THE KEY TO FUNCTIONAL ANALYSIS:
"WHAT ELSE WILL DO THE JOB"

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Tom was born and raised in Detroit. He worked in his father's machine shop before completing his BSME in 1974 and moving to Ford Motor Company as a product design engineer. He was introduced to Value Engineering in 1979 during his graduate study at the University of Detroit.

Tom landed in Florida in 1984, with his wife and two children where, for the past 8 years, Tom has been a change agent for Harris Corporation. He contributes major success where Value Engineering, Design to Cost, and Functional Analysis is applied at the system level. Currently, Tom has received three patents awards by applying Value Engineering.

ABSTRACT

This paper contains case studies which evaluate problems using functional and cost analysis using different perspectives to allow selection of the optimum solution

INTRODUCTION

A good functional description of the technical requirements starts the process. Time and/or costs must be calculated for each element of the total process to determine where the cost drivers are. The design technique must provide an understanding of "HOW" the solution was derived from the problem description.

In the next stage the problem solver considers solutions using many different perspectives, so that new ideas can be introduced.

THE PROCESS

Some engineers and problem solvers don't search all possibilities when seeking a solution, because they know or think too much about the expected outcome. Usually, the same solutions are recommended because problems are approached using the same perspective and analytical process every time. A chef in a restaurant is not likely to solve a problem using the same perspective as an aerospace engineer. When a leader describes the problem using good functional descriptions, the problem solvers are more likely to have creative ideas that are outside the bounds of typical solutions. Solutions to problems depend greatly on the perspective taken during the description the problem.

Judging the final solution for optimization should include cost to importance ratios, as well as the cost effectiveness of making the change. The features that are most important, should cost the most, and the costs to implement should be reasonable for the task.

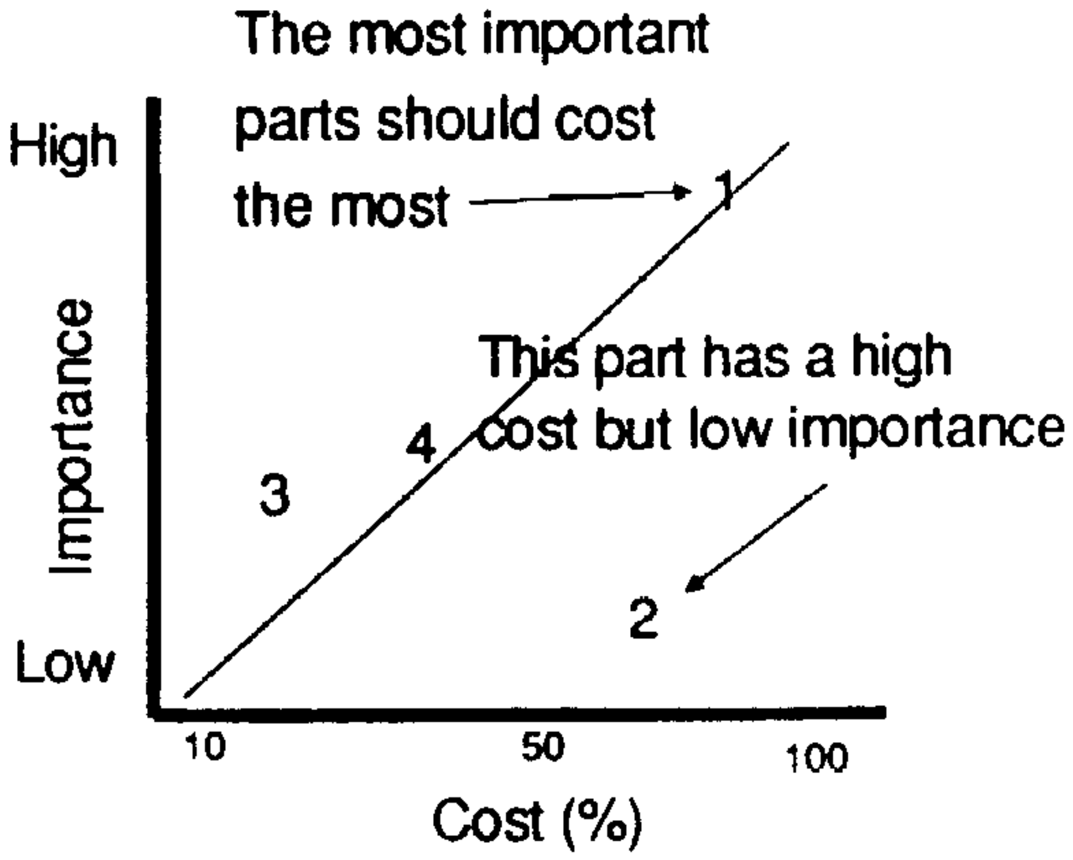

Figure 1 Cost to Importance

In making the transition from a word to a solution and then judging it, the questions to be asked is "What else will do the job?". This is when the perspective of different problem solvers comes into play. The examples of this article demonstrate the process of solving problems by emphasizing the following steps:

1. Provide a good problem statement using functional relationships
2. Determine the importance (cost, time, etc.) of all features
3. Construct FAST diagrams
4. Concentrate on the design implementation
5. Ask "What else will do the job ?"

Example #1 - THE COLD HOTEL

The way your mind associates words is a complex issue, but the results can begun to be understood using the first example. During a visit to a conference in Miami Beach, some cold temperatures hit the Florida area. Everything in the hotel room, including the bed and furniture coasted down to a crisp 50 degrees. At this temperature it is very difficult to get any sleep. The hotels don't experience this problem often and are not prepared to heat their hotels.

Problem statement:

You must heat the hotel room to be warm and able to comfortably sleep so you can attend a SAVE meeting in the morning.

The problem statement describes the necessary requirements to the problem solvers, using the words "HEAT" and "WARM". Asking the question "What produces "HEAT" in a hotel room, a person might begin to visualize the hotel room and consider all the sources that would "Conduct HEAT". Why? So you can become "WARM". The television produces heat, so does the radio, lamp, and coffee maker. Unfortunately none or all of them are sufficient to raise the temperature of a 5000 cubic foot room ten degrees. Using the words HEAT and WARM from the problem statement didn't provide a quick solution. Is there another word that gets us closer to the solution ?

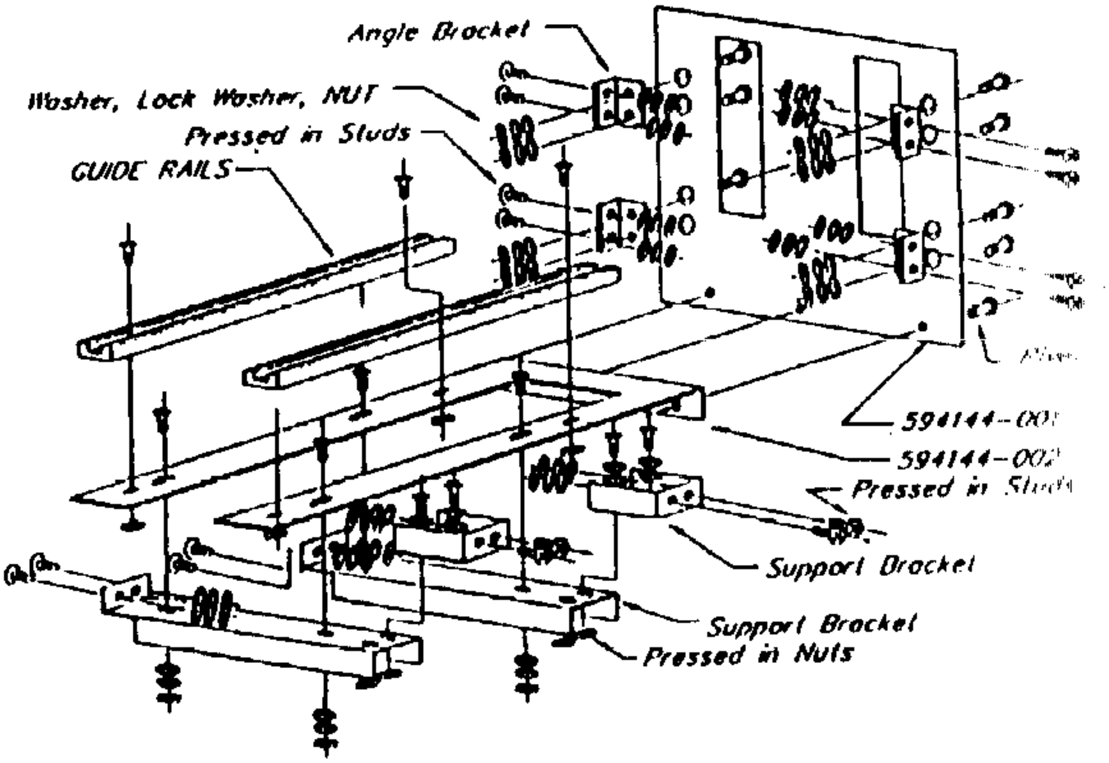

Figure 2, First Bracket Design

One word closely associated with the final solution is the word "HOT". Almost as quickly as you read this word (HOT) you can associate the words "HOT WATER", or "HOT SHOWER" to a solution. Turn on the shower, and the steam ("HOT" water) will raise the temperature in the room.

This example demonstrates the power of careful word description in the beginning of the analytical process. The mind can find solutions by using implied solutions without creative limits. This phenomenon can be used to leverage excellent design implementation.

Example #2 - ELECTRONIC ENCLOSURES

An electronics supplier was designing a controller console about the size of a Personal Computer. Inside this box, a power supply must be mounted. The implementation of this design required a system of brackets for mounting the power supply. The surfaces inside the box were not parallel enough for a good fit and serviceability. The manufacturing variability of the box was built into the brackets by using slotted holes for attachment, This design required only two brackets and a few fasteners.

The original design consisted of a complicated arrangement of brackets and plates to perform the function of "HOLD — POWER SUPPLY". Manufacturing variability caused design #1 to have adjustable sliding features in X, Y, and Z directions for assembly. Only the function "hold--power supply" must be considered in the solution of this problem. This is so because only the primary functions will be served in a better design, and no consideration is given to secondary functions.

Problem statement

How else can a power supply be fastened into an adjustable box?

To approach the problem, first develop a list of all the parts with functions, and costs. Then determine if the part serves primary or secondary functions. In this case the primary function is hold--power supply. Secondary functions support the primary functions.

Part	Function	Cost	Prime	Second
Bracket #1	Hold Power Supply	$4.50	x	
Bracket #2	Hold Power Supply	4.50	x	
Bracket #3	Hold Brackets 1 & 2	3.00		x
Bracket #4	Holds Bracket 3	2.50		x
Bracket #5	Holds Bracket 3	2.50		x
Bracket #6	Holds Bracket 4 & 5	2.50		x
Bracket #100	Holds Bracket 98 & 99	2.50		x

	Total Cost	$ 350		

Table 6 - Functions of Bracket System in Design # 1

A pattern emerges from the Table #6. Some brackets perform secondary functions, that is, if the brackets were removed, the primary function could still be performed. These secondary brackets are candidates for combination with other parts or elimination. What if all the secondary functions were served by brackets 2 & 3? Only the brackets that come in contact with the power supply can be retained in the design.

Design # 2 built the functions of bracket 3 & 4 into bracket 1 & 2. The adjustment feature was provided by the mounting shelf made from bracket 1 & 2 at virtually no cost increase to the brackets. This change resulted in the elimination of over 190 parts.

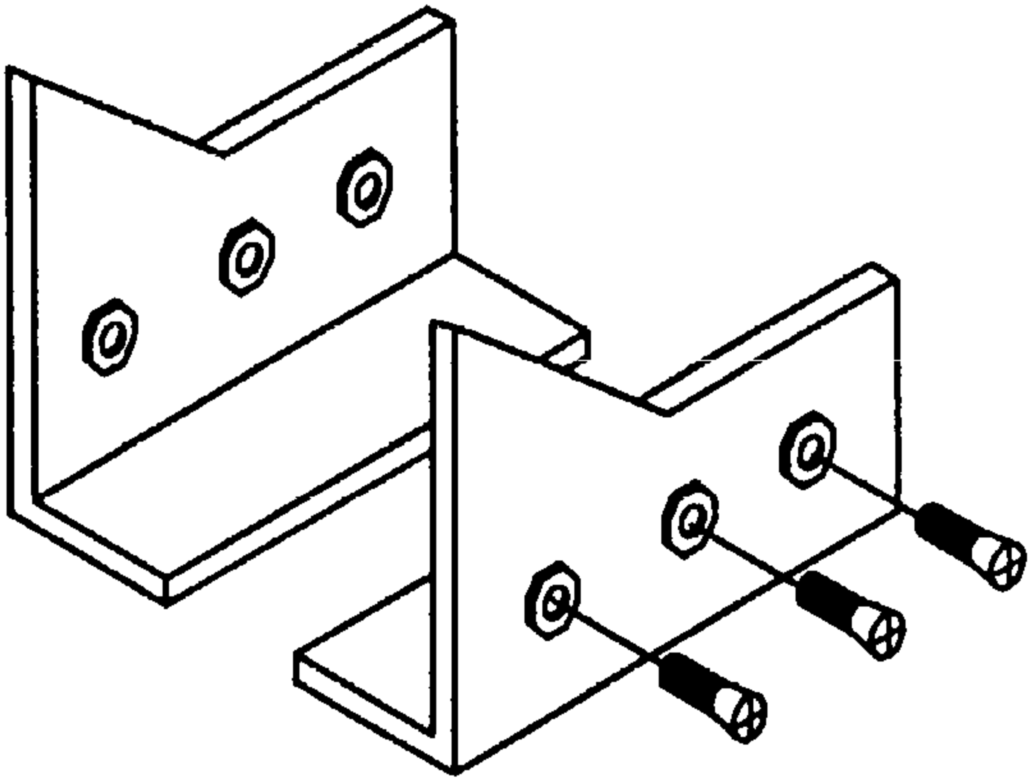

Figure 3, New Bracket Design

The two piece design reduced the number of unique parts to 4, reducing the cost to 15% of the original cost.

Function	Part Design # 1	Design #2
Power supply attachment	**Bracket 1 & 2**	**Bracket 1 & 2**
Adjustment feature	**Bracket 3 & 4**	
House Power supply	**Power supply**	

The new system makes use of the cost to importance ratios to identify that the secondary brackets are not important at all! The cost of the secondary brackets remain high, even though they don't serve primary functions. In reaching this design, the secondary functions are switched to primary functions. That is, the secondary functions are included in the primary functions by enhancing the primary parts. Manufacturing variances are taken care of by the adjustability of the primary bracket, which is not found in the first design. The first design relied on the secondary brackets to provide that function.

Example #3 - THE WHEEL ORNAMENT

Ornamentation in the form of trademarks, plaques, and symbols are used by many companies to establish product identity. Wheel ornamentation is commonly used by the automakers. Their marketing organization argue that the function of a wheel ornament is to establish--identity. The ornament must establish--identity of the model (functional solution). Some existing solutions serve only primary functions of cover--hardware, placing styling (establish--identity), second in importance.

The cost of the example ornament was too high, and the styling was three years old, limiting the ability to attract new customers. To begin seeking a solution, let's describe the system functions of the ornamentation as:

1. Cover hardware (lug nuts and spindle)
2. Establish product identity (from the competition)

3. Ensure Safety

Table #2 (below) presents the relationship of the required functions, the part that serves the function, the cost of the part, and the percentage of the total cost of each item. Attention should be given to the most important item establish--identity which is the major reason for the ornamentation. The bulge lug nuts and the spring clips function only as a means to retain the ornament on the wheel.

Required functions	Part	Cost	% of total
Attach plastic			
create force	**bulge lug nuts**	**$ 1.70**	**40%**
create force	**spring clips**	**.95**	**23%**
establish identity	**plastic case**	**1.50**	**37%**
ensure safety	**plastic case**	**na**	
cover lugs	**plastic case**	**na**	
cover spindle	**plastic case**	**na**	
cover axle shaft	**plastic case**	**na**	

Table #2 - Design #1 Spring clip retention

In Design #1, 70% of the cost is contributed by the retention system. Only 30% of the total cost is contributed by the most important function of establish--identity. The retention system is a secondary function to the ornament itself, since a retention system is not required, if there is no ornament. If you take the retention system away, there is still a need for the ornament.

Focusing on the required function of Attach--Plastic leads to asking the question:

"What else will perform the required function Attach--Plastic?**"**

If my design were a license plate holder ...

...the retention system would consist of three plastic inserts that are snapped into a square hole and allow a threaded screw to penetrate a hole in the center of the insert causing a positive locking feature.

This design uses inexpensive screws to hold the wheel ornament in place - using a technique that is superior to the existing design. A further analysis of the cost reveals the impact of this change.

Required functions	Part	Cost	% of total
Attach plastic			
1.create force	**Inserts**	**$ .30**	**15%**
2.create force	**Screws**	**.10**	**5%**
3.establish identity	**plastic case**	**1.50**	**80%**
4.ensure safety	**plastic case**	**na**	
5.cover lugs	**plastic case**	**na**	
6.cover spindle	**plastic case**	**na**	
7.cover axle shaft	**plastic case**	**na**	

Table #3 - Design #2 "T" anchor retention

Since the plastic case satisfies most of the functional requirements (3, 4, 5, 6, and 7), it should cost the most. In Design #2 the cost and importance are in par with each other, since the plastic case now makes up 80% of the total cost. The proposed retention system makes up only 20% of the total cost versus 55% in the old design (Design #1). Substituting this "T" anchor retention system also reduces the total cost by 65%.

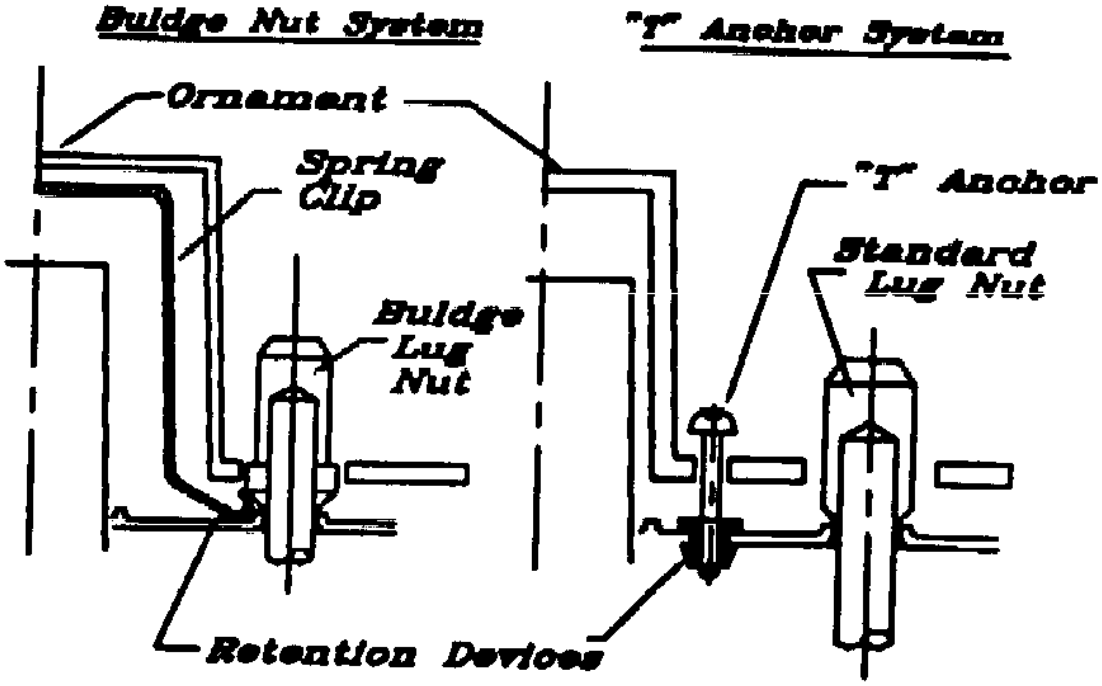

Figure 4, Bulge and "T" Anchor Retention System

Placing importance on the most desired feature forced a new design of the retention system which is a secondary function to the ornament. Asking "what else can perform the required function" led to analyzing the problem with perspective of a license plate holder. This design costs much less, is easier to manufacture, and balanced the cost to importance ratio.

Example #4 - SEMICONDUCTOR

A U.S. company was having difficulties in refurbishing the source assembly in their ion implanter machine used to make semiconductor chips. (The source assembly is like a big light bulb whose filament eventually burns out and needs replacement.) To help with this task, a Japanese semiconductor consultant was hired to make productivity observations on the refurbishment of the main component, the source assembly. The goal was to reduce the time it takes to changeover a source assembly from filament burn-out to start-up of a refurbished unit. An idle machine was not able to produce any product while the operators changed a source assembly. The theoretical service time was 45 minutes.

Being an expert in time study for ionizer source rebuilding, the consultant described faster cleaning techniques and ambidextrous movements that allow the operator to service the machine more quickly. Some mechanical revisions were also suggested, but were minor compared to improved cleaning techniques. The major challenge in the refurbishing procedure was to prevent any large amount of contaminants to remain on the source assembly after cleaning, and make sure the assembly didn't leak any water. If either of these problems occurred, then pull--vacuum could take hours and even days.

Problem statement:

Reduce changeover time
Make changeover time more consistent

First, the steps of the process were identified and the time (out of the 45 minutes) required to perform those functions was determined.

Process / Function	Time	% of Total Time
Release vacuum	**1 sec**	**.0001**
Remove fasteners/supplies	**5 min**	**11**
Remove source	**1 min**	**2**
Clean chamber	**5 min**	**11**
Install unit	**5 min**	**11**
Check continuity	**5 min**	**11**
Pull Vacuum & Burn-In filament	**24 min - 3 hrs**	**53 - 90%**
Total Time	**45 minutes**	

Table #4 - Functional Description of Refurbish Process

Pull--vacuum took 50% of the changeover time and check--continuity made up 10%. Check--continuity was required because the operator was unable to see the assembly features during installation. The re-installed unit was verified by testing with a voltmeter because, improper electrical assembly could result in shorting or other circuit problems. This operation was cumbersome because the outer shell of the source assembly was removed during this continuity check to allow the operator access to the critical surfaces.

This problem is split into two sub-problems: 1. Check--continuity, 2. Pull--vacuum.

Problem Statement 4a.

Check--continuity without a voltmeter.

How else can I check continuity without using vision ?

Note: This statement could be a blind person's perspective (no vision) in solving the problem.

The contact to the surface of the source was made with a wire probe approximately 0.060 diameter. If continuity could be verified with a different sense other that vision, that might allow the outer shell to be assembled in full, ready for installation. The improved design uses a clicking sound by taking advantage of the spring characteristic inherent in the wire contact. A small groove was machined into the contact surface of the source which allowed the wire to click into place and verify that the contact had been made. Even with this simple and quick change, 10% of the repair time was eliminated for a very small investment of time and resources.

The operation of "pull--vacuum" and "burn--in" element demands 80% of the repair time and is the most unpredictable. A water leak could cause a team of people hours if not day to clean and repair. All of the time that this $ 1,000,000 machine is waiting to "pull--vacuum", it does not produce anything.

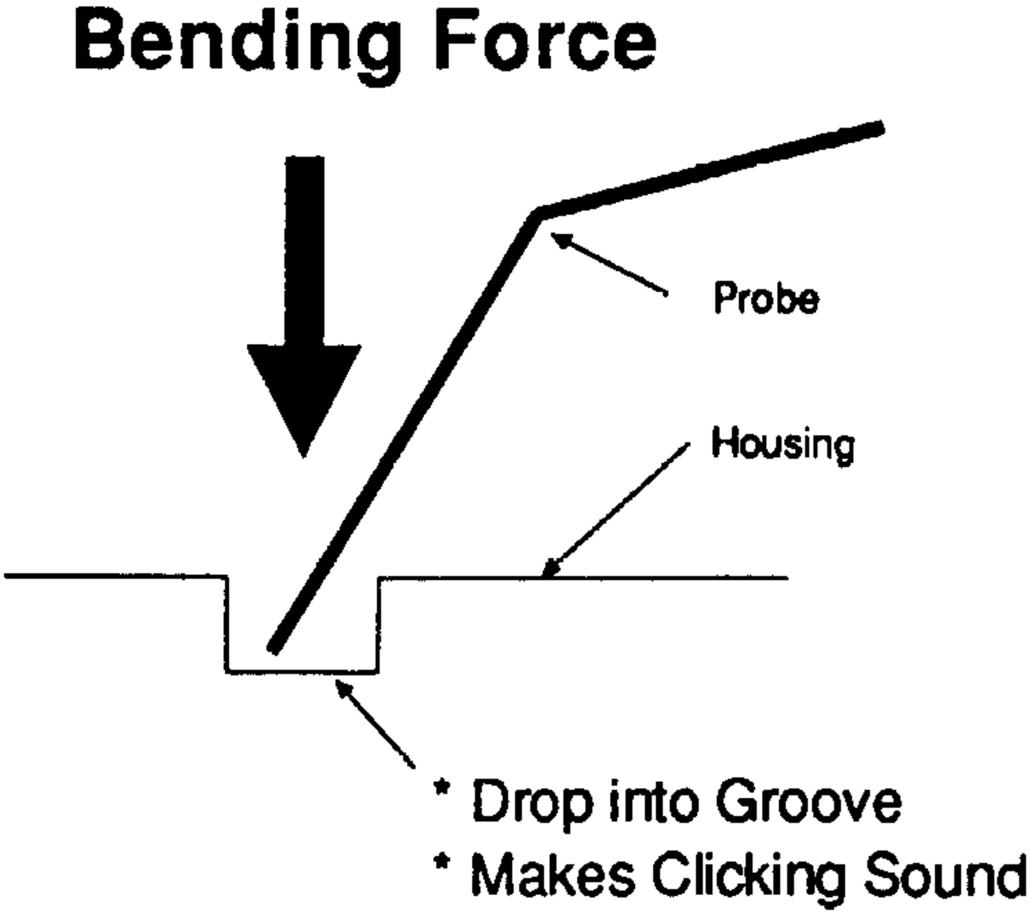

Figure 5, Checking Continuity with a "Clicking Sound"

Problem Statement 4b.

current machine design said that the process could not use a lower vacuum costing only $7,000. Sensitivity of the prototype design was tested in a single chamber, electronically regulated, low vacuum burn-in system. Because the refurbished unit was not demanded on short notice, it was acceptable to have longer

How else can the function "burn--in" be conducted for the filament ?

Pull--vacuum can be accomplished outside of the $1,000,000 implanter by building a stand-alone vacuum chamber. However, two major roadblocks were: Vacuum levels required a $ 100,000 pump making it difficult to justify; the producers of the burn-in period for the source assembly.

Since the unit was assembled into the implanter after "burn in" the start up times were lowered to 5 minutes.

Function	Time	% of Total Time
Release vacuum	**1 sec**	.001
Remove fasteners / supplies	**5 min**	24
Remove source	**1 min**	**.04**
Clean chamber	**5 min**	**24**
Install unit	**5 min**	
Check continuity	**N.R.**	
Pull Vacuum & Burn-In	**5 min - 10 min**	**24%**

Total Time 21 minutes

Table #5 - Functional Description of Revised Process

This problem was solved using systematic functional analysis. Sensitivity to the cost and relative importance helped to identify items that were overpriced. Asking "what else can perform the function" helped to point to the final solution. Since a low cost, low vacuum solution worked, the repair time was reduced from 45 minutes to 21. The repair pull--vacuum time now represents only 25% of the process, and check--continuity is performed using sound instead of vision.

CONCLUSIONS

Exploring new perspectives can be a powerful tool. Success is greatly enhanced with a good functional description at the beginning of the analytical procedure. A cost and importance must be assigned to each design feature. The most important features of a design should cost the most, and the least important should be eliminated or cost reduced. This will focus attention to the most critical features of a design, and minimize unwanted items. "How else can the function be performed?" should be asked to discover alternate designs that more closely reflect the functional requirements and their importance. This emphasis will work equally as well on processes involving only time.