FINAL REPORT

CONTRACT NO. DTNH22-81-C-07330

SYSTEMS ANALYSIS APPROACH TO INTEGRATING AIR BAGS INTO A PRODUCTION READY SMALL CAR

PHASE I RESULTS

DE LOREAN DMC-12 EXPLORATORY CRASH TESTS

Fitzpatrick Engineering

Restraint Systems Design and Development

Final Report

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Systems Analysis Approach to Integrating Air Bags into a Production Ready Small Car.

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Prepared by:

Fitzpatrick Engineering
Route 5, Box 495A
Warsaw, IN 46580

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

Fitzpatrick Engineering
RESTRAINT SYSTEMS DESIGN AND DEVELOPMENT
ROUTE 5, BOX 495A • WARSAW, IN 46580 PHONE: 219 267 4421

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1.0 Background

In March of 1981, Fitzpatrick Engineering was awarded a contract by NHTSA to use a "systems analysis approach" to integrate air bag restraint systems into a "production ready, small car".

The term "systems analysis approach" is used to convey the concept of using high speed digital computing techniques to design and integrate an airbag restraint system into the subject car that is optimally compatible with its crash environment. If successful, the necessity of conducting a large number of preliminary tests prior to converging to the final design will be eliminated since the many parameters that affect restraint system performance can be investigated in a more efficient manner. We say more efficient manner because the cost and time for the computer approach should be less than what would be spent for a trial and error approach that relies on a large number of rather expensive tests.

The reason for using a "production ready, small car" was two-fold. First, there is a need to demonstrate that the restraint system design that evolves through the systems analysis approach will perform effectively in a structurally unmodified, production car. Second, the car should be less than 3000 lb total weight to reflect the current trend to smaller vehicles.

The vehicle chosen by NHTSA for this program was the DeLorean sports car. This vehicle is a two-passenger, rear engine car with gull wing doors and a stainless steel exterior skin as shown in Figure 1. The main structural frame is constructed

DeLorean Sports Car

Figure 1.

of steel and roughly resembles an "X" with the middle of the X comprising the center spine that runs through the passenger compartment. Figure 2 shows this X-frame. Fastened to the main X-frame is a fiberglass body constructed glass reinforced panels and foam filled beams as shown in Figure 3. The vehicle curb weight is approximately 2700 lb.

Fitzpatrick Engineering's main tasks in this contract were to:

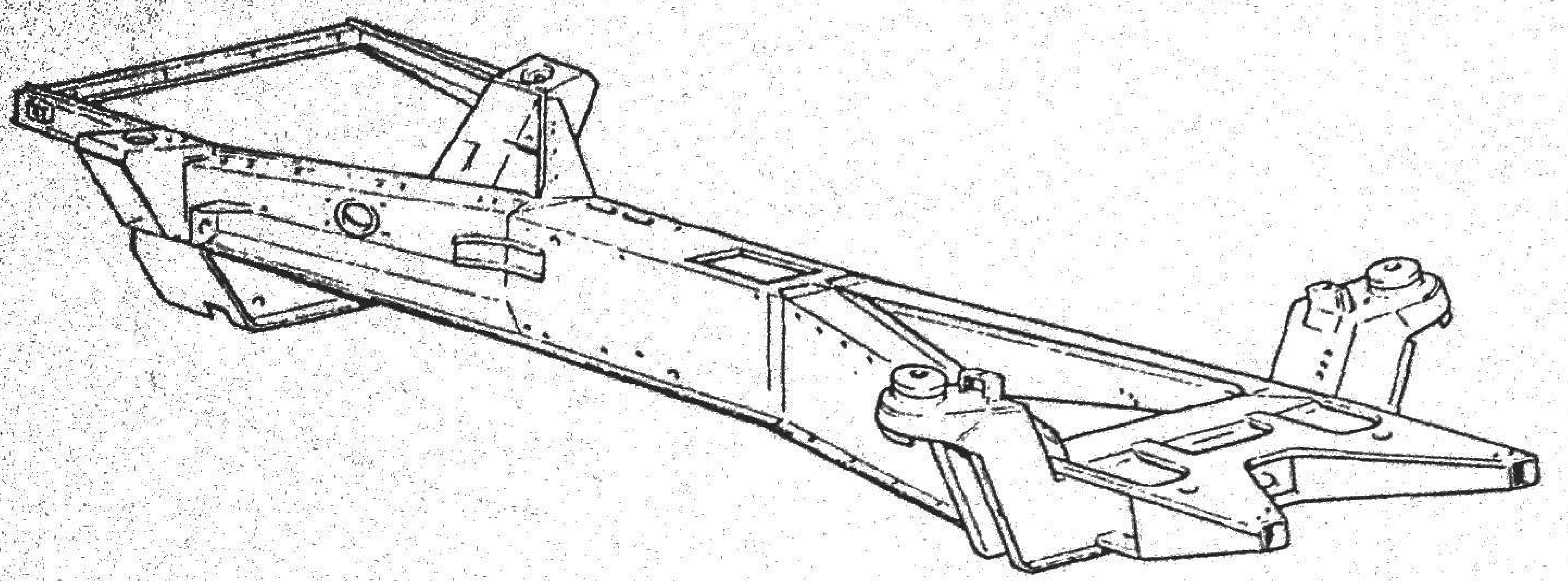
a) Design a preliminary driver and passenger airbag restraint system using computer techniques.

b) Specify the restraint system components to be used in the two barrier crash tests and recommend test velocities.

c) Direct the test contractor, Dynamic Science, on the integration and installation of the restraint systems into the DeLorean.

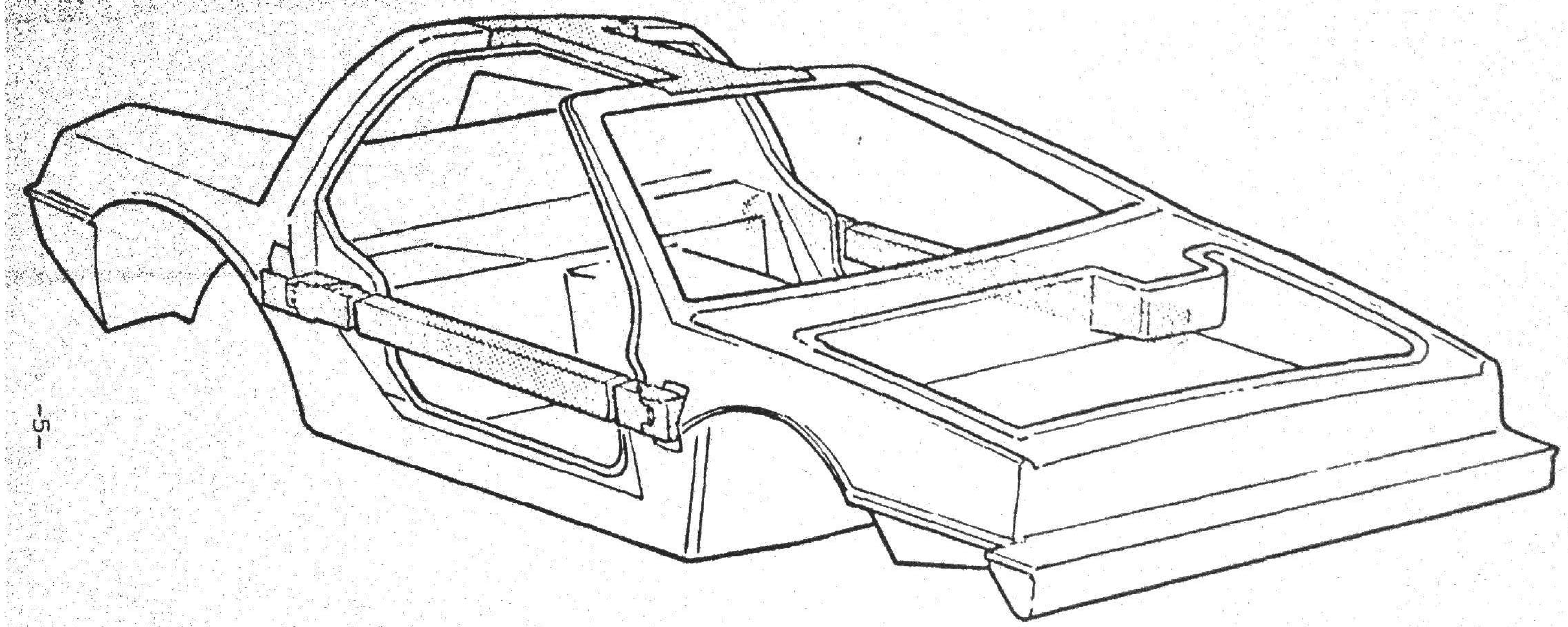
d) Perform as Engineering Test Director for the two, frontal, barrier crash tests.

The purpose of these two crash tests were primarily to determine the structural response of the DeLorean at two different crash speeds and to provide an early indication of the performance potential of the computer derived restraint systems in this systems analysis approach to airbag integration.



DeLorean "X" Frame

Figure 2.



DeLorean Fiberglass Underbody

Figure 3.

2.0 Pre-Test Computer Simulations

Fitzpatrick Engineering studied existing crash data for the DeLorean at 30 mph as well as the passenger compartment interior design and volume and overall vehicle structural design. Based upon this study, we recommended that the test speeds for the upcoming crash tests be 35 and 40 mph. This recommendation was made to representatives of NHTSA and DeLorean Motor Co. at a meeting held at DOT headquarters in Washington D.C.

In our judgement, the most information could be learned from these test speeds since the vehicle had already been crashed at 30 mph by DeLorean Motor Co. with very good structural performance and since the merits of the systems analysis approach of restraint systems design would be tested more severely at the higher impact speeds. However, since we didn't know the crash pulse at these higher speeds, the preliminary computer simulations were of a qualitative nature. That is, we estimated the crash pulse at 35 and 40 mph based upon the 30 mph crash pulse and then conducted a series of computer runs in which we:

a) chose the airbag shapes and volumes,

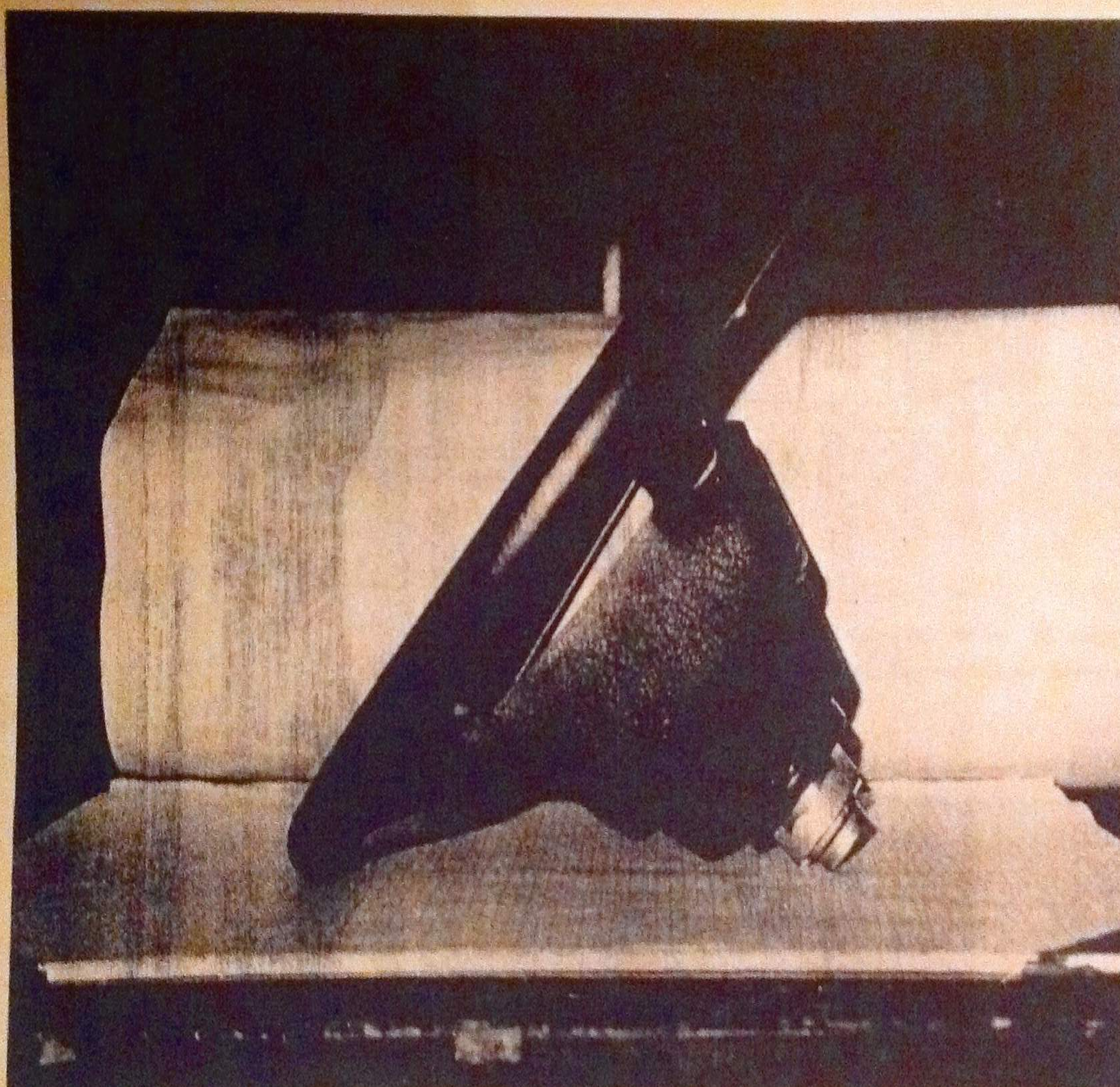
b) evaluated eight different passenger inflators (including the possibility of using two "driver type" inflators instead of the one cylindrical type passenger inflator),

c) evaluated the restraint system performance at 10 and 15 msec sensing times to determine crash sensor specifications,

d) investigated the effect of staging the "driver type" inflators simulated for the passenger system to select the inflator configuration that would optimally satisfy the requirements of the forward positioned child as well as the normally seated adult.

In addition to the computer simulations, we made a subjective evaluation of the DeLorean interior to decide on the way the restraint system components would be installed in the vehicle. The result of the computer simulations using the DRAC and PAC computer models and this inspection of the vehicle led to conclusions that aided in selection of the preliminary airbag restraint system components as listed below.

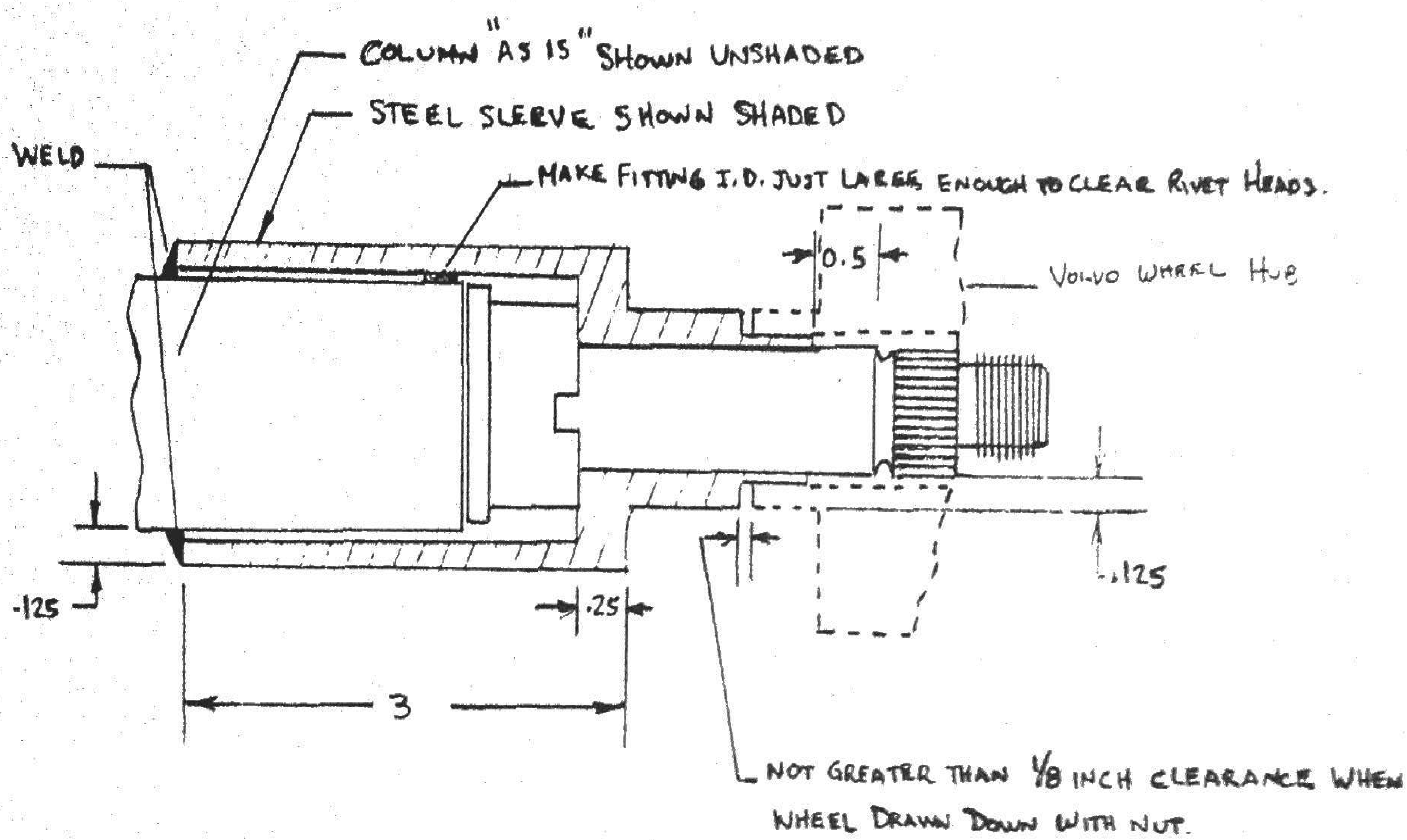
Component	Type Selected	Basis for Selection
Steering Wheel	1979 Volvo GT	Production DeLorean wheel does not have volume available for inflator and airbag installation. Volvo wheel does and also is designed to deform during crash. Stiffened spokes by addition of 0.067" thick strap. Figure 4 shows Volvo wheel.
Steering Column	DeLorean with reinforced steering shaft (Figure 5)	Steering shaft reinforced to prevent bending as static tests indicated that shaft was "borderline". Figure 6 shows underneath view after first crash test. Note tilt adjust mechanism.
Knee Restraint	Aluminum honeycomb	Dependable with known crush characteristics. Covered with aluminum skin with vinyl cover (Figure 7).
Inflator, Passenger	Thiokol/ Mercedes	Selected two "driver type" inflators based upon computer predicted satisfactory performance for range of passenger sizes and positions. Also production line is set up.



Volvo Steering Wheel

Figure 4.

DMC Steering Shaft Reinforcement

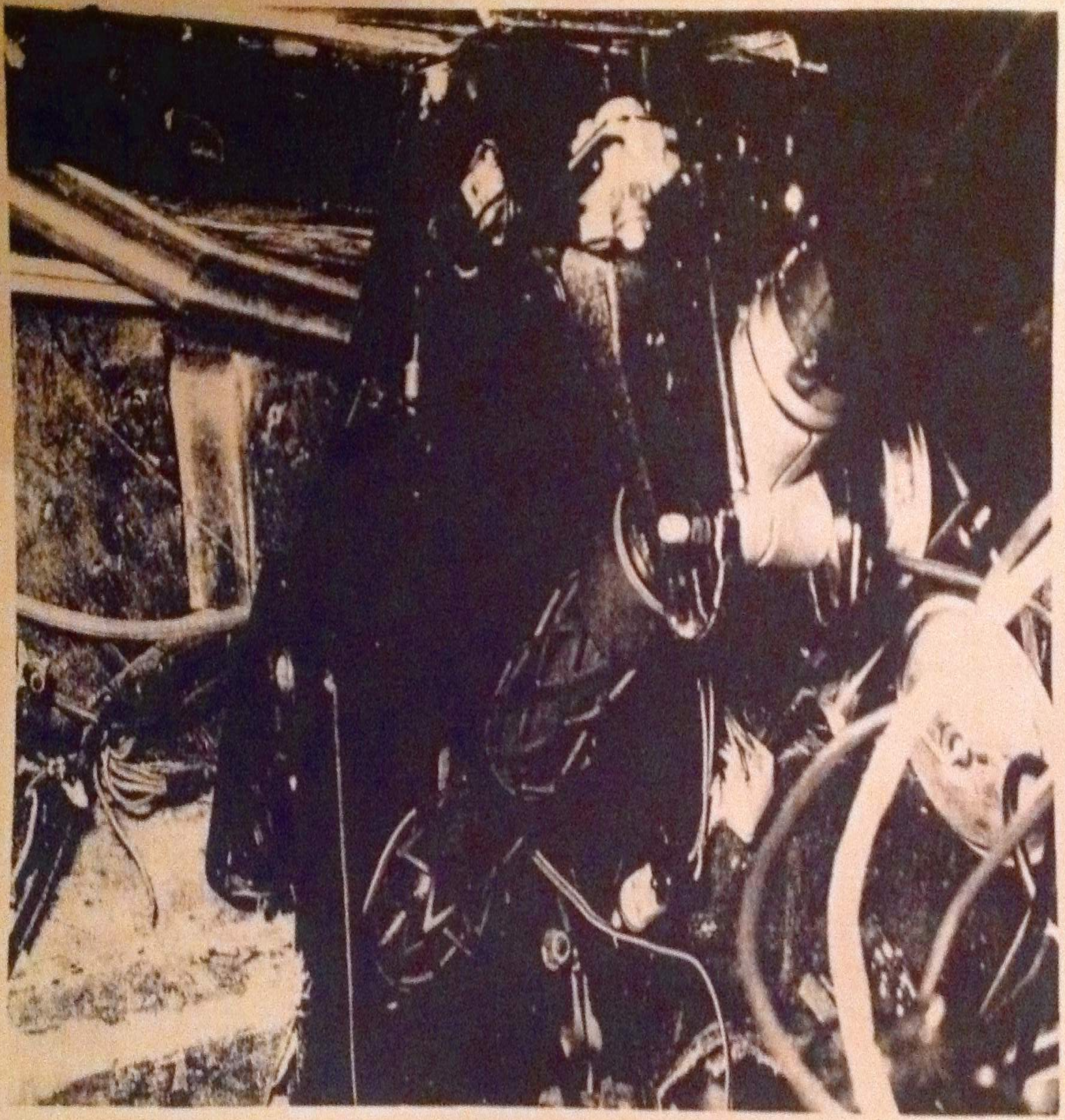


Steps

1. Disassemble steering Ass'y so measurements can be made for shaft reinforcing piece
2. Make steel sleeve
3. Weld to existing shaft Ass'y as shown
4. Reassemble entire steering Ass'y including all housings and turn signals, etc.

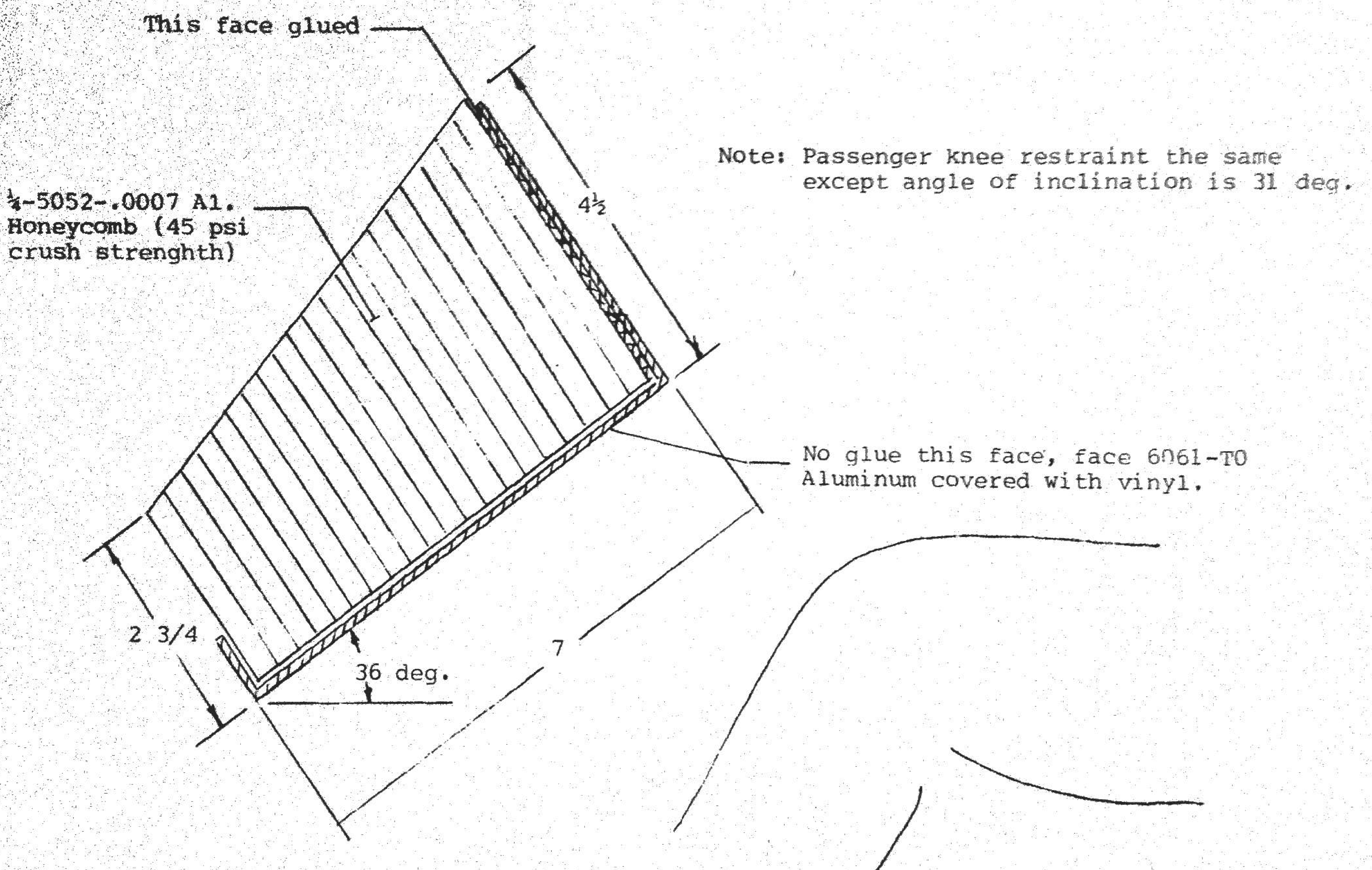
DeLorean Steering Shaft Reinforcement

Figure 5.



DeLorean Steering Column from Underneath

Figure 6.



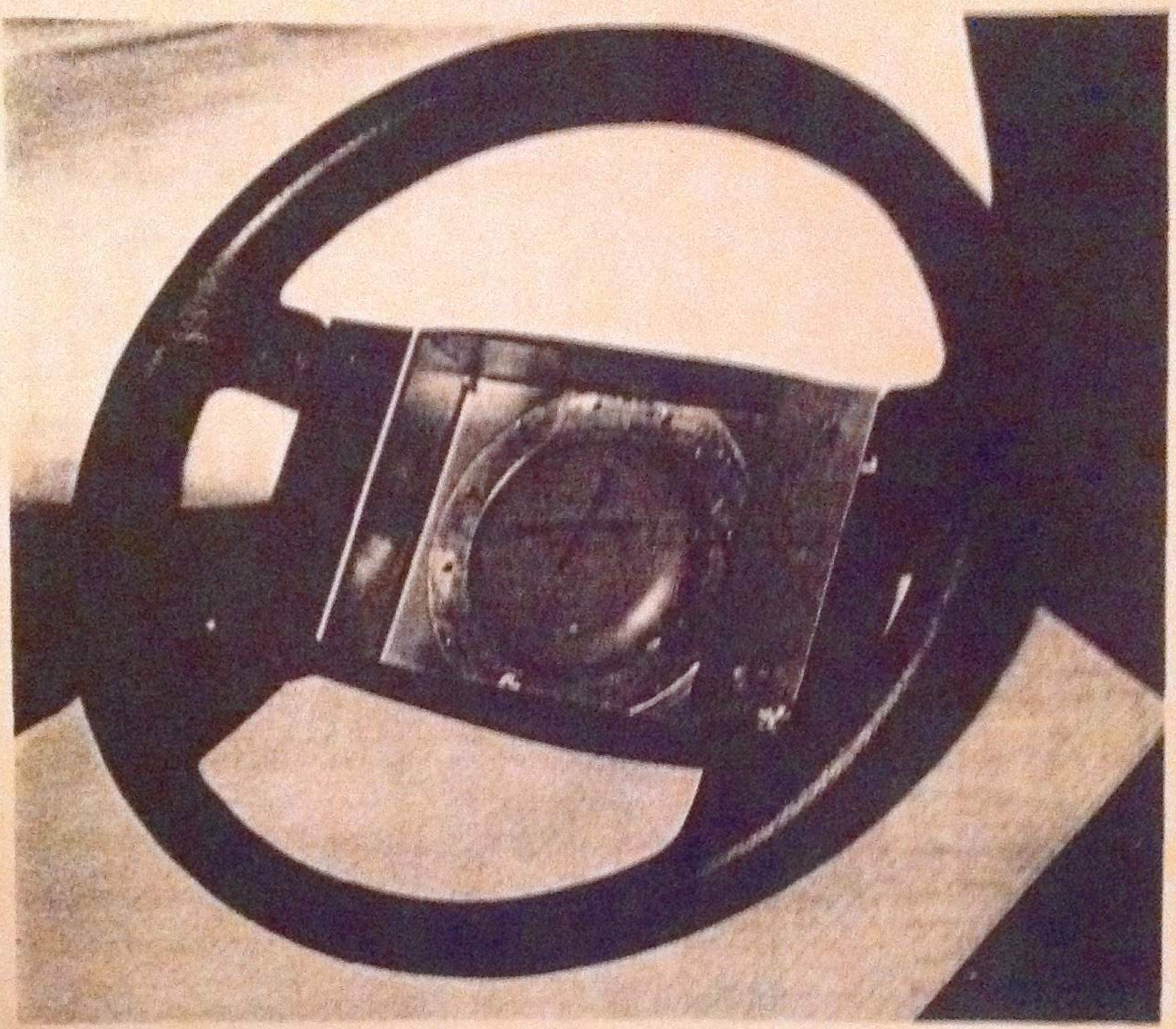
Delorean Knee Restraint

Figure 7.

Component	Type Selected	Basis for Selection
Inflator, Driver	Thiokol/ Mercedes	Used same inflator as on passenger side since predicted performance was satisfactory and a single part number could be used for all inflators in car. Figure 8 shows the inflators installed in driver and passenger modules.
Airbags	Fitzpatrick Engineering design, Talley manufactured	Size, shape, volume and vent areas determined by computer simulation. Drawings furnished to Talley for manufacture (Figures 9 and 10).
Packaging	Fitzpatrick Engineering design	Past experience used to design housings, adapters, modules and support structure to locate restraint systems in vehicle (Figs 11-16).

3.0 Integration of Restraint Systems into Vehicle

Once the computer derived restraint system components had been selected, ordered and finally obtained from the manufacturers, Fitzpatrick Engineering sent a representative to Dynamic Science, the NHTSA selected test contractor, to direct the integration of the restraint components into the first test vehicle. During this integration effort our objective was to effect the integration in a cost effective manner that would be fairly typical of what, if not how, it might be done in production. That is, we attempted to use prototype shop techniques to fabricate

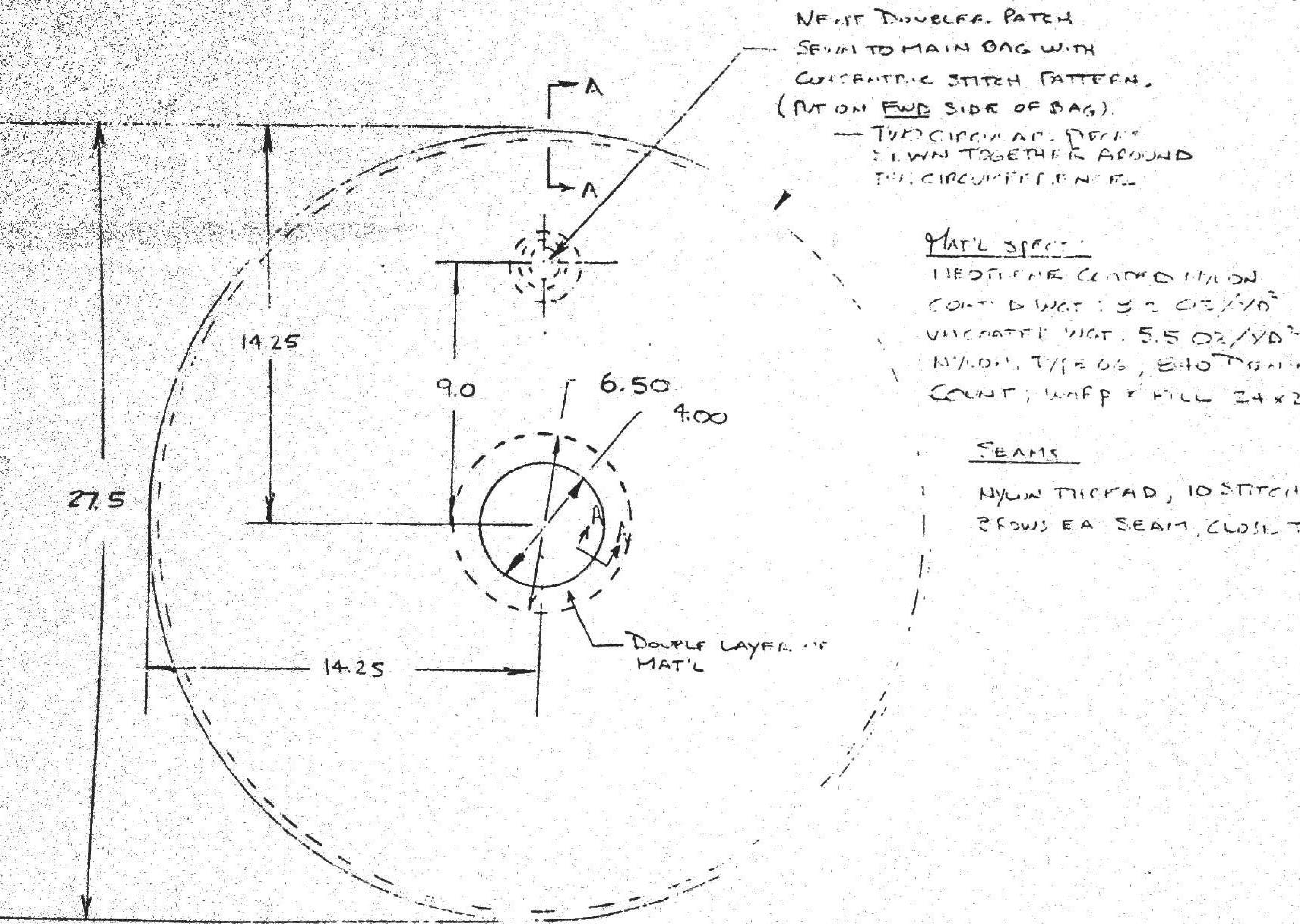


Inflator Installed in Driver Module

Inflator Installed in Passenger Module

Figure 8.

DMC-12 DRIVER AIRBAG ~ MOD II



DIMENSIONS SHOWN ARE FINISHED DIMENSIONS

Figure 9.

M.7. 8-26-8

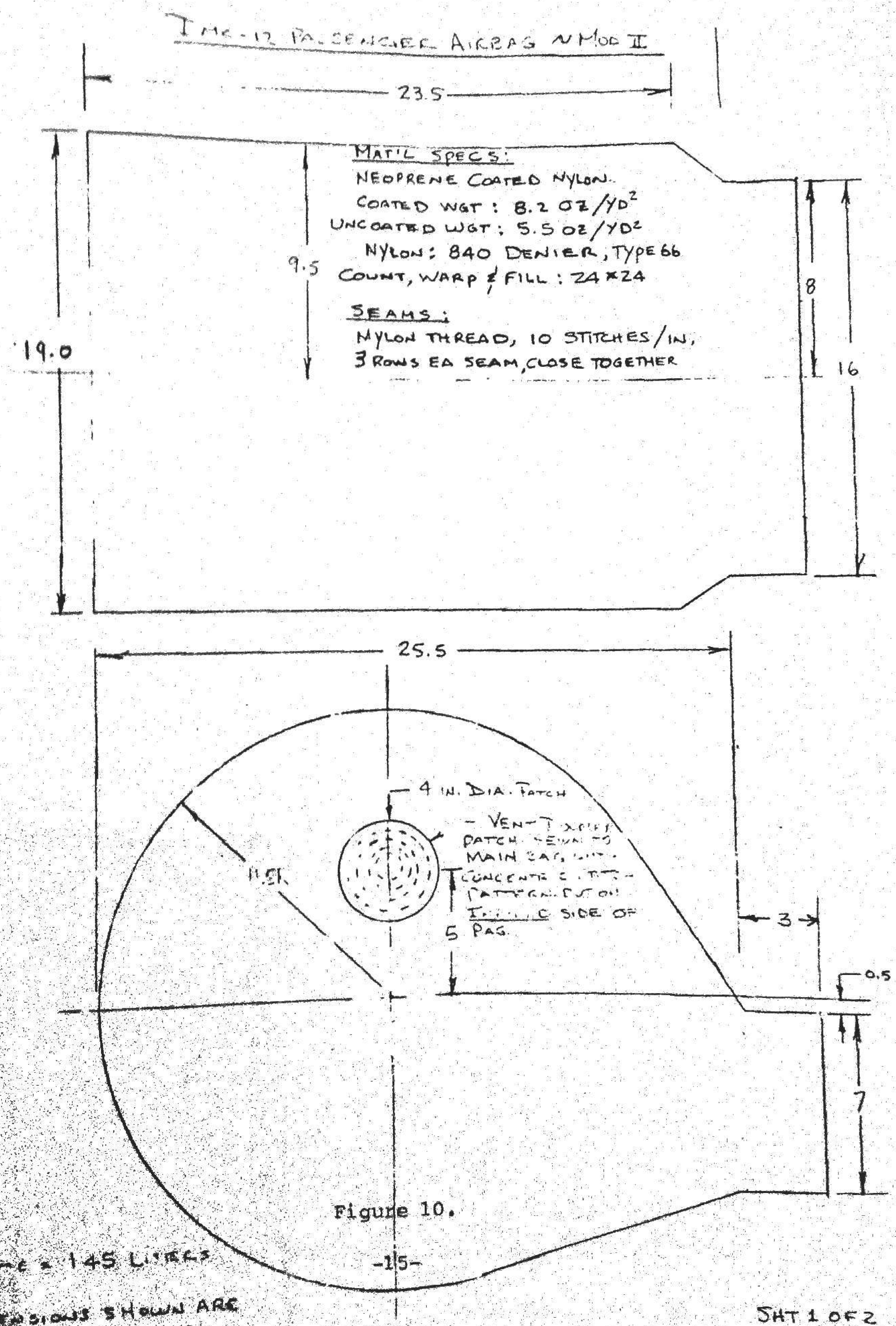
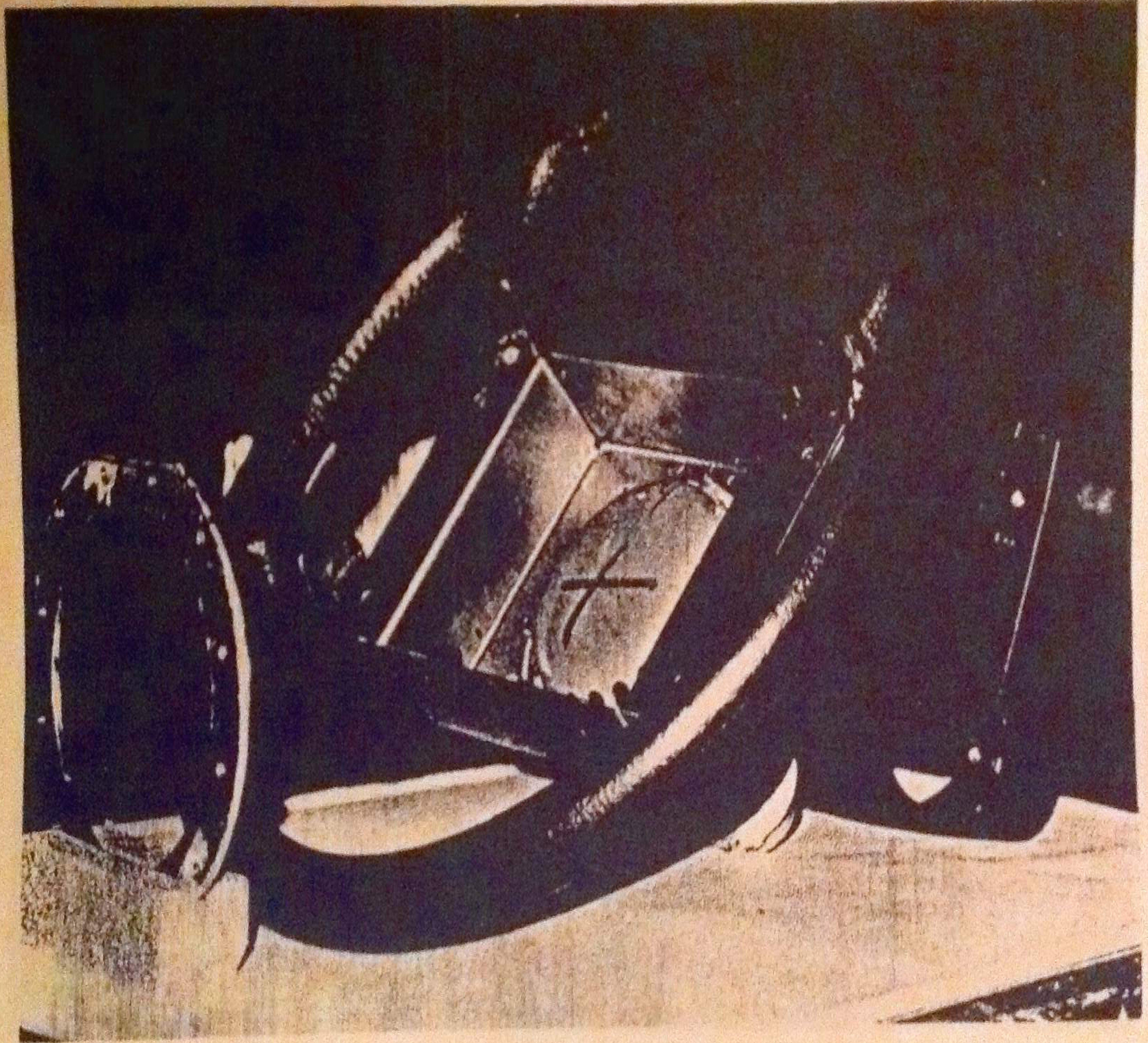
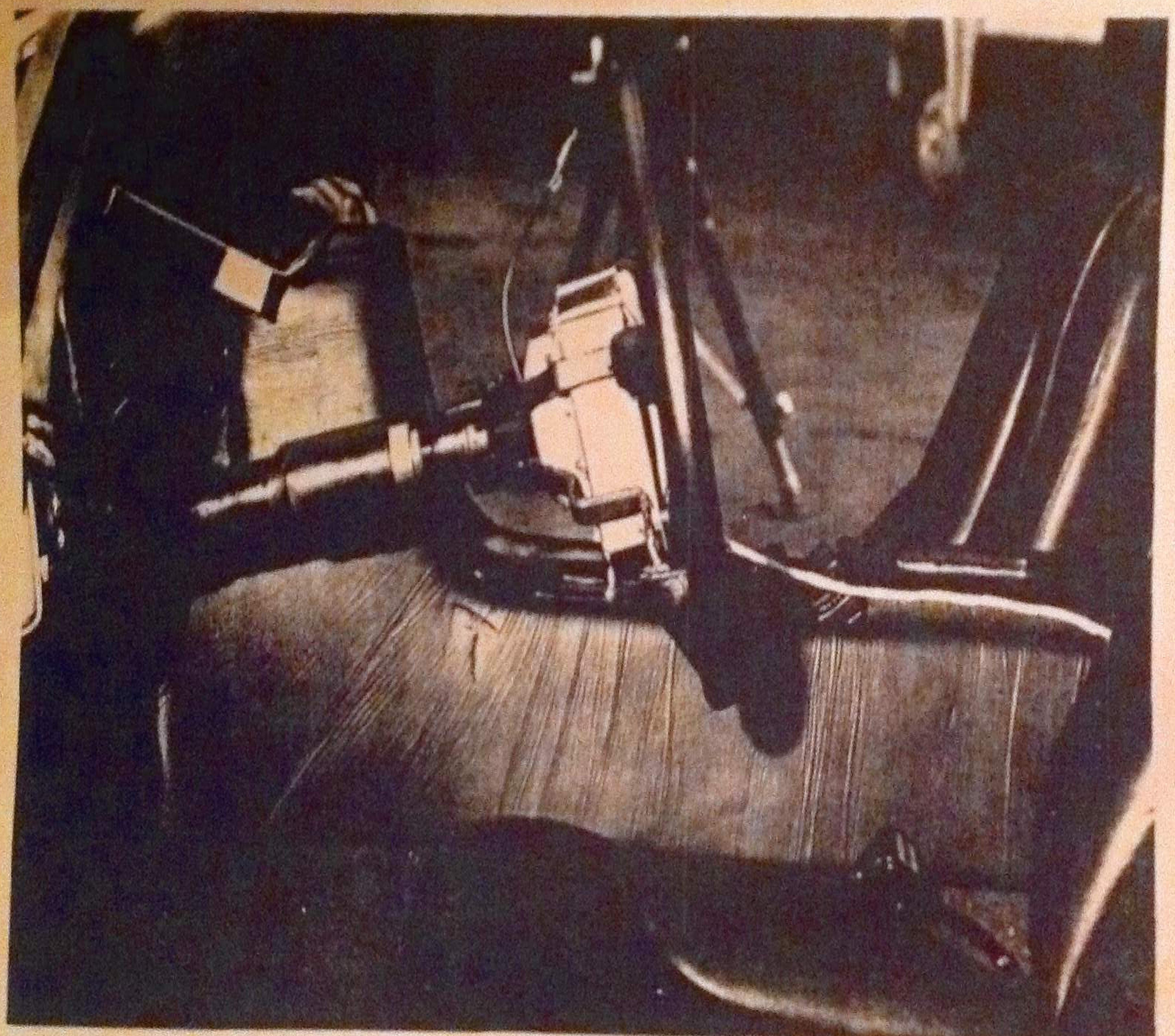

TMK-12 PASSENGER AIRBAG N MOD II
23.5
MAT'L SPECS:
NEOPRENE COATED NYLON
COATED WGT: 8.2 OZ/YD²
UNCOATED WGT: 5.5 OZ/YD²
NYLON: 840 DENIER, TYPE 66
COUNT, WARP & FILL: 24×24
SEAMS:
NYLON THREAD, 10 STITCHES/IN.
3 ROWS EA SEAM, CLOSE TOGETHER
9.5
19.0
8
16
25.5
4 IN. DIA. PATCH
MAIN BAG
SIDE OF
BAG
5
3
0.5
7
VOLUME = 145 LITERS
DIMENSIONS SHOWN ARE
FINISHED DIMENSIONS
SHT 1 OF 2
M.Z. 8-26-5

Figure 10.



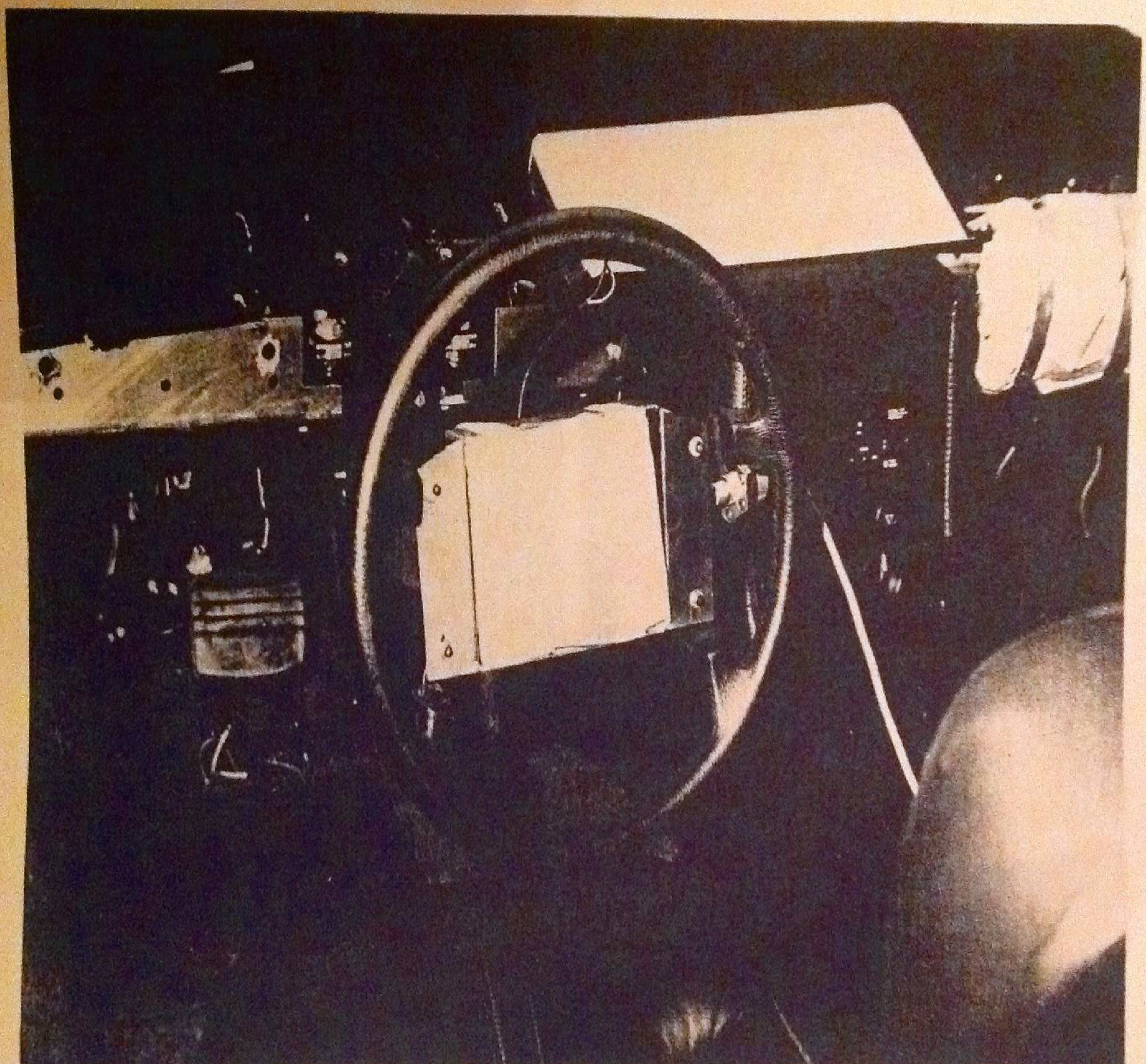
<u>Driver Module Components</u>

Figure 11.



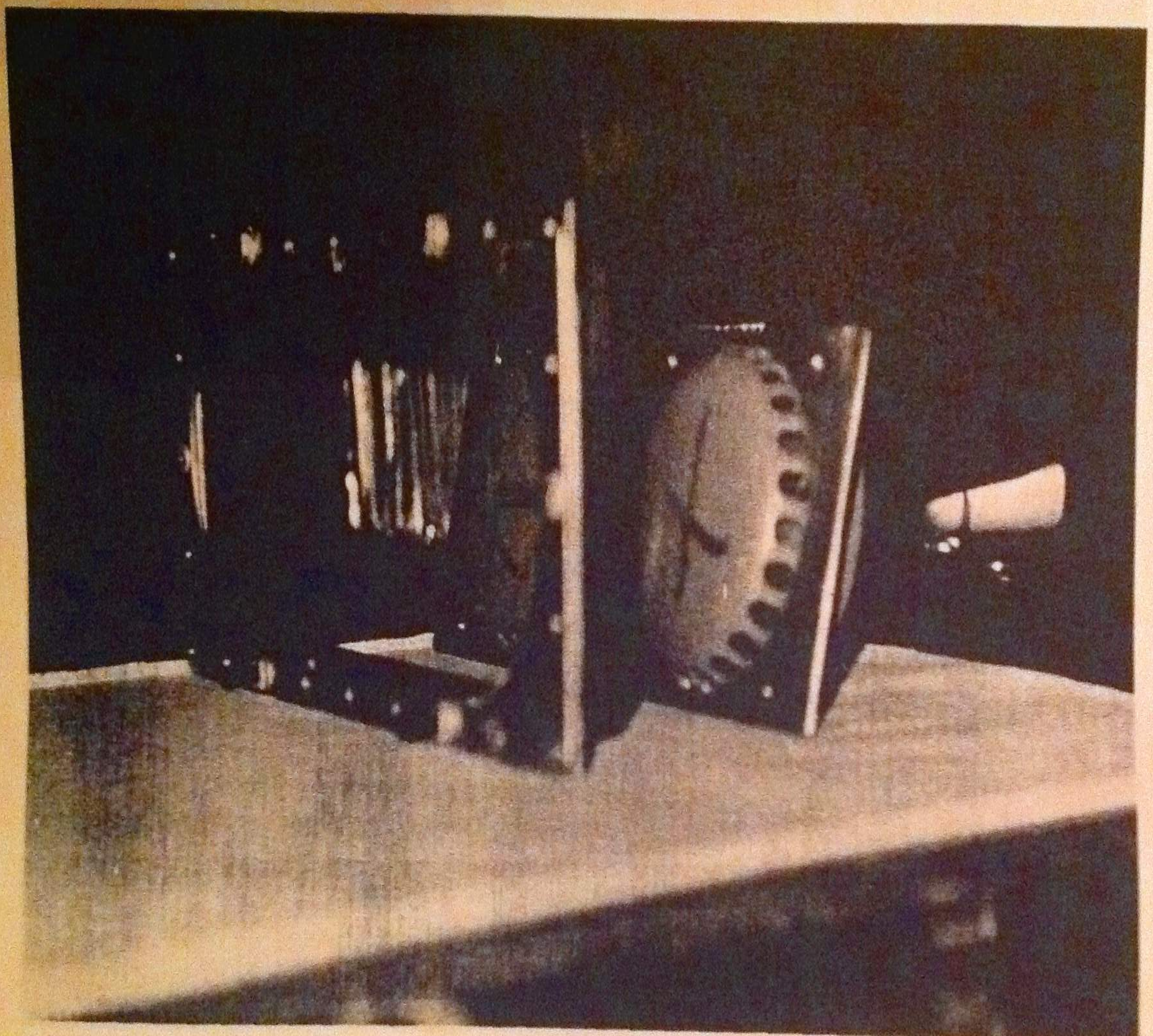
Driver Module Installation (shown w/o housings)

Figure 12.



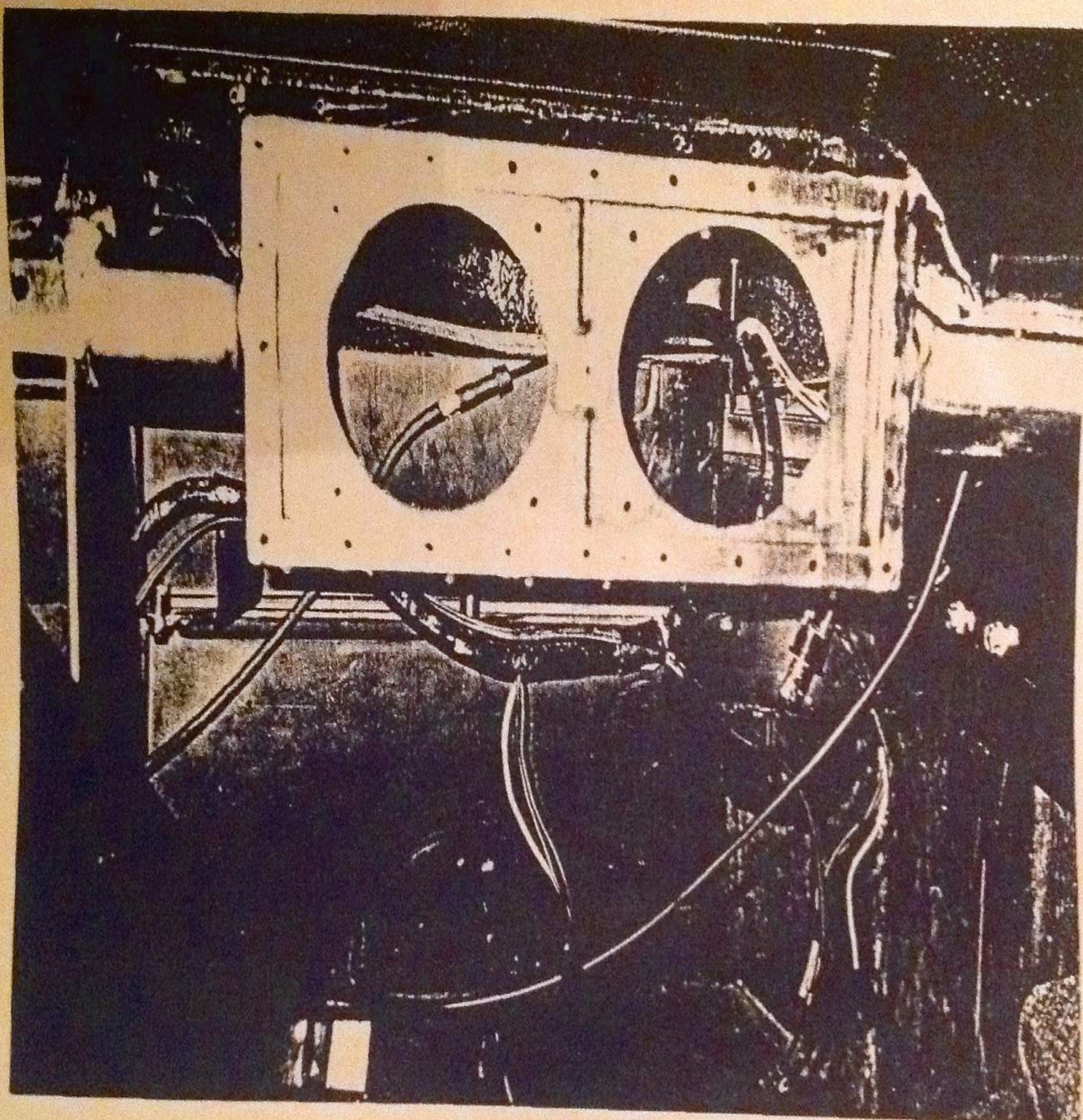
Driver Module Installation (shown w/o housings and cowl)

Figure 13.



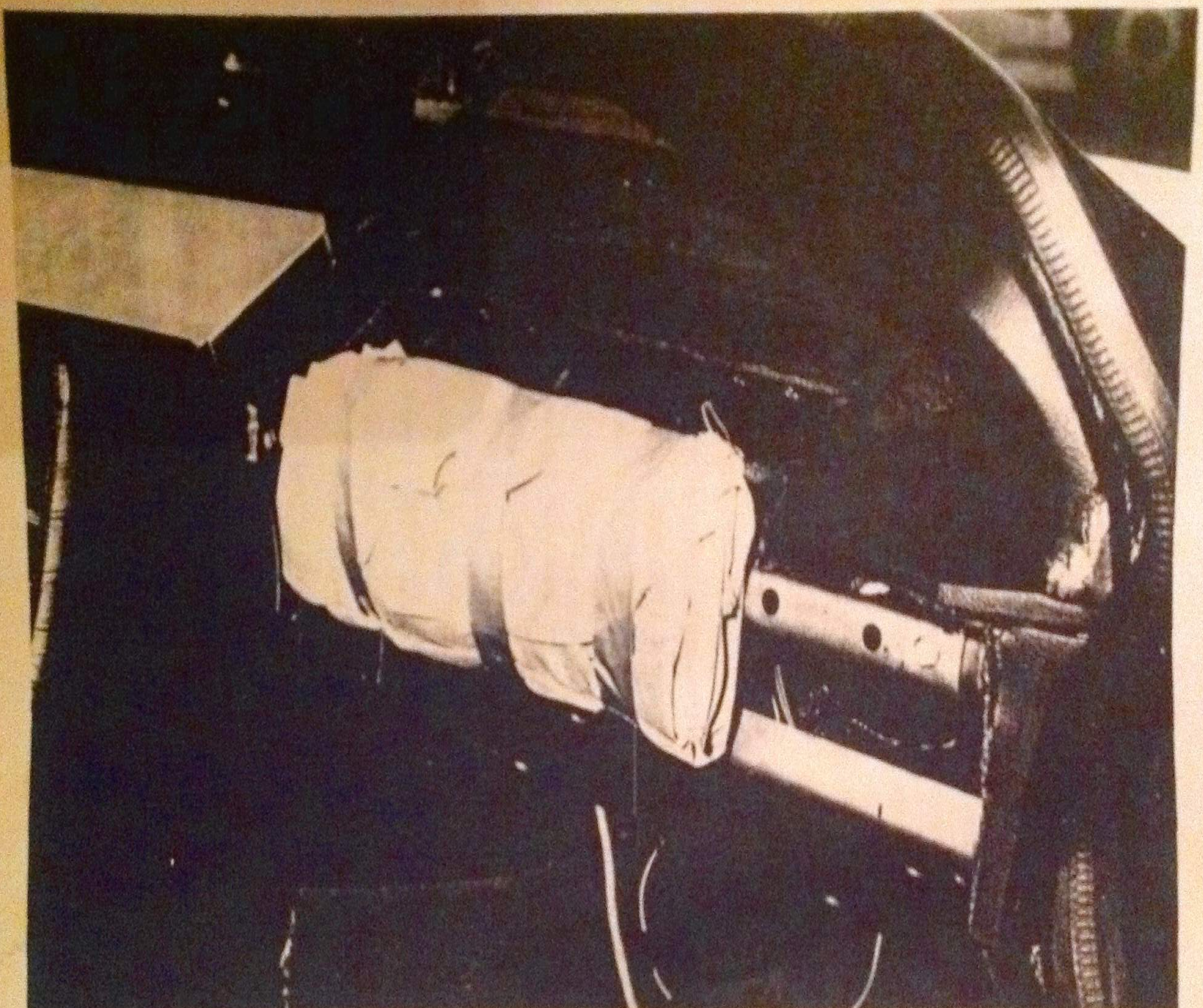
Passenger Module Components (minus airbag)

Figure 14.



Passenger Module Inflator Mount

Figure 15.



Passenger Airbag System (shown w/o covers)

Figure 16.

structure that would approximate the method by which various restraint system components could be mounted. Very briefly, the method used was to bolt 12 gage sheet steel to the fiberglas A-Posts and tunnel to provide mounting surfaces for the knee restraints and the passenger airbag module. By using this method of attachment and the relatively small module design shown in Figure 8, it was possible to effect this integration without infringing on the space occupied by the air conditioner or glove box.

4.0 Test Results

For these two preliminary crash tests it was mutually agreed by the CTM and Fitzpatrick Engineering that the airbag inflation would be activated by a contact switch located on the bumper. In addition, this contact switch would operate in series with a built in electronic delay of ten milliseconds so that the computer selected delay of ten milliseconds from bumper contact until squib ignition would be realized. Again, based upon computer simulation, we decided to activate the driver airbag and the first level of the passenger airbag at the ten millisecond point but then wait another seven milliseconds to initiate the second passenger inflator. In this way we could obtain a gas flow profile that was, theoretically at least, more satisfactory for both the normally seated adult and the forward positioned child.

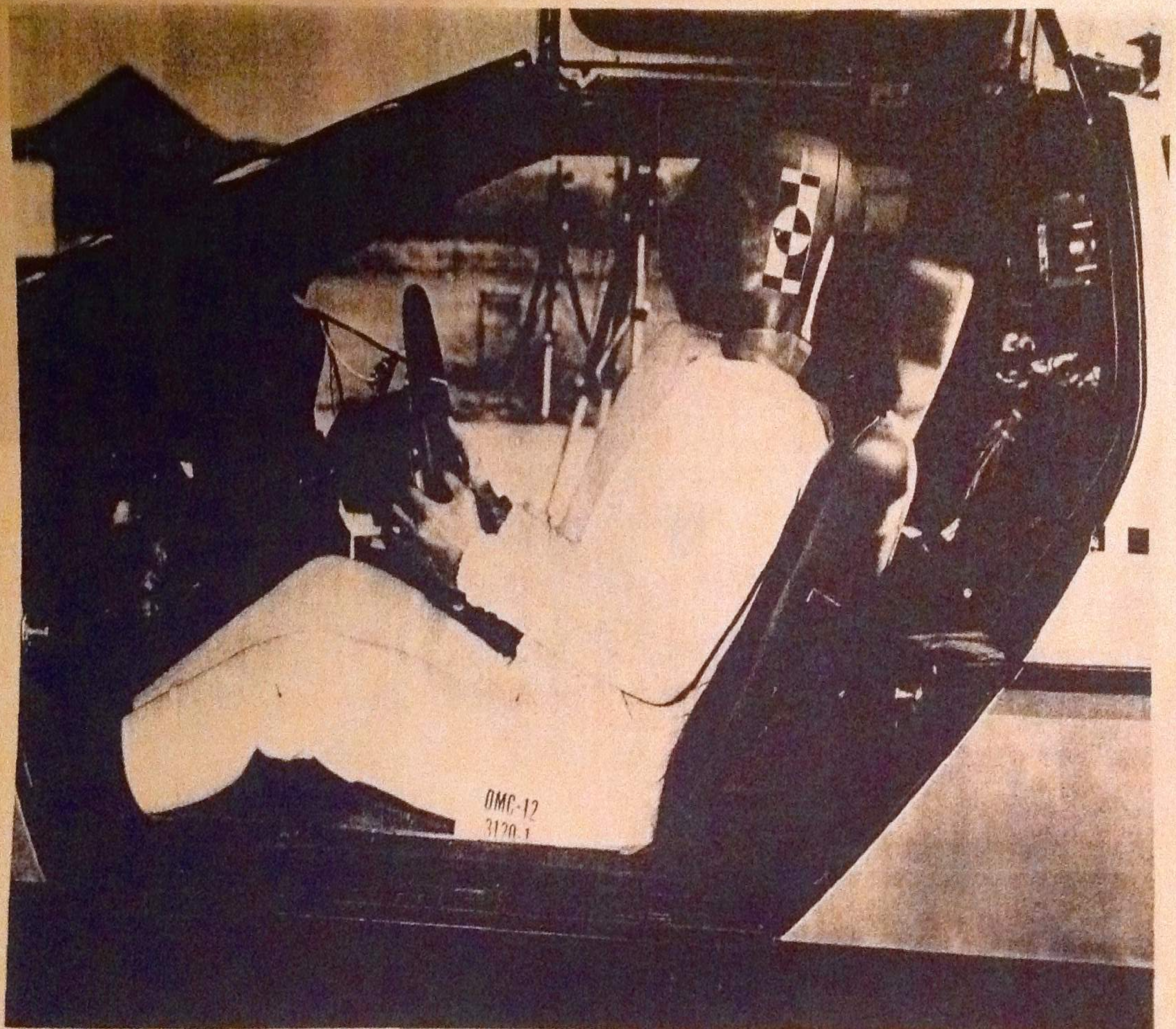
The reason a contact switch was used rather than a crash sensor was due to the uncertainty as to the firing time we would obtain with commercially available sensors actuated by the, as yet unknown, DeLorean crash pulse. However, in order to learn as much as possible about what the sensing time of some commercially available sensors might be, three different types of sensors were "piggybacked" on the two tests.

4.1 Crash Test No. 1

The first crash test was conducted on September 24, 1981 at a test speed of 36 mph and was a full frontal impact into a rigid barrier. In this first test the steering column was purposely prevented from stroking during dummy loading so that we could evaluate the performance of the other driver restraint system components. We especially wanted to determine whether the combination of the airbag and crushable steering wheel could absorb sufficient energy so that the stroking column would not be needed.

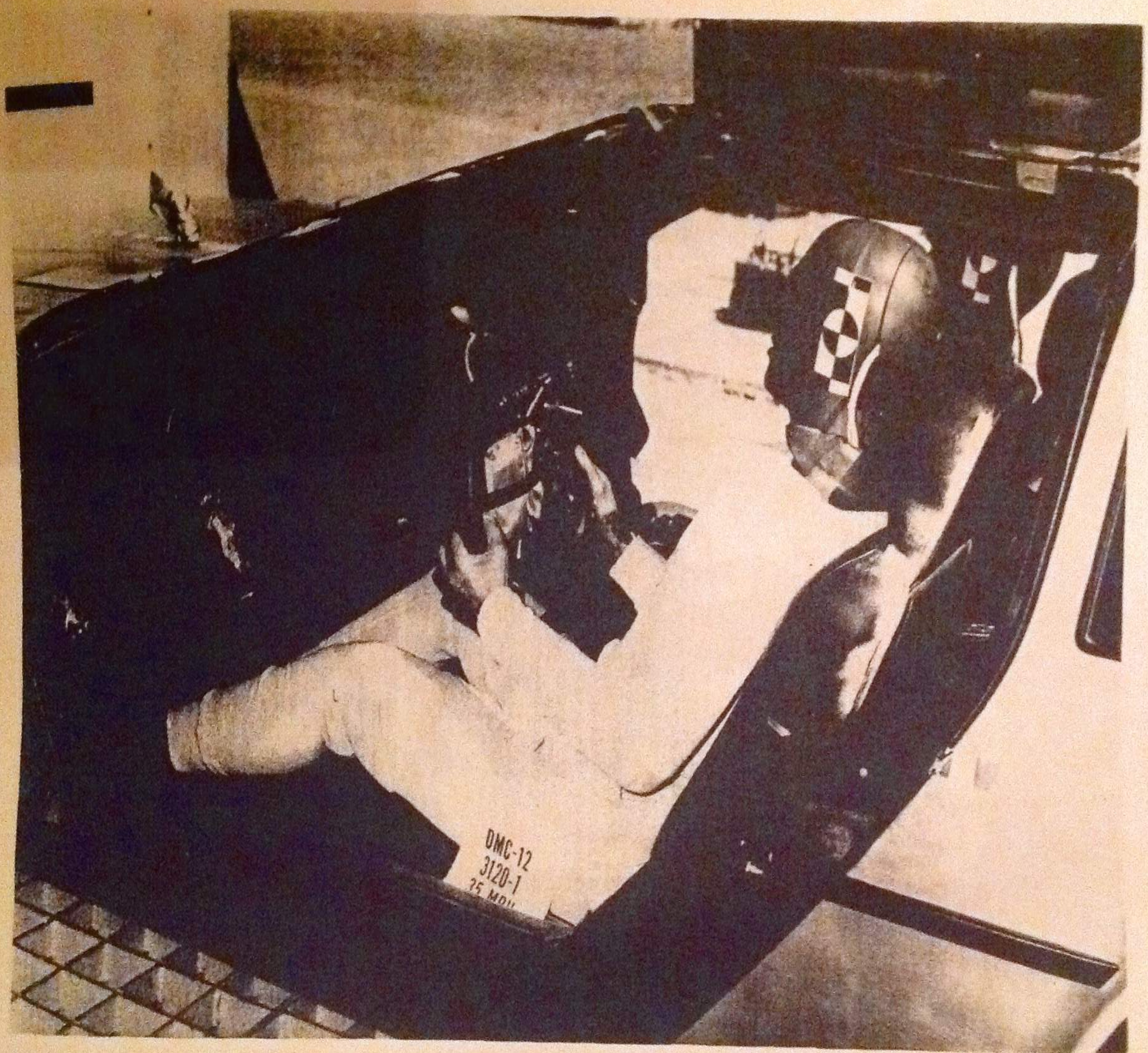
Figures 17 through 20 show the pre-test relationships between the 50^{th} percentile dummies and their respective restraint systems. The seats were both placed in their mid-adjust, fore-aft positions. The test weight of the car with dummies, instrumentation and 5 gallons of Stoddard solvent in the fuel tank was 3351 lb. Figures 21 through 23 show the vehicle prior to test (although the doors were ajar when these photos were taken, they were securely latched before the test).

The dummy injury measures for this first test are shown in the table following the figures.



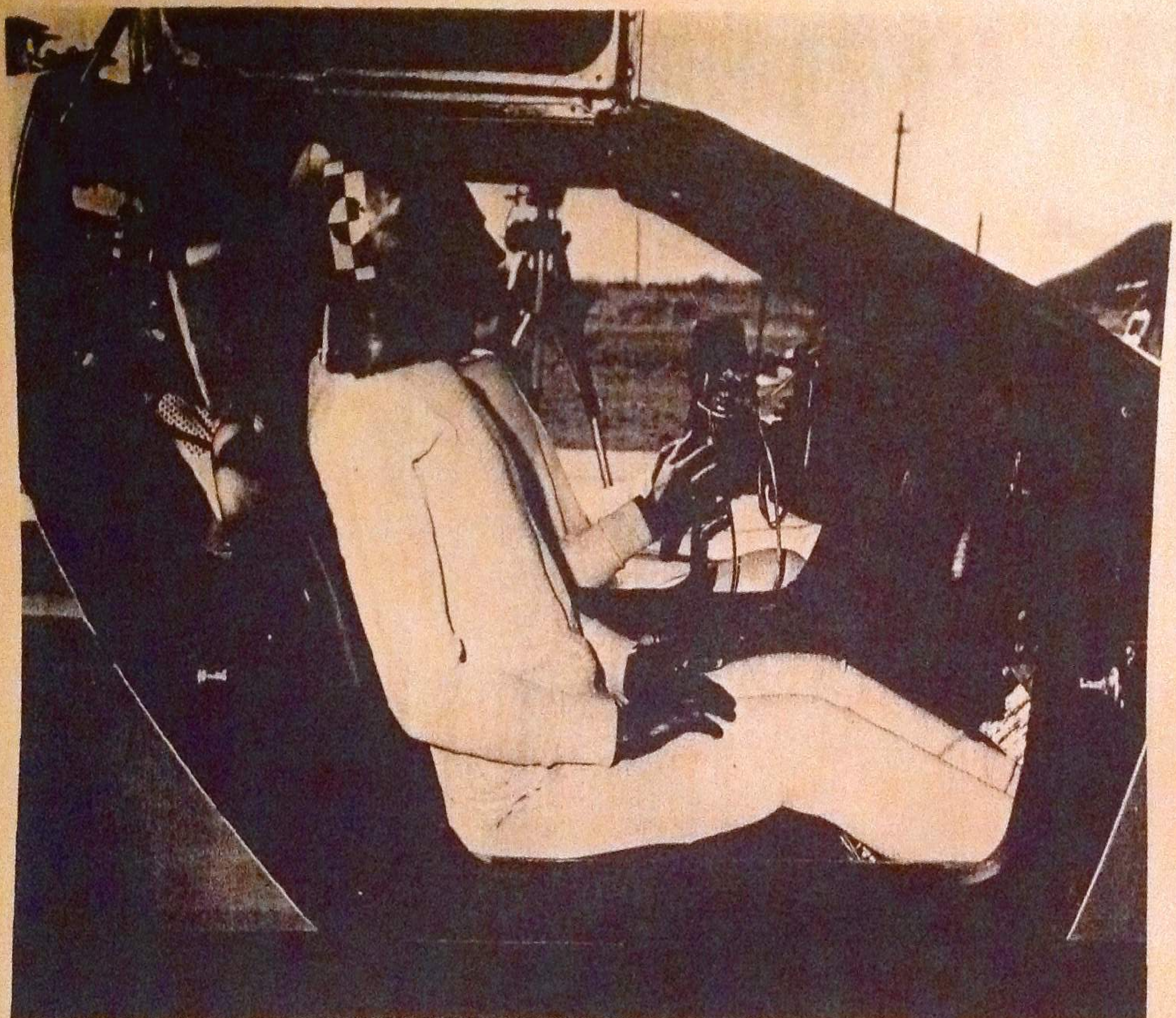
Test No. 1, Side View, Driver Restraint System

Figure 17.



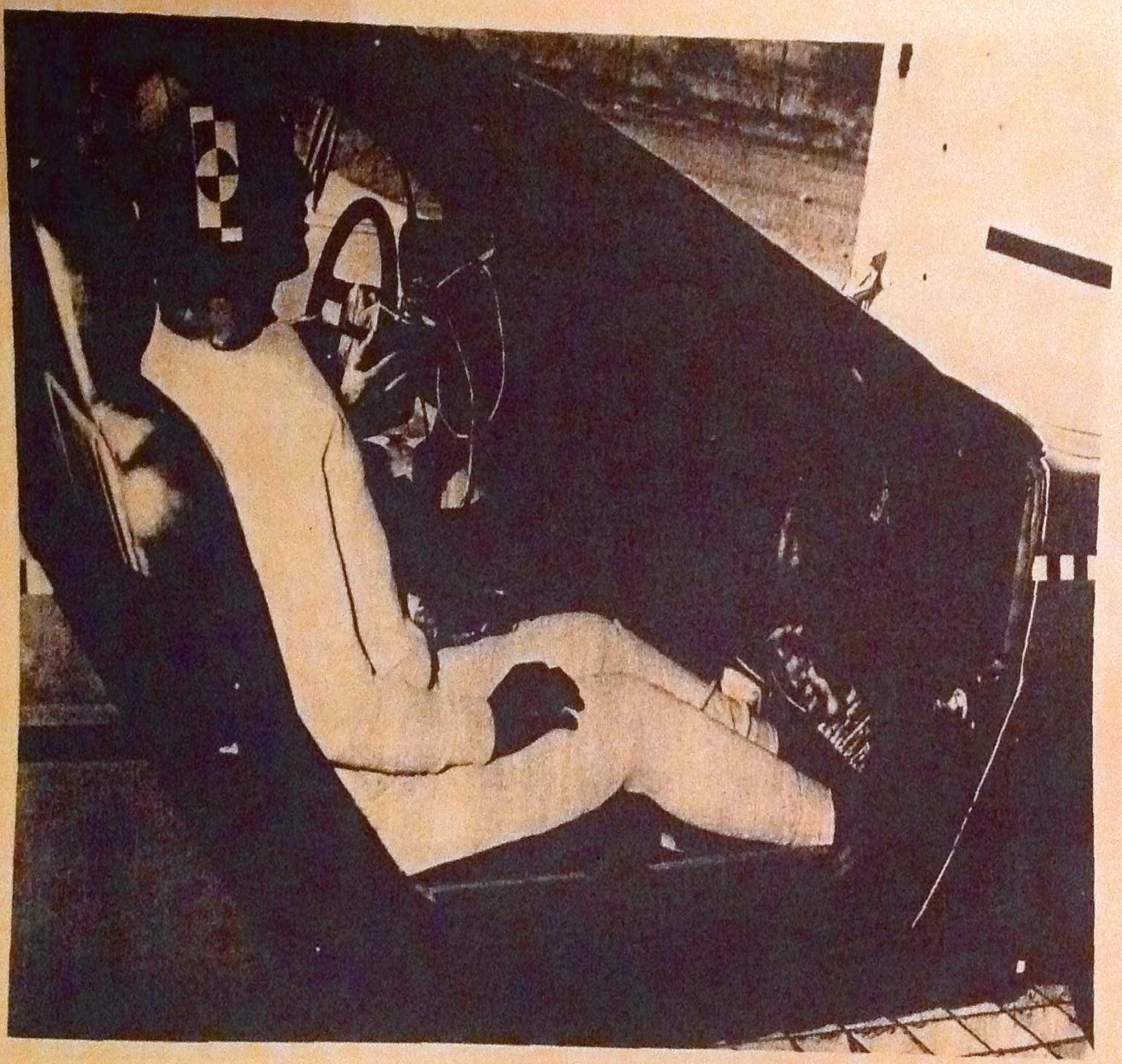
Test No. 1, 3/4 View, Driver Restraint System

Figure 18.



Test No. 1, Side View, Passnger Restraint System

Figure 19.



Test No. 1, 3/4 View, Passenger Restraint System

Figure 20.