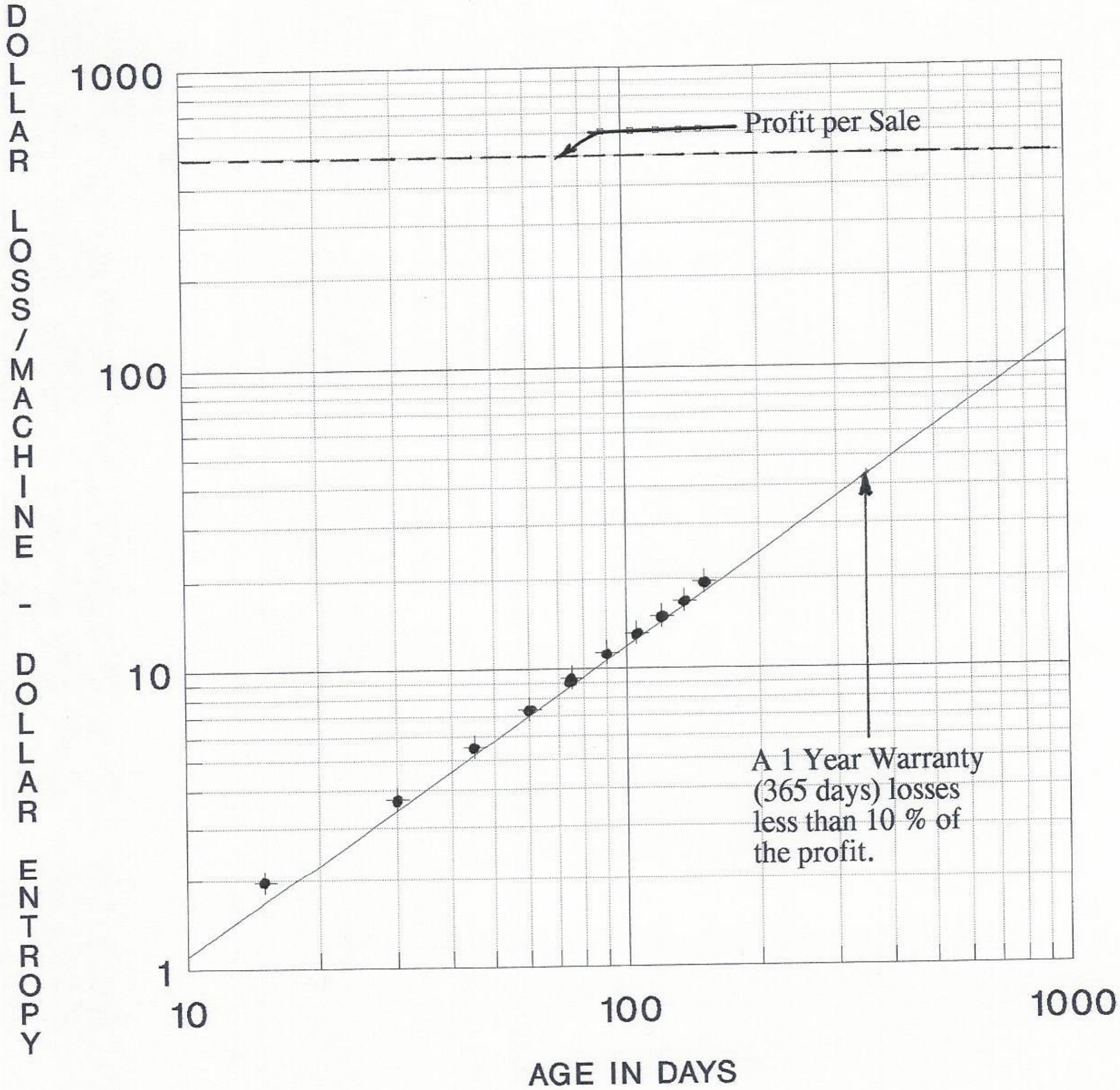
This is a clear example of how a catastrophic factor can make a design to be unacceptable because the **Jump in Dollar Entropy** is so great that it destroys profitability. It's just another example of the importance of **Rule #1 in the development of DESIGN RELIABILITY.**



DOLLAR ENTROPY PLOT

Figure 1

ENTROPY PLOT WITH CATASTROPHIC EVENT



DOLLAR ENTROPY PLOT

Figure 2

ENTROPY PLOT WITHOUT CATASTROPHIC EVENT

APPENDIX

In considering the problem of estimating losses from the so-called **Catastrophic Factors** it must be admitted that we are not dealing with determinate situations which can be predicted exactly as to when or how they will occur. What we actually have is a probabilities situation for which statistical data must be gathered and studied for each and every accidental event relevant to any particular devastating outcome which would give a product design a bad name. For this reason what is needed is complete teamwork by experts on accident statistics, designers, insurance personnel, manufacturing experts, quality control people, and reliability engineers in products produced, as well as experts on human reliability and capability variance. This is the only way an organization can hope to make logical estimates of possible losses to be expected due to catastrophic factors. Furthermore, the total volume of items sold to customers in the field will determine the amount of exposure to the risks of devastating events. For all these reasons we have to be careful not to judge a product by merely the number of cases of serious human loss, but rather the rate of occurrence per item out in the field. It must be realized that the producer selling the most items of a certain class can expect more bad accidents, other things being equal. It is a fact of life that the greater the exposure is, the more bad events we can expect. The conclusion we come to must be the result a careful statistical analysis of accident totals over specific time periods (for example, fiery accidents per year), as well as the probabilities involved in the environments where products are used, together with the exposure factors generated by sales volumes.