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of Transportation
**National Highway
Traffic Safety
Administration**

**People Saving People**
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April 1997

**Final Report**

# Cost Analysis of the Mercedes-Benz Occupant Detection System for Air Bag Shut-Off

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# 1 - INTRODUCTION

The DOT/National Highway Traffic Safety Administration ( NHTSA ) initiated this Project to obtain the variable manufacturing costs and lead time estimates for an Occupant Detection System for Air Bag Shut Off that could be implemented on US passenger vehicles. This system is intended for use in the front passenger seat. The variable manufacturing costs are to be based on "high production volume" manufacturing processes. Tooling costs and lead time estimates are to be based on total US production implementation. The Mercedes-Benz System was used as a basis for the development of these estimates.

A list of vehicles that represented a cross section of front passenger seat and air bag electrical system configurations was developed for analysis of implementation requirements. This list also represented the majority of vehicles sold in the US. The list concentrated on those vehicles that could have a child, or small person, sitting in the front seat. Therefore, the list included pick up type vehicles as well as those that are normally labeled passenger vehicles.

NHTSA furnished the Mercedes-Benz Occupant Detection System for Air Bag Shut Off hardware that was used as a basis for this analysis. The evaluation of this system was based on typical US manufacturing processes and tooling methods. The basic design was not changed.

The results of the effort are presented in the Executive Summary and the Results Section of this report. More detailed discussions of the approach, methodology and implementation considerations are presented in other Sections of this report.

# 2 - EXECUTIVE SUMMARY

The objective of this project is to develop the variable manufacturing costs and lead time estimates of an "occupant detection system for air bag shut off". The Mercedes-Benz system was used as a base for developing this data. Photographs of the hardware ( supplied by NHTSA ) are presented in Figures 1 through 5. This is a production system currently available in the US.

The system consists of a switch pad which fits beneath the upholstery on the front passenger seat and a wiring harness that connects the switch pad to the vehicle air bag wiring harness. With this system, the passenger air bag is normally in a non-detonation state and a person of sufficient weight sitting on the switch pad closes the circuit through depressing pressure points in the switch pad. A relatively light weight person ( a child ) would not depress the pressure points sufficiently to close the circuit.

Figure 6 is a schematic representation of how the system is located in the vehicle. The air bag wiring circuitry is designed so that the switch pad circuitry is interdicted just ahead of the lead to the passenger air bag detonator. Figure 7 presents a schematic of this circuitry for the Mercedes-Benz system, Figure 8 shows the same system prior to implementing the shut off system and Figure 9 presents a representative method of interdiction of the shut off system into a typicle US vehicle air bag wiring circuitry.

Assessment of the cost to implement this concept into the total US market was accomplished by first developing the variable manufacturing costs of the Mercedes-Benz system, then conducting an evaluation of twenty ( 20 ) US production vehicles relative to their current air bag systems and front seat configurations. The air bag systems were evaluated relative to the ease of interdicting a shut off switch into the circuitry. The front seat configurations were evaluated relative to the sitting area ( bench seat, split seat, bucket seat ) that a front seat passenger would sit and; consequently, the area that a "switch pad" would have to cover. Figures 10 through 12 present examples of bucket, bench and split seat configurations used in front seat applications. These twenty ( 20 ) vehicles represent a cross section of the highest production volume vehicles and the range of models that people with children use for transportation and are produced by the major manufacturers. A list of these vehicles is on Page 26 of Section 3.

The interdiction of an "occupant detection system for air bag shut off" by Mercedes-Benz into their air bag system was relatively easy and inexpensive because they had ample pin

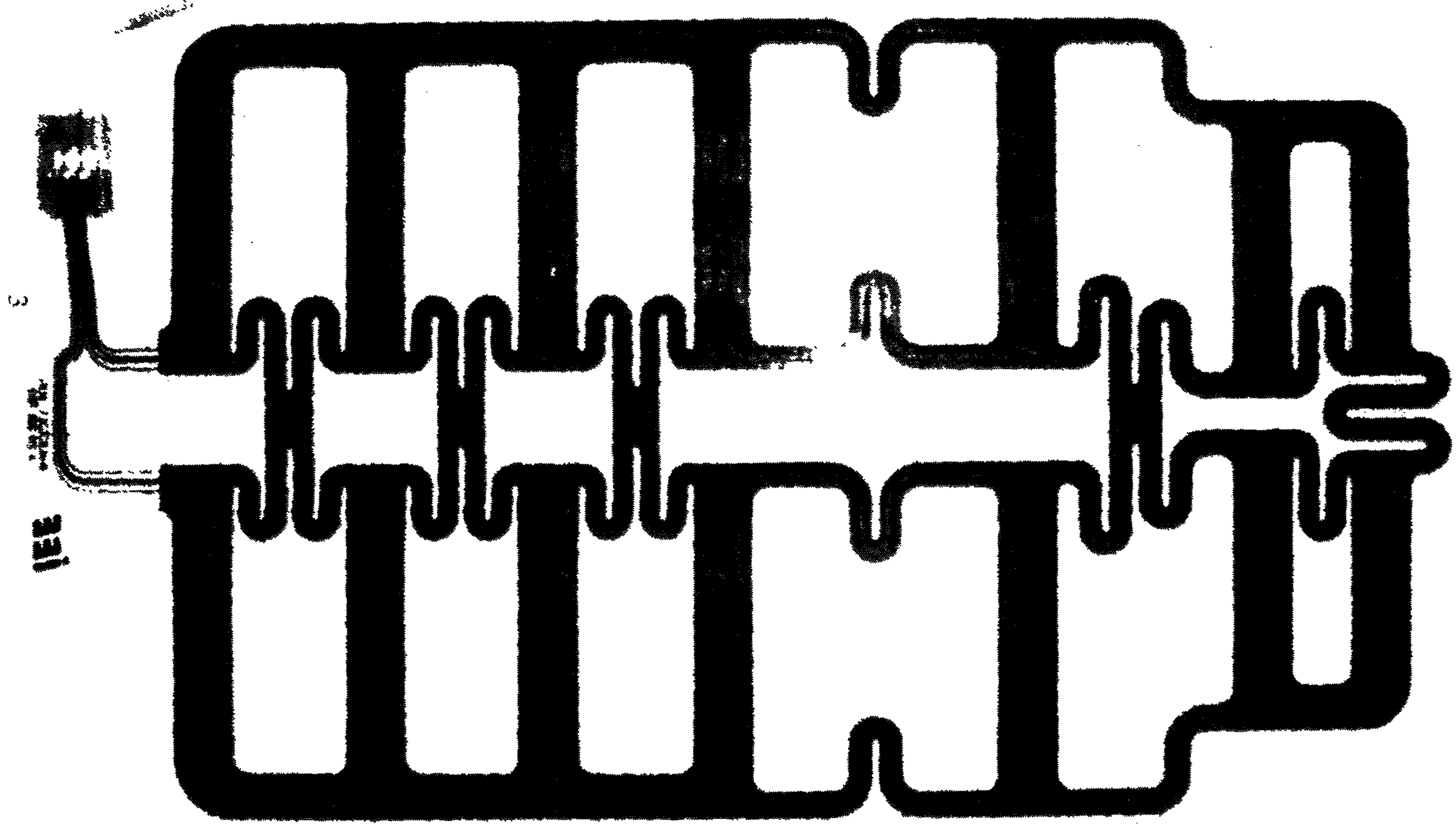


Figure 3

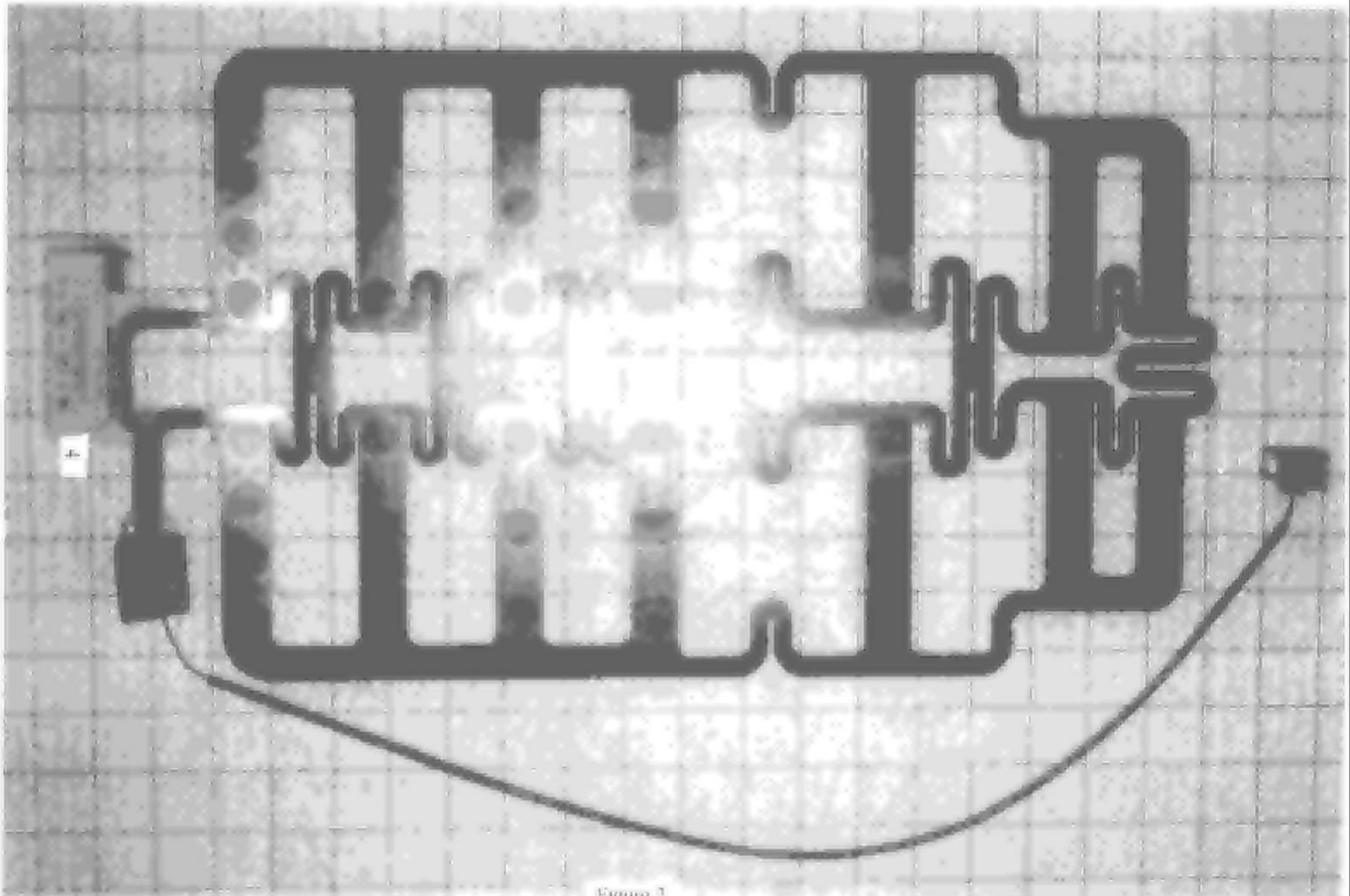


Figure 2

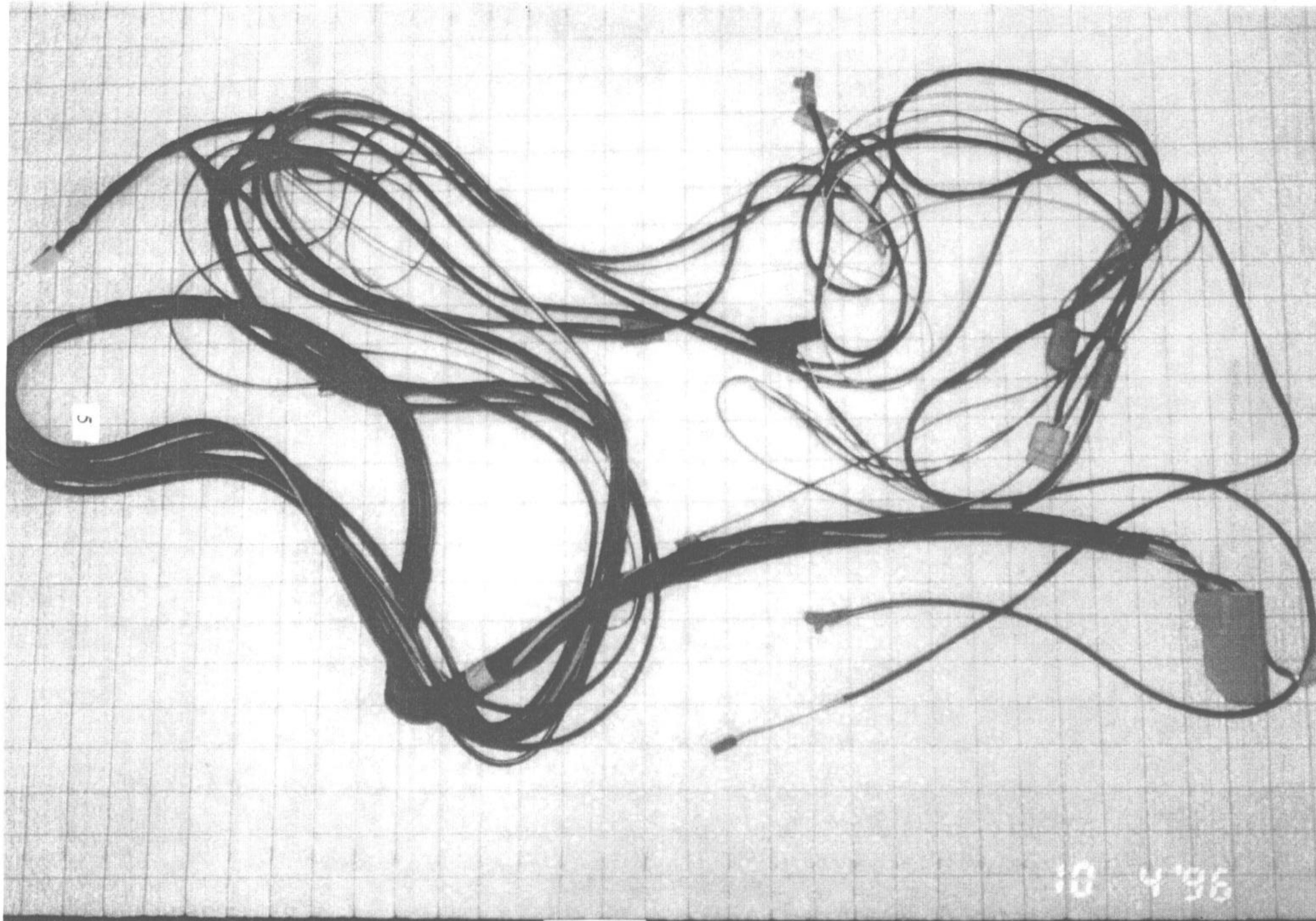



Figure 3

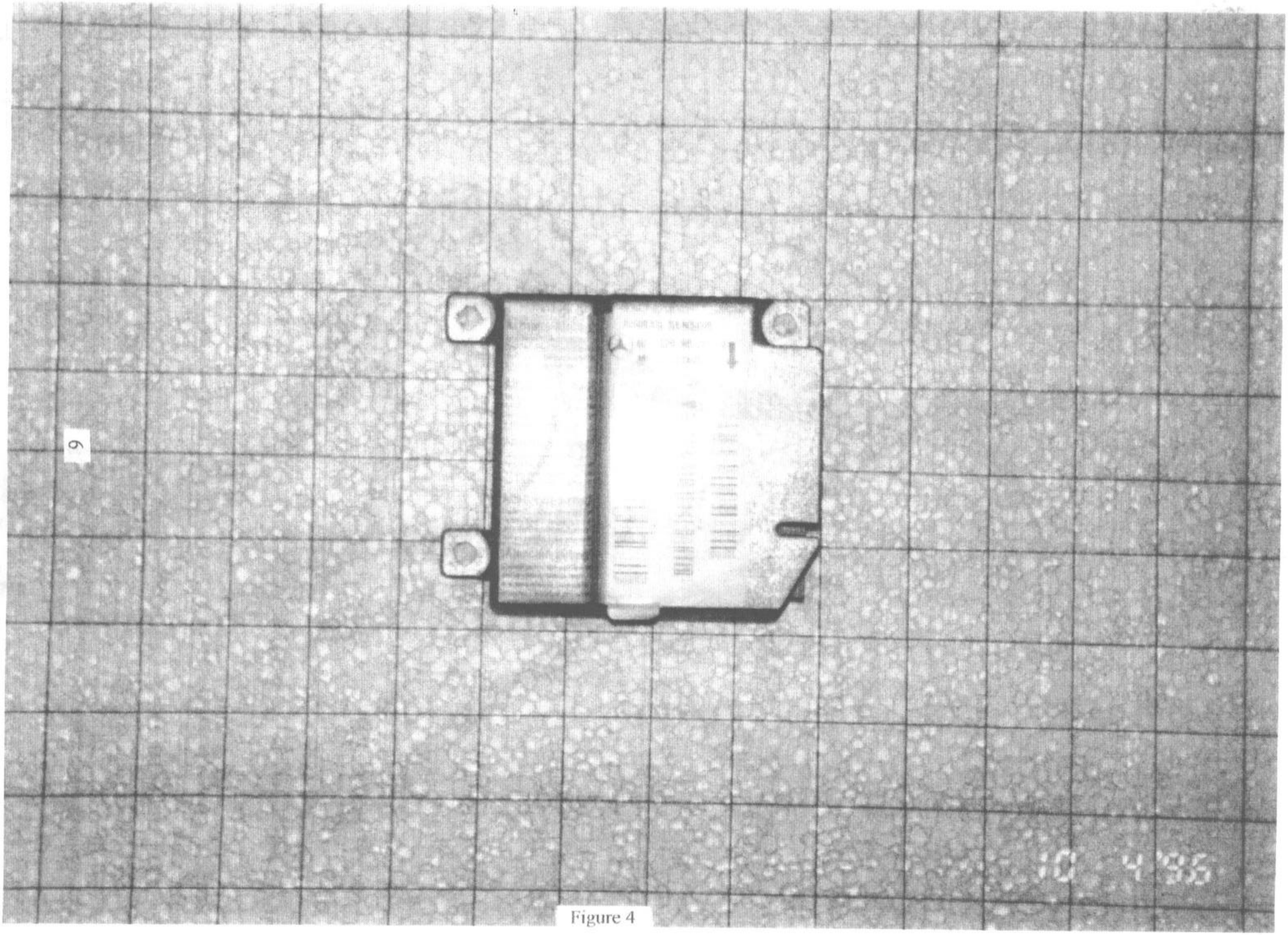



Figure 4

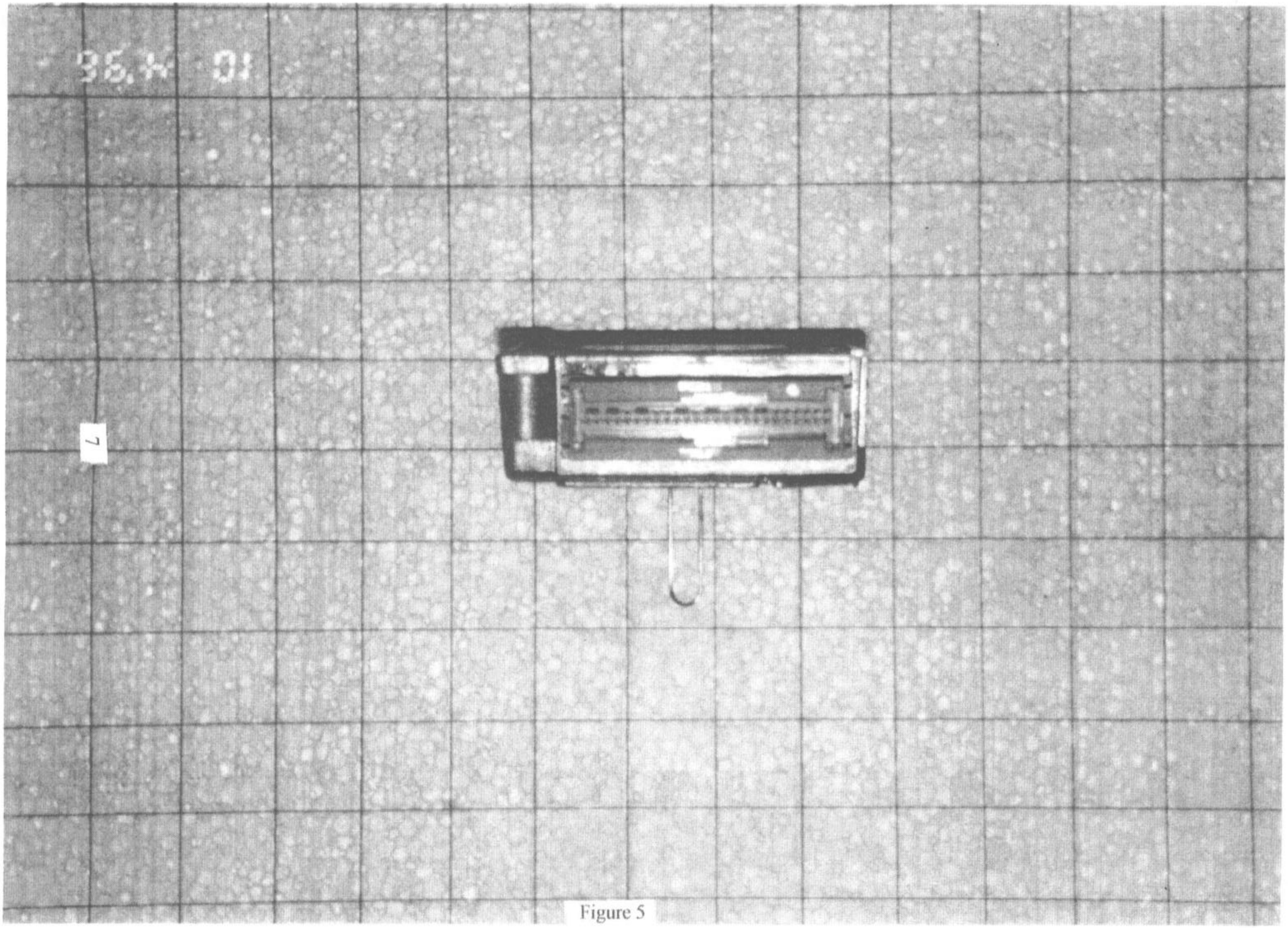


Figure 5

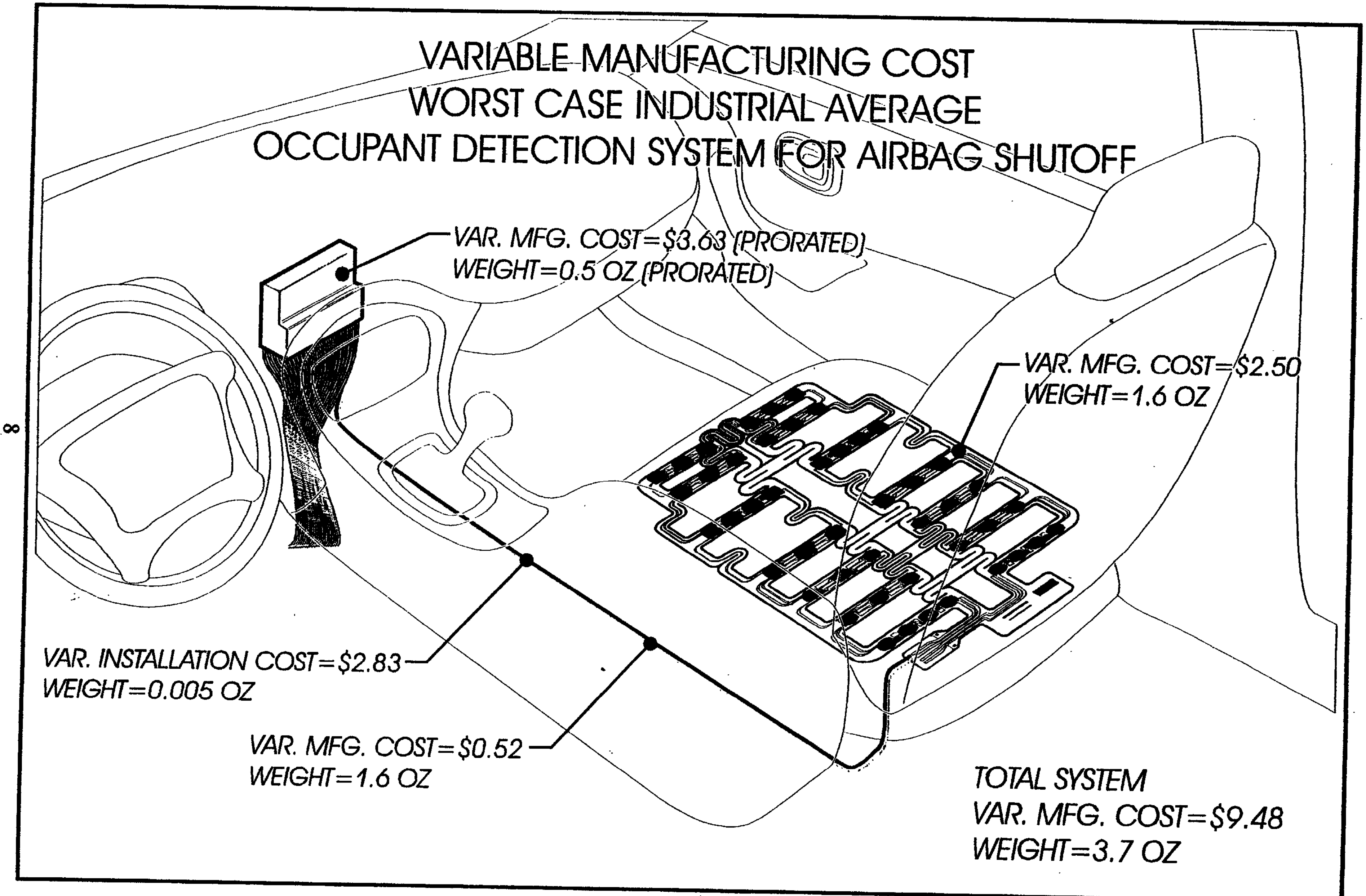
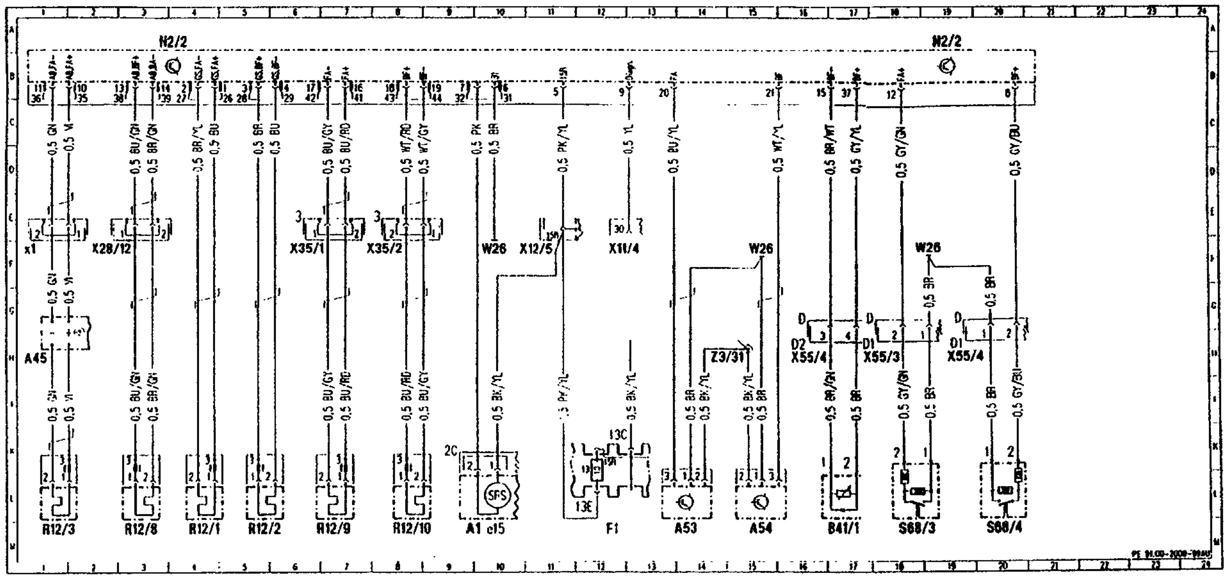

VARIABLE MANUFACTURING COST
WORST CASE INDUSTRIAL AVERAGE
OCCUPANT DETECTION SYSTEM FOR AIRBAG SHUTOFF
VAR. MFG. COST=$3.63 (PRORATED)
WEIGHT=0.5 OZ (PRORATED)
VAR. MFG. COST=$2.50
WEIGHT=1.6 OZ
VAR. INSTALLATION COST=$2.83
WEIGHT=0.005 OZ
VAR. MFG. COST=$0.52
WEIGHT=1.6 OZ
TOTAL SYSTEM
VAR. MFG. COST=$9.48
WEIGHT=3.7 OZ

Figure 6

# 1996 E-CLASS MERCEDES BENZ

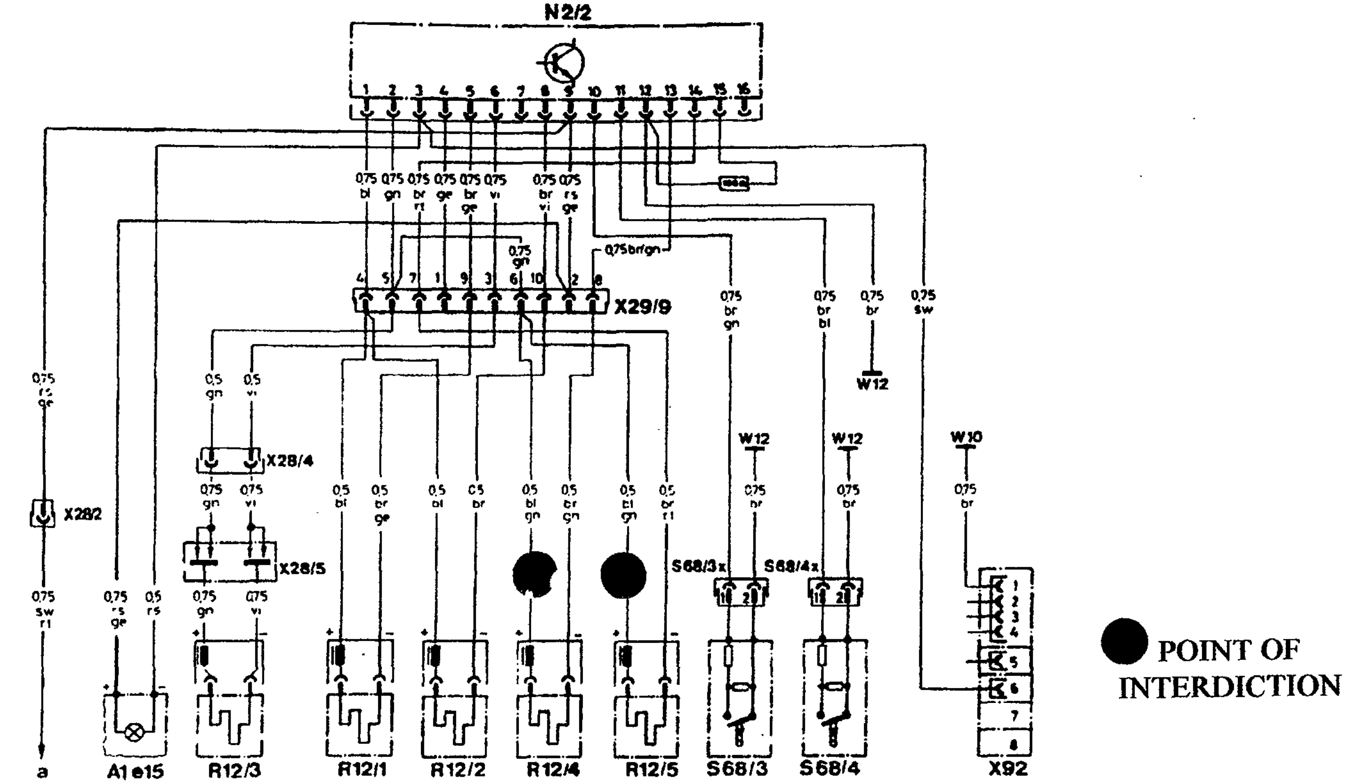



| | | |
|---|---|---|
| A1 | Instrument cluster | 9M |
| A1e15 | SRS MIL | 10M |
| A45 | Horn/airbag clock spring contact | 1H |
| A45x1 | Horn/airbag clock spring contact connector | 1F |
| A53 | Left side airbag sensor | 14M |
| A54 | Right side airbag sensor | 15M |
| B41/1 | Front passenger seat occupied recognition sensor | 17M |
| F1 | Fuse and relay box | 12M |
| F1-13 | Fuse 13, circuit 15R | 12K |
| N2/2 | SRS control module | 3A<br>19A |
| R12/1 | Left front ETR squib | 4M |
| R12/2 | Right front ETR squib | 5M |
| R12/3 | Driver AB squib | 1M |
| R12/8 | Front passenger AB squib | 3M |
| R12/9 | Left side airbag squib | 6M |
| R12/10 | Right side airbag squib | 8M |
| S68/3 | Left front seat belt buckle switch (AB/ETR) | 18M |
| S68/4 | Right front seat belt buckle switch (AB/ETR) | 20M |

| | | |
|---|---|---|
| W26 | Ground (SRS control module) | 10F<br>15F<br>18F |
| X11/4 | Data link connector (DTC readout) | 12F |
| X12/5 | Terminal block, circuit 15/15R (FFS) | 10F |
| X28/12 | AB intermediate connector | 2F |
| X35/1 | Left front door/FFS connector | 6F |
| X35/2 | Right front door/FFS connector | 7F |
| X55/3 | Left ESA connector block | 17H |
| X55/4 | Right ESA connector block | 16H<br>19H |
| Z3/31 | Circuit 15R connector sleeve, (fused, sidebag) | 14H |

Figure 7

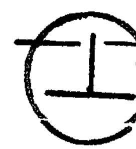
# 1994 E-320 MERCEDES BENZ




a - Unfused Power Supply
A1e15 - SRS Warning Light
N2/2 - Control Unit
R12/1 - Left Front ETR Detonator
R12/2 - Right Front ETR Detonator
R12/3 - Driver Airbag Detonator
R12/4 - Passenger Airbag Detonator No. 1
R12/5 - Passenger Airbag Detonator No. 2
S68/3 - Driver Belt Buckle Switch
S68/3x - Driver Belt Buckle Switch Connector
S68/4 - Passenger Belt Buckle Switch
S68/4x - Passenger Belt Buckle Switch Connector
W10 - Battery Ground
W12 - Center Console Ground
X28/2 - Airbag & Belt Tensioner Power Supply Connector
X28/4 - Clockspring Connector (Lower)
X28/5 - Clockspring Connector (Upper)
X29/9 - SRS System Connector
X92 - Diagnostic Connector

MERCEDES-BENZ WIRE COLOR ABBREVIATIONS

bk - Black
bl Or bu - Blue
br - Brown
ge Or yl - Yellow
gn - Green
gr Or gy - Gray
pk - Pink
rs - Unknown
rt Or rd - Red
sw - Black
vi - Violet
ws Or wt - White

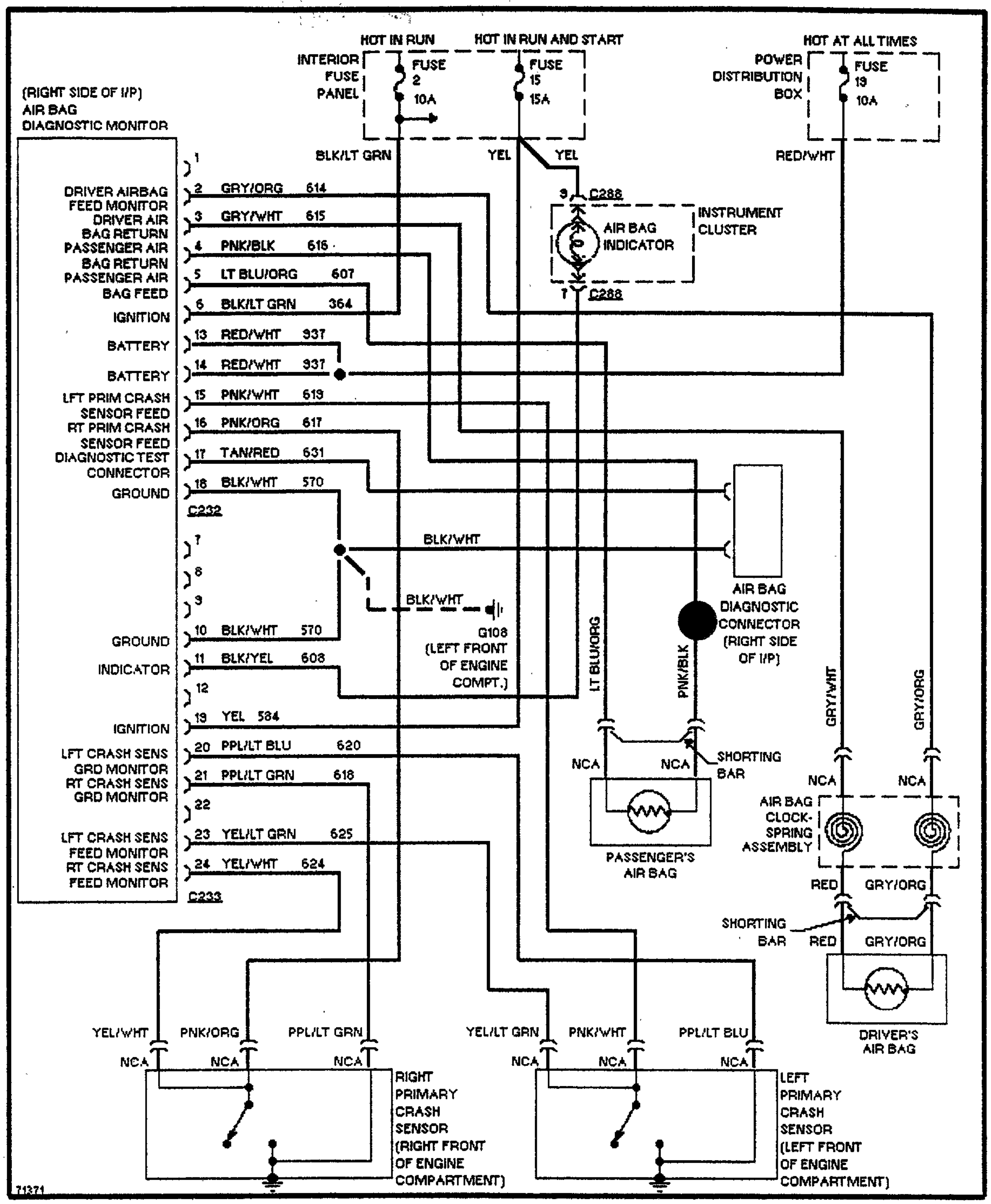


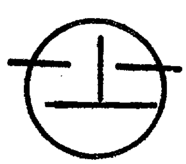
PRESSURE SWITCH ARRAY WITH RESISTOR

94C43093

Figure 8

# 1995 FORD RANGER



PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

● POINT OF INTERDICTION

Figure 9



MARK UPS
BY LUDTKE AND ASSOCIATES


Figure 10

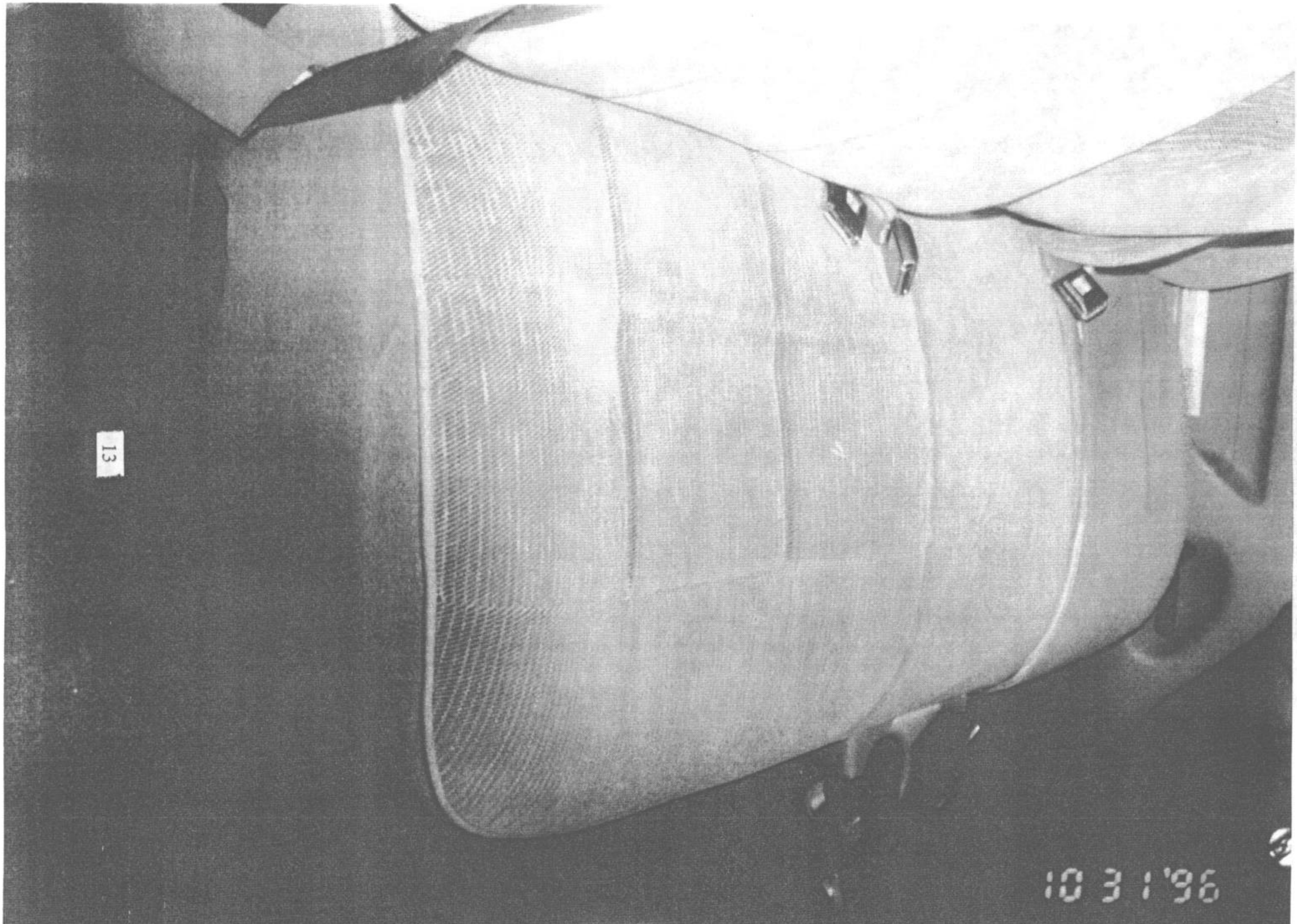



Figure 11

Figure 12

capacity in the air bag harness connector for an additional system, the air bag wiring circuitry design permitted relatively easy interdiction; and, they have one seat switch pad size.

Some current US vehicles also have additional pin capacity and interdiction of a shut off system into the main air bag wiring circuitry would be relatively easy. However, some vehicle manufacturers do not currently have additional pin capacity and their wiring circuitry would require additional development work and testing. Most US vehicle manufacturers have multiple seat options ( bench, split and bucket ). Therefore, these manufacturers would need multiple seat switch pad sizes.

The switch pad manufacturing process is schematically represented in Figure 13 and a description of each process step is shown in Figure 14. The size of the switch pad would not alter the process.

The variable manufacturing cost of implementing an "occupant detection system for air bag shut off" concept similar to the Mercedes-Benz system into the total US fleet is presented in Table 1. These costs consider the above discussed wiring circuitry and connector rework on some vehicles and multiple switch pad sizes.

Lead time estimates for development and manufacturing implementation for the US fleet is presented in Figure 15..

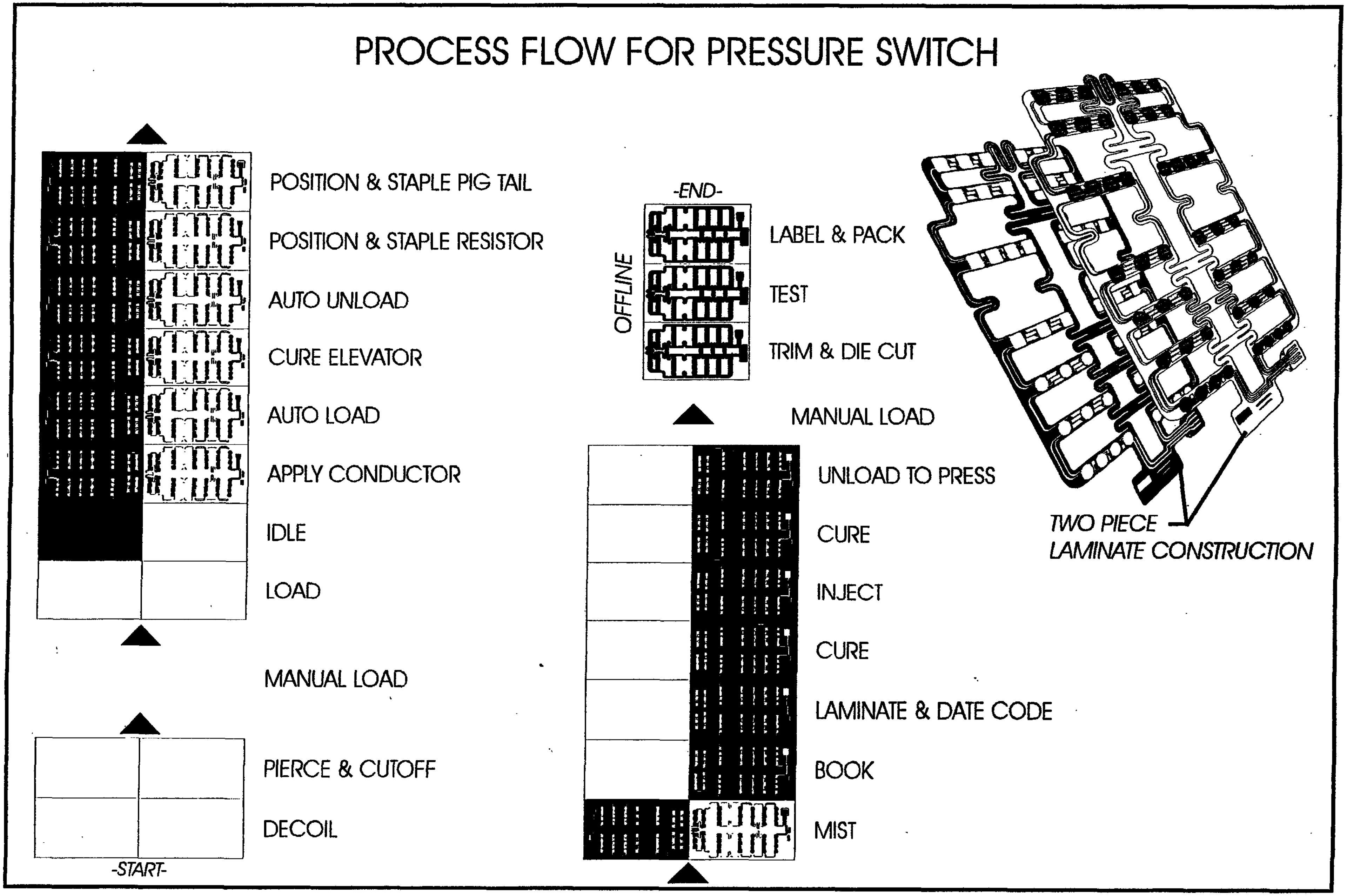

PROCESS FLOW FOR PRESSURE SWITCH
POSITION & STAPLE PIG TAIL
POSITION & STAPLE RESISTOR
AUTO UNLOAD
CURE ELEVATOR
AUTO LOAD
APPLY CONDUCTOR
IDLE
LOAD
MANUAL LOAD
PIERCE & CUTOFF
DECOIL
-START-
-END-
OFFLINE
LABEL & PACK
TEST
TRIM & DIE CUT
MANUAL LOAD
UNLOAD TO PRESS
CURE
INJECT
CURE
LAMINATE & DATE CODE
BOOK
MIST
TWO PIECE
LAMINATE CONSTRUCTION

Figure 13

## Process Description - Pressure Pad Switch
## Dual Lane Pallet Transfer System

Coil A: .0075" thick polyester or polyvinyl film 22" wide.
Coil B: Same as Coil A except black gauze backing, bonded with vinyl paint.

Side by Side Transfer Line

| COIL A | COIL B |
|---|---|
| Decoil | Decoil |
| Pierce & Cutoff | Pierce & Cutoff |
| Stack | Stack |
| * Manual | |
| Load | Load |
| Idle | Idle |
| Apply Conductor | Apply Conductor |
| Auto Load | Auto Load |
| Cure | Cure |
| Auto Unload | Auto Unload |
| Resistor - Position & Staple | P/N & Identify |
| Pig Tail - Position & Staple | Logo |
| Mist | |
| * Manual - Book | Empty |
| Laminate | Empty |
| Cure | Empty |
| Inject | Empty |
| Cure | Empty |
| Manual - Unload to Press | Empty |

End of Transfer

* Off-line Trim (Die Cut)
- Inspect
- Lable & Pack

* Utility Operator
- Loads Coil Stock
- Changes Mask, etc
- Relieves other operators
- 4 men total - 12-15 second cycle

Figure 14

# Passenger Side Air Bag Detection Switch and System Support
# Variable Manufacturing Costs

| | Material Cost | Labor Cost | Variable Burden Cost | Estimated Variable Cost |
|---|---|---|---|---|
| Increase in Seat Cost | $1.05 | $0.36 | $1.09 | $2.50 |
| Increase in Air Bag Control Module Cost (Pro-rated) | $3.33 | $0.09 | $0.21 | $3.63 |
| Increase in Air Bag Wire Harness Cost | $0.48 | $0.01 | $0.03 | $0.52 |
| Increase in Final Assembly Cost | | $0.47 | $2.36 | $2.83 |
| Total Variable Increase | $4.86 | $0.93 | $3.69 | $9.48 |

| | |
|---|---|
| Estimated Tooling Cost | $134,912 |
| Estimated Capital Equipment cost | $1,514,256 |

Note: Variable manufacturing cost estimate is based on Mercedes-Benz type hardware.

Table 1

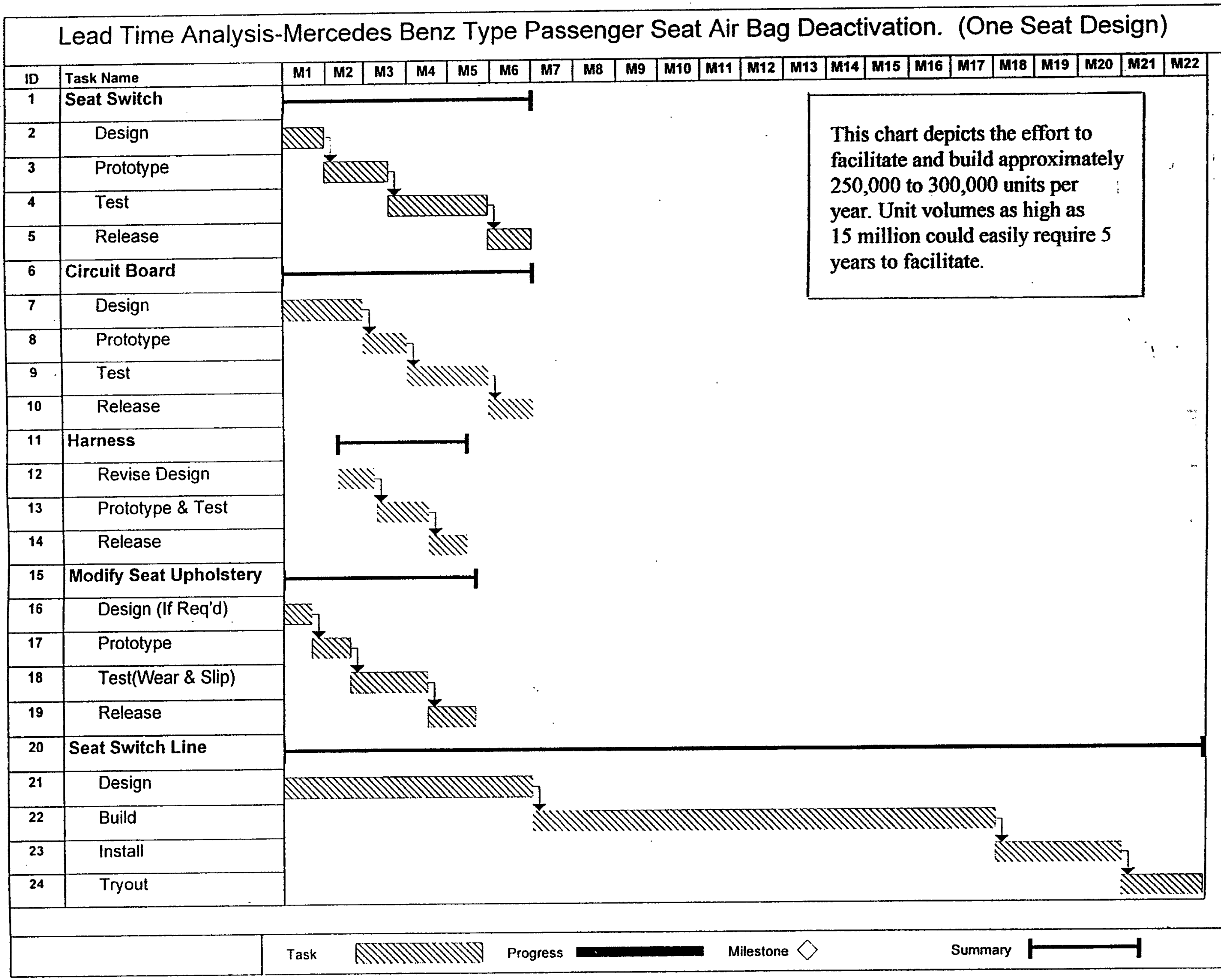

Lead Time Analysis-Mercedes Benz Type Passenger Seat Air Bag Deactivation. (One Seat Design)
ID
Task Name
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12 M13 M14 M15 M16 M17 M18 M19 M20 M21 M22
1 Seat Switch
2 Design
3 Prototype
4 Test
5 Release
6 Circuit Board
7 Design
8 Prototype
9 Test
10 Release
11 Harness
12 Revise Design
13 Prototype & Test
14 Release
15 Modify Seat Upholstery
16 Design (If Req'd)
17 Prototype
18 Test(Wear & Slip)
19 Release
20 Seat Switch Line
21 Design
22 Build
23 Install
24 Tryout
This chart depicts the effort to facilitate and build approximately 250,000 to 300,000 units per year. Unit volumes as high as 15 million could easily require 5 years to facilitate.
Task
Progress
Milestone
Summary

Figure 15

# DISCUSSION, APPROACH and METHODOLOGY

The following paragraphs discuss the approach and methodology used to develop the variable manufacturing costs, tooling costs, equipment costs and lead time estimates of an "occupant detection system for air bag shut off". The Mercedes-Benz system was used as a base for this analysis.

The Mercedes-Benz "occupant detection system for air bag shut off" hardware was received from NHTSA. This is a production designed system used in vehicles available for purchase in the US. It should be noted that this system does not necessarily reflect a design configuration that would be incorporated into a relatively low priced vehicle designed and produced in the US. However, it is a system in production and is suitable for use as a base for this project. Variations in the cost of other designs that would be implemented for other types of vehicles would be minimal and would not significantly change the estimates generated by this effort.

The Mercedes-Benz hardware was first photographed in the assembled configuration. These photographs are presented in Figures 13 through 17. One of the figures presents the air bag wiring harness into which the air bag shut off system is connected.

The hardware was weighed and then disassembled for the manufacturing process analysis. The disassembly is in reverse order of the production assembly process and is supervised by the manufacturing engineer to ensure that the processes are noted. Further disassembly of the parts were conducted where manufacturing process details were not clear. The weight data provided guidelines for estimating weights of the various materials used in the different parts.

It should be noted that the manufacturing process analysis was based on a production volume of 250,000 units per year. Variable manufacturing costs do not significantly decrease as the annual production volume increases beyond this amount and this is the reason that this production value is selected for this type of analysis. This is also the annual production volume that has been a standard for NHTSA cost studies for several years.

There are four seat manufacturers that supply the major portion of the seats for the US automobile industry. The average annual vehicle production in the US is currently around 15,000,000. The "sitting area" of most seats is approximately the same, therefore, the production of these systems for some seat suppliers could be several multiples of the 250,000 increment. This does not pose a problem in developing the variable manufacturing

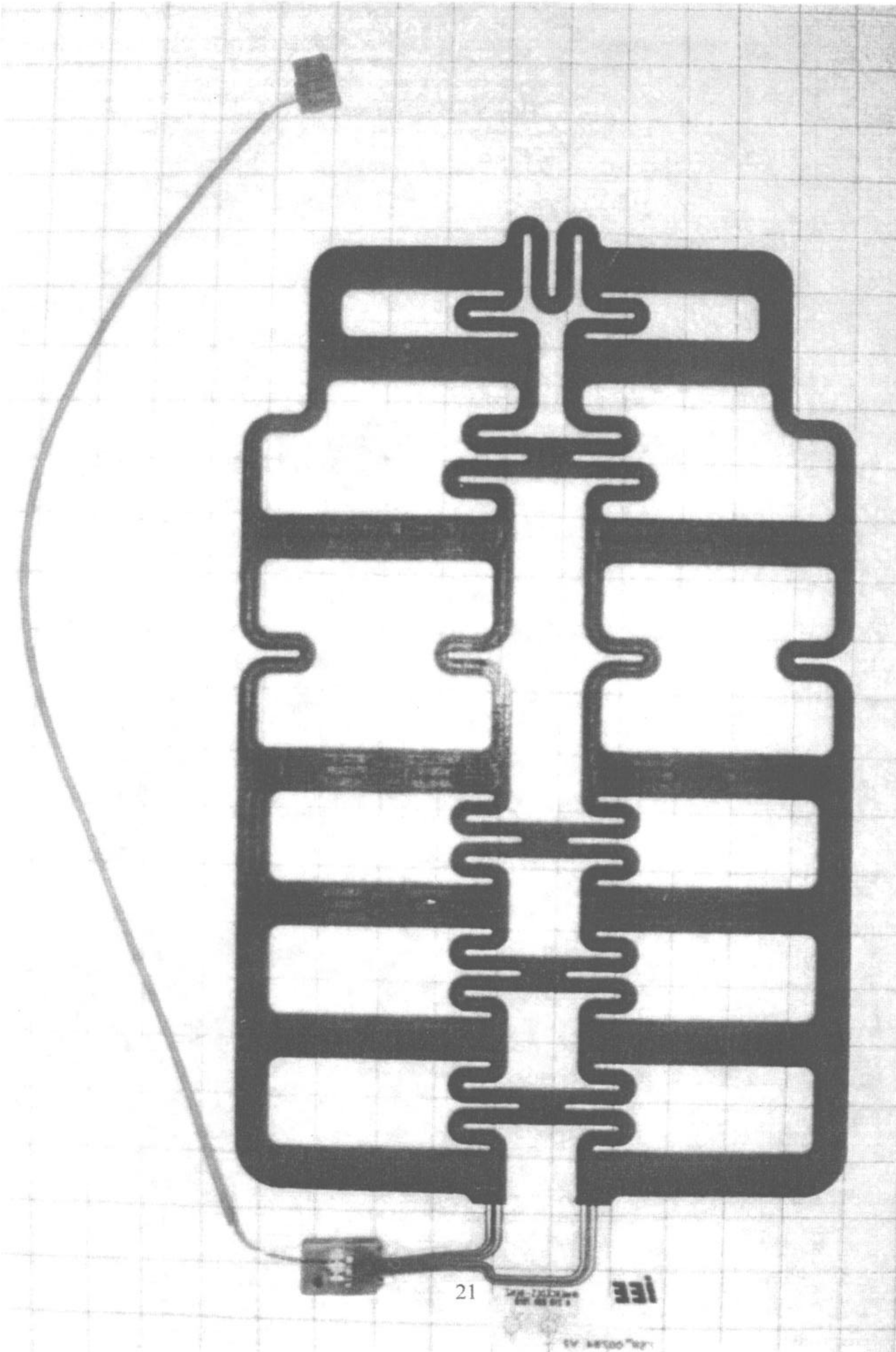


Figure 16

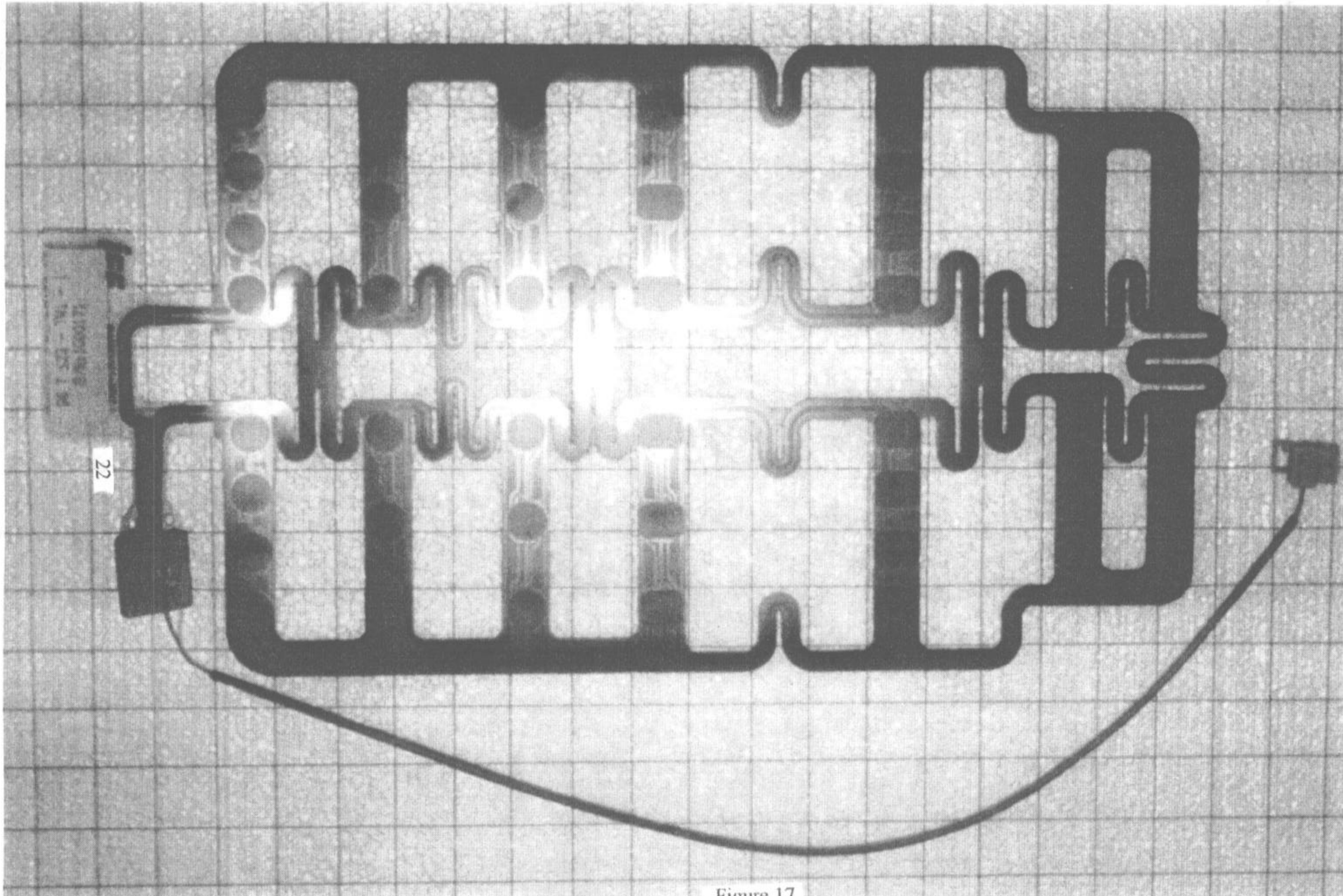


Figure 17

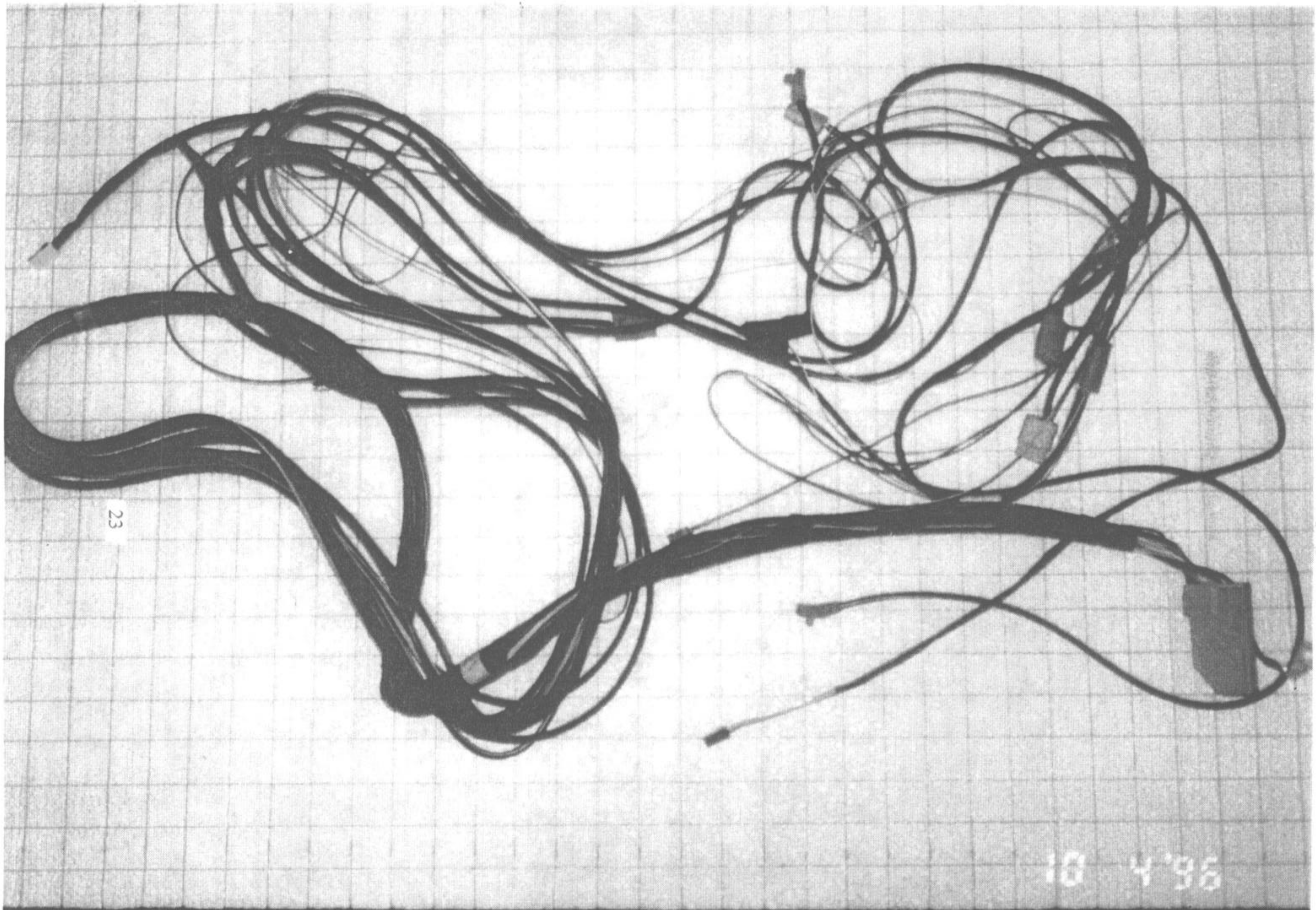



Figure 18

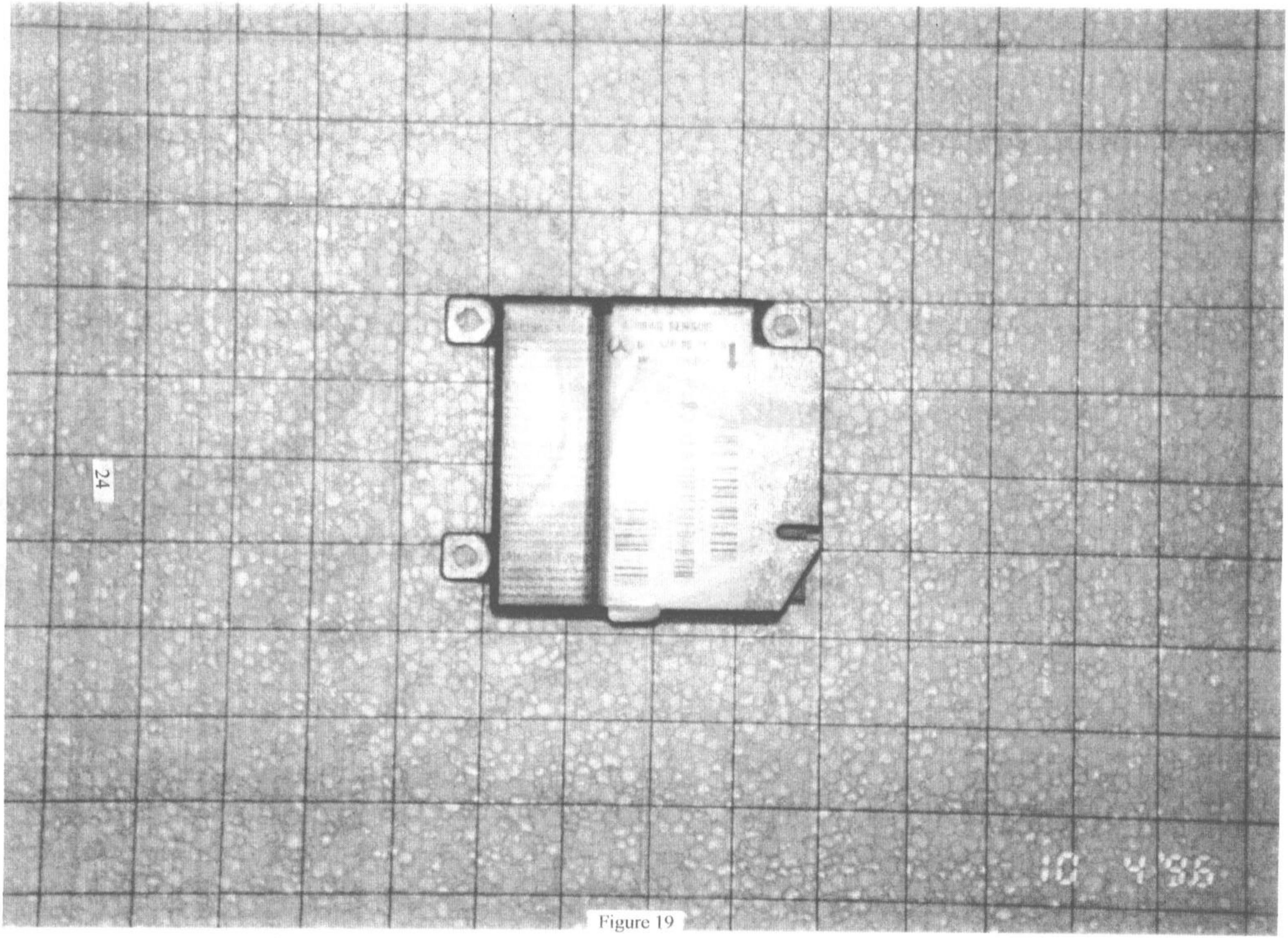



Figure 19

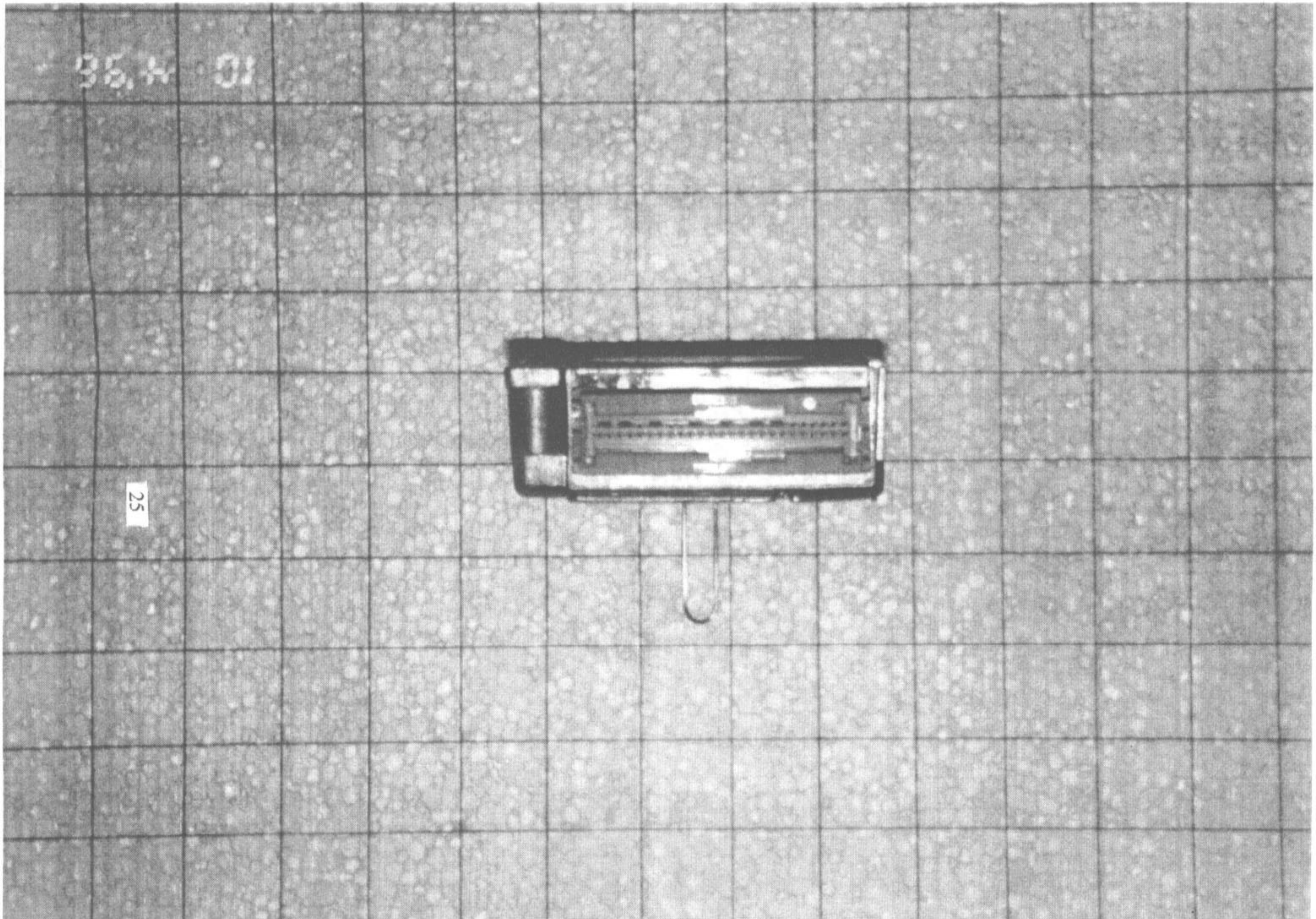


Figure 20

costs, but it will pose a problem in developing the manufacturing capability and in estimating time required for total implementation into the total US industry.

Detail information from the process analysis was compiled and prepared for entry into a computer program. This includes identification of each process in sequence; e.g., respective pieces of tooling and costs, equipment, labor categories and process cycle times.

The number of different models of "passenger type" vehicles sold in the US were evaluated to develop a list of vehicles for the analysis that would represent a comprehensive cross section of front seating area configurations and also represent the majority of "passenger type" vehicles sold in the US. "Passenger type" vehicles represent those vehicles which people with children would use for transportation. Therefore, this list includes pickups as well as passenger vehicles. The list includes the highest production volume vehicles from the major automotive manufacturers. Initially a list of nine ( 9 ) vehicles was generated and submitted to the COTR for approval. However, upon further investigation this list was expanded to include twenty ( 20 ) vehicles in order to increase the percentage of vehicles covered relative to the total number sold annually in the US. The list of vehicles is as follows:

1. 1996 1/2 - 1997 Ford F-150
2. 1995 Ford Taurus*
3. 1995 Ford F-150*
4. 1995 Ford Ranger
5. 1995 Ford Explorer
6. 1995 Lincoln Continental
7. 1995 Chevrolet C 1500*
8. 1995 Chevrolet K 1500
9. 1995 Chevrolet Lumina*
10. 1995 Cadillac DeVille
11. 1996 Dodge Ram*
12. 1995 Dodge Ram
13. 1995 Chrysler Town & Country*
14. 1995 Dodge Intrepid*
15. 1995 Honda Civic
16. 1995 Honda Accord*
17. 1995 Toyota Tercel
18. 1995 Toyota Camry*
19. 1996 Mercedes-Benz E Class
20. 1995 Mercedes-Benz E 320

Those vehicle models designated by ( * ) were from the original list of nine ( 9 ).

An air bag system wiring schematic for each of the above vehicles was obtained for review and analysis for the best interdiction method and location of the "air bag shut off system".

Figures 18 through 37 present each wiring schematic and the suggested interdiction location. These marked up circuits are not an attempt to redesign in detail the schematics but to show graphically how they might be adapted to utilize a passenger side occupant seat sensor. While the schematics differ in line layout, nomenclature and detail identification, they all function the same way, as outlined below:

- Detect a crash
- Detonate a controlled explosion
- Explosion expands an air bag

The occupant ( passenger ) detection system for air bag shut off interdicts the electrical system just prior to the signal to detonate the controlled explosion, as shown in the modified schematics.

The Mercedes-Benz is a full size luxury vehicle. The seat width of the front seat in this vehicle is larger than the seat width of US manufactured sub-compact and compact vehicles. The seating area of the intended single passenger sitting position is relatively the same in all vehicles, particularly for bucket seats. It should also be noted that front located bench seats, especially pickups, and "split" seats on passenger vehicles, offer a larger seating area than vehicles with bucket seats. The bench and split seats provide for three ( 3 ) people in the front seating area ( driver and two ( 2 ) passengers). However, when two ( 2 ) people are in the front seat ( driver and one ( 1 ) passenger), the passenger has a chance to "move" around and in this case the switch pad would have to cover a larger area. If a switch pad, sized for a bucket seat were used on a bench seat it is possible for the single passenger to sit in a position that would not activate the passenger air bag. As a result, the average total vehicle switch pad area is larger than the area of the intended sitting area for bucket seats.

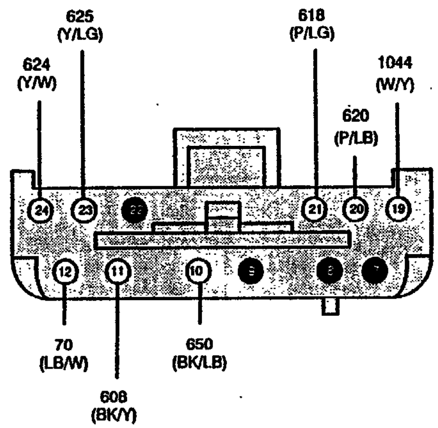
Because of the above stated considerations, a survey of the vehicles listed above, designated with an ( * ), was conducted to ascertain an average area and a min/max area so that material requirements for this cost analysis could be made. Figures 38 and 39 present a representative bench seat and a split seat. There are different split seats, some are 50/50, some are 40/60 and some feature a separate center seat, as pictured above.

Disassembled hardware parts were photographed after the manufacturing process analysis task to document the inner details of the components. These photographs are presented in Figures 40 through 44.

# 46–3 AIR BAGS

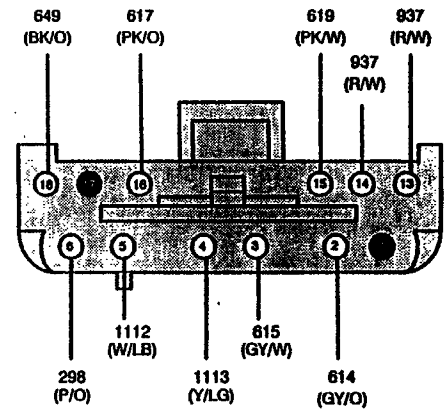







C208 (BLACK)
AIR BAG DIAGNOSTIC MONITOR

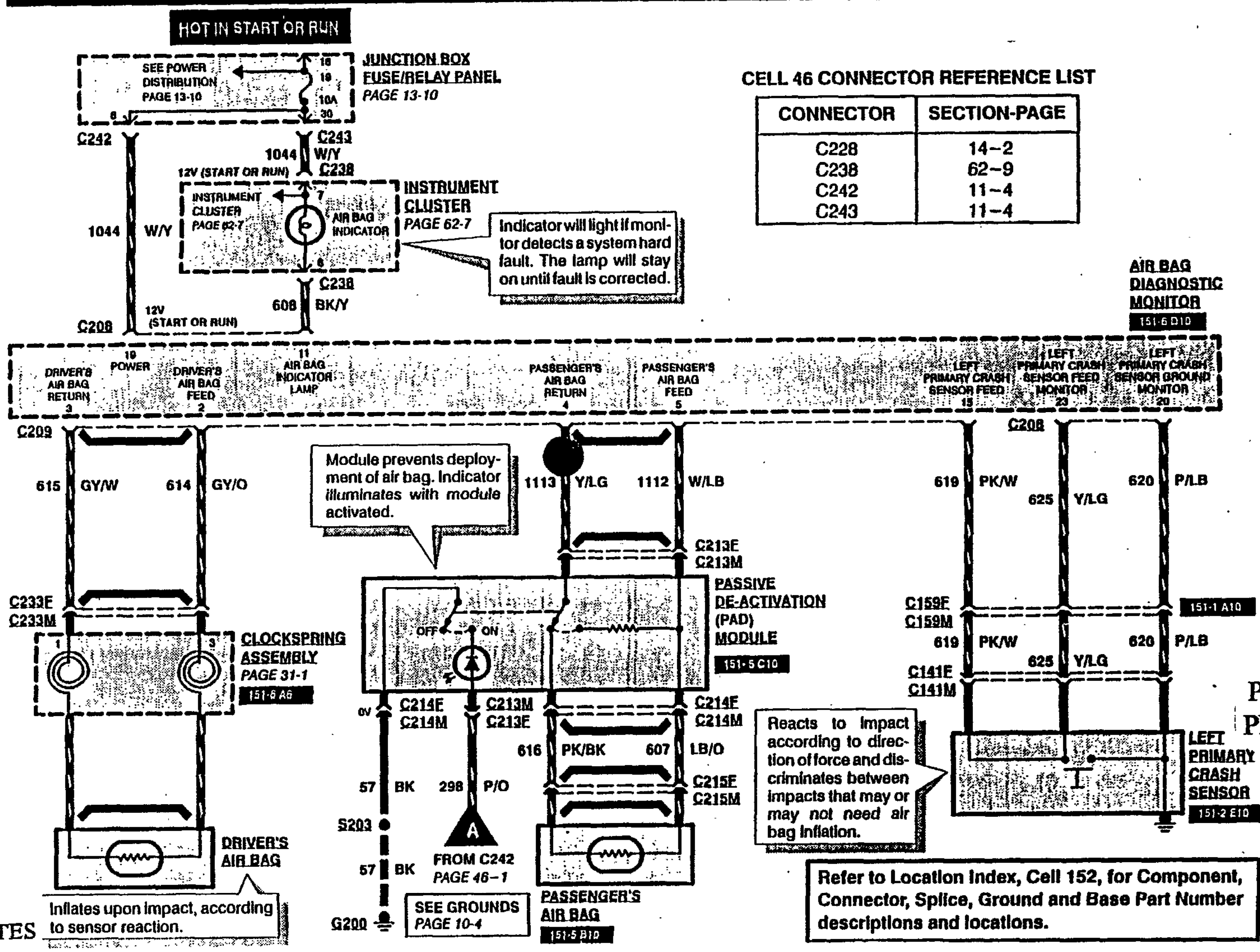
| PIN | CIRCUIT | CIRCUIT FUNCTION |
|---|---|---|
| 7 | — | NOT USED |
| 8 | — | NOT USED |
| 9 | — | NOT USED |
| 10 | 650 (BK/LB) | Ground |
| 11 | 608 (BK/Y) | Air Bag Indicator Control |
| 12 | 70 (LB/W) | Diagnostic Request |
| 19 | 1044 (W/Y) | Power (RUN or START) |
| 20 | 620 (P/LB) | Primary Crash Sensor Ground Monitor (LH) |
| 21 | 618 (P/LG) | Primary Crash Sensor Ground Monitor (RH) |
| 22 | — | NOT USED |
| 23 | 625 (Y/LG) | Primary Crash Sensor Feed Monitor (LH) |
| 24 | 624 (Y/W) | Primary Crash Sensor Feed Monitor (RH) |




C209 (GRAY)
AIR BAG DIAGNOSTIC MONITOR

| PIN | CIRCUIT | CIRCUIT FUNCTION |
|---|---|---|
| 1 | — | NOT USED |
| 2 | 614 (GY/O) | Driver's Air Bag Feed |
| 3 | 615 (GY/W) | Driver's Air Bag Return |
| 4 | 1113 (Y/LG) | Passive De-activation (PAD) Module Return |
| 5 | 1112 (W/LB) | Passive De-activation (PAD) Module Feed |
| 6 | 298 (P/O) | Vehicle Power (12V) (RUN) |
| 13 | 937 (R/W) | Vehicle Power (12V) |
| 14 | 937 (R/W) | Vehicle Power (12V) |
| 15 | 619 (PK/W) | Primary Crash Sensor Feed (LH) |
| 16 | 617 (PK/O) | Primary Crash Sensor Feed (RH) |
| 17 | — | NOT USED |
| 18 | 649 (BK/O) | Ground |

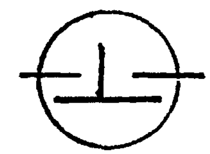
Figure 21




**CELL 46 CONNECTOR REFERENCE LIST**

| CONNECTOR | SECTION-PAGE |
|---|---|
| C228 | 14–2 |
| C238 | 62–9 |
| C242 | 11–4 |
| C243 | 11–4 |

POINT OF INTERDICTION



PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

MARK UPS
BY LUDTKE AND ASSOCIATES

Figure 21 ( Cont. )

# 46–1 AIR BAGS

1997 F-150

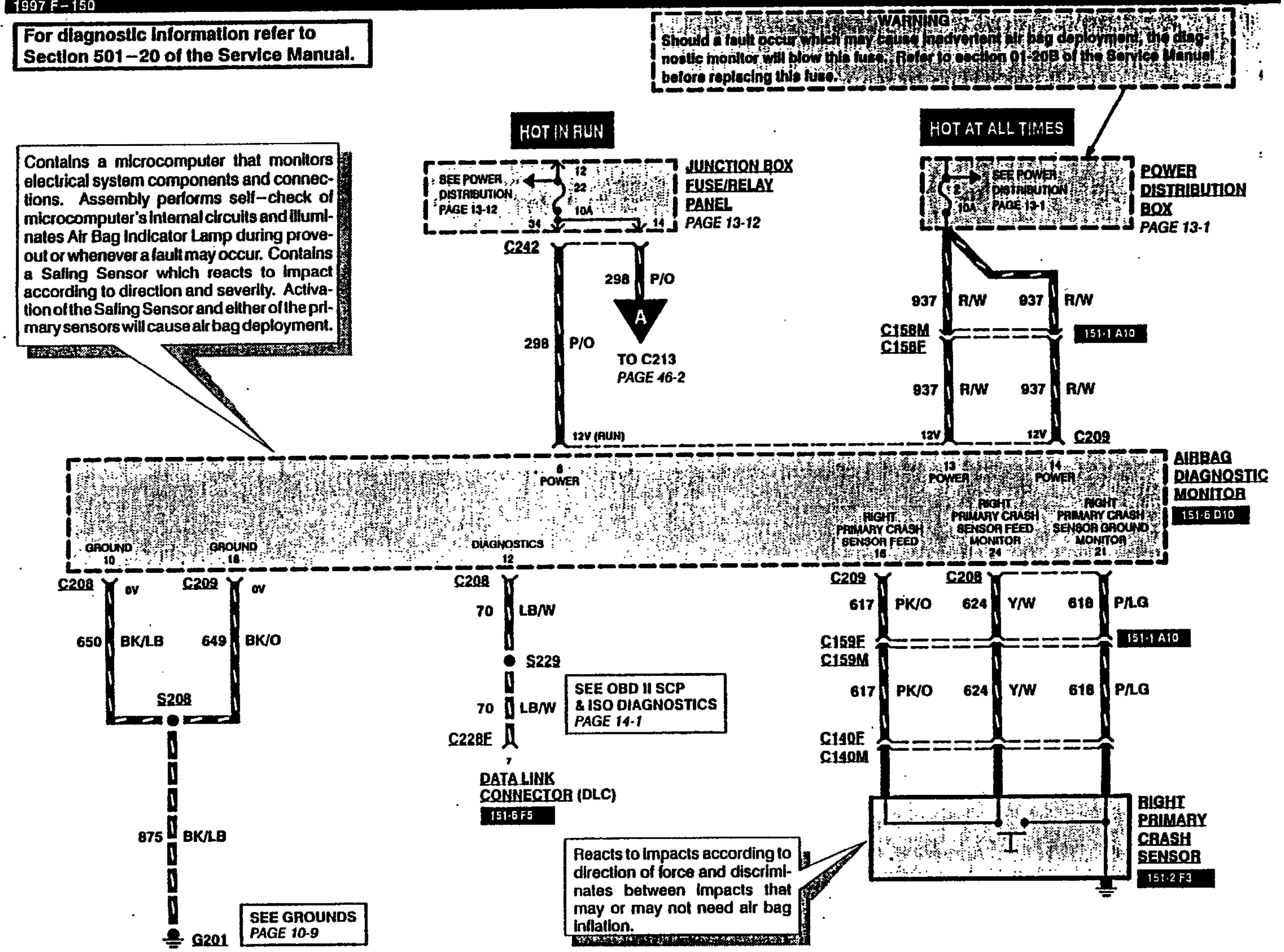
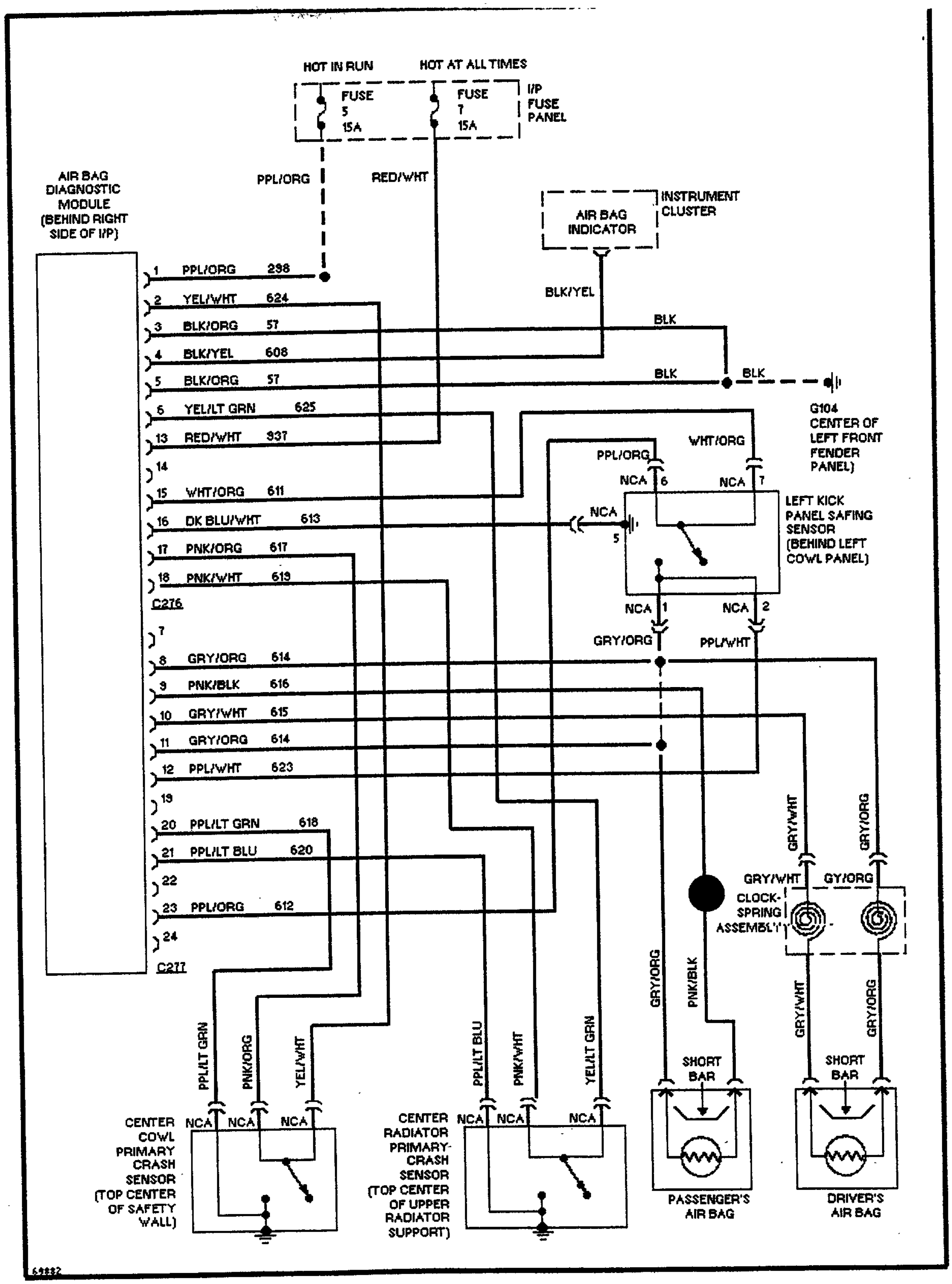
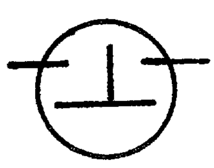



Figure 21 ( Cont. )

# 1995 FORD TAURUS



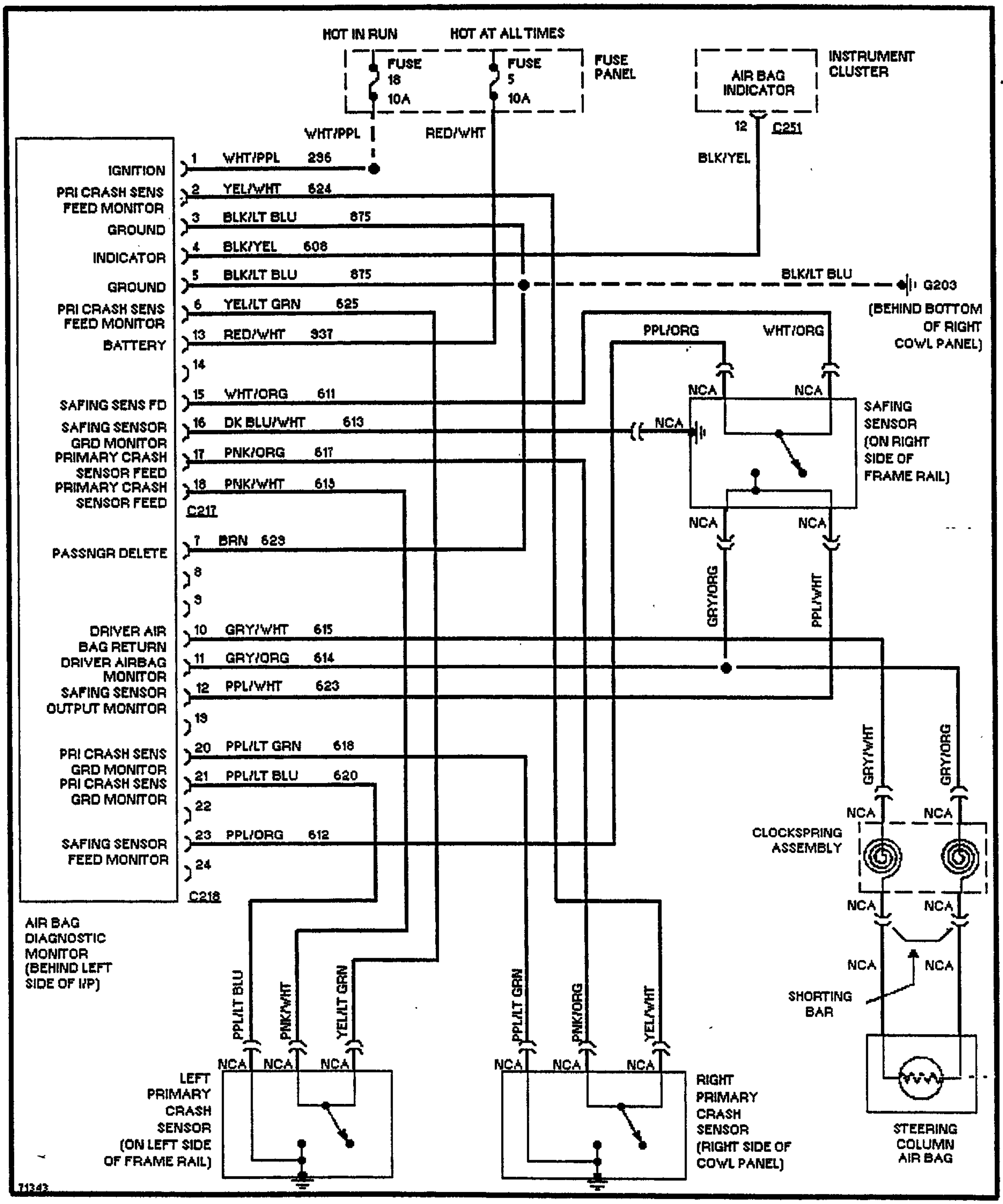
**PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR**

**POINT OF INTERDICTION**

MARK UPS
BY LUDTKE AND ASSOCIATES

Figure 22

# 1995 FORD F-150



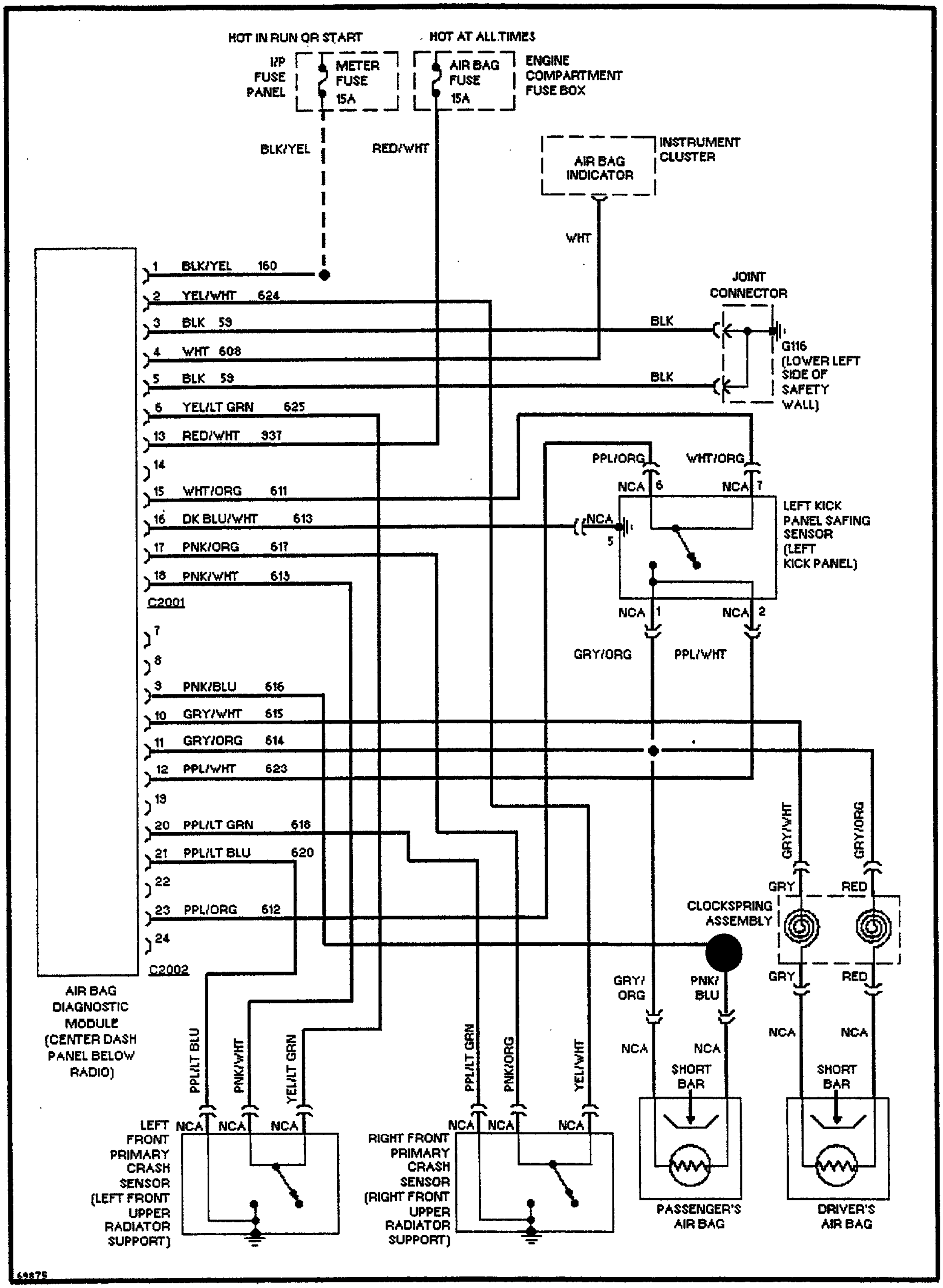

STEERING WHEEL
AIRBAG ONLY OFFERED

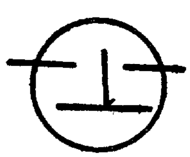
Figure 23



MARK UPS
BY LUDTKE AND ASSOCIATES

# 1995 FORD ESCORT



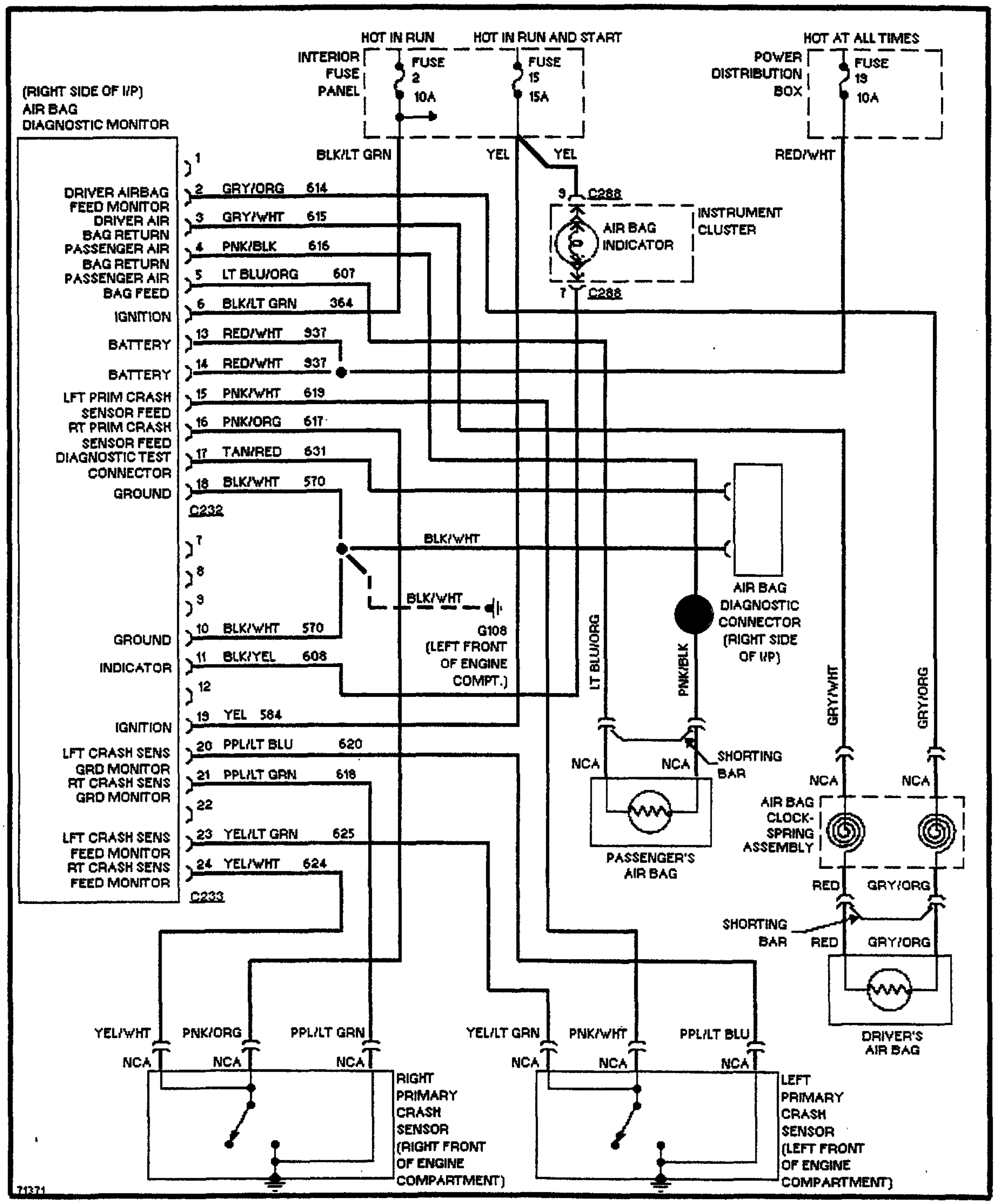
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

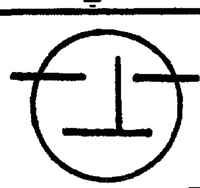
POINT OF INTERDICTION

Figure 24

MARK UPS
BY LUDTKE AND ASSOCIATES

# 1995 FORD EXPLORER



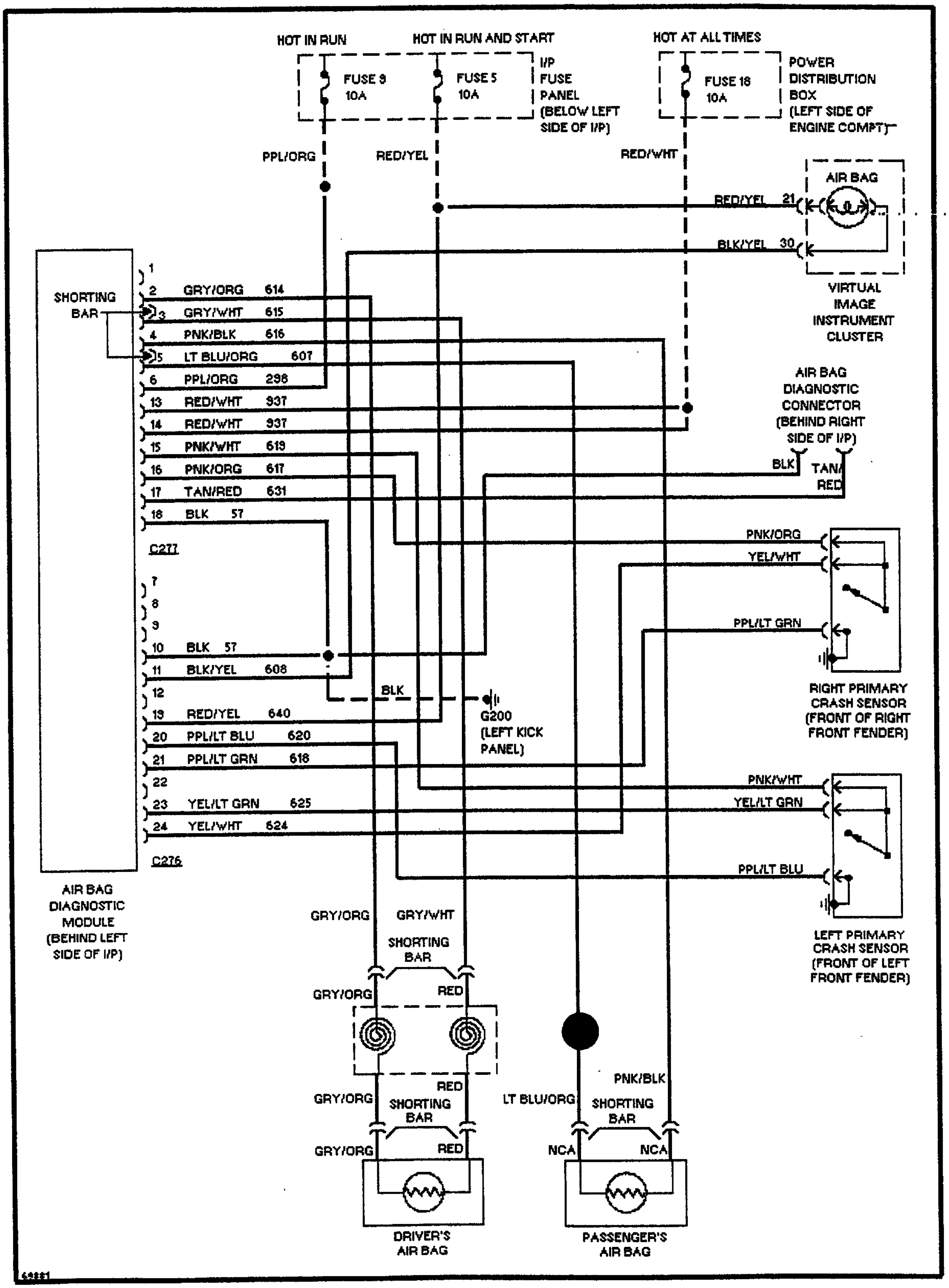
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

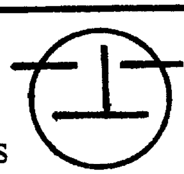
● POINT OF INTERDICTION

MARK UPS
BY LUDTKE AND ASSOCIATES

Figure 25

# 1995 LINCOLN CONTINENTAL



PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

● POINT OF INTERDICTION

MARK UPS
BY LUDTKE AND ASSOCIATES



Figure 26

# 1995 CHEVROLET LUMINA

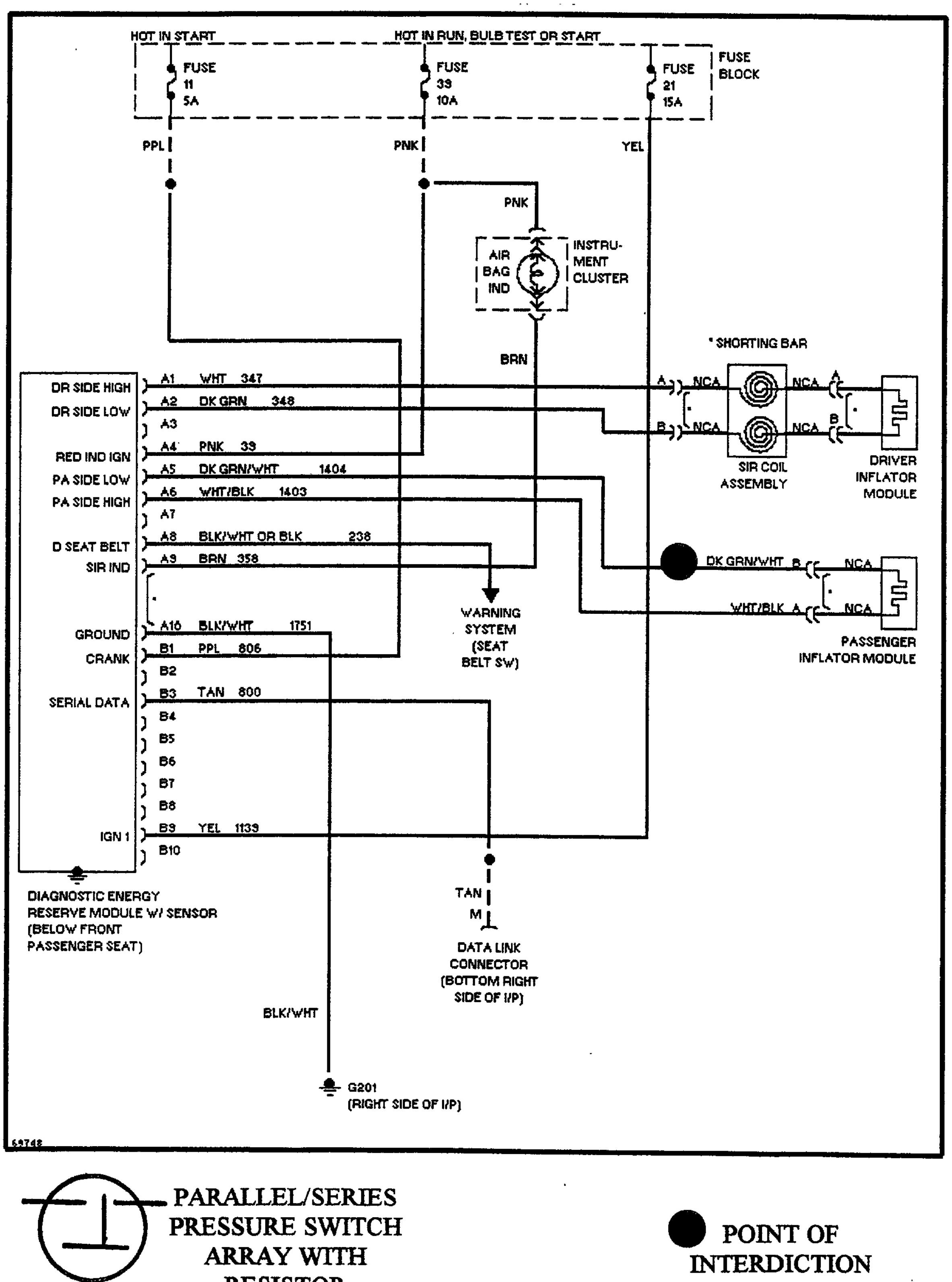
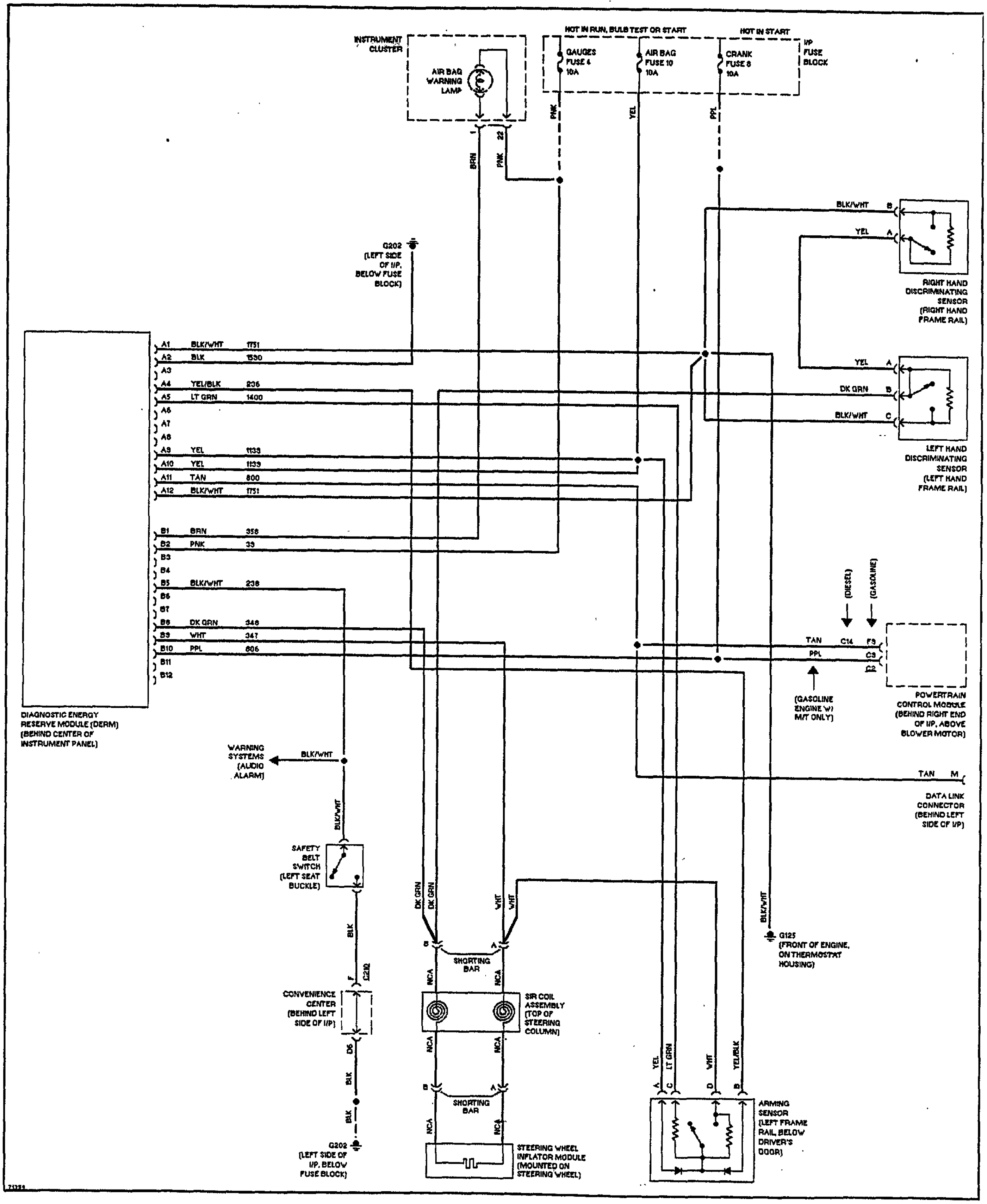



Figure 27

MARK UPS
BY LUDTKE AND ASSOCIATES

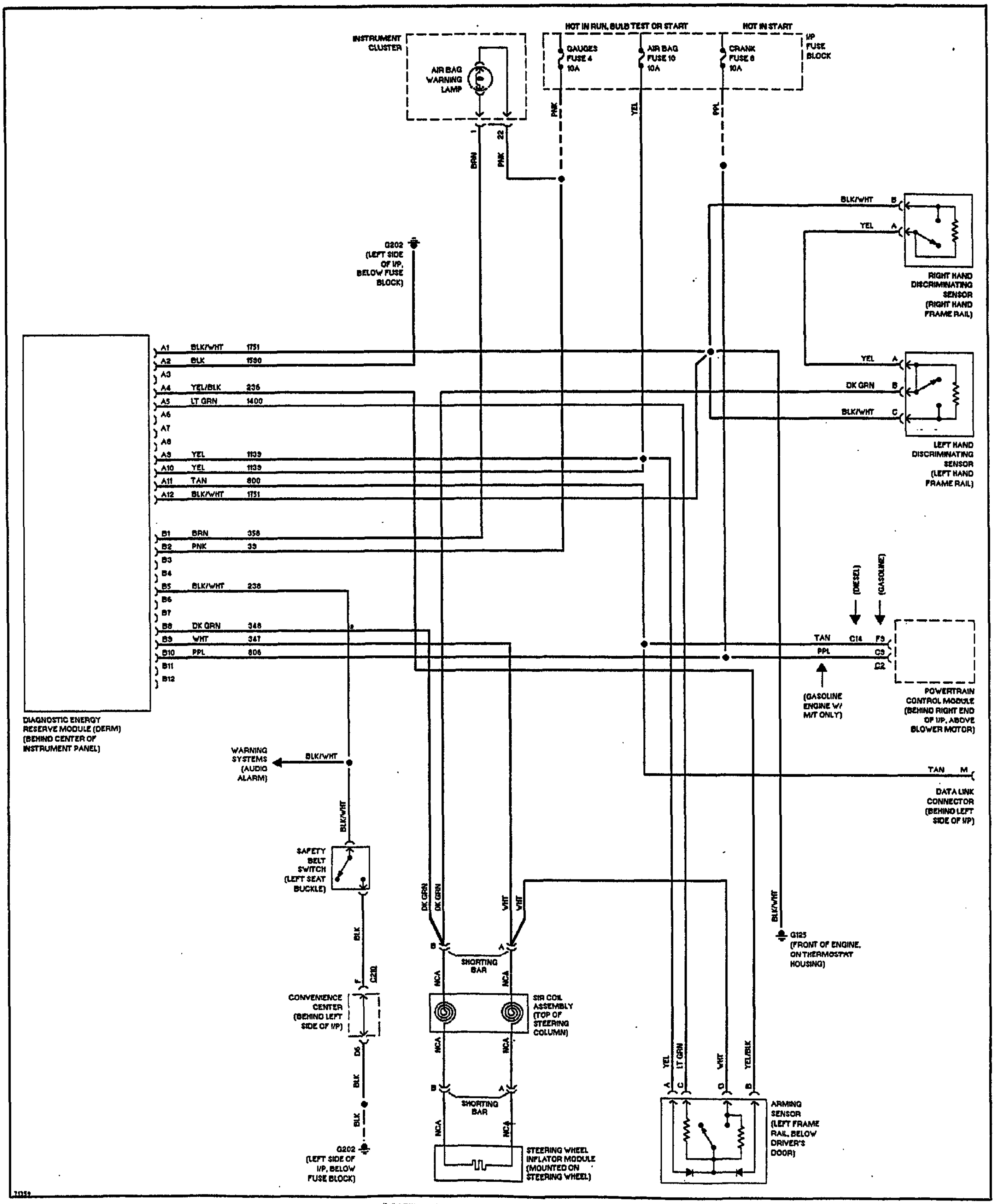
# 1995 CHEVROLET C1500




STEERING WHEEL
AIRBAG ONLY OFFERED
Figure 28

MARK UPS
BY LUDTKE AND ASSOCIATES

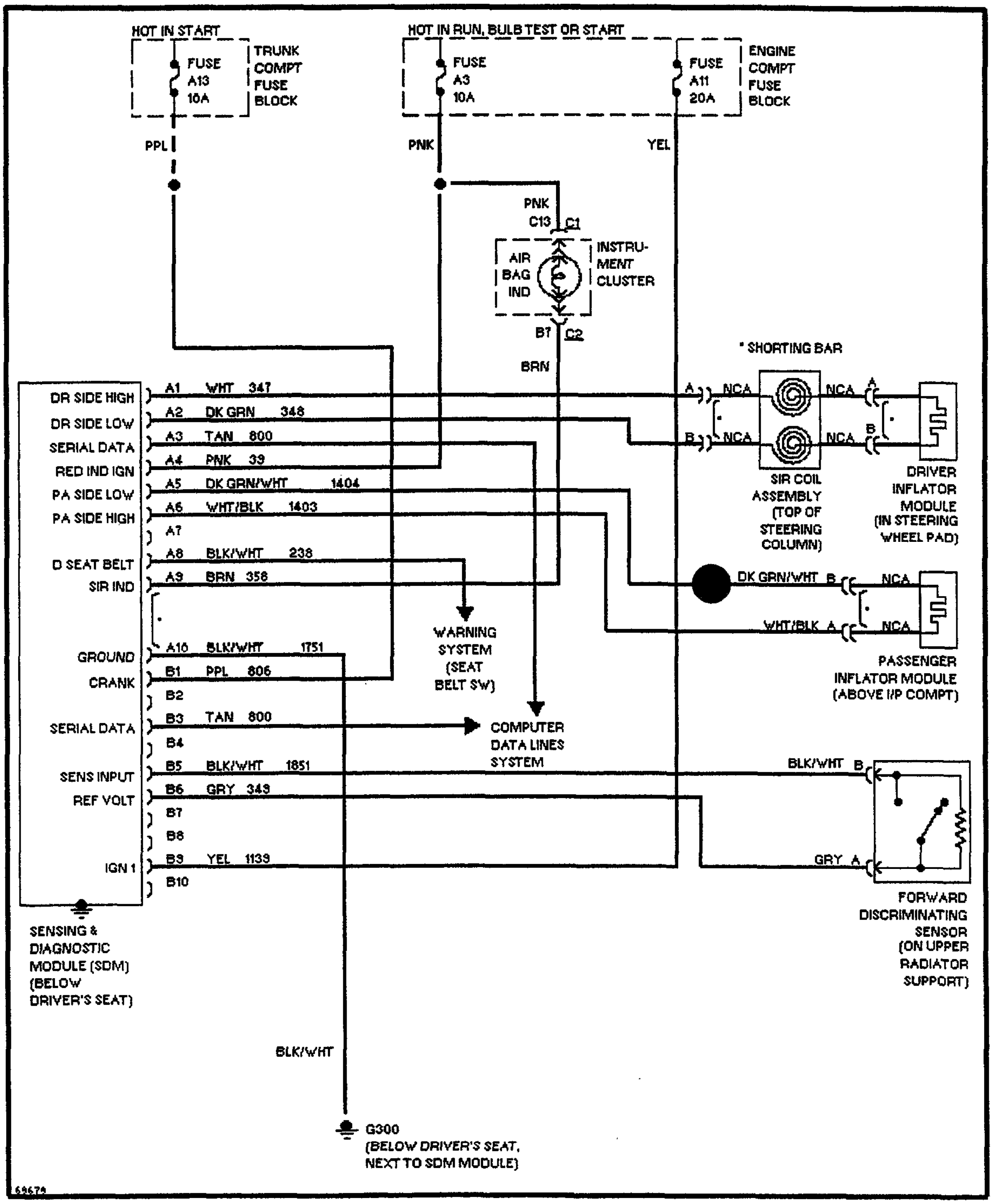
'995 CHEVROLET K1500

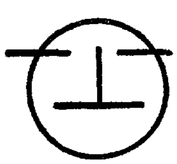



STEERING WHEEL
AIRBAG ONLY OFFERED
Figure 29

MARK UPS
BY LUDTKE AND ASSOCIATES

# 1995 CADILLAC DEVILLE



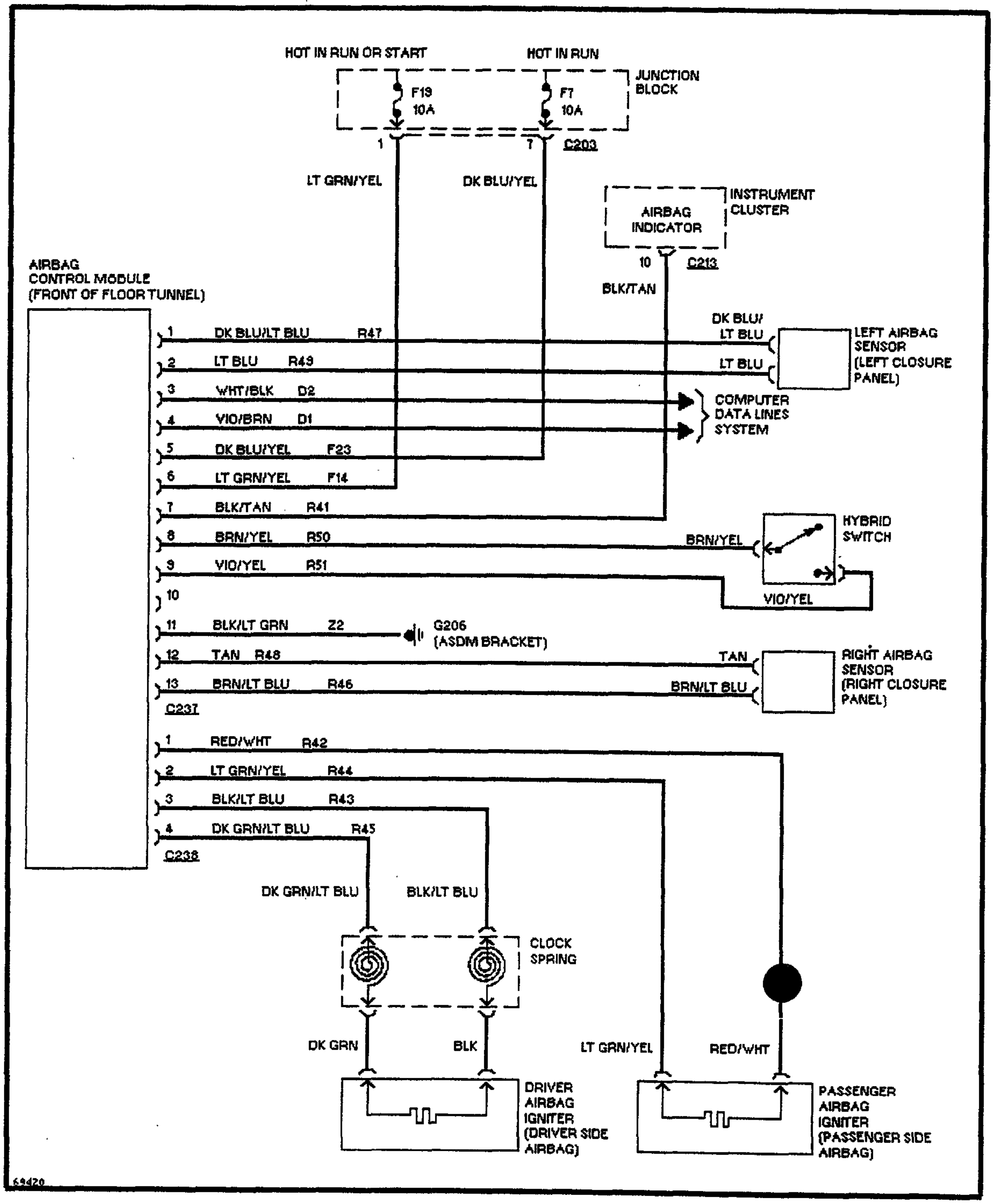
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

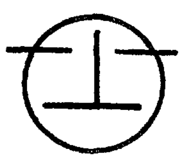
POINT OF INTERDICTION

Figure 30

MARK UPS
BY LUDTKE AND ASSOCIATES

# 1995 DODGE INTREPID



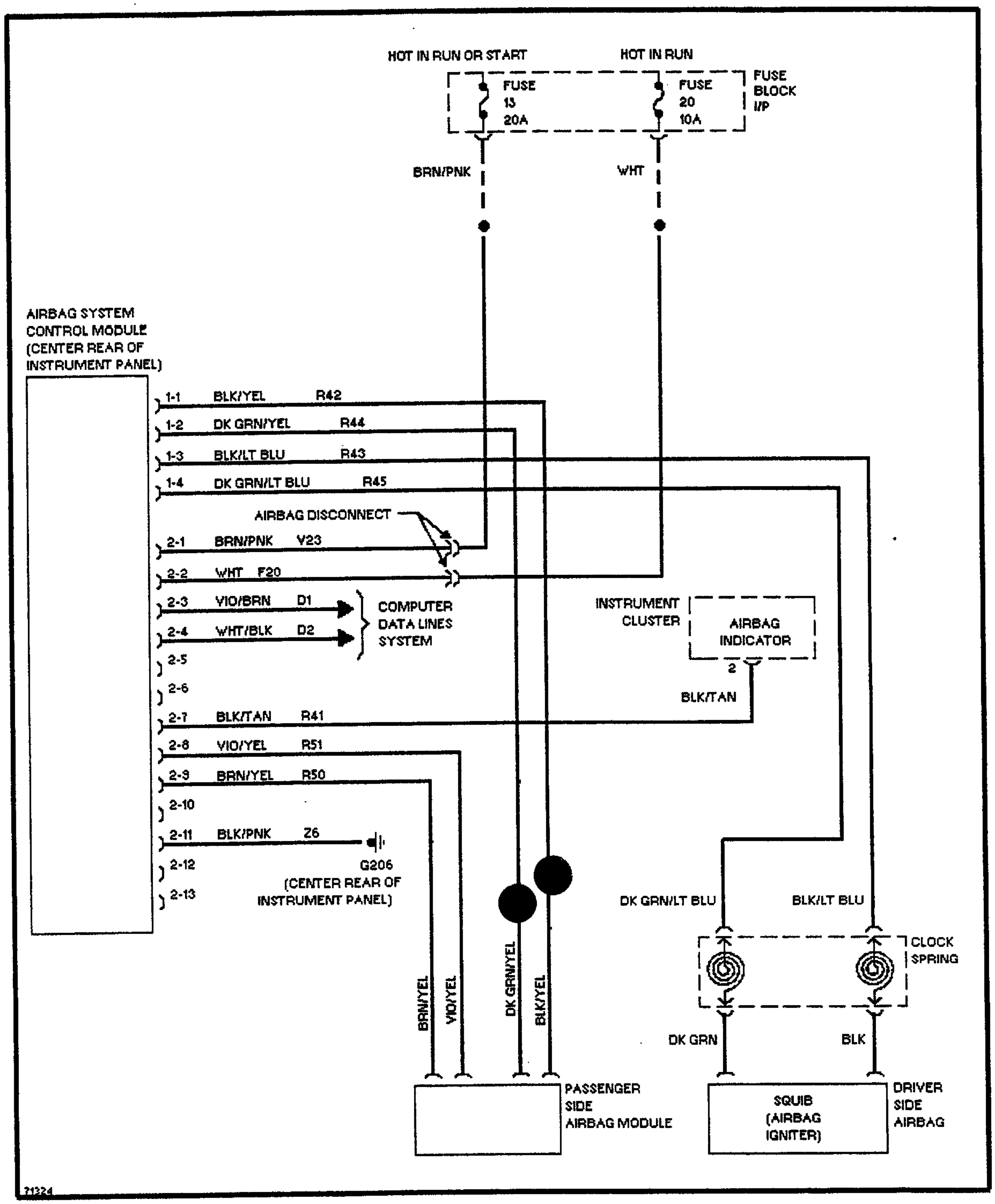
**PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR**

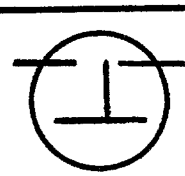
● **POINT OF INTERDICTION**

MARK UPS
BY LUDTKE AND ASSOCIATES

Figure 31

# 1995 CHRYSLER TOWN & COUNTRY



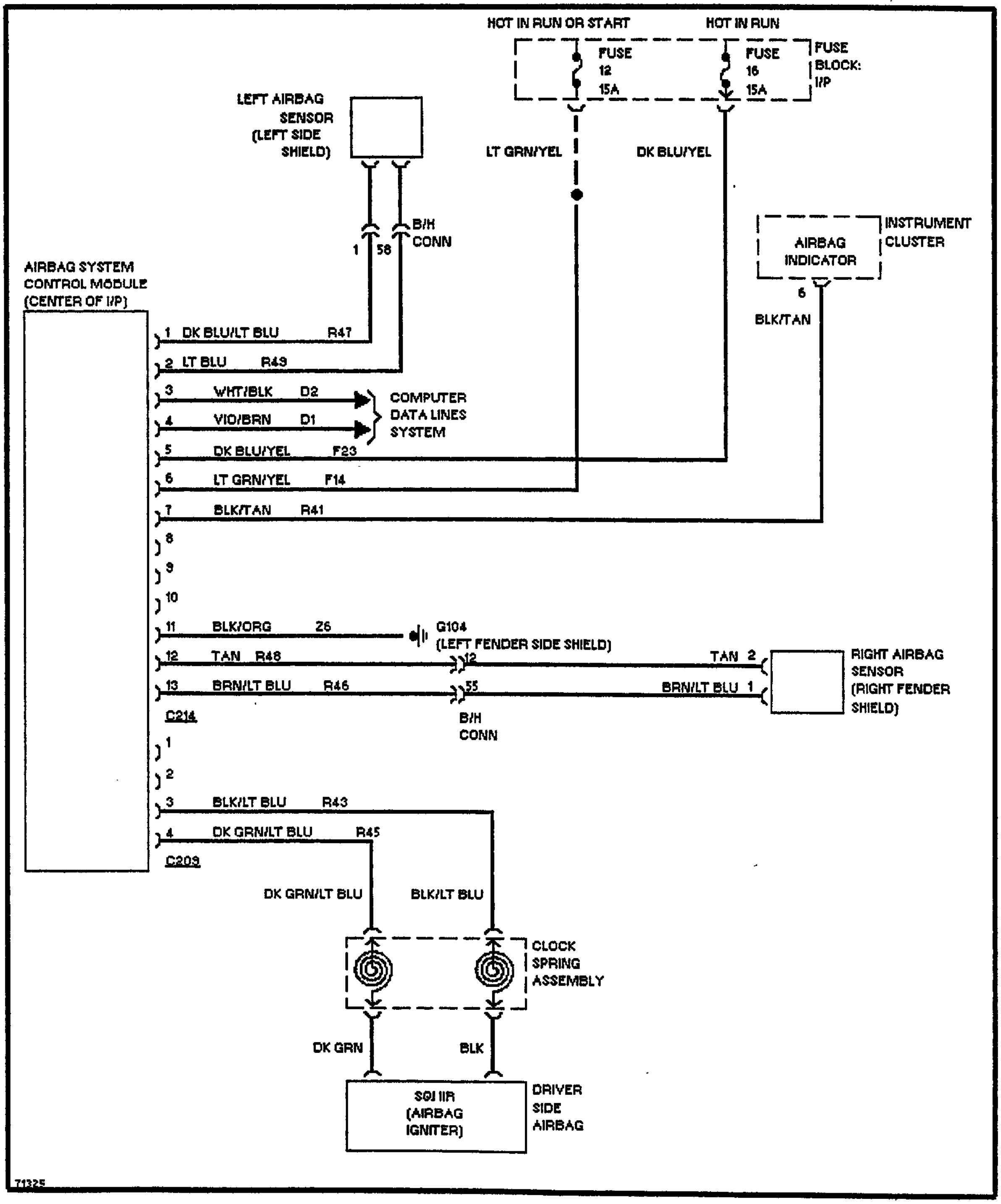
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

POINT OF INTERDICTION

MARK UPS
BY LUDTKE AND ASSOCIATES

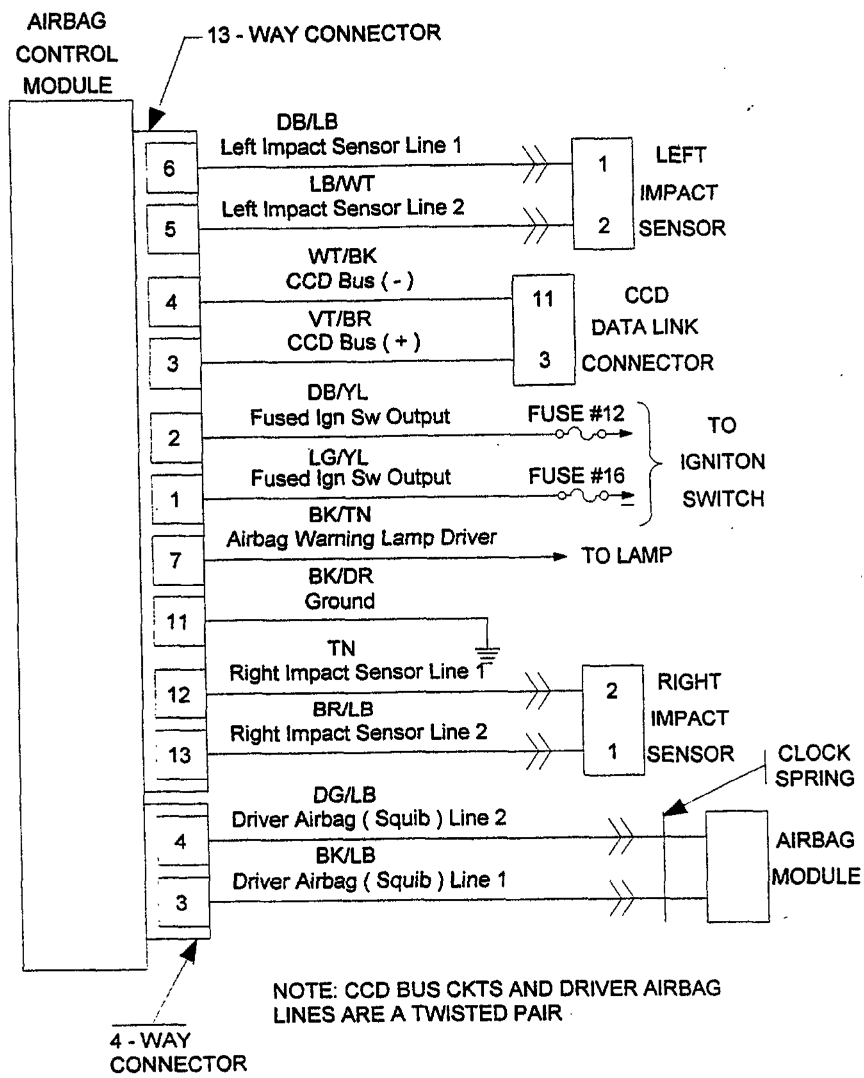
Figure 32

# 1995 DODGE RAM




STEERING WHEEL
AIRBAG ONLY OFFERED
Figure 33

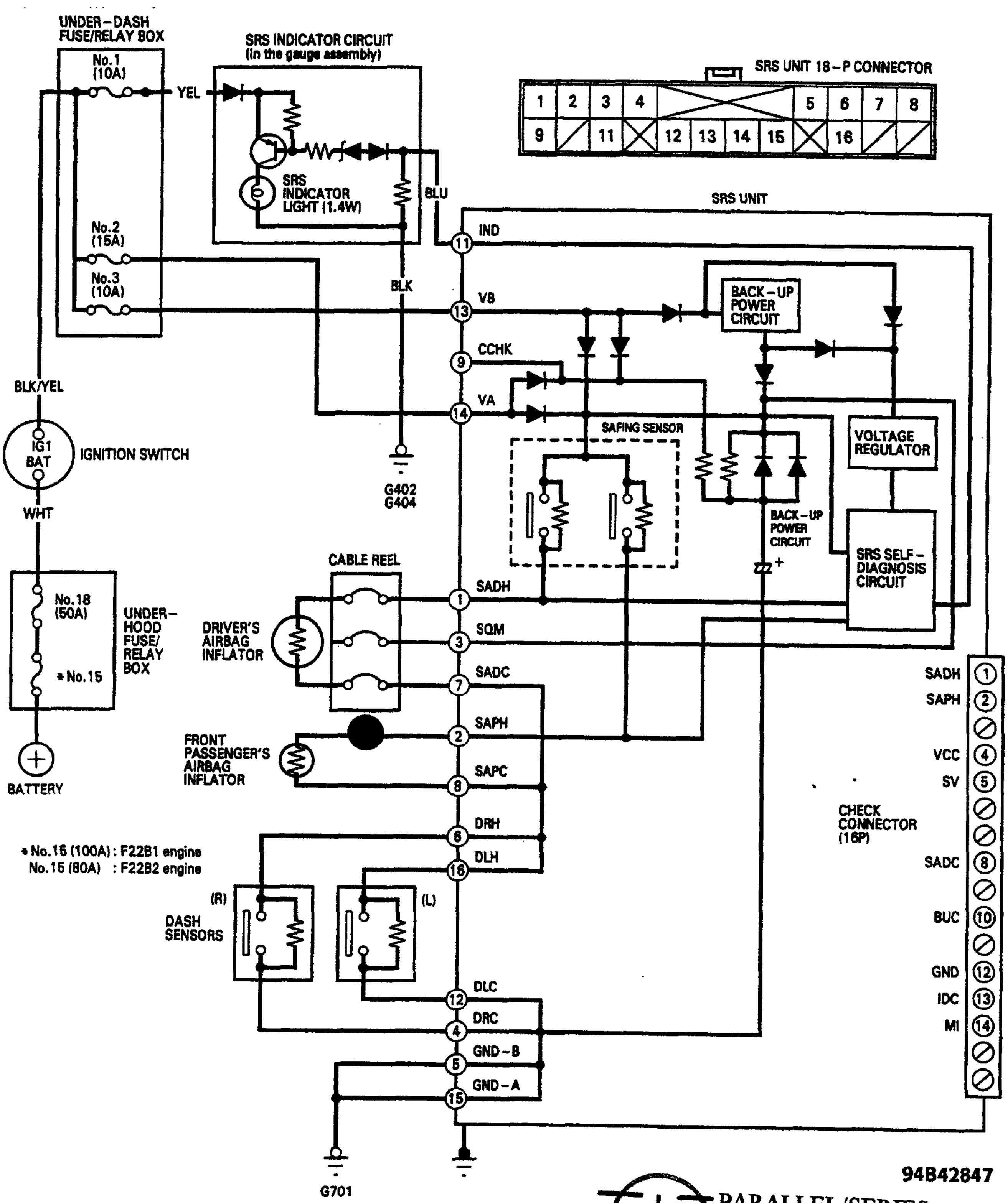
## AIRBAG SYSTEM




**STEERING WHEEL**
**AIRBAG ONLY OFFERED**

Figure 34

# 1995 HONDA ACCORD



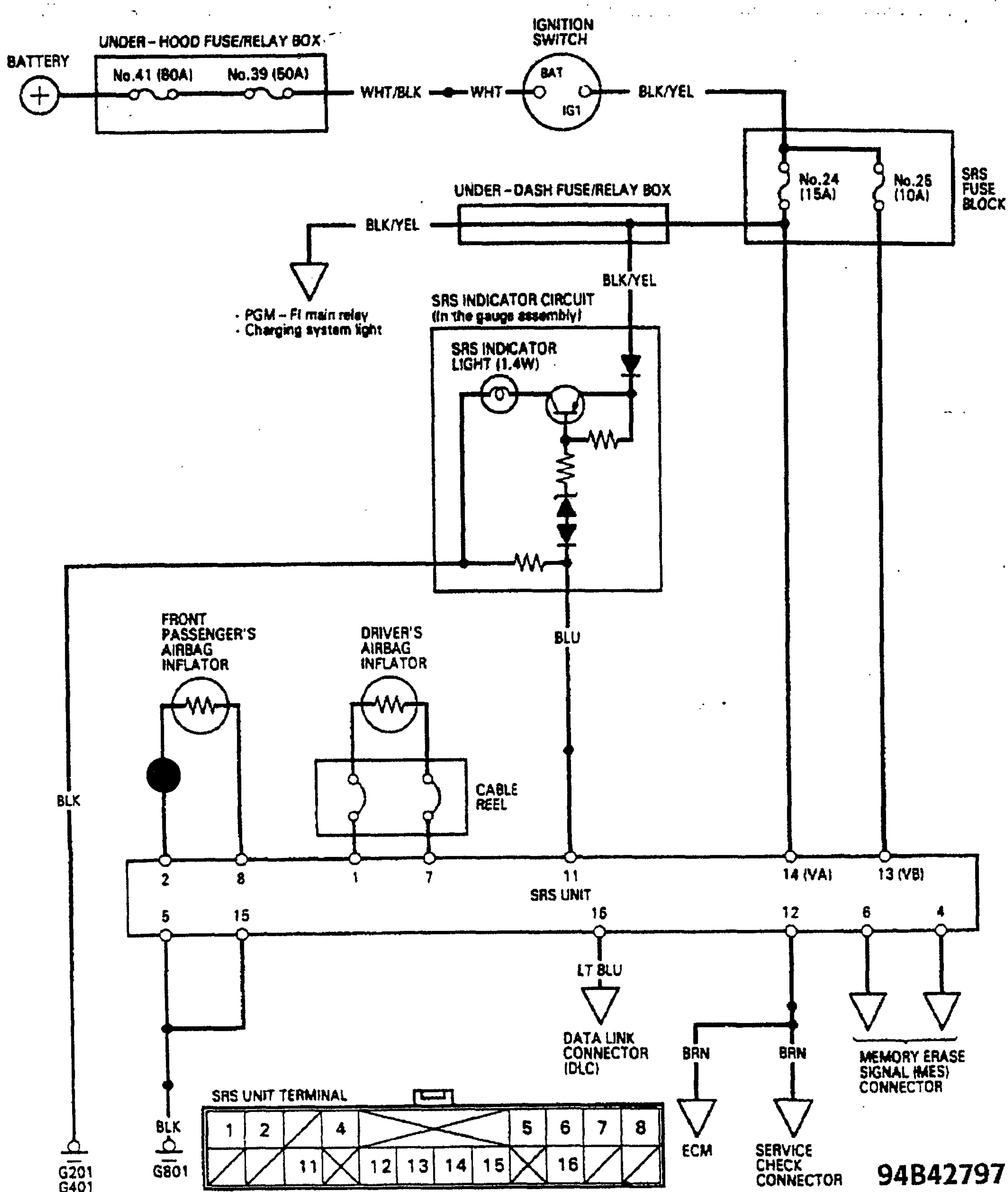

POINT OF INTERDICTION

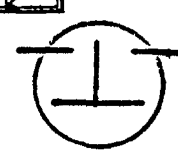
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

Figure 35

MARK UPS
BY LUDTKE AND ASSOCIATES

# 1995 HONDA CIVIC



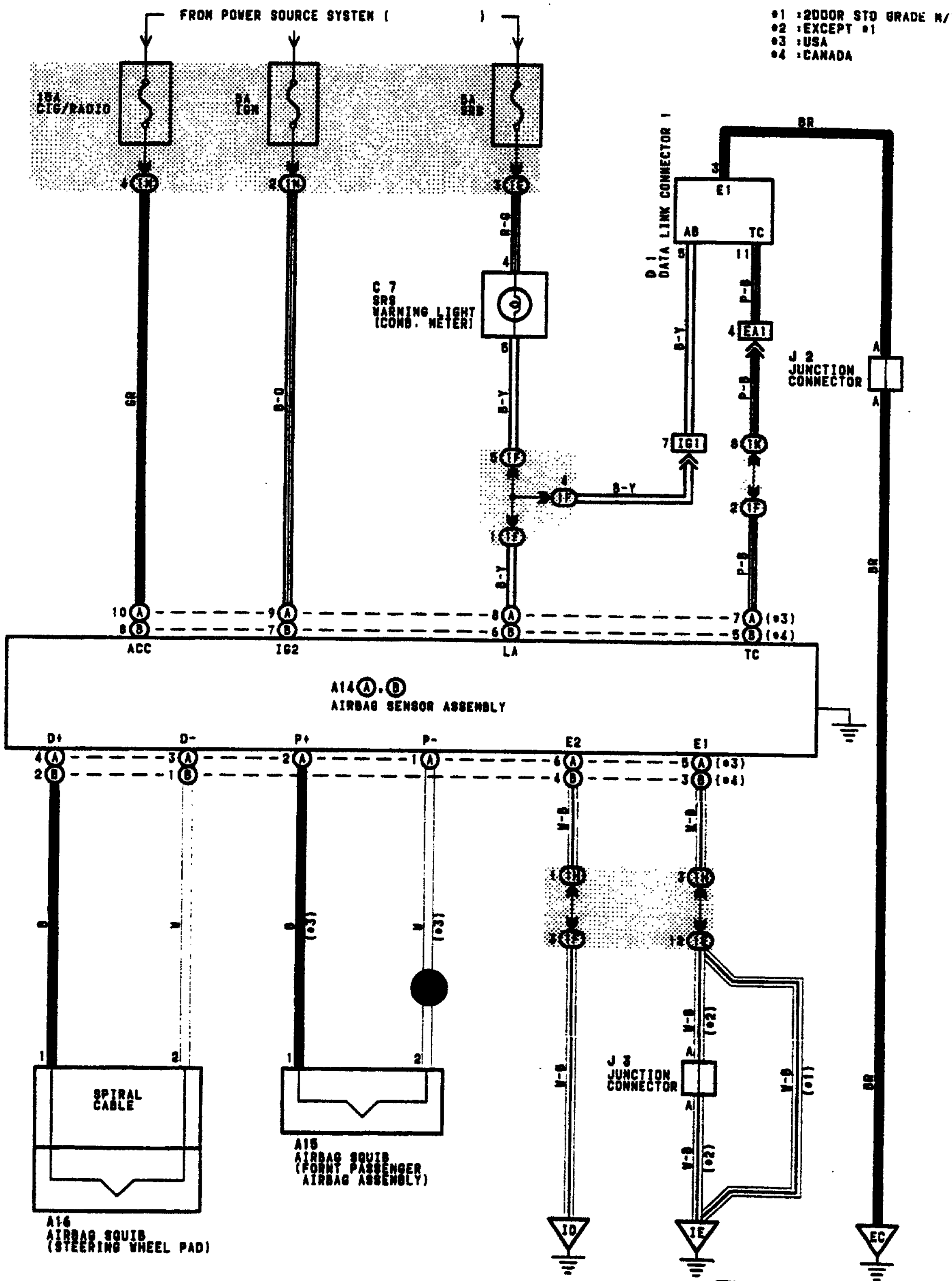
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

● POINT OF INTERDICTION

Figure 36

MARK UPS
E. LUDTKE AND ASSOCIATES

# 1995 TOYOTA TERCEL




95126490

Figure 37

46

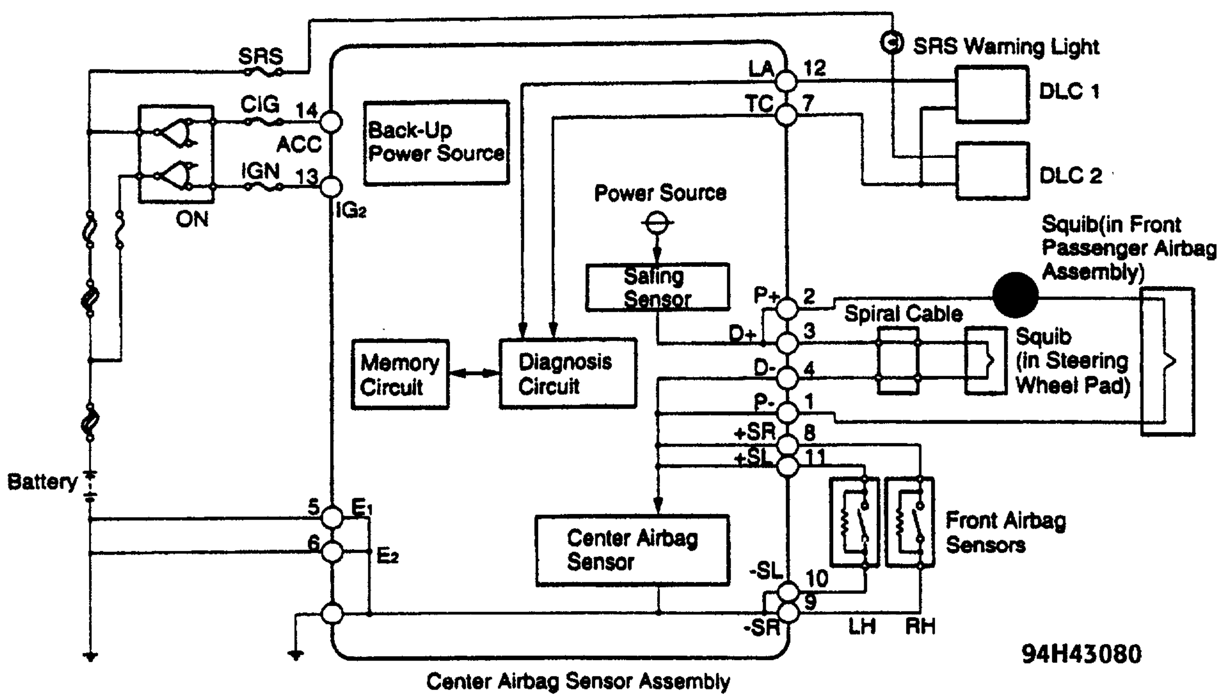
● POINT OF INTERDICTION

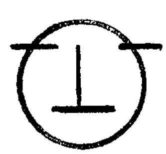
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

MARK UPS
BY LUDTKE AND ASSOCIATES

# 1995 TOYOTA CAMRY

## TRW



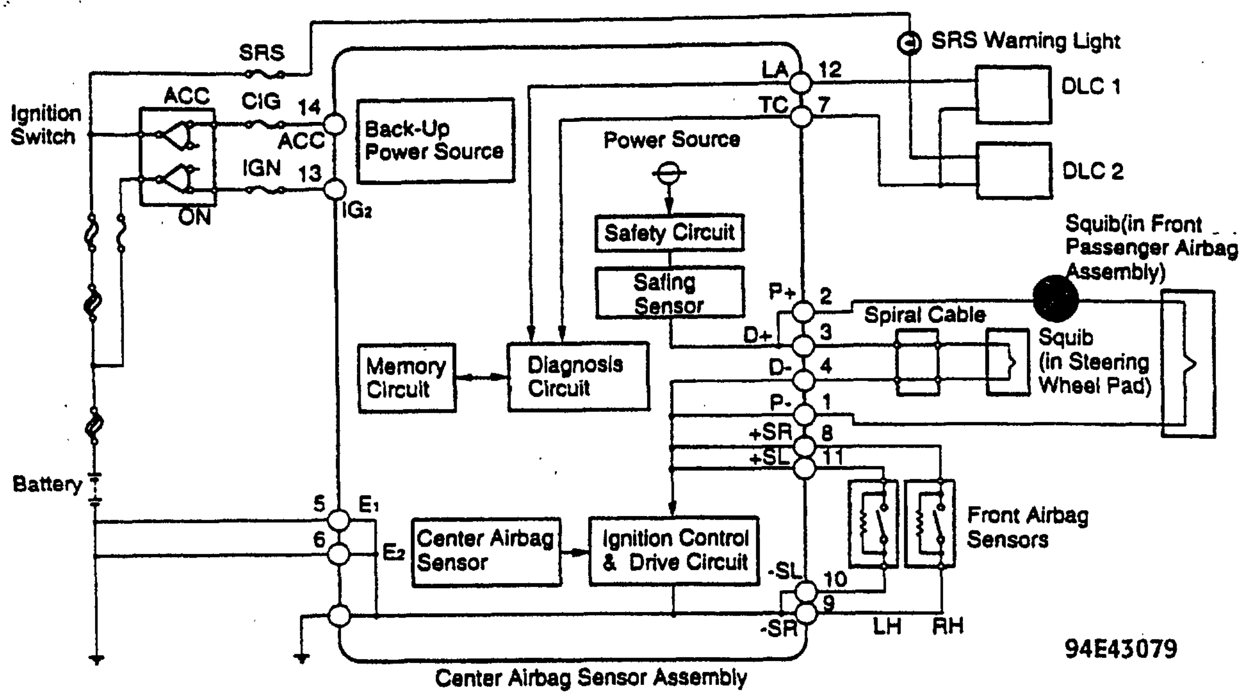
PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

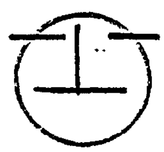
● POINT OF INTERDICTION

Figure 38

1995 TOYOTA CAMRY

NIPPEN DENSO

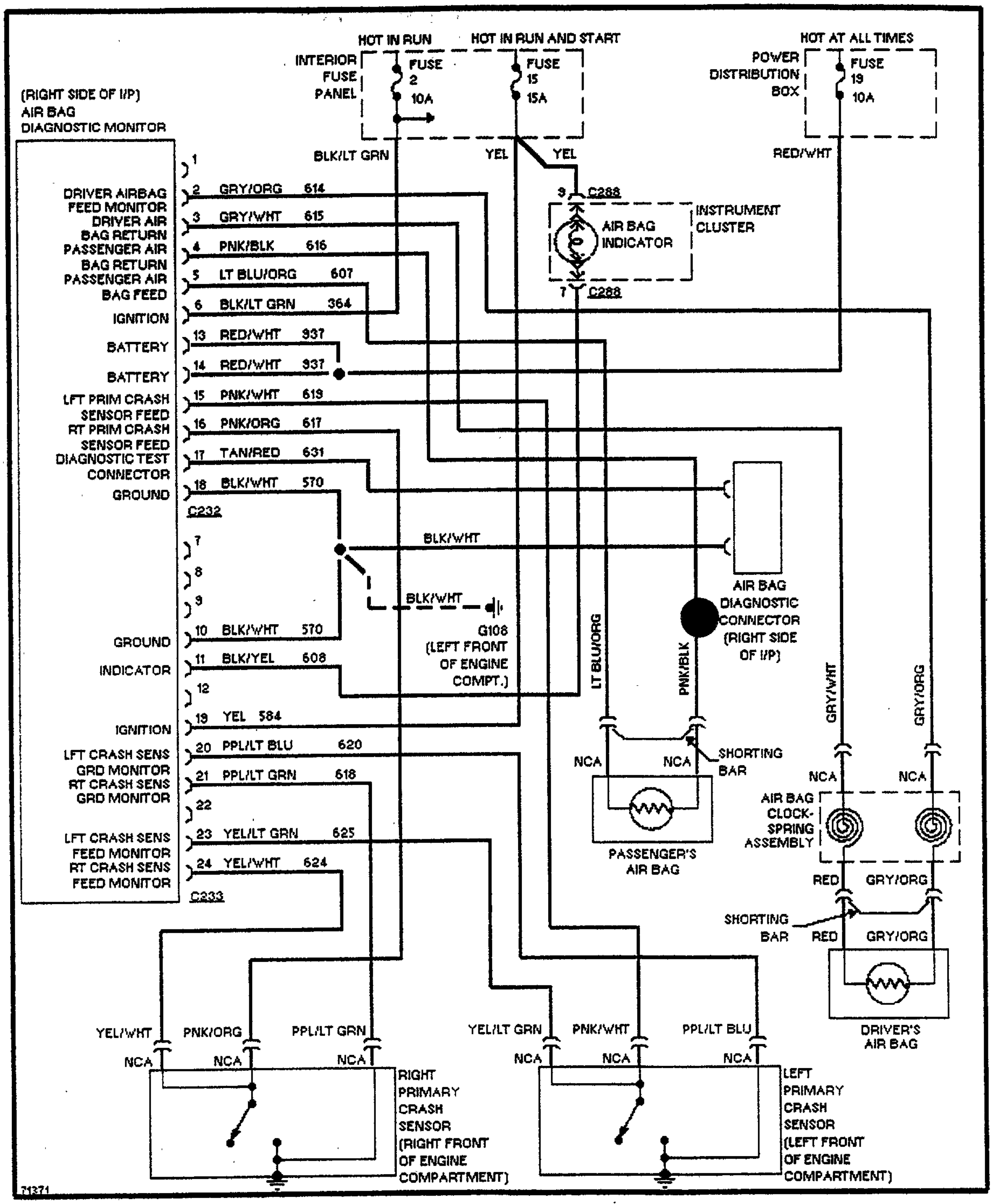


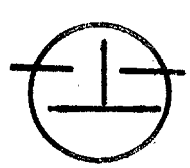



PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

POINT OF INTERDICTION

Figure 39



PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

● POINT OF INTERDICTION

Figure 40



MARK UPS
BY LUDTKE AND ASSOCIATES

Figure 41

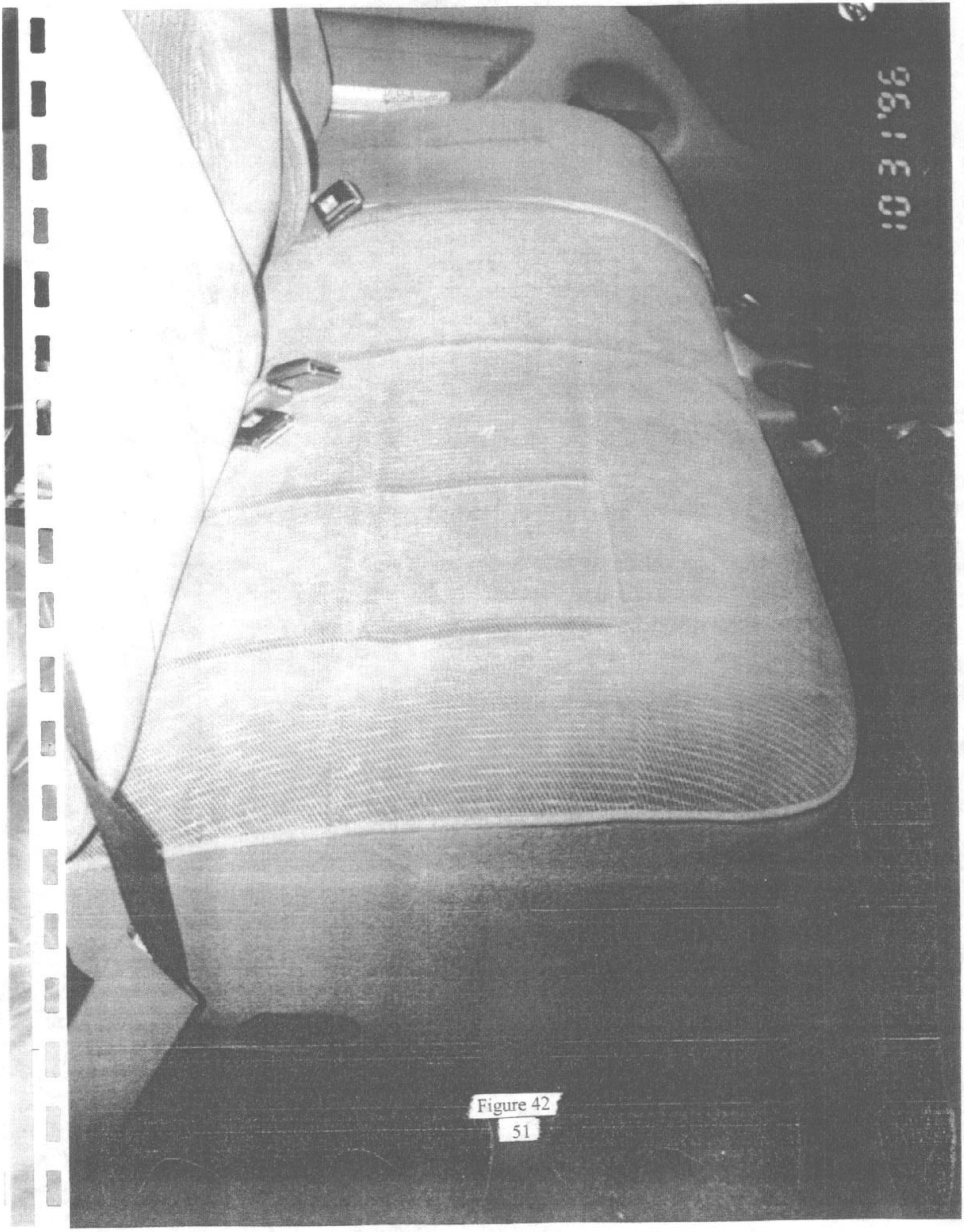



Figure 42

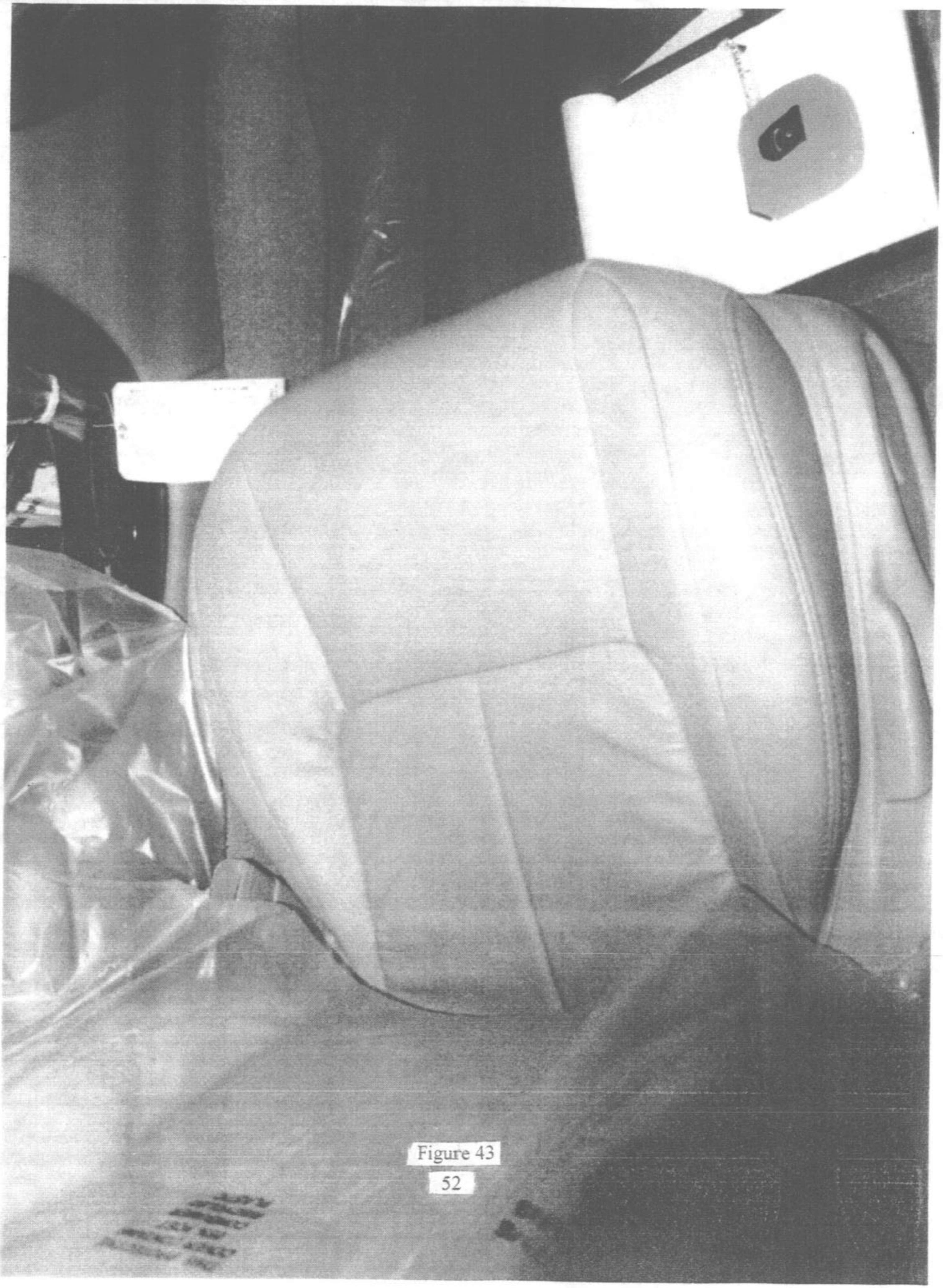


Figure 43

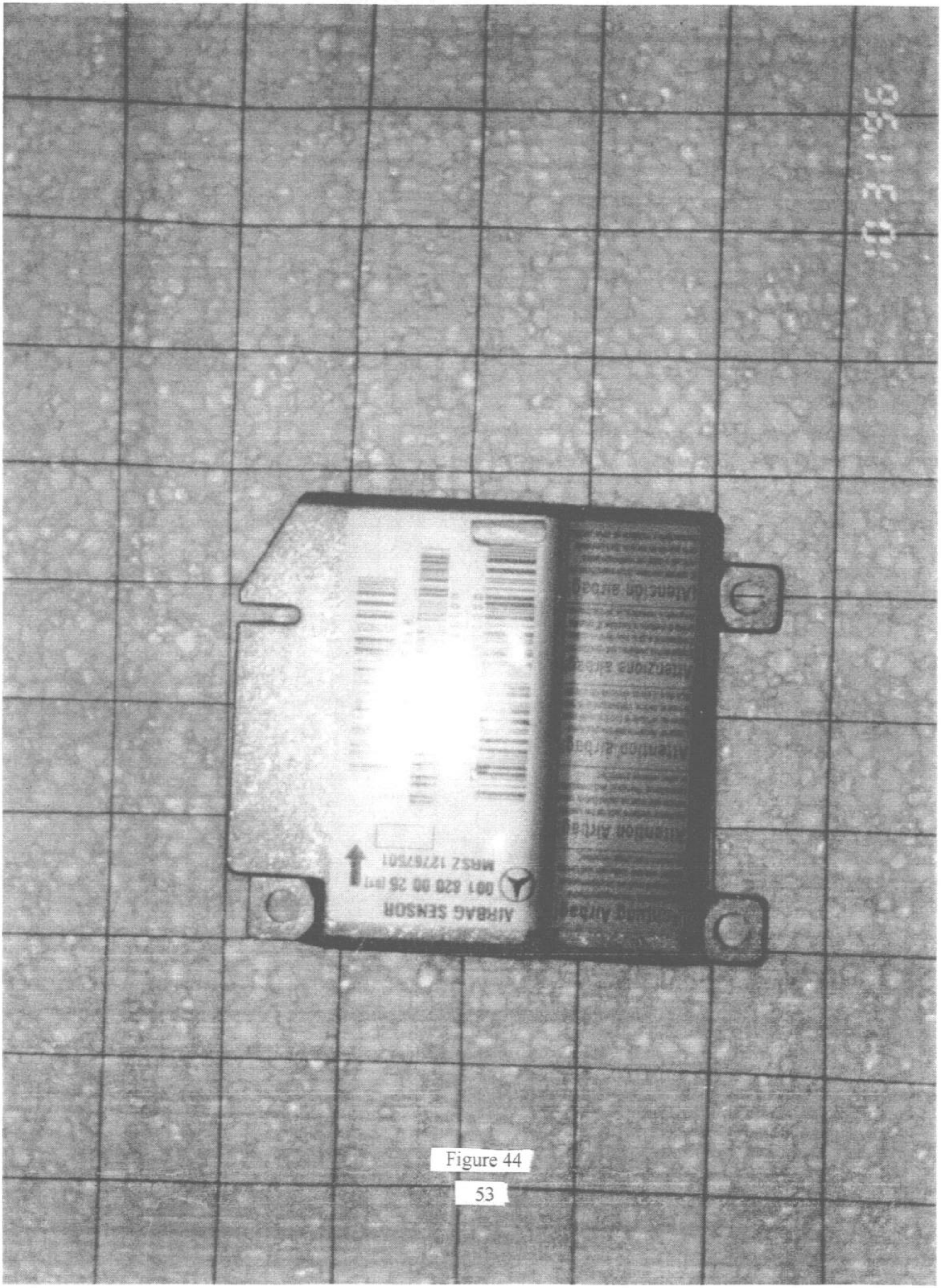



Figure 44

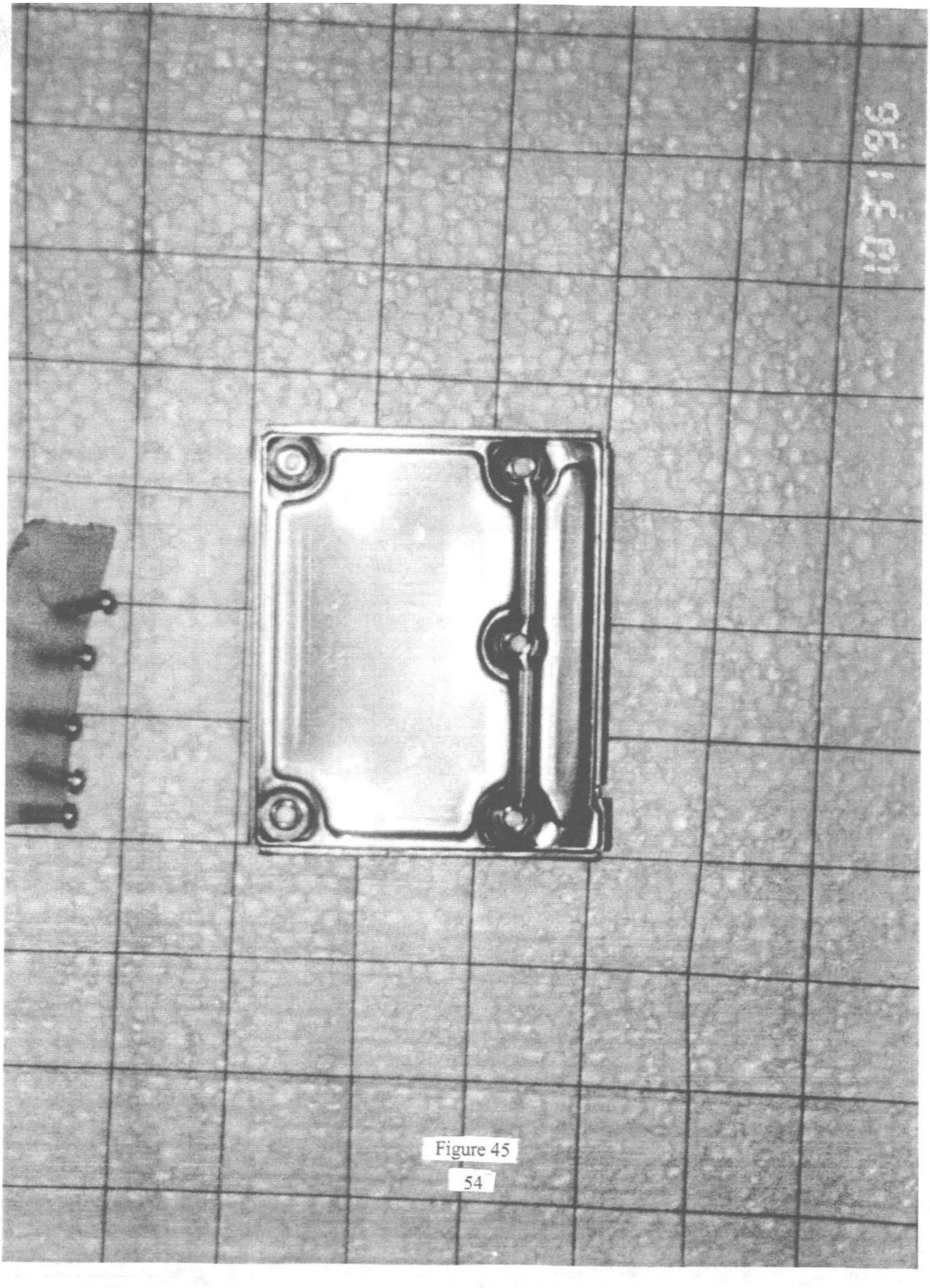



Figure 45

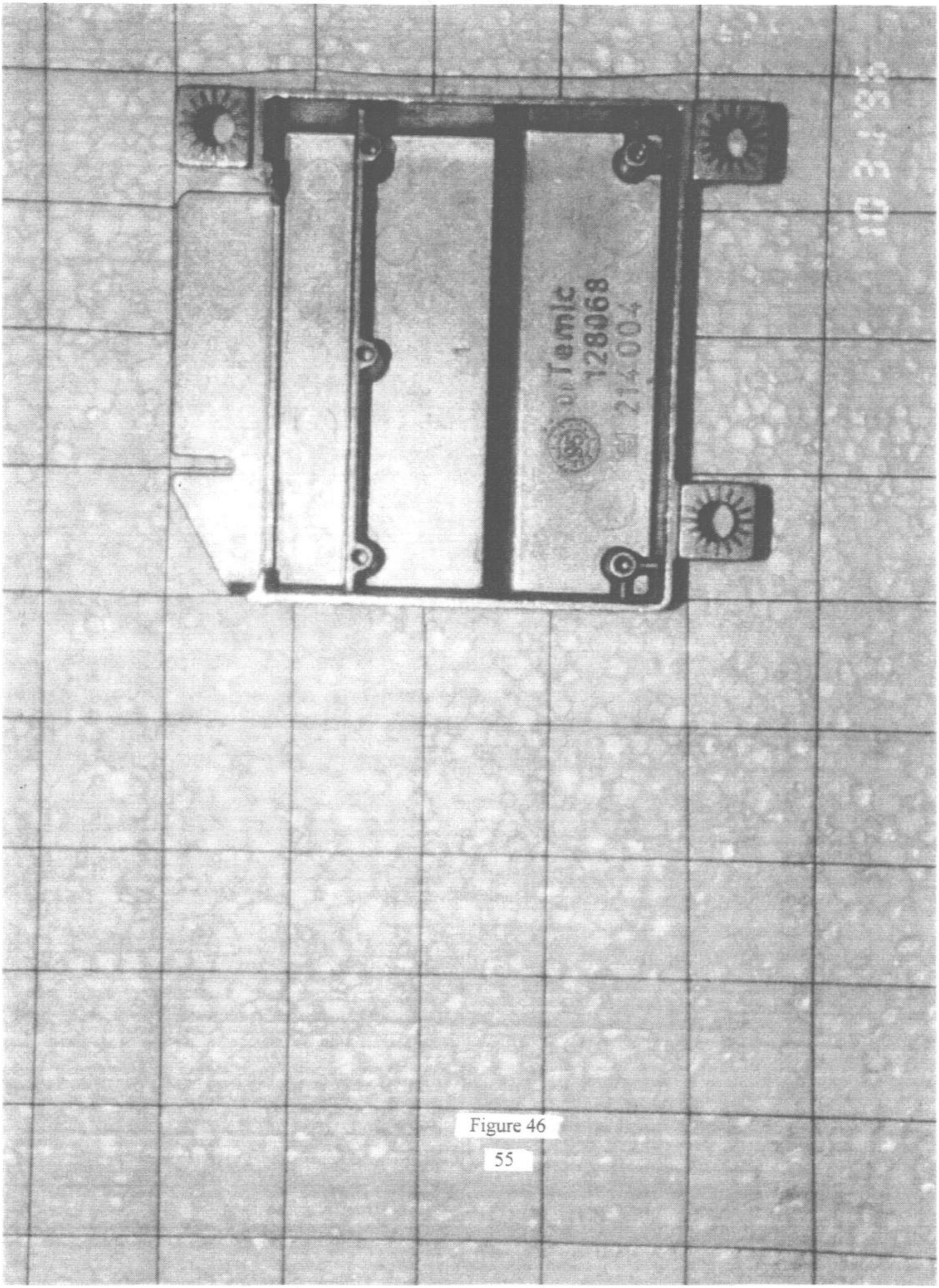



Figure 46

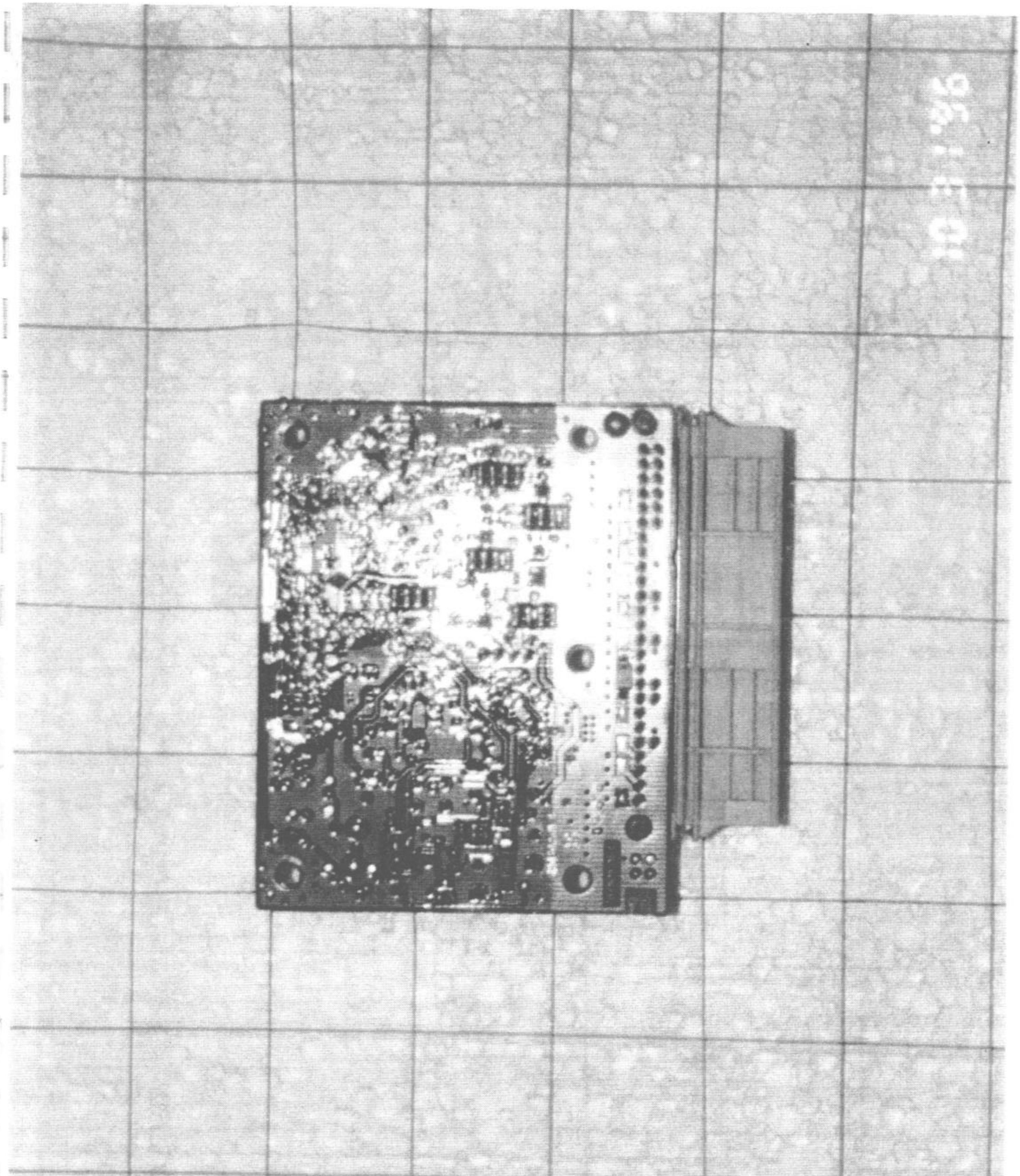


Figure 47

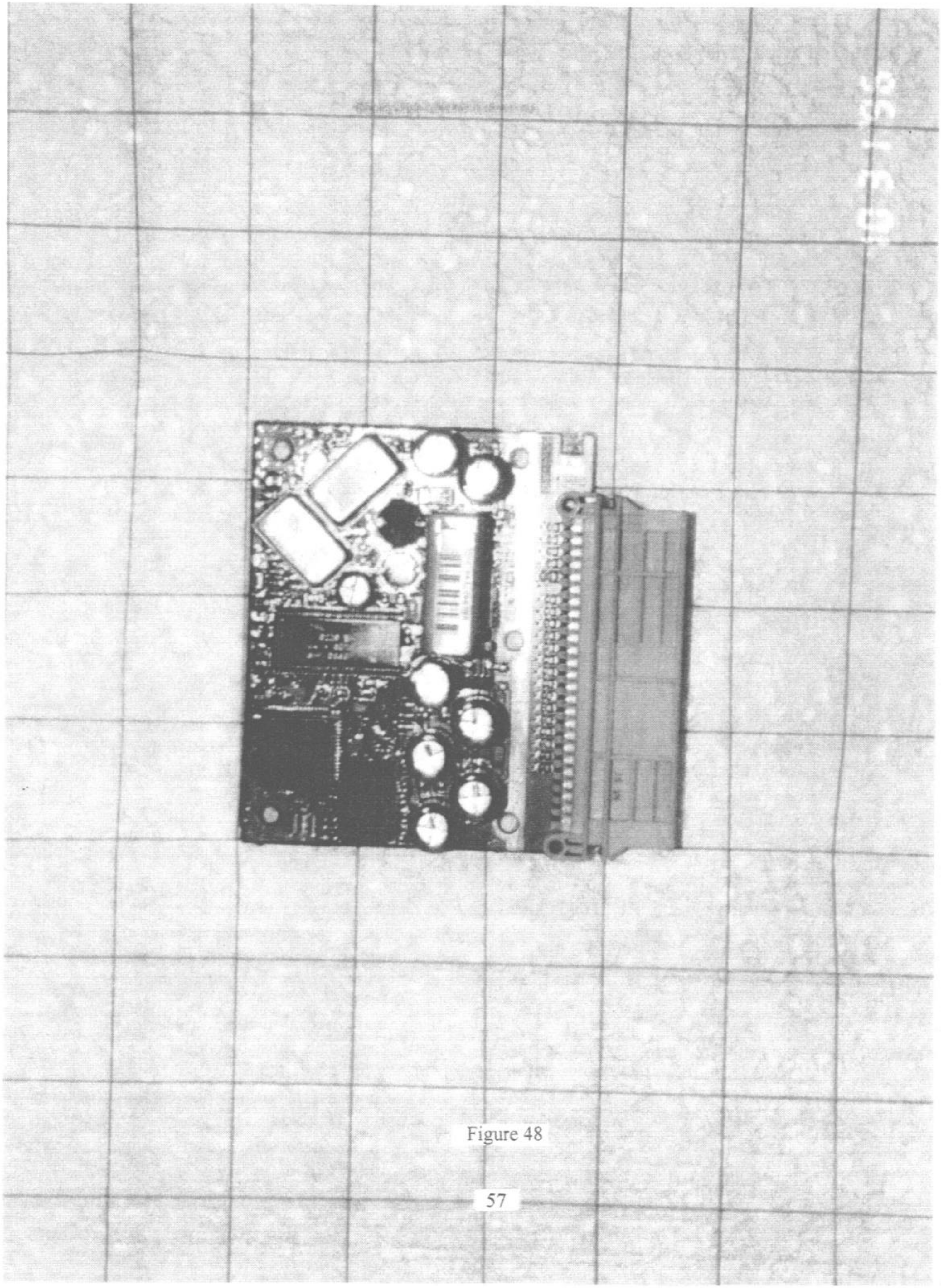


Figure 48

The manufacturing process, tooling, equipment identification, cycle times and labor category data resulting from the manufacturing process activity were entered into the computer program for development of cost data. The results were then summarized and, submitted to the COTR for review.

The hourly labor rates used for this study were Metropolitan Detroit area automotive union rates. This assumes that all of the work would be conducted in the Detroit area by unionized companies. If the seat and electrical component suppliers elect to produce the hardware in other areas of the country, or outside the US ( i.e., Mexico) then the cost would be less than those developed by this effort. This approach was approved by the COTR.

Two ( 2 ) cost summary charts were developed to cover a range of estimated variable manufacturing costs, ( See the Results Section for these charts ). One chart reflected the cost of the Mercedes-Benz System as it would be for a US production of this system. This chart reflects the condition where a US automotive manufacturer currently has an air bag wiring system connector with additional unused connection pins and a wiring circuitry that facilitates ease of implementing a concept similar to the Mercedes-Benz system. The cost of implementing the interdiction of an air bag shut off capability into this type of system is relatively minimal. The other chart reflects the cost where an automobile manufacturer does not have additional unused pins in the air bag wiring connector and would have to significantly redesign the wiring circuitry and would have to cover bench and split seats with comparatively larger seating areas. The later condition requires redesign of the connector, design of several switch pads, conducting subsequent development tests and additional fabrication facilities. These additional activities and materials will result in a higher cost than that of a Mercedes-Benz type system. This chart reflects a worst case condition for implementing the interdiction of an air bag shut off system.

Lead time estimates for implementing the air bag shut off systems into the entire US automobile industry were also developed. Total implementation presents a problem in that manufacturing capacity for 15,000,000 units per year has to be generated. Considerations for the logistics of vehicle model change-over and introduction of new seats within a vehicle life span have to be considered. These considerations create an "industry wide" lead time estimate that may seem long relative to the size and type of the product being implemented.

The average cost of implementing the system for the entire US automotive industry is somewhere between the two charts. This is difficult to determine because detailed drawings of the circuitry for all the vehicles was not acquired under this effort and is beyond the scope of this project.

# 4 - RESULTS

A schematic of the "occupant detection system for air bag shut off" is presented in Figure 49. This schematic shows the orientation of the system in the vehicle including the switch pad on the seat and its wiring harness to the connector on the main air bag system wiring harness located in the instrument panel.

A typical vehicle air bag wiring schematic is presented in Figure 50 showing a suggested method of interdiction of the shut off system to the main air bag wiring system. The point of interdiction is indicated by the red dot which is in the lead to the passenger air bag detonator. The red circle indicates the type of switch where the weight of the occupant on the seat pad will close the circuit so that the detonator will ignite upon a sudden deceleration. This is a suggested method and not intended to be the only way to accomplish the interdiction.

Figures 51 presents the air bag system wiring schematic of the 1994 E-320 Mercedes-Benz air bag system before shut off system inclusion. The schematic also shows how this system could incorporate the shut off system by the red dot. Figure 52 presents the air bag system wiring schematic of the 1996 E-Class Mercedes-Benz after the inclusion of the "occupant detection system for air bag shut off" was incorporated.

The manufacturing process of the seat switch pad, developed for the purpose of generating the variable manufacturing cost, is presented in Figure 53. A correlating description of each process step is shown in Figure 54.

The variable manufacturing costs for the "occupant detection system for air bag shut off" are presented in Tables 2 and 3. Table No. 2 presents the cost of implementing a system similar to the Mercedes-Benz system where the manufacturer has available pins in the air bag wiring harness connector, requires only minimal adjustments to the air bag wiring circuitry and has only one seat switch pad size. Table No. 3 presents the variable manufacturing costs for a system where the manufacturer does not currently have available pins in the air bag wiring harness connector, requires considerable redesign of the wiring circuitry and has to provide more than one seat switch pad size to accommodate the shut off system for a wide range of vehicles. The costs for this system were arrived at by developing the cost of the complete connector and wiring circuit and then pro-rating the cost by the ratio of pins added for the shut off system relative to the total pins in the connector.

These cost, as stated in the previous Section are based on Detroit area unionized labor rates.

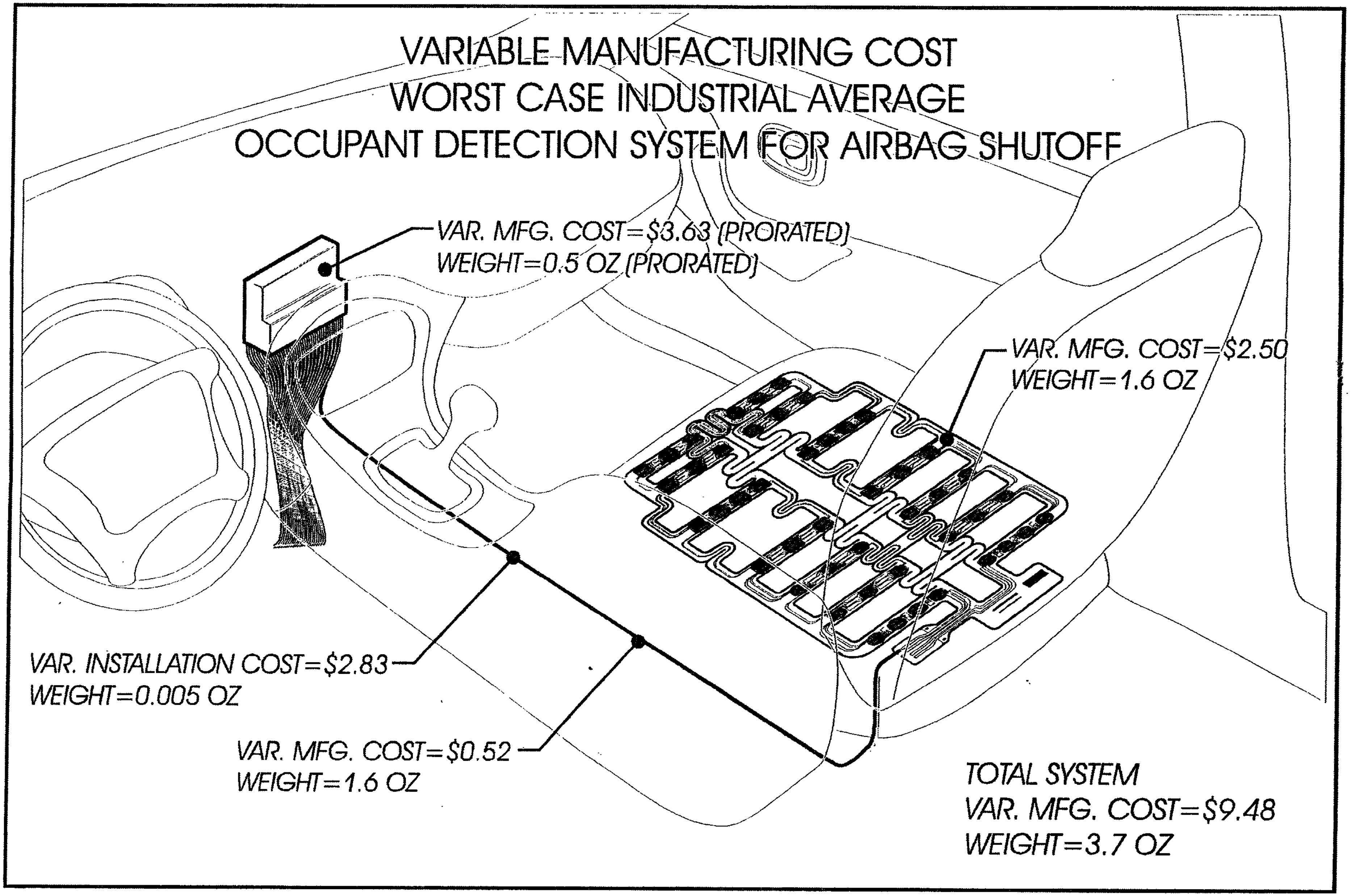
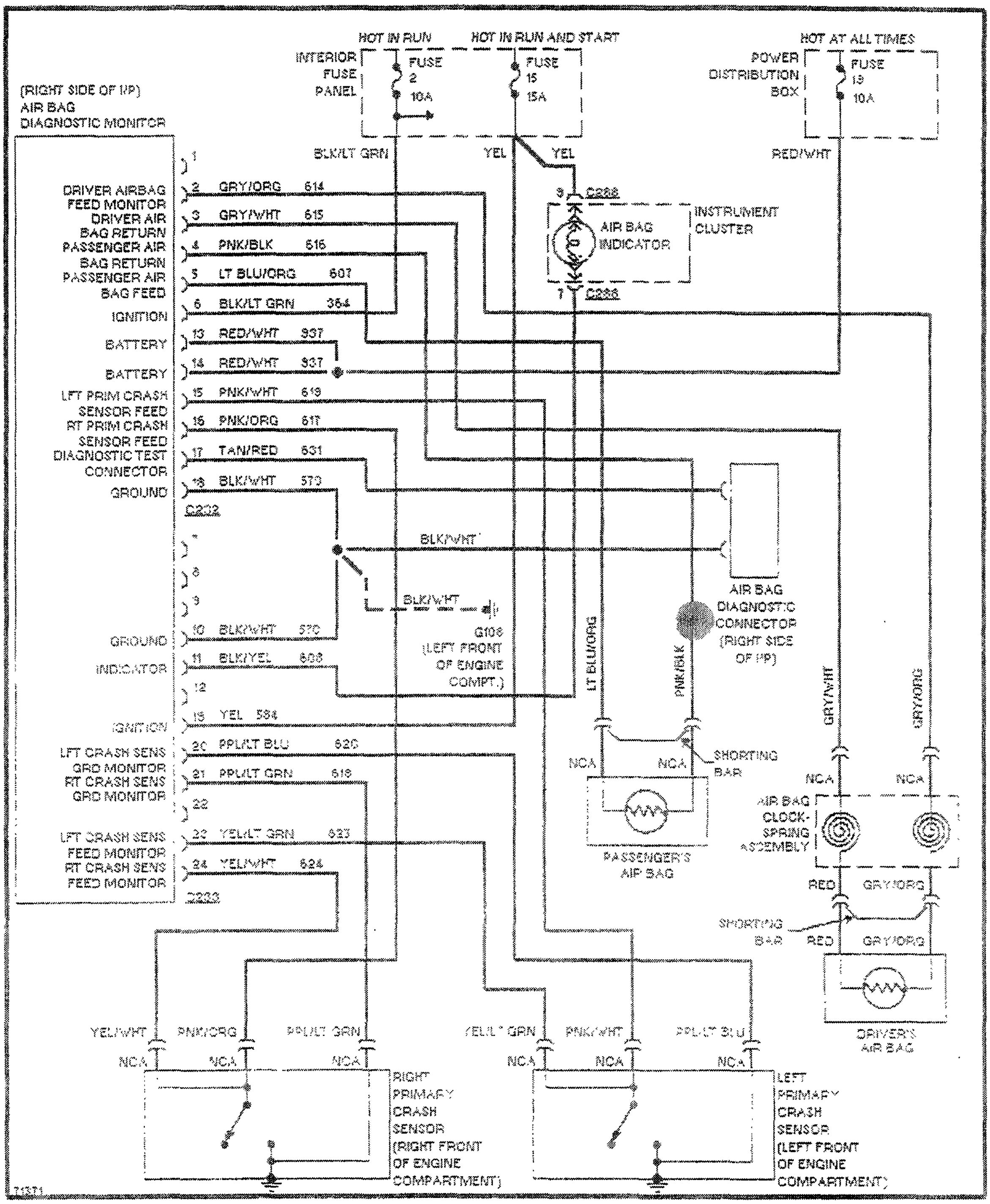
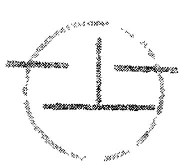

VARIABLE MANUFACTURING COST
WORST CASE INDUSTRIAL AVERAGE
OCCUPANT DETECTION SYSTEM FOR AIRBAG SHUTOFF
VAR. MFG. COST=$3.63 (PRORATED)
WEIGHT=0.5 OZ (PRORATED)
VAR. MFG. COST=$2.50
WEIGHT=1.6 OZ
VAR. INSTALLATION COST=$2.83
WEIGHT=0.005 OZ
VAR. MFG. COST=$0.52
WEIGHT=1.6 OZ
TOTAL SYSTEM
VAR. MFG. COST=$9.48
WEIGHT=3.7 OZ

Figure 49

# 1995 FORD RANGER



PARALLEL/SERIES PRESSURE SWITCH ARRAY WITH RESISTOR

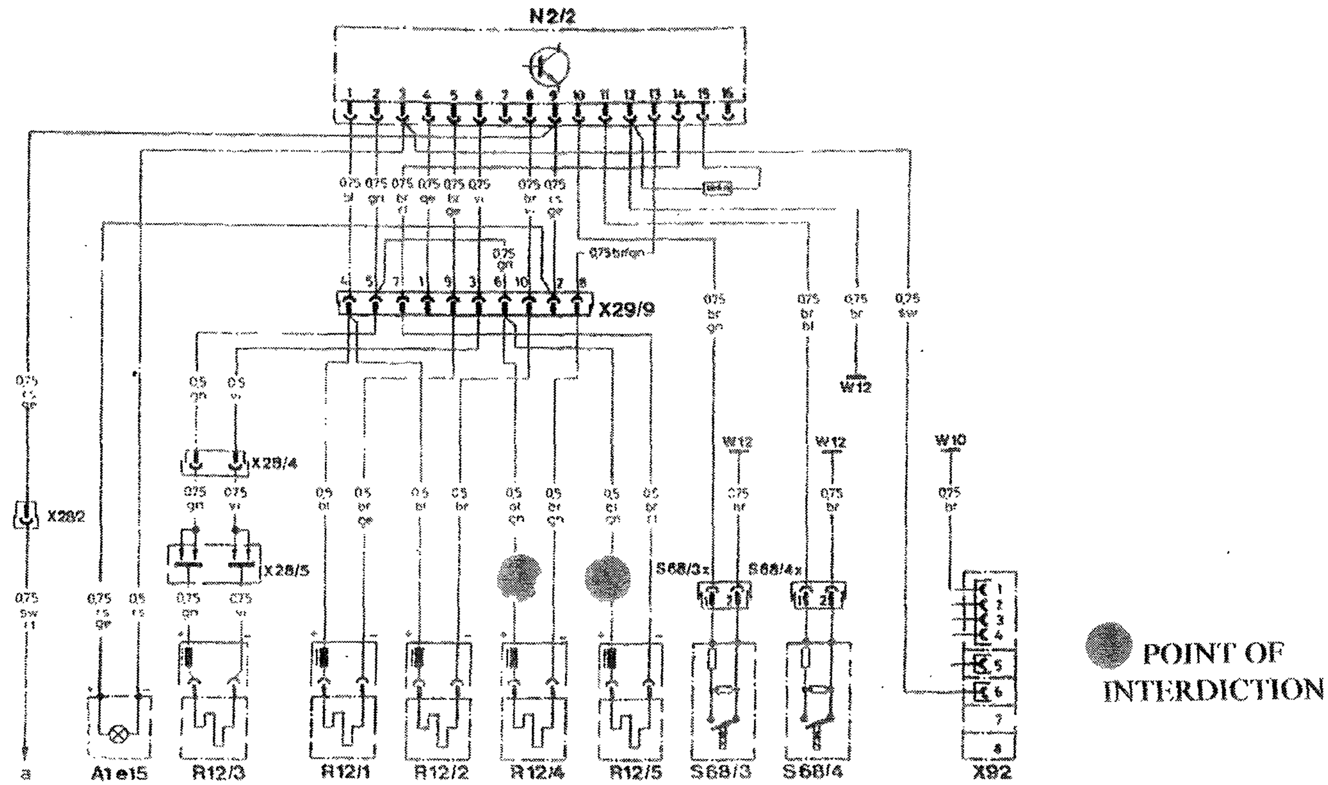
POINT OF INTERDICTION

Figure 50



MARK UPS
BY LUDTKE AND ASSOCIATES

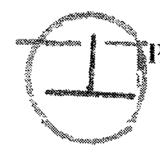
# 1994 E-320 MERCEDES BENZ




a – Unfused Power Supply
A1e15 – SRS Warning Light
N2/2 – Control Unit
R12/1 – Left Front ETR Detonator
R12/2 – Right Front ETR Detonator
R12/3 – Driver Airbag Detonator
R12/4 – Passenger Airbag Detonator No. 1
R12/5 – Passenger Airbag Detonator No. 2
S68/3 – Driver Belt Buckle Switch
S68/3x – Driver Belt Buckle Switch Connector
S68/4 – Passenger Belt Buckle Switch
S68/4x – Passenger Belt Buckle Switch Connector
W10 – Battery Ground
W12 – Center Console Ground
X28/2 – Airbag & Belt Tensioner Power Supply Connector
X28/4 – Clockspring Connector (Lower)
X28/5 – Clockspring Connector (Upper)
X29/9 – SRS System Connector
X92 – Diagnostic Connector

MERCEDES-BENZ WIRE COLOR ABBREVIATIONS

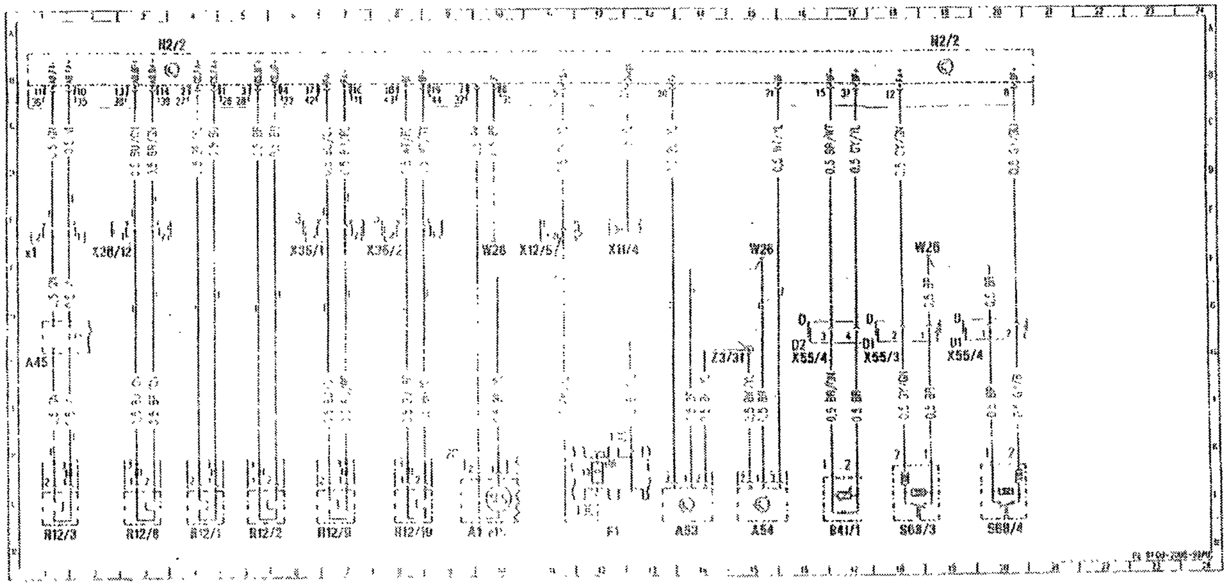
| | |
|---|---|
| bk – Black | pk – Pink |
| bl Or bu – Blue | rs – Unknown |
| br – Brown | rt Or rd – Red |
| ge Or yl – Yellow | sw – Black |
| gn – Green | vi – Violet |
| gr Or gy – Gray | ws Or wt – White |


PRESSURE SWITCH ARRAY WITH RESISTOR

94C43093

Figure 51

# 1996 E-CLASS MERCEDES BENZ




| | | |
|---|---|---|
| A1 | Instrument cluster | [illegible] |
| A1e15 | SRS MIL | 10A |
| A45 | [illegible] clock spring contact | [illegible] |
| A45x1 | [illegible] clock spring contact connector | [illegible] |
| A53 | Left side airbag sensor | [illegible] |
| A54 | Right side airbag sensor | [illegible] |
| B41/1 | Front passenger seat occupied recognition sensor | [illegible] |
| F1 | Fuse and relay box | [illegible] |
| [illegible] | Fuse [illegible] circuit [illegible] | [illegible] |
| R2/2 | SRS control module | [illegible] |
| | | [illegible] |
| R12/1 | Left front ETR squib | [illegible] |
| R12/2 | Right front ETR squib | [illegible] |
| R12/3 | Driver AB squib | [illegible] |
| R12/6 | Front passenger AB squib | [illegible] |
| R12/9 | Left side airbag squib | [illegible] |
| R12/10 | Right side airbag squib | [illegible] |
| S68/3 | Left front seat belt buckle switch (AB-ETR) | [illegible] |
| S68/4 | Right front seat belt buckle switch (AB-ETR) | [illegible] |

| | | |
|---|---|---|
| W26 | Ground [illegible] | [illegible] |
| | | [illegible] |
| | | [illegible] |
| X11/4 | Data link connector (DTC readout) | 12F |
| X12/5 | Terminal block, circuit [illegible] | 10I |
| X28/12 | [illegible] connector | 2F |
| X35/1 | Left front [illegible] connector | 6F |
| X35/2 | Right front [illegible] connector | 7F |
| X55/3 | Left [illegible] connector | 12H |
| X55/4 | Right [illegible] connector | [illegible] |
| | | [illegible] |
| Z3/31 | [illegible] connector [illegible] | [illegible] |

Figure 52

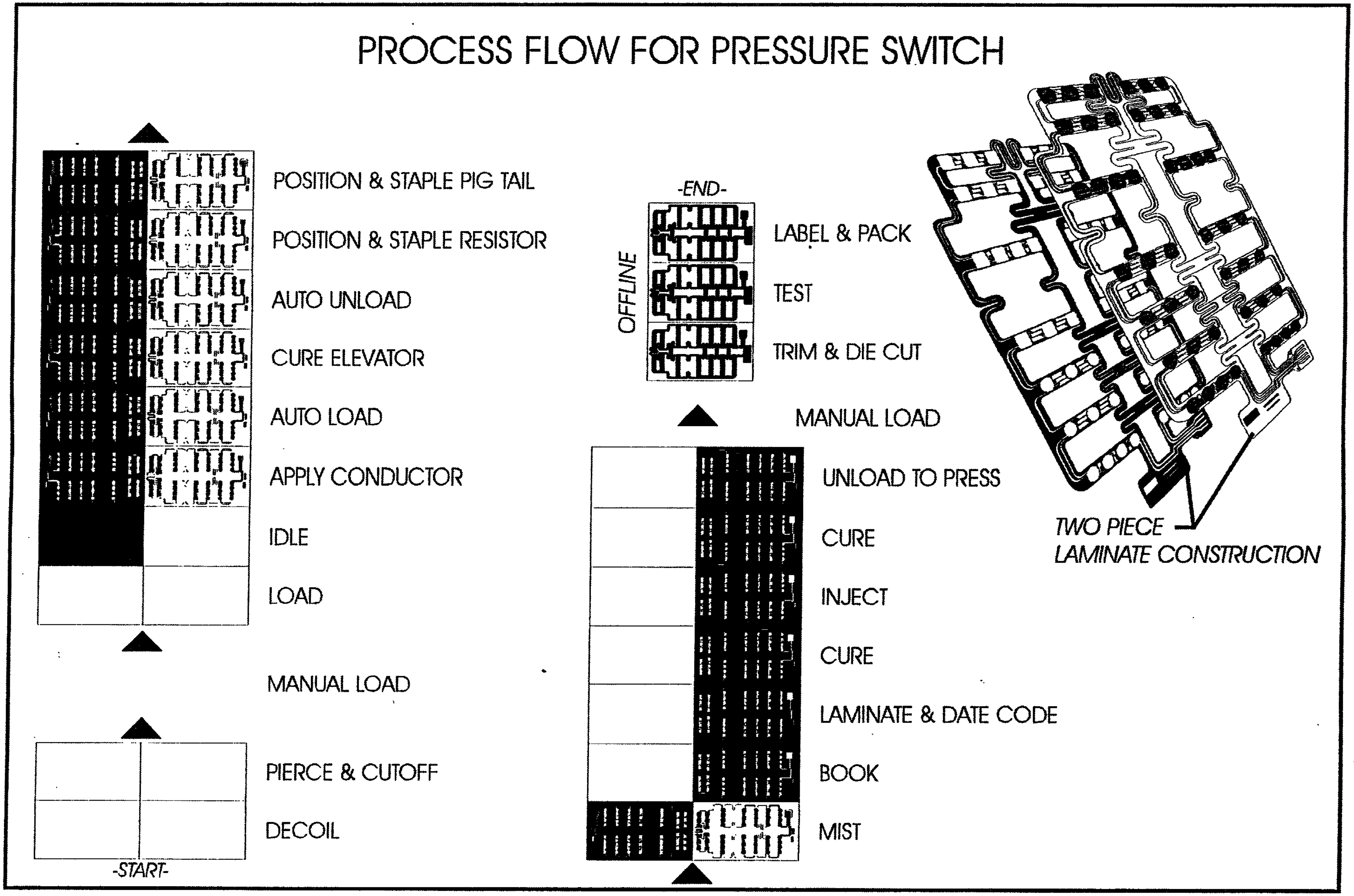

PROCESS FLOW FOR PRESSURE SWITCH
POSITION & STAPLE PIG TAIL
POSITION & STAPLE RESISTOR
AUTO UNLOAD
CURE ELEVATOR
AUTO LOAD
APPLY CONDUCTOR
IDLE
LOAD
MANUAL LOAD
PIERCE & CUTOFF
DECOIL
-START-
-END-
OFFLINE
LABEL & PACK
TEST
TRIM & DIE CUT
MANUAL LOAD
UNLOAD TO PRESS
CURE
INJECT
CURE
LAMINATE & DATE CODE
BOOK
MIST
TWO PIECE
LAMINATE CONSTRUCTION

Figure 53

Process Description - Pressure Pad Switch
Dual Lane Pallet Transfer System

Coil A: .0075" thick polyester or polyvinyl film 22" wide.
Coil B: Same as Coil A except black gauze backing, bonded with vinyl paint.

Side by Side Transfer Line

| COIL A | COIL B |
|---|---|
| Decoil | Decoil |
| Pierce & Cutoff | Pierce & Cutoff |
| Stack | Stack |
| * Manual | |
| Load | Load |
| Idle | Idle |
| Apply Conductor | Apply Conductor |
| Auto Load | Auto Load |
| Cure | Cure |
| Auto Unload | Auto Unload |
| Resistor - Position & Staple | P/N & Identify |
| Pig Tail - Position & Staple | Logo |
| Mist | |
| * Manual - Book | Empty |
| Laminate | Empty |
| Cure | Empty |
| Inject | Empty |
| Cure | Empty |
| Manual - Unload to Press | Empty |
| End of Transfer | |

* Off-line Trim (Die Cut)
 Inspect
 Lable & Pack

* Utility Operator
 Loads Coil Stock
 Changes Mask, etc
 Relieves other operators
 4 men total - 12-15 second cycle

Figure 54

# Passenger Side Air Bag Detection Switch and System Support
## Variable Manufacturing Costs

| | Material Cost | Labor Cost | Variable Burden Cost | Estimated Variable Cost |
|---|---|---|---|---|
| Increase in Seat Cost | $1.05 | $0.36 | $1.09 | $2.50 |
| Increase in Air Bag Control Module Cost | $0.27 | $0.07 | $0.14 | $0.48 |
| Increase in Air Bag Wire Harness Cost | $0.48 | $0.01 | $0.03 | $0.52 |
| Increase in Final Assembly Cost | | $0.47 | $2.36 | $2.83 |
| Total Variable Increase | $1.80 | $0.91 | $3.62 | $6.33 |

| | |
|---|---|
| Estimated Tooling Cost | $134,912 |
| Estimated Capital Equipment cost | $1,514,256 |

Note: Variable manufacturing cost estimate is based on Mercedes-Benz type hardware.

Table 2

# Passenger Side Air Bag Detection Switch and System Support
## Variable Manufacturing Costs

| | Material Cost | Labor Cost | Variable Burden Cost | Estimated Variable Cost |
|---|---|---|---|---|
| Increase in Seat Cost | $1.05 | $0.36 | $1.09 | $2.50 |
| Increase in Air Bag Control Module Cost | $3.33 | $0.09 | $0.21 | $3.63 |
| Increase in Air Bag Wire Harness Cost | $0.48 | $0.01 | $0.03 | $0.52 |
| Increase in Final Assembly Cost | | $0.47 | $2.36 | $2.83 |
| Total Variable Increase | $4.86 | $0.93 | $3.69 | $9.48 |

Estimated Tooling Cost $134,912
Estimated Capital Equipment cost $1,514,256

Note: Variable manufacturing cost estimate is based on Mercedes-Benz type hardware

Table 3

The costs are also based on annual production increments of 250,000. This is the standard annual production quantity that NHTSA has used for its costs analysis studies for several years.

Lead Time estimates for development and manufacturing system implementation are presented in Figures 55. Figure 55 presents the time required for a Mercedes-Benz type system and the costs presented in Table 2.

A review of twenty ( 20 ) vehicle air bag wiring schematics indicate that it is relatively easy to adapt the electrical circuit to utilize the passenger side occupant sensor. Tables 4 and 5 present a list of 1997 domestic vehicles that could easily incorporate this system.

# 5 - CONCLUSIONS and RECOMENDATIONS

The occupant detection system for air bag shut off appears to be relatively easy to implement and the cost is relatively low. There are no major development or implementation problems and the requirements are within the current state-of-art. However, some consideration should be made if the system is incorporated into bench seats or split seats. The hazard is that if a seat switch sized for a bucket seat is used for a bench, or split seat, a single passenger could move around to a location that would not activate the passenger air bag and could result in severe injury or a fatality.

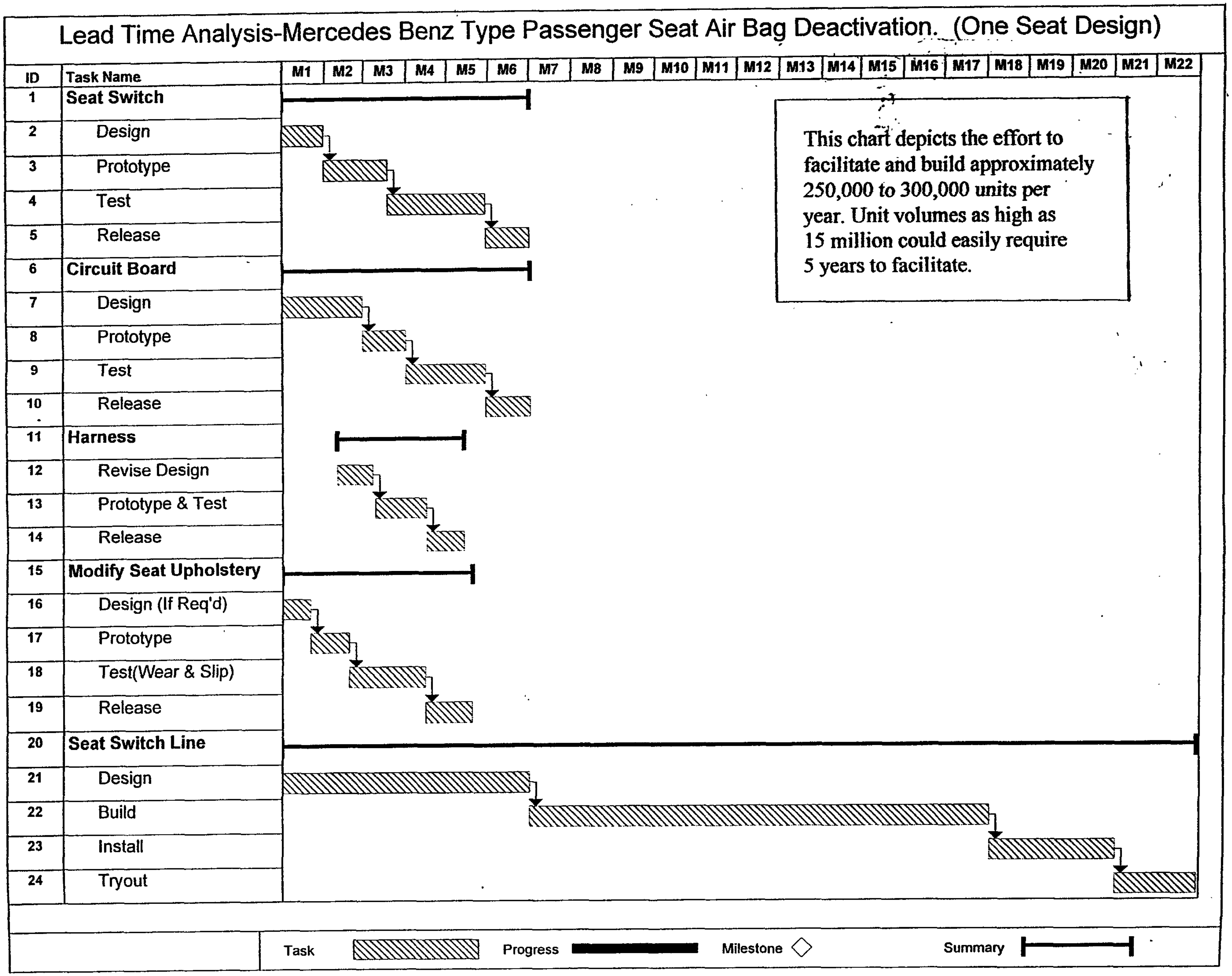

Lead Time Analysis-Mercedes Benz Type Passenger Seat Air Bag Deactivation. (One Seat Design)
ID
Task Name
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12 M13 M14 M15 M16 M17 M18 M19 M20 M21 M22
1 Seat Switch
2 Design
3 Prototype
4 Test
5 Release
6 Circuit Board
7 Design
8 Prototype
9 Test
10 Release
11 Harness
12 Revise Design
13 Prototype & Test
14 Release
15 Modify Seat Upholstery
16 Design (If Req'd)
17 Prototype
18 Test(Wear & Slip)
19 Release
20 Seat Switch Line
21 Design
22 Build
23 Install
24 Tryout
This chart depicts the effort to facilitate and build approximately 250,000 to 300,000 units per year. Unit volumes as high as 15 million could easily require 5 years to facilitate.
Task
Progress
Milestone
Summary

Figure 55

It appears that the following list of 1997 domestic products air bag electrical circuits could easily be modified to except the circuitry required for the occupant detection sensor.

GENERAL MOTORS PRODUCTS

Buick
- Century
- LeSabre
- Park Avenue
- Skylark

Chevrolet
- Cavalier
- Malibu
- Lumina
- Monte Carlo
- Camaro
- Corvette
- Venture
- Astro
- Express Van
- Blazer
- Tahoe
- Suburban
- S-Series
- C-Pick Up
- K-Pick Up

Pontiac
- Sunfire
- Grand Am
- Bonneville
- Firebird
- Trans Sport

Cadillac
- Catera
- DeVille/Concours
- Seville
- Eldorado

Geo
- Metro
- Prism
- Tracker

Oldsmobile
- Acheva
- Cutlass
- Cutlass Supreme
- Intrique
- Eighty-Eight LS
- Eight-Eight LSS
- Regency
- Aurora
- Silhouette
- Bravada

Saturn
- Sedan
- Coupe
- Wagon
- GM EVI

GMC
- Savana
- Jimmy
- Youkon
- Suburban
- Sonoma
- Sierra

Table 4

FORD MOTOR PRODUCTS

Ford
- Aspire
- Escort
- Contour
- Taurus
- Crown Victoria
- Probe
- Mustang
- Thunderbird
- Windstar
- Aerostar
- Explorer
- Expedition
- Ranger
- F-150 Series
- Econoline
- Club Wagon

Lincoln
- Continental
- Town Car
- Mark VIII

Mercury
- Tracer
- Mystique
- Sable
- Cougar XR7
- Grand Marquis
- Villager
- Mountaineer

CHRYSLER CORPORATION PRODUCTS

Chrysler
- Cirrus
- Concorde
- LHS
- Sebring
- Town & Country

Eagle
- Summit
- Vision
- Talon

Plymouth
- Neon
- Breeze
- Prowler
- Voyager

Dodge
- Neon
- Stratus
- Intrepid
- Avenger
- Caravan
- Ram Wagon

Jeep
- Wrangler
- Cherokee
- Grand Cherokee

Table 5

# APPENDIX A

# ASSET CENTER COSTING METHODOLOGY

## INTRODUCTION

The following pages discuss the Asset Center Costing Methodology used for this project. As stated in other pages of the Final Report, this Methodology has been used on previous NHTSA cost analysis projects and; therefore, the results are consistent with other cost data generated on the other NHTSA projects.

# MANUFACTURING COSTING METHODOLOGY

The methodology used in the development of manufacturing costs follow the standard cost estimating procedures used by Pioneer. This methodology is discussed below.

INITIAL EVALUATIONS

Manufacturing engineers analyze the part or assembly and list each of the manufacturing processes, or operations required to complete the fabrication cycle from the raw material to the finished product.

DETAILED PROCESSING AND COST ESTIMATING

Process engineers and cost estimators, under the direction of manufacturing engineers, conduct a detailed process and cost analysis for each part and assembly. All information developed during this analysis is recorded on the form shown in Figure 1. A Process/Cost Sheet is made out for each part and subassembly. The results are summarized to obtain the total assembly cost.

Two costs are developed in this process, variable cost and manufacturing cost. The variable cost contains only those costs associated with the manufacture of the part or assembly. Manufacturing cost consists of the variable cost plus fixed burden costs.

An example of the process and cost estimating process shown in Figure 1 is discussed in the following paragraphs. This is the manufacturing process sheet for forming a bumper face bar. The process sheet entries include all operations from straightening the sheet steel to the final forming of the bumper.

The column headings and other items of interest on the process sheet are:

| | |
|---|---|
| •OPER (Upper left corner) | Each operation is coded in this column. For this part seven distinct operations are required and are coded 10 through 70. |
| •VOL | The production volume at which the items are being costed. |
| •REQ | The number of pieces per year required of the piece being costed. It is a product of VOL (Volume Per Year) and P/A (Pieces Per Assembly). |
| •OPERATION DESCRIPTION | Each distinct operation is described. |
| •TYPE OF EQUIPMENT | Capital Equipment employed in each operation. |
| •M/P | Number of men required for each operation. |

LS AA U L AR EN PEI IO HE

DRAWING DATE

| OPER | OPERATION DESCRIPTION VOL. 300,000 P/A REQ. 300,000 | TYPE OF EQUIPMENT | M/P | PCS/HR. / MINS. | LABOR COST / LABOR RATE | OCC HOURS | | BURDEN RATE | BURDEN COST | VAR COST / MFG COST | DIE MODEL $1000 | TOOLING $1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flex Roll & Apply Drawing | Flex | | 400 | .1628 | | V | 32.217 | .0670 | .2298 | | |
| 10 | Compound | Roll | 4 | .500 | .3255 | .00208 | M | 93.389 | .1942 | .3570 | -0- | -0- |
| | Rough Blank | 300 Ton | | 400 | .0977 | | V | " | .0805 | .1782 | | |
| 20 | | Press | 2 | .300 | .3255 | .00250 | M | " | .2335 | .3312 | -0- | 9 |
| | Draw (Use Automatic Unloader) | Toggle | | 400 | .0488 | | V | " | .0805 | .1293 | | |
| 30 | | Press | 1 | .150 | .3255 | .00250 | M | " | .2335 | .2823 | 7.5 | 72 |
| | Cam From Top & Bottom, Pierce Parking Lite | 84x120" | | 400 | .0977 | | V | " | .0805 | .1782 | | |
| 40 | Openings & (9) Holes on Front Surface | SS Press | 2 | .300 | .3255 | .00250 | M | " | .2335 | .3312 | -0- | 62 |
| | Cam Trim Both Ends, Flange (2) P/L | " | | 400 | .0488 | | V | " | .0805 | .1293 | | |
| 50 | Openings | | 1 | .150 | .3255 | .00250 | M | " | .2335 | .2823 | -0- | 50 |
| | Fin. Flg. (2) Openings, Pierce (2) Pkg. Slots | | | 400 | .0488 | | V | " | .0805 | .1293 | | |
| 60 | & Cam Pierce, Bottom Attaching Holes | | 1 | .150 | .3255 | .00250 | M | " | .2335 | .2823 | 4.0 | 48 |
| | Finish Cam Cup Engs | | | 400 | .0977 | | V | " | .0805 | .1782 | | |
| 70 | | | 2 | .300 | .3255 | .00250 | M | " | .2335 | .3312 | 4.5 | 43 |

73

39

NEXT OPER.

NEXT ASSY.

| SHT | COIL | GAGE | QUAL | MAT'L | | PCS | ROUGH WT |
|---|---|---|---|---|---|---|---|
| X | | 121 | DQ | HR | 33" x 91" = | 2 | 48.0724 |
| | | | | .950 | Fine Grain | | |
| | | | | | $.1571 X 48.0724 lbs. | | 7.5522 |
| | | | | | (11.57# of Scrap | - | .1736 |
| | | | | | @ .015 = .1736 | | 7.3786 |
| | | | | | Scrap Credit) | | |

COST PER LB .1571 MAT'L COST 7.3786

PART NAME FACE BAR - FRONT BUMPER (1) REQUIRED

| SKETCH - REMARKS VOLUME | TOOL COST | |
|---|---|---|
| TRY-OUT | | |
| | 284,160 | 00 |
| | MACH. & FACILITIES | |
| EQUIP | 2,050,000 | 00 |
| INSTALLATION | 164,000 | 00 |
| FREIGHT | 61,500 | 00 |
| TOTAL | $2,275,500 | 00 |

| | | | |
|---|---|---|---|
| TOTAL VAR LABOR & BURD | 1.1523 | | |
| TOTAL MFG LABOR & BURD | 2.1975 | $26.5 | $284 |
| MATERIAL | 7.3786 | KEY ☐ | |
| SCRAP 1% | .0738 | NON KEY ☐ | |
| SET UP | | VOL | |
| OTHER | | UPC | |
| MARK UP 10% | | | |
| TOTAL VAR. COST | 8.7047 | PART NO | 22010 |
| TOTAL TRANS. COST | 9.6499 | | |

T & FC / PP JOB NO. 2744 PEM-3-80-A PROCESS ENG V.H. DEPT NO. 1

DATE 3-10-81

Figure 1

- **PCS PER HR/MINS** — PCS/HR is the pieces produced per hour per operation.

  MINS is the minutes per piece to process one piece through each operation.

- **LABOR COST/RATE** — LABOR COST is the direct labor dollars per piece.

  LABOR RATES is the direct labor dollars per minute (including fringes).

- **OCCU. HOURS** — The time, in hours, that it takes to process the part through the operation. For example, if the production rate is 400 pieces per hour, the occupancy hours is one hour divided by 400 pieces per hour or .0025 hours per piece.

- **BURDEN RATE** — There are two burden rate entries, "V" for Variable Burden Rate and "M" for Manufacturing Burden Rate. "V" includes set-up costs, in-bound freight, perishable production tools, and other miscellaneous costs that vary with volume changes. "M" includes variable and fixed burden. Fixed burden covers taxes, insurance, depreciation on capital equipment and building, maintenance costs that do not vary with volume. See Figure 6 for a more definitive list of burden factors for both variable and fixed.

- **BURDEN COST** — Per piece burden cost is calculated by multiplying each burden rate by the occupancy hours.

- **VAR COST/MFG COST** — VAR COST is the variable burden plus direct labor cost. MFG COST is the cost of each operation including direct labor, variable burden, and fixed burden.

- **DIE MODELS** — Unique die models required for each operation.

- **TOOLING** — Dies, fixtures and other special tooling required for each operation. Tooling and equipment costs are summarized in the lower middle section of the Process/Cost Sheet.

- **MATERIAL** — Material is noted and cost calculated in the special box located on the lower left corner of the sheet. Column headings in this area are self-explanatory. The type of material is determined in several ways; i.e., by specification on drawing, by chemical analysis, by contacting appropriate technical personnel responsible for material selection. Once the correct material specification is obtained appropriate sources are contacted to obtain the cost per pound of the material in the form and quantity required to produce the part.

**•TOOLING COST SUMMARY**

The total tooling cost for a given part is summarized in the lower middle section of the Process/Cost Sheet. The tooling cost is reported as a lump sum, leaving specific amortization up to the client. Tooling is an expense item and may be amortized in the year of use. Competitive economics, however, may preclude this move, so that a more extended amortization period may be used. Since this is a variable subject to the client's marketing strategy, tooling amortization is not a standard entry on these sheets. As a general rule, the automotive firms amortize major tools and dies over a three year period. Pioneer has reported consumer costs which include the amortized tooling cost, usually in summary documents, if requested by the client.

**•EQUIPMENT COSTS**

The lower middle section of the Process/Cost Sheet summarizes cost of equipment, equipment installation and freight, and the cost of all pieces of equipment required to meet the production schedule. For instance, if the annual requirement is 300,000 units, and shops work two shifts (4000 hours, or 250 days times 16 hours per day), the planning rate of production per operation is 93 units per hour (300,000/4,000/.8, inherent delay factor), and if the equipment selected for the particular process can only produce 50 pieces per hour, it is assumed that two such processes, or pieces of equipment, will be installed to meet the schedule.

**•PART OR ASSEMBLY COST SUMMARY**

Costs for producing the part are totaled in the lower right side of the form. The entries are:

TOTAL VARIABLE LABOR AND BURDEN -
Direct labor plus variable burden.

TOTAL MANUFACTURING LABOR AND BURDEN -
Direct labor, variable burden and fixed burden.

MATERIAL -
Total material cost.

SCRAP -
An allowance for scrap based on experience (% of Var. Cost).

MARKUP -
Since this is a part involving inter-divisional transfer, a markup is included.

TOTAL VARIABLE COST -
The sum of items (a), (c) and (d).

TOTAL TRANSFER COST -
The sum of (b), (c), (d) and (e). This part is obviously a very high material sensitive part since approximately 70% of the transfer cost is reflected in the cost of steel.

All subassembly and final assembly costs will also be developed on these process sheets.

A work flow chart illustrating the methodology used to build up assembly cost is presented in Figure 2.

Figure 3 presents a flow diagram of the cost build-up from basic cost items through consumer costs.

<u>COST METHODOLOGY VIA COMPUTER PROGRAM</u>

To permit more expeditious data processing, Pioneer uses a computer program to make all of the calculations discussed above.

Using the computer requires that the manufacturing engineer process the part being costed, select the equipment required, and define the operation cycle time. Figure 4 illustrates the Process/Cost Sheet prepared by the manufacturing engineer for the computer method. Note the equipment code specified for each operation. From this information the computer selects the appropriate labor and burden rates, as well as equipment costs. Using the cycle time specified on the Process/Cost Sheet for the given equipment code, the computer calculates the labor cost, occupancy hours, variable burden and manufacturing burden; it is also programmed to determine the multiples of a given machine required for an operation to produce the required number of pieces per hour. This is particularly important where costs are determined for a series of different production rates, where a process may not change from one rate to another, but only

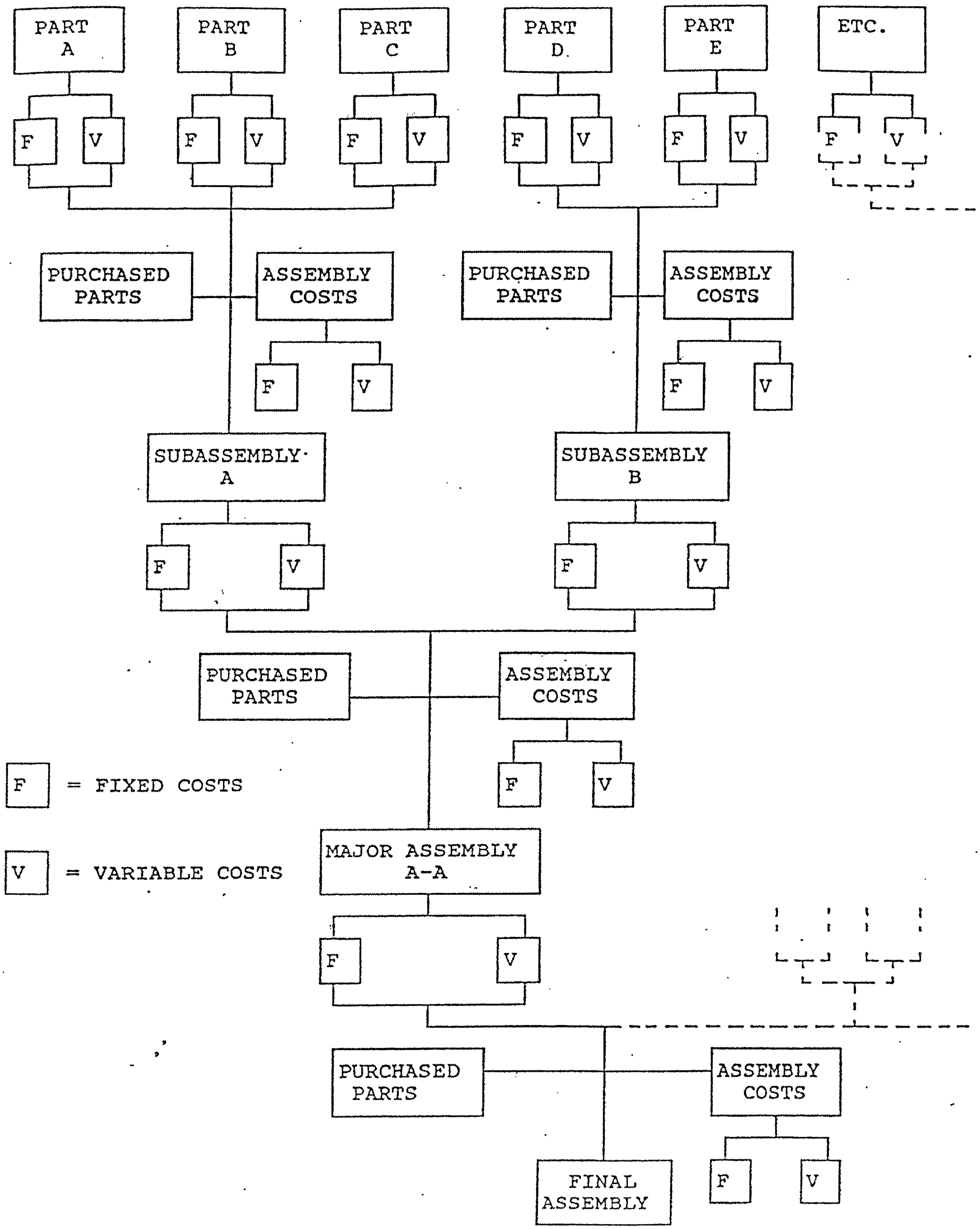

PART A
PART B
PART C
PART D
PART E
ETC.
F
V
PURCHASED PARTS
ASSEMBLY COSTS
SUBASSEMBLY A
SUBASSEMBLY B
F = FIXED COSTS
V = VARIABLE COSTS
MAJOR ASSEMBLY A-A
FINAL ASSEMBLY

Figure 2

DETERMINATION OF MANUFACTURING AND CONSUMER COST

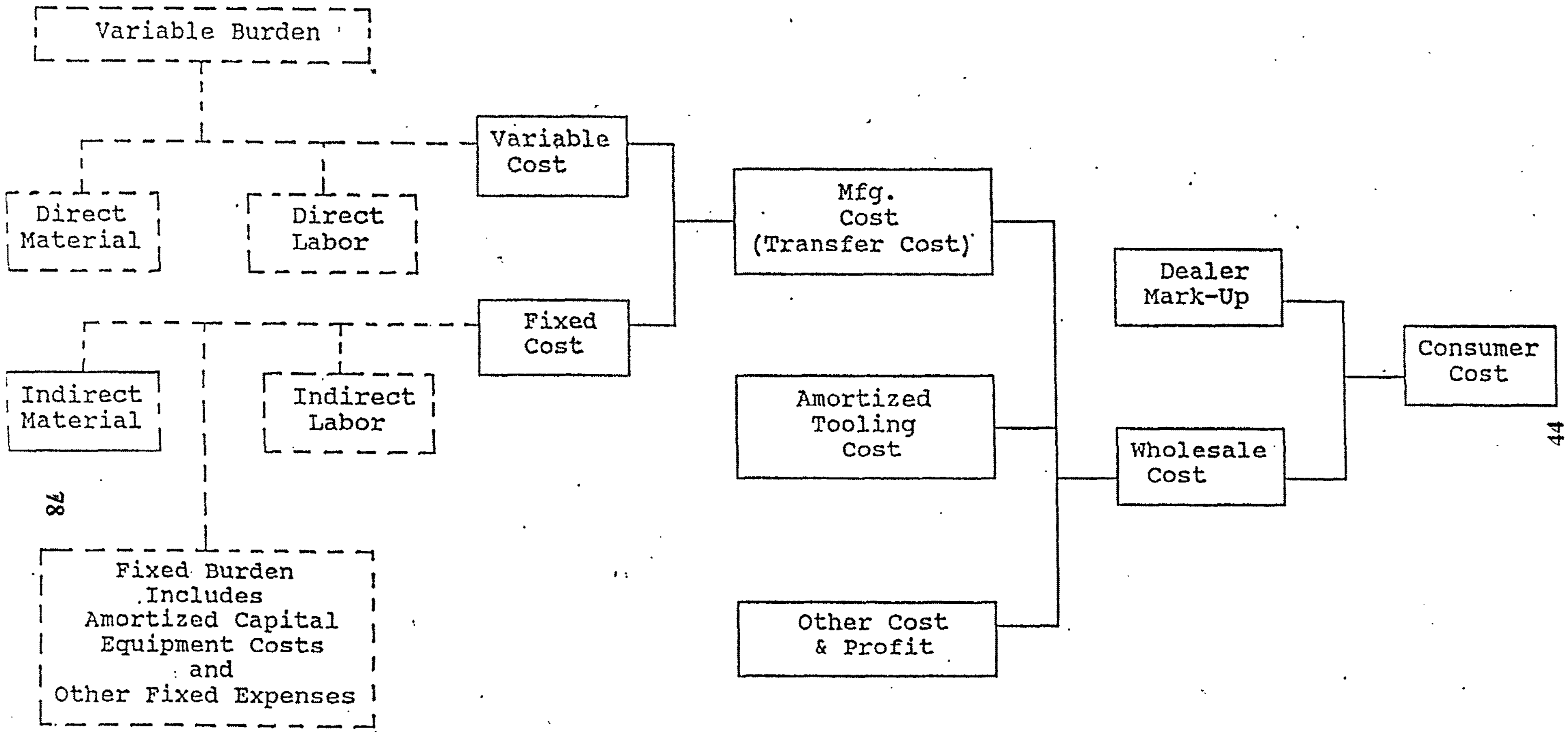



Figure 3

ESTIMATING DEPARTMENT OPERATION SHEET

DRAWING DATE *N.A.*

| OPER # | OPERATION DESCRIPTION VOL. *400,000* P/A *1* REQ. *400,000* | TYPE OF EQUIPMENT | M/P | PCS/HR. / MINS. | LABOR COST / LABOR RATE | OCC HOURS | BURDEN RATE | BURDEN COST | VAR COST / MFG COST | DIE MODEL $(000) | TOOLING $(000) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | *ROUGH BLANK FROM SHEET* / *AUTO LOAD & EJECK* | *801* | *1* | *.12* | | | V / M | | | | |
| 20 | *DRAW COMPLETE* / *AUTO LOAD AND EJECT* | *801* | *1* | *.16* | | | V / M | | | | |
| | *TURN PANEL OVER* / *AUTO ROLLOVER FIXT.* | | *0* | *.16* | | | V / M | | | | |
| 30 | *TRIM BINDER STOCK - PIERCE LOCK & HANDLE HOLES - AUTOLOAD & EJECT* | *801* | *0* | *.16* | | | V / M | | | | |
| 40 | *FORM HEM FLANGE - 3 SIDES & BELT FLANGE - AUTO LOAD & EJECT* | *801* | *0* | *.16* | | | V / M | | | | |
| 50 | *FINISH FORM BELT FLANGE* / *AUTO LOAD & EJECT* | *801* | *1* | *.16* | | | V / M | | | | |
| | | | | | | | V / M | | | | |
| | | | | | | | V / M | | | | |
| 79 | | | | | | | V / M | | | | 45 |
| | | | | | | | V / M | | | | |
| | | | | | | | V / M | | | | |
| | | | | | | | V / M | | | | |
| | NEXT OPER. / NEXT ASSY. | | | | | | V / M | | | | |

| SHT | COIL | GAGE | QUAL | MAT'L | | PCS | ROUGH WT |
|---|---|---|---|---|---|---|---|
| ✓ | | *.032* | *DQ* | *CRS* | *34.9 x 52.7* | *1* | *16.64* |
| | | | | | *ZINCRO METAL* | | |

COST PER LB *.2935* MAT'L COST *$4.91*

PART NAME *DOOR - OUTER PANEL - IN/WHITE*

| SKETCH - REMARKS | TOOL COST |
|---|---|
| VOLUME | |
| TRY-OUT | |
| | MACH. & FACILITIES |
| INSTALLATION | |
| FREIGHT | |
| HAND. EQUIP. | |

| | |
|---|---|
| TOTAL VAR. LABOR & BURD | |
| TOTAL MFG LABOR & BURD | |
| MATERIAL | |
| SCRAP | 1% |
| SET UP | |
| OTHER | |
| MARK UP | 10% |
| TOTAL VAR. COST | |
| TOTAL TRANS. COST | |

KEY ☐
NON KEY ☐
VOL. ____
UPC ____
PART NO

T & FC / PP    JOB NO. *ZC909*    PEM-3-00-A    PROCESS ENG *[illegible]*

Figure 4

TG005 PROJECT - 1D

PIONEER ENGINEERING
MANUFACTURING COST ANALYSIS

17.00.05

OLUME- 400,000 P/A- 1
ART #- 1 DESC- DOOR - OUTER PANEL - IN/WHITE UPG-

| PER | OPERATION DESCRIPTION | EQUIP | M P | STD MIN | LAB COST LAB RATE | OCC HRS. | BURDEN RATE | BURDEN COST | VAR MFG COST | DIE MODEL | TOO $00 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 010 | ROUGH BLANK FROM SHEET AUTO LOAD & EJECT | 8D1 | 1.00 | .12 | .0381<br>.3174 | .0020 V | 66.12 | .1322 | .1703 | 0 | . |
| 020 | DRAW COMPL. AUTO LOAD, EJECT & TURNOVER | 8D1 | 1.00 | .16 | .0508<br>.3174 | .0027 V | 66.12 | .1785 | .2293 | 0 | . |
| 030 | TRIM BINDER STK. & PIERCE LK. & HDL. HLS | 8D1 | .00 | .16 | .0000<br>.3174 | .0027 V | 66.12 | .1785 | .1785 | 0 | .( |
| 040 | FORM HEM FLANGE 3 SIDES & BELT FLANGE | 8D1 | .00 | .16 | .0000<br>.3174 | .0027 V | 66.12 | .1785 | .1785 | 0 | .( |
| 050 | FIN. FORM BELT FLANGE COMPLETE | 8D1 | 1.00 | .16 | .0508<br>.3174 | .0027 V | 66.12 | .1785 | .2293 | 0 | .( |

NNUAL REQ- 400,000
AT CODE -
OST/LB - .294
CRAP FAC - .0%
OUGH WT - 16.69
INAL WT - 10.40 OTHER- .00

LAB MIN - .4400 0
LABOR $ - .1397 .(
BURDEN V- .8462
SCRAP - .0000 TOTAL VAR 5.8928
MATERIAL- 4.9069

Figure 5

As a result, Pioneer has gained confidence in the reliability of its "Asset Center" burden rates.

Figure 6 lists the factors that have been considered in the determination of the Pioneer burden rates. The ratio of application of these costs between fixed and variable burden are not shown inasmuch as this is considered proprietary.

COST METHODOLOGY VARIANCE

Estimating, as the name implies, is not an exact science, rigidly controlled by natural laws. There are variables. The variables are:

1. The method of manufacture of the part.
2. The skill of the estimator.
3. The applicable labor and burden rates used by the estimator.
4. The estimating methodology.

Each of these variables is capable of producing differences in cost estimates of the same part.

Much of estimating is based on judgment. The first variable, method of manufacture, is judgment dominated. How a part is to be made is conditioned by the estimator's background and work experiences. For example, because one estimator's background is stamping intensive, chances are his judgments (opinions), reflecting a higher degree of skill, will produce a highly reliable estimate of a sheet metal part. The same man, estimating a machined part, will not produce as reliable an estimate.

In many cases there is no single, best way to make a part. When the production volume is large enough to justify a double tool-up, for example, some manufacturers will deliberately tool the same part differently in order to gain operating experience in their search of optimum methods. For example: Today, door panels-both inner and outer-are produced singly by one automotive company, and doubly (two-at-a-time) by a competitor. In each case, production volumes are similar. What factors prompted these dissimilar tool-ups? Presumably, both methods were considered by each process engineer before the final choice. Each had to consider the "economics" of both methods. Is one "more right" than the other? What this illustrates is the flexibility inherent in the estimating process.

Some men, cautious by nature, will play it safe and "throw in two or three more operations".(1) This generosity is, in turn, compounded by the multiplier effect-three to five times-when the burden cost is applied.

From these examples, it is easy to see how estimating variances can occur in the first two variables.

(1)Operations = Steps in the manufacturing sequence.

PIONEER ENGINEERING & MANUFACTURING

BURDEN FACTORS

| FIXED | VARIABLE |
|---|---|
| Salaries & Fringes | Salaries & Fringes |
| Maintenance Repair (Grounds & External Bldg.) | Maintenance Repair (Internal Bldg. & Production Equip.) |
| Welding Equipment | Welding Equipment |
| Material Handling | Material Handling |
| Non-Capitalized Project Expense | Power Tools |
| Preproduction Expense (set up as a fixed cost) | Expense Tools |
| | Set-Up |
| Dies (Maintenance) | Dies |
| Operating Supplies | Operating Supplies |
| Office Supplies | Office Supplies |
| | Welding Supplies |
| Janitor Supplies | Janitor Supplies |
| Misc. Supplies | Misc. Supplies |
| Heating | |
| Transportation | Transportation |
| Electric Power & Light (based on min. rate x usage set by utility) | Electric Power & Light |
| | Fuel |
| Water | Water |
| Communications (Wats) | |
| Plant Protection | |
| | Other Purchased Services (i.e. Kelly Girls) |
| Non-Production Freight | Non-Productive Freight |
| Company Car & Travel Expense | |
| Executive Fringes & Services | |
| State & Local Taxes | |
| Insurance | |
| Depreciation | |
| Pensions & Leaseholds | |

Figure 6

The third variable, labor and burden rates, is the most abused element in cost estimating. The reason is that most estimators are excellent mechanics and engineers, know manufacturing techniques, but are poor financiers-most have only a rudimentary comprehension of how burden rates and burden costs are developed and applied. Their principal interest is in developing the manufacturing sequence, and specifying the equipment and tooling. Of second importance (interest) is the selection of the proper labor and burden rates. This step, performed almost casually by most estimators, is perhaps the most important in the estimating process because of the multiplier effect (most estimators calculate the burden cost of an operation by multiplying the direct labor cost by a burden percentage factor, usually two to eight times the labor cost).

Most manufacturing operations involve a single machine, such as a punch press, run by a single operator. To illustrate how the typical estimator develops a cost estimate, assume such a machine, run by a single operator, performing a forming operation, a sheet metal parts, 300 parts per hour are produced in this operation. The direct labor, therefore, is .2 minutes per part (60/300). Assuming a direct labor cost of $10.00 per hour, the labor cost for this operation comes to:

$$\frac{.2 \times \$10.00}{60} = \$0.33$$

The next step is the calculation of the burden or factory overhead. Estimating departments have a schedule of burden rates, a specific rate for a specific machine, developed by the plant comptroller.

One of the methods used in calculating burden is to multiply the direct labor cost for a given operating by a percentage factor: i.e., 300%, 400%, etc. These percentage factors are developed from historical data accumulated over a number of accounting periods. These factors usually are based on data covering a whole department (sometimes on data which is not broken down below that of a whole plant). Consequently, the factors can be influenced by departmental conditions not specifically related to the operation itself. Burden rates based on historical data can very easily include inefficiencies that get lost in the overall departmental or plant operation.

Burden costs developed as a percentage of labor are still related to the type of equipment. It should be noted that labor can vary relative to a piece of equipment depending upon the complexity of the part and specific operation performed, but the burden remains the same. As an illustration of this and expanding on the example discussed above:

Labor Cost ($.033) x Burden Factor (300%) = $.099.

The combined labor and burden cost for this operation, then is $.033 + $.099 = $.132.

Assume in our example that a second man, a helper, is required to man the stamping press. The labor cost now becomes $.006 per operation per part. The unwary estimator will often assume that the burden cost should then be 300% x .066, or $.198.

This is obviously false since the overhead doesn't double simply because another man has been added. Only the incremental costs, in this situation, associated with addition of the second man should be added to the base cost calculated earlier. The estimator should "up the cost" of the operation by only the direct labor cost of the second man ($.033). The burden cost would remain as it was when one man operated the press. The new cost for the press operation, now manned by an operator and a helper is:

$.033 + $.033 + $.099 = $.165.

Another problem which occurs frequently in estimating is the application of burden to an unmanned manufacturing operation. For example, assume a sequence of six press operations required to make a stamping. The first, or blanking operation, required two operators to remove the blank, dope it with lubricant and insert it in the draw die of the following operation, making sure that the two blanks have not stuck together (a double blank could wreck the draw die). The next three operations are loaded and unloaded mechanical, the part is even inverted between operations thee and four, all without operator intervention. The final operation, a cam-piercing operation, requires one operator who removes the part, applies a dab of paint for identification and hangs the part onto a conveyor.

What cost does the estimator assign to each operation? If he is using the burden percentage method, there is no problems with the first and final operations since these have operators. The estimator simply calculates the direct labor cost for each of these, then multiplies these by the burden percentage rates to obtain the burden cost, making sure, of course, that he has not doubled the burden cost in the first operation which has two operators.

The problem arises when the estimator tries to apply his formula to those operations which are unmanned. There is no direct labor cost, nothing he can multiply by his burden percentage rate. The unwary estimator will frequently assume that since there is no labor cost there can be no burden cost.

We know this to be false since all of the burden elements-with the exception of fringe benefits-are still there whether an operator is present or not.

Another method of burden cost calculation used by Pioneer is the "Burden Center" concept. Whereas the "Burden Percentage" method covers a full department, sometimes an entire plant, the "Burden Center" approach considers a much smaller entity: a single machine plus only those expenses directly associated with the operation of the machine. These expenses are both variable (expenses which vary with product volume changes) and fixed (expenses which are unaffected by volume changes).

Typical variable expenses considered in burden would be (this is not a complete list):

- -- Indirect Labor
- -- Perishable Tools
- -- Fuel
- -- Maintenance
- -- Fringe Benefits
- -- Utilities

Typical fixed and non-variable expenses would be:

- -- Taxes
- -- Amortization
- -- Some Clerks & Janitors
- -- Insurance
- -- Some Supervision
- -- Some Utility Bills

A pro rata share of each of these elements is assigned to each burden center. The result is a carefully developed, localized cost for a specific machine or other asset, reflecting only those expenses unique to that machine. These costs are stated in "dollars per machine hour" giving rise to the expression: Machine Hour Rate.

"Burden Center" rates can be generated by historical data, or they can be developed from equipment specifications and requirements for power, lubrication, light, heat, indirect labor, average maintenance, material handling, and other costs required to keep the equipment operating. The latter method of burden development is beneficial when developing costs for a new plant or facility where historical data has not been developed. Another advantage in the latter approach is that nominal burden costs can be developed around nominal equipment production rates.

Costs developed around nominal production rates for a piece of equipment are an important consideration when assessing production costs. For example, a piece of equipment has a theoretical production rate for which it is designed. This theoretical rate may not be achieved because of inherent equipment and human operational conditions. However, "nominal" rates have been established through experience of an acceptable "efficient" plant. Well managed plants can achieve these nominal rates. All costs analyses should be developed around burden rates based on "nominal" production standards. Costs developed with burden rates established with other than nominal standards should not be used for comparison because they include variances in production inefficiencies and do not have a common base. Pioneer costs are established around nominal production rates.

There are other cost methodologies. One such method uses the cost-per-pound approach. Under this method, the parts of a car, for example, are grouped by classes of material: steel stampings, castings, forging, molded plastics, etc. The cost of each part is divided by its finished weight, and a cost-per-pound obtained: a "meat market" approach. Pioneer does not endorse this method because of its dependence on a straight-line relationship between weight and cost. For example, if a seven-pound brake drum cost $3.50, will a nine-pound drum cost $4.50? ($.50 per pound). Unlikely. The labor and burden will remain essentially the same for each size of drum, but the material cost, obviously, will be different. In spite of its imprecision, the method has some utility: as a "rough-and-dirty" indicator of approximate cost, as a crude verification that the estimate is "in the ball park".

# APPENDIX B

## NAMES, QUALIFICATIONS

## and

## PARTICIPATION of RESEARCHERS

## INTRODUCTION

This project was mainly ( 95% ) conducted by Norman F. Ludtke and Richard F. Heitsch. Qualifications of the principle participants is as follows:

### Norman F. Ludtke

Mr. Ludtke has been a product design engineer for 45 years in the missile and automotive industries. During these years he has also served in the following management positions; Chief Draftsman, Research Supervisor, Program Manager, Chief Engineer, Vice President of Research and Development, Executive Manager of CAE. These management positions have covered approximately 39 of the 45 years stated above.

Mr. Ludtke has been conducting projects for NHTSA for 25 years, 21 of these years have been on cost analysis projects. This experience has provided a thorough knowledge of the requirements of NHTSA for their cost analysis efforts. In addition, Mr. Ludtke has been very involved in the development of the Asset Center Cost Methodology which is the standard costing methodology used by NHTSA for their programs. In addition to NHTSA, these types of cost programs have been conducted for DOT/TSC, US/DOE, Jet Propulsion Labs, Sandia, Gas Research Institute, US/DOD, SAE, GM, Owens Corning, United Technology, etc..

Mr., Ludtke holds a paten on an all pneumatic missile guidance and control system which was recommended by the US Army Missile Command for use on the MARS Missile System. Other commercial products have been developed over the years which are in use in the commercial area.

This combined experience makes Mr. Ludtke uniquely qualified to conduct this project.

Mr. Richard F. Heitsch

Mr. Heitsch has been involved in manufacturing engineering for 44 years. During these years Mr., Heitsch has been involved in all aspects of manufacturing engineering including; time study, processing, tool and equipment design, equipment installation, cost analysis and gauge design. These efforts have covered automotive ( high volume ) to bowling alley equipment ( low volume ).

Eleven ( 11 ) of these years have included projects for NHTSA on cost analysis projects. Mr. Heitsch has also been very involved in the development of the Asset Center Costing Methodology. He has been instrumental in developing a computer program for use in conducting Asset Center Costing analysis efforts. This is a propriety computer program developed for use on NHTSA and other clients cost analysis projects. Mr. Heitsch has been involved in the projects for the clients listed under the discussion of Mr. Ludtke's experience. Mr. Heitsch worked under Mr. Ludtke for nine of the eleven years that he has been involved in NHTSA cost analysis projects. They have a lot of combined experience working on these types of projects.

Mr. Heitsch is uniquely qualified for this project because of the above experience.