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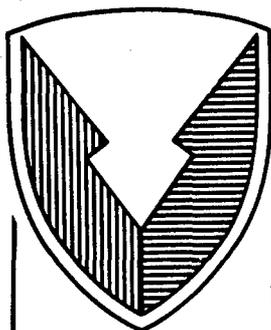
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C E N T E R

Technical Report



No. 13524

FINITE ELEMENT ANALYSIS OF
HIGH-MOBILITY MULTIPURPOSE WHEELED VEHICLE (HMMWV) FRAME
WITH PROPOSED DRAIN HOLES

MARCH 1991

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20031219028

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE 15 March 1991	3. REPORT TYPE AND DATES COVERED Final 10 Sep 90 - 26 Oct 90	
4. TITLE AND SUBTITLE Finite Element Analysis of High Mobility-Multipurpose Wheeled Vehicle (HMMWV) Frame with Proposed Drain Holes		5. FUNDING NUMBERS	
6. AUTHOR(S) Stephen G. Lambrecht Roberto P. Garcia			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Tank-Automotive Command AMSTA-RYC Warren, MI 48397-5000		8. PERFORMING ORGANIZATION REPORT NUMBER 13524	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release: Distribution is Unlimited		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) It was reported that High-Mobility Multipurpose Wheeled Vehicle (HMMWV) frames were rusting out in tropical climates due to salt water resting in the frame rails. In order to alleviate this problem, a proposal to drill four drain holes into the HMMWV frame rail was made. The purpose of this report was to perform finite element analysis (FEA) on the HMMWV frame to determine if the proposed drain holes lower the structural integrity of the frame.			
14. SUBJECT TERMS Finite Element Analysis, HMMWV, Vehicle Frame			15. NUMBER OF PAGES 34
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

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1.0. INTRODUCTION

The High-Mobility Multipurpose Wheeled Vehicle (HMMWV) is currently being used at various military bases around the world. These vehicles are the replacement of the M151 Jeep Vehicle. They come in various configurations such as the M998 pickup truck, the M996 ambulance and the M1026 four-door hardtop version. These vehicles utilize full frames to which the body, engine, and suspension are attached. Figure 1-1 below depicts a typical HMMWV.

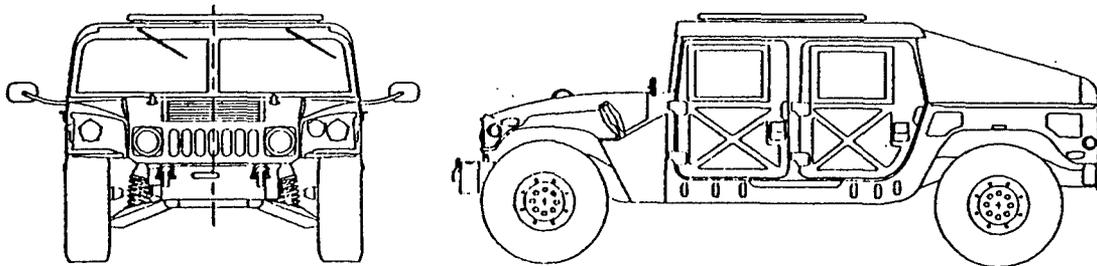


Figure 1-1. M1026 HMMWV

According to field reports, the HMMWV frames are rusting out beyond repair in Hawaii within five years of service. This was thought to be caused by salt water resting in the frame rails. In order to remedy this problem, AMSTA-MTC at the U. S. Army Tank-Automotive Command (TACOM) proposed the drilling of four, two per frame rail, 0.5-inch drain holes in the bottom of the frame rails. Figure 1-2 illustrates the drain hole locations. The Computer-Aided Engineering Branch (AMSTA-RYC) was tasked to perform a structural analysis of the frame with the drain holes to determine if this solution was feasible.

2.0. OBJECTIVE

The objective of this project was to compare the standard HMMWV frame to one with the four 0.5-inch drain holes. Finite Element Analysis (FEA) was to be used to determine if the drain holes would damage the structural integrity of the frame.

3.0. CONCLUSIONS

The result of the finite element analysis showed no adverse stress condition on the frame with the 0.5-inch drain holes

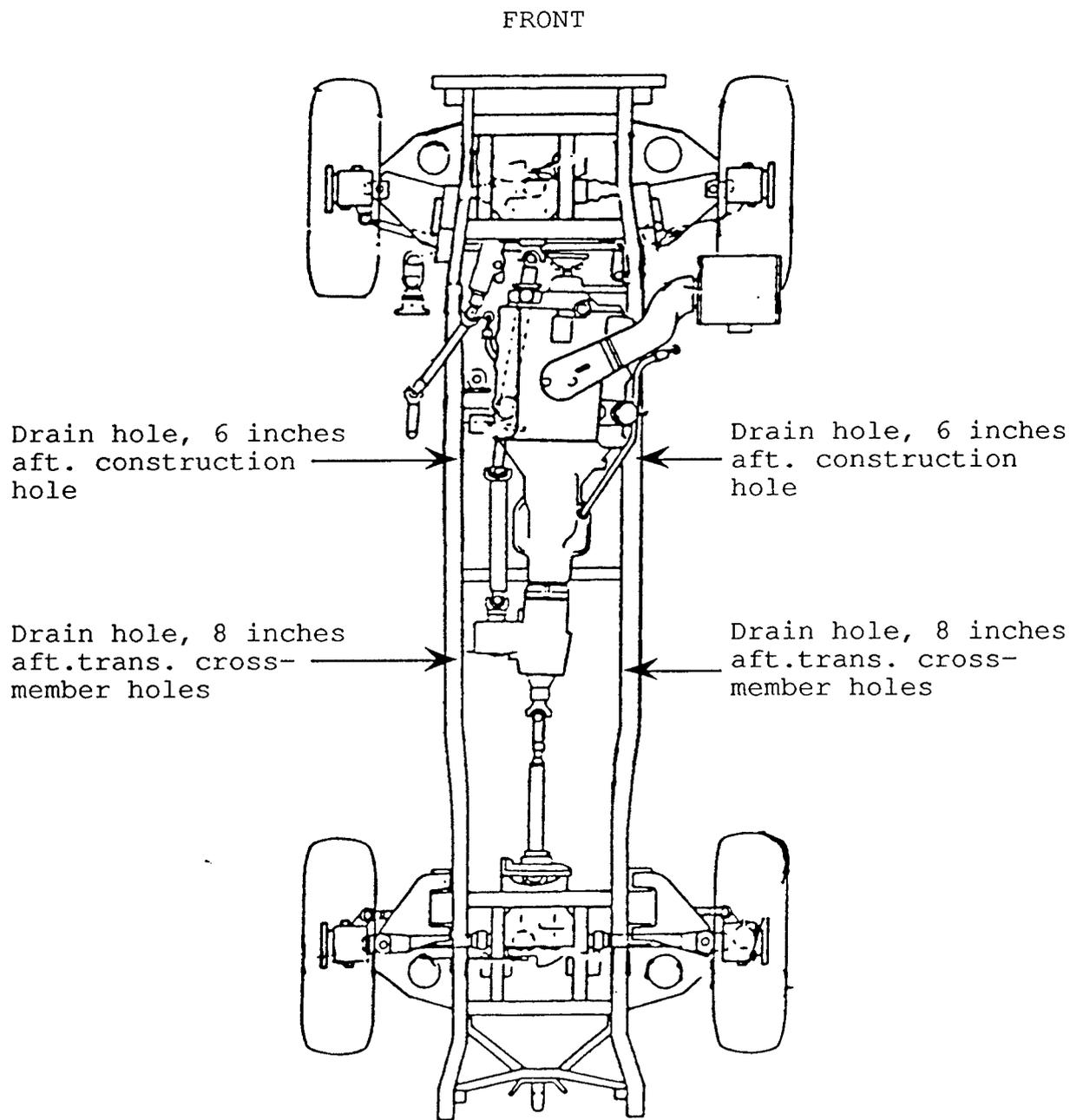


Figure 1-2. Proposed Drain Hole Locations

as compared to the one without. None of the results indicate a reduction in frame integrity due to the drain holes for the simulation conducted.

The results of this report are based on a steady-state static analysis only. No fatigue analysis or prototype tests were performed for this project.

4.0. RECOMMENDATIONS

Though the drain holes do not reduce the strength of the frame, they are a source for oxidation to begin. This is especially true if the holes are drilled after the rust-proofing is applied, leaving bare exposed metal. It is recommended that extra rustproofing be applied around the drain holes.

5.0. DISCUSSION

5.1. Finite Element Method

The finite element method is an analysis technique for solving the differential equations of complex problems. The finite element method has become a valuable tool for modeling structural, mechanical, thermal, and fluid systems. Basically, the finite element method is the subdividing of complex continuous structures into discrete regions, or finite elements. The elements have specific points called nodes that define the geometry of the element as well as provide points at which physical information can be entered, and received from, the element. Such information which can be entered include force, temperatures, and flow rates. Information which could result include stress, flux, and pressure. Behavior of each finite element can be described by a set of functions involving the nodal displacements in that element.

It is desirable that the behavior of the model closely exhibits the behavior of the actual physical structure. For this reason, there are many types of elements which differ in their geometries and their allowable degrees of freedom. Such element types include truss, beam, shell, and solid elements. The choice of element shape is left to the skill of the engineer. The more regular, that is, square in shape the element is, the more accurate the results. This project used shell elements which, unlike solid elements, are two-dimensional and needed a numerical value for the thickness to be assigned.

5.2. Finite Element Software

5.2.1. I/FEM. The Intergraph Finite Element Modeling System, (I/FEM) is a computer-aided engineering software package for general-purpose finite element modeling and analysis. I/FEM uses interactive graphics allowing the analyst to create the model, perform the analysis, and evaluate the results. I/FEM was developed by Intergraph Corp. For this project, I/FEM was used as a modeler only.

5.2.2. PATRAN. Patran is a pre/postprocessing software package developed by PDA Engineering. For this project, PATRAN was used to translate the I/FEM model to an ABAQUS input deck. PATRAN was also used as a postprocessor which allows the analyst to view the results of the analysis in graphical form. All of the stress and displacement color contour plots in this report were created using PATRAN.

5.2.3. ABAQUS. ABAQUS is a large-scale finite element analysis program capable of analyzing complex structures. The analyst first needs an input file, which in this case was created using PATRAN. The input file defines the shape and material properties of the model as well as boundary conditions and loads. The program then assembles and solves a system of equations and outputs the results. ABAQUS was developed by Hibbitt, Karlsson, & Sorensen, Inc.

5.3. Finite Element Models

The finite element model contains all the information needed to run the analysis for the frame. This model defines the actual shape and dimensions of the frame, the materials used and their properties, and any boundary conditions and force loadings. Two different models were used for this project: the standard HMMWV frame and the frame with the four 0.5-inch drain holes. The two models were identical except for the addition of the four 0.5-inch drain holes.

5.3.1. Geometry and Elements. The geometry, or actual shape and dimensions of the frame, was constructed first. This geometry was done using I/FEM which uses Intergraph's Engineering Modeling System (I/EMS) to create the model. The geometry was created using surfaces.

Once the geometry was completed, the nodes and elements were made, also using I/FEM. Four and three-noded shell elements were used for this project. The standard HMMWV frame model contained 1747 nodes and 1728 elements. The model of the HMMWV frame with the 0.5-inch drain holes contained 2074 nodes and 2007 elements. Figure 5-1 shows the completed finite element model of the frame without drain holes. Figure 5-2 shows the finite element model of the HMMWV frame with drain holes. The frame in Figure 5-2 is upsidedown so the drain holes are visible.

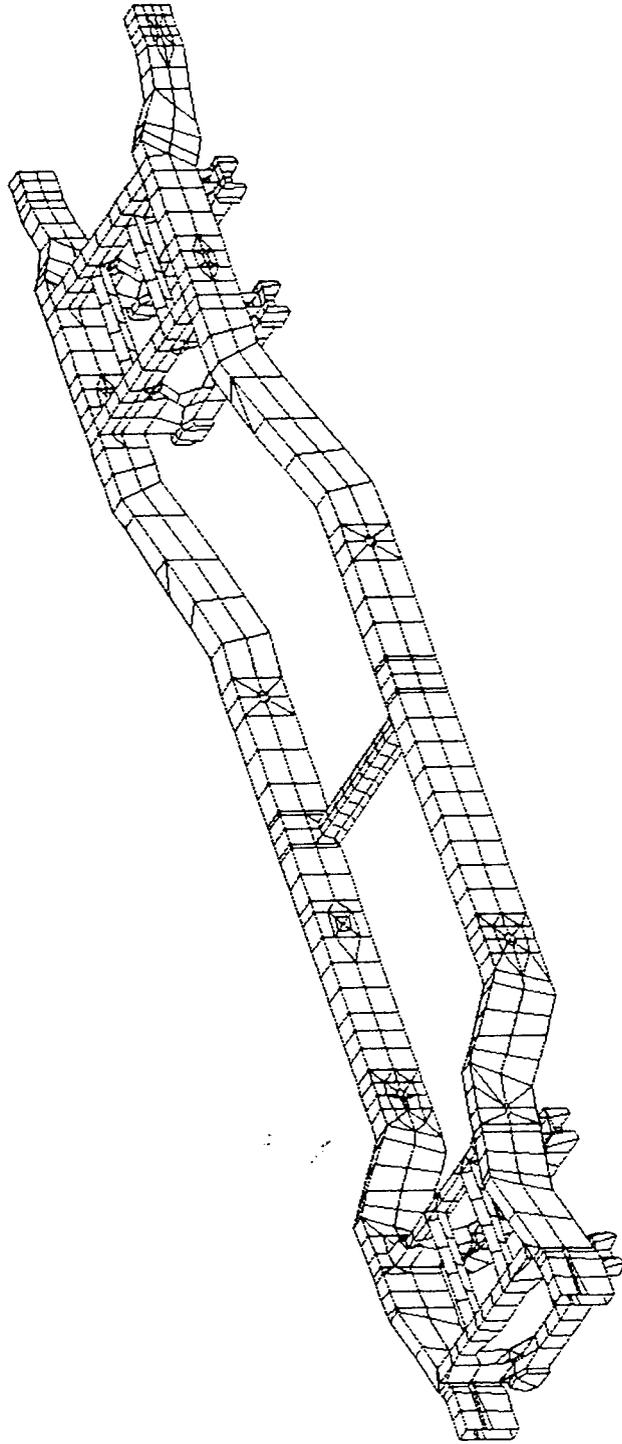


FIGURE 5-1. FINITE ELEMENT MODEL OF HM1414U FRAME

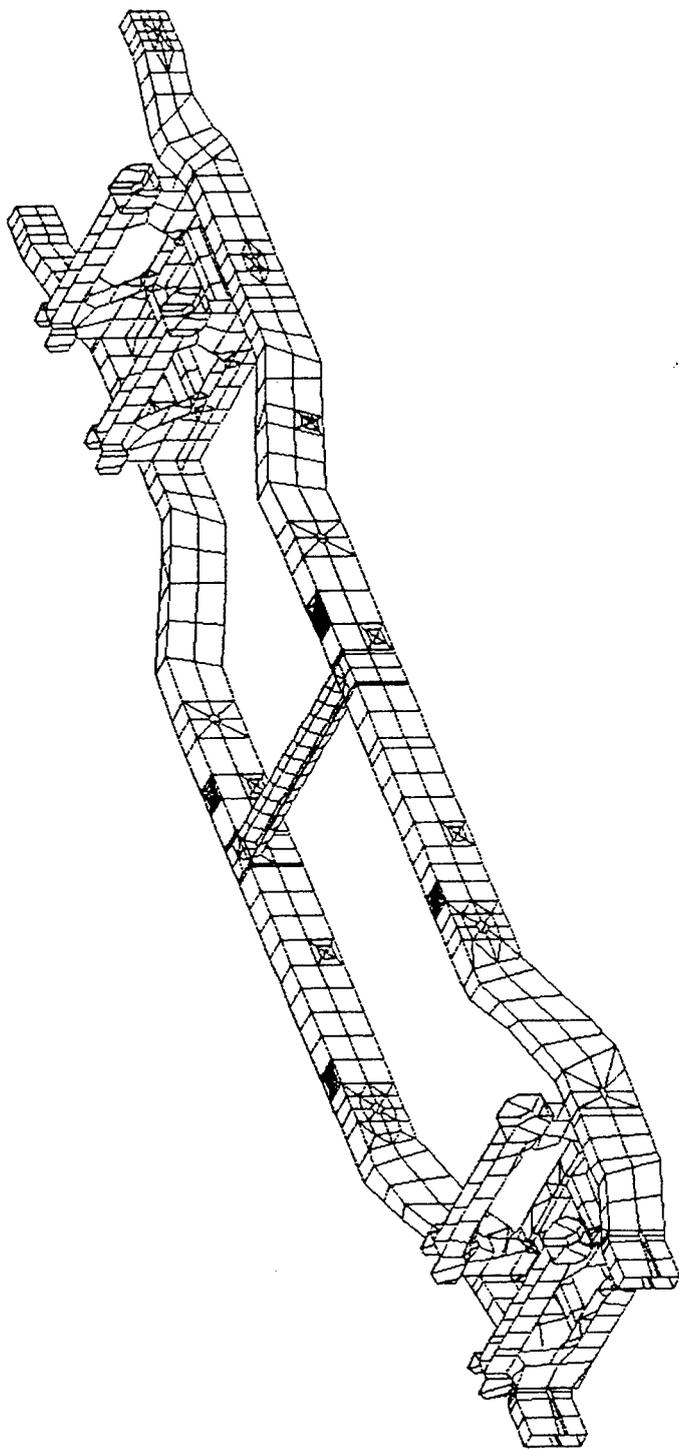


FIGURE 5-2. MODEL OF HMMWV FRAME WITH FOUR DRAIN HOLES

5.3.2. Materials. The material and property assignments were done using I/FEM. The entire model was assigned the one material. The HMMWV frame is made of ASTM A607 Grade 50 steel. The properties used are listed in TABLE 5-1 below.

<u>Property</u>	<u>Value</u>
Young's Modulus, E	29 x 10 ⁶ psi
Density, ρ	0.284 lb/in. ³
Poisson's Ratio, ν	0.30
Ultimate Strength	65 ksi
Yield Strength	50 ksi
Shear Strength	30 ksi

TABLE 5-1. ASTM A607 Grade 50 Properties¹

Since shell elements were used, the thicknesses had to be assigned. The frame rails, braces, and crossmembers were 0.1196-in. thick. The actual brackets that hold the crossmembers to the frame rails were not modeled, but in the areas that they were located, the thickness was increased to simulate their presence. After the materials and thicknesses were assigned, the models were translated from I/FEM to a PATRAN data file.

5.3.3. Loading Conditions and Constraints. The current HMMWV frame rail configuration was designed to withstand a constant steady load of approximately 3.9 g's. This was the test that was used to compare the two frame models, a 3.9 g acceleration in the gravitational direction, which simulates an air drop. A total vehicle weight of 5640 lb was used. TABLE 5-2 below shows the breakdown of the weights. The "REST" item below includes the body, cargo, and driver.

ENGINE	=	650 lb
TRANSMISSION	=	182 lb
FRAME	=	754.431 lb
REST	=	4053.569 lb
<u>TOTAL</u>	=	<u>5640 lb</u>

TABLE 5-2. Breakdown of Frame Loadings

The above weights were added to the models as mass loads and were applied using PATRAN.

¹Marks' Standard Handbook for Mechanical Engineers, 8th Edition, McGraw-Hill Book Company, 1978, p 6-28.

The frame was constrained at the suspension spring mounting brackets. The vehicle was considered to be bottomed out before accelerations were applied for a worst-case condition. Figure 5-3 shows the locations of the constraints and mass loading points.

At this point the models were optimized and a PATRAN neutral file was created. Model optimization is the renumbering of nodes and elements to reduce the number of calculations needed to solve the system of equations. Then using a translator, an ABAQUS input file was created. The PATRAN/ABAQUS translator writes information from PATRAN into a format that ABAQUS can read.

5.4. Discussion of Results

After the models were completed and the ABAQUS input file created, the analysis was run on a Cray-2 Supercomputer. The actual analysis took about 10 minutes. Several output files are created from the results. The ABAQUS.FIL file was translated back to PATRAN on the VAX 8800. TABLE 5-3 below lists the results of the analysis for the two HMMWV frames.

	<u>Standard Frame</u>	<u>Frame W/Holes</u>
Von Mises Stress	16,243 psi	16,245 psi
Max Shear Stress	3,754 psi	3,754 psi
Max Principal	16,407 psi	16,412 psi
Max Deflection	0.0894 in.	0.0894 in.

TABLE 5-3. HMMWV Frame Analysis Results

As can be seen from the results above, the drain holes have no effect on the overall strength of the frame. The slight differences between the stresses are within the error bound of the analysis, therefore no realistic difference exists between the two cases. The Von Mises stress above takes into account the shear stress effect, as well as the normal stress. The Von Mises criterion, also known as the Maximum Distortion Energy criterion, is a yield criteria for ductile materials under plane stress. According to the criterion, a given structural component is safe as long as the maximum value of the distortion energy per unit volume in that material remains smaller than the distortion energy per unit volume required to cause yield in the standard tensile test specimen of the same material.² The Von

²Beer, F. P. and E. R. Johnston, Jr., Mechanics of Materials, McGraw-Hill Book Company, 1981, p. 316

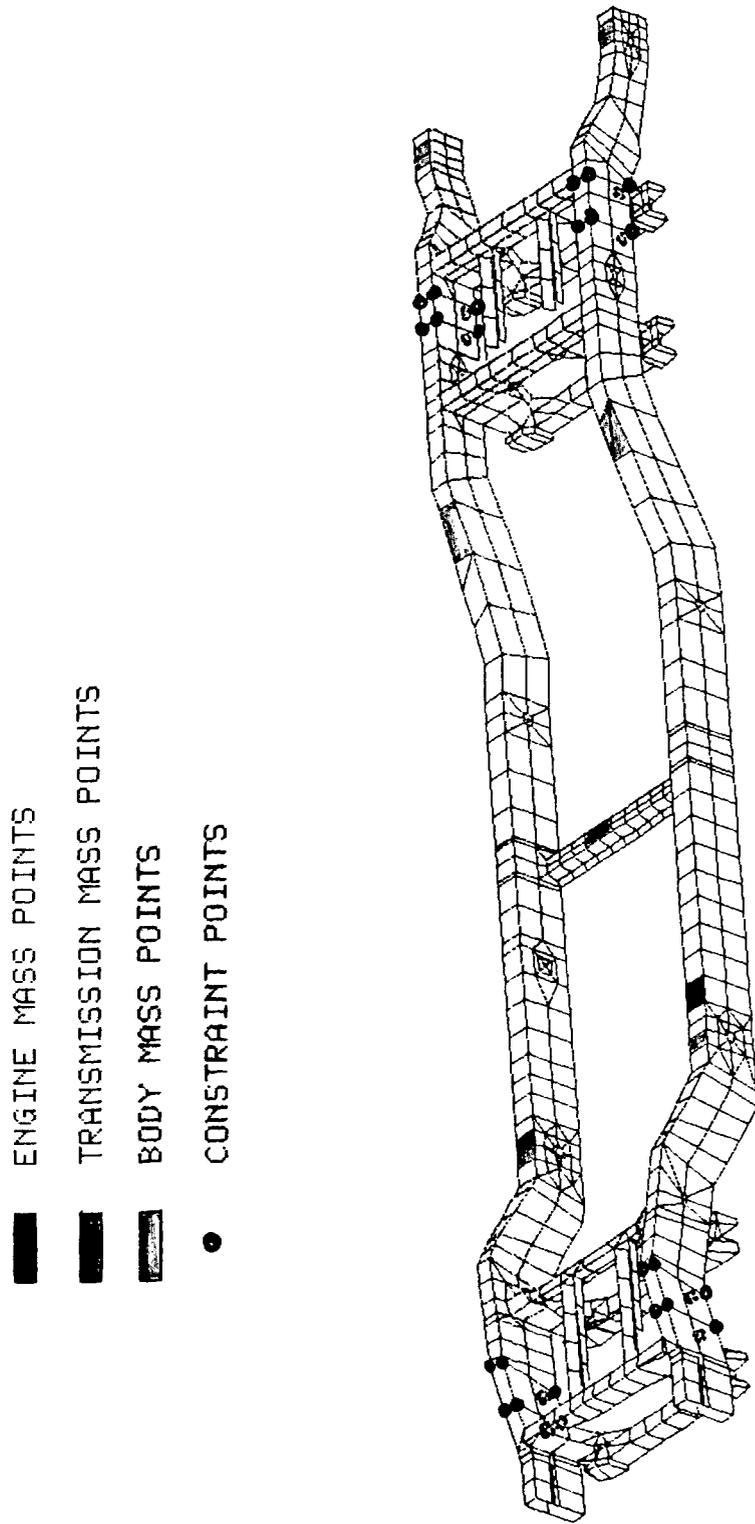


FIGURE 5-3. CONSTRAINTS AND MASS LOADING LOCATIONS

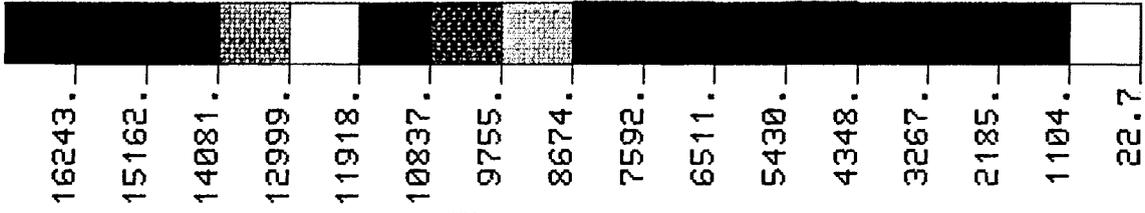
Mises stresses from this analysis are below the yield strength of the material, therefore there is no indication of a failure.

There are two sets of color contour plots of the results of this analysis. Appendix A shows the results of the standard HMMWV frame and Appendix B shows the plots of the results of the frame with the drain holes. As can be seen by the color plots, the largest displacement on both models, occurred at the center of the transmission crossmember. The highest stresses occurred at the four constrained locations, as was expected.

There was a stress concentration at the drain holes, especially the left front drain hole, as can be seen by the last plot in Appendix B. The highest Von Mises stress at this hole was 11,736 psi, which is well below the highest stress of the whole frame, which was 16,245 psi.

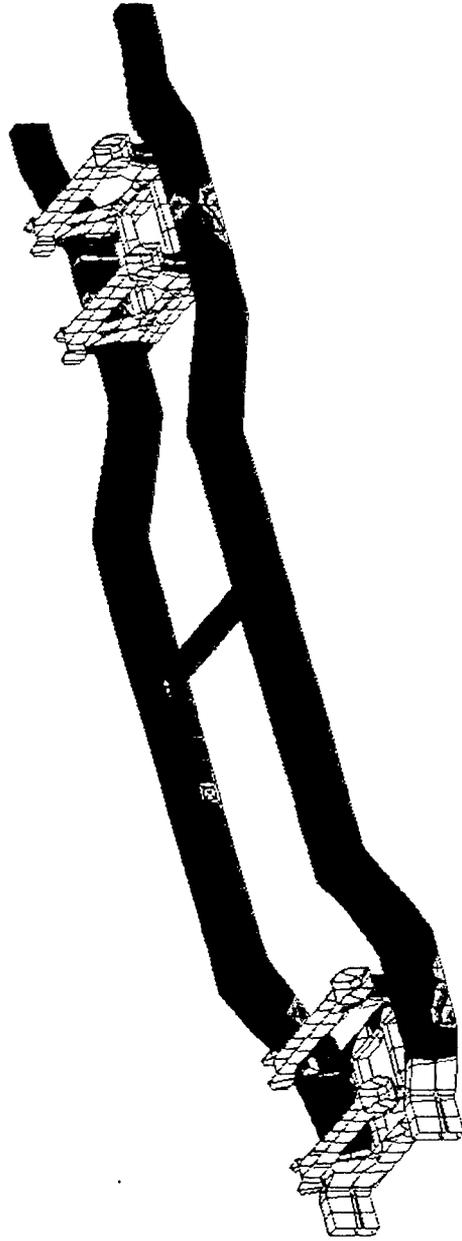
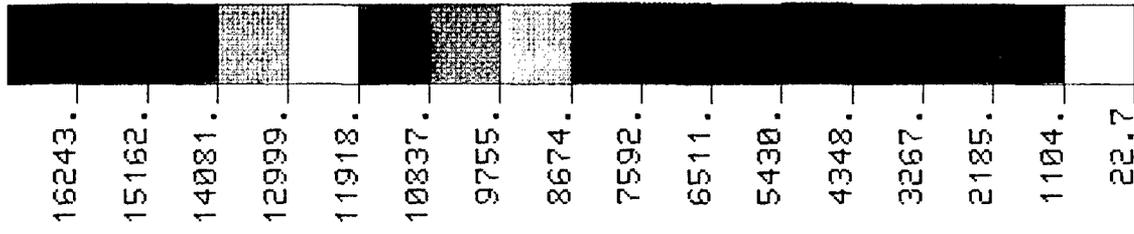
APPENDIX A
Result Plots of Standard Frame

VON MISES STRESS (PSI)



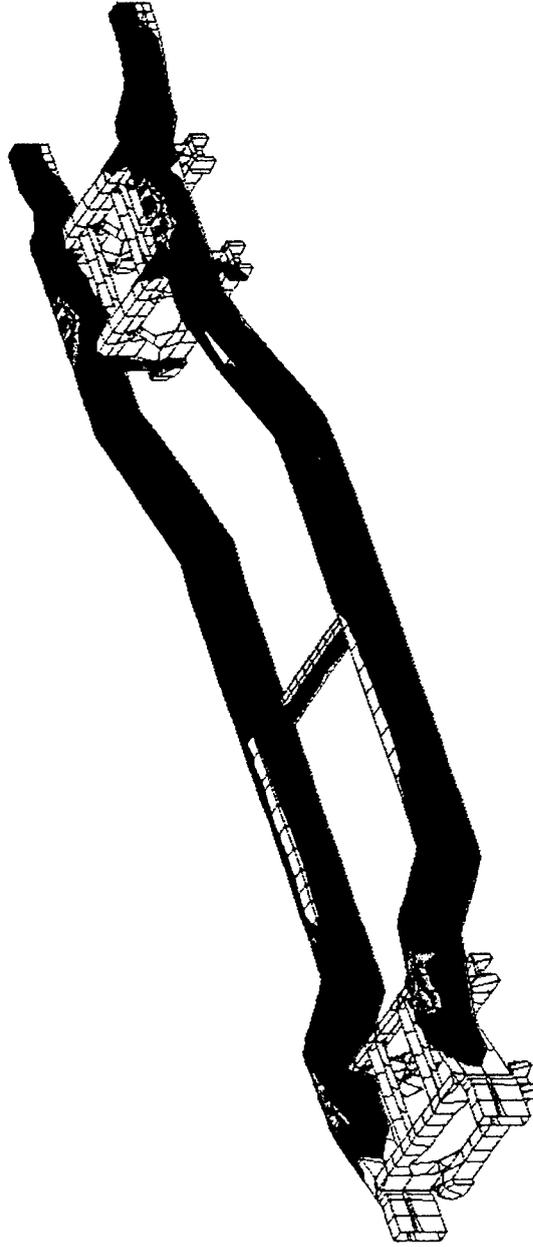
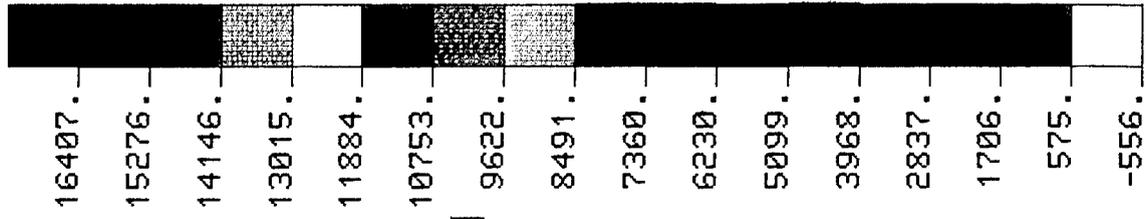
HMMUJ FRAME WITHOUT DRAIN HOLES

VON MISES STRESS (PSI)



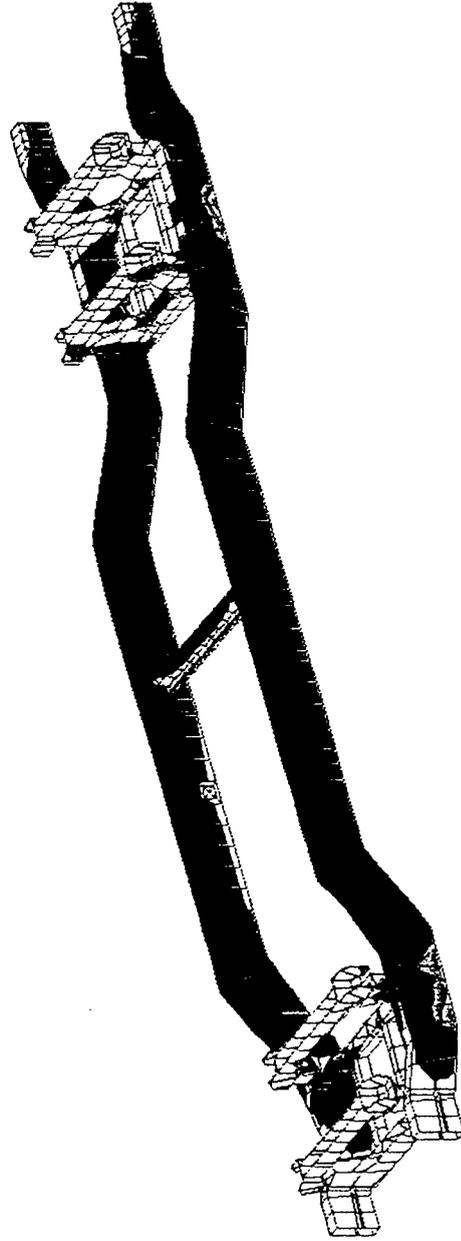
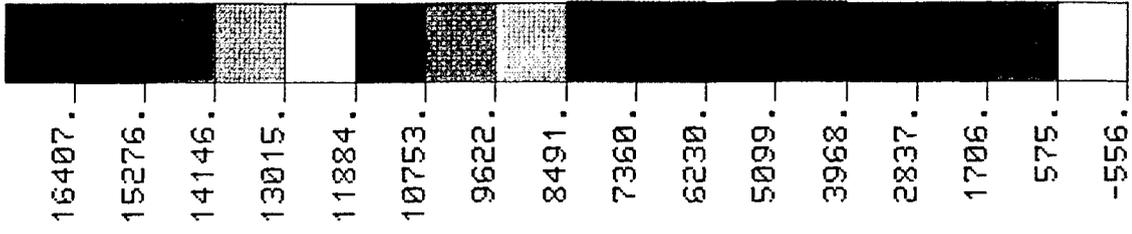
HMMWV FRAME WITHOUT DRAIN HOLES

MAX PRINCIPAL STRESS (PSI)



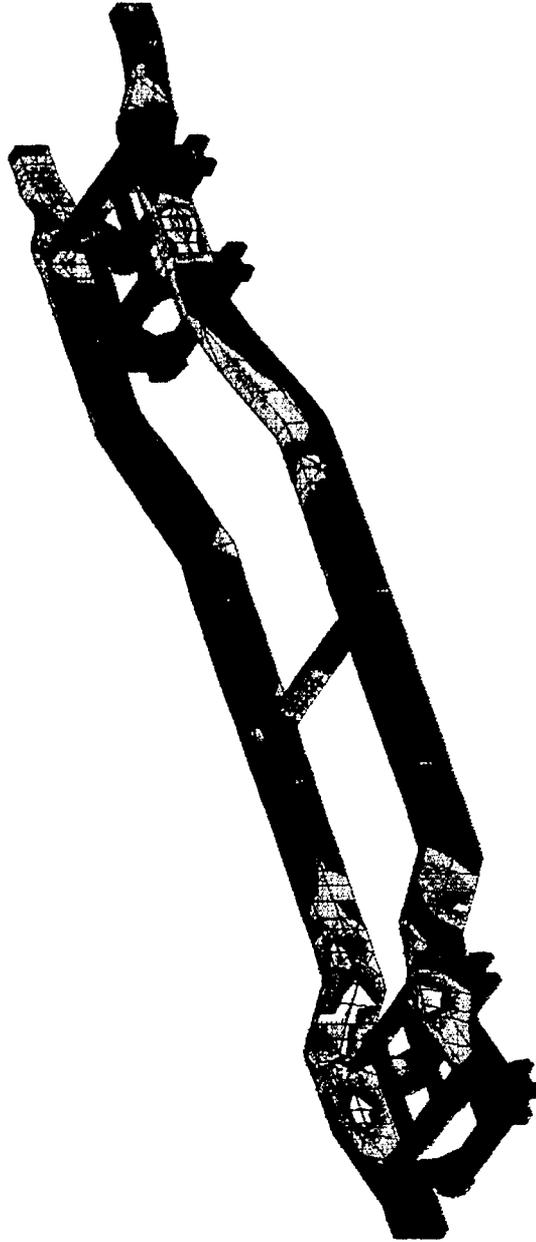
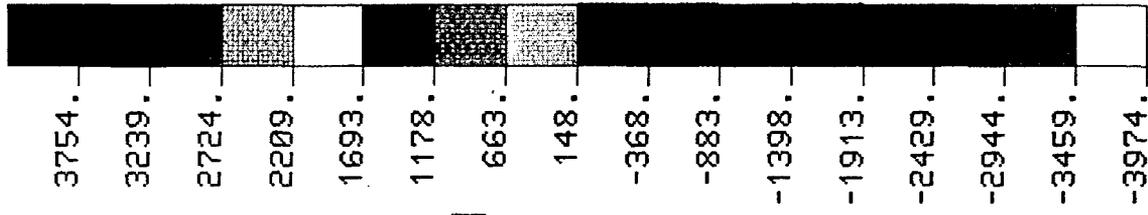
HMMWV FRAME WITHOUT DRAIN HOLES

MAX PRINCIPAL STRESS (PSI)



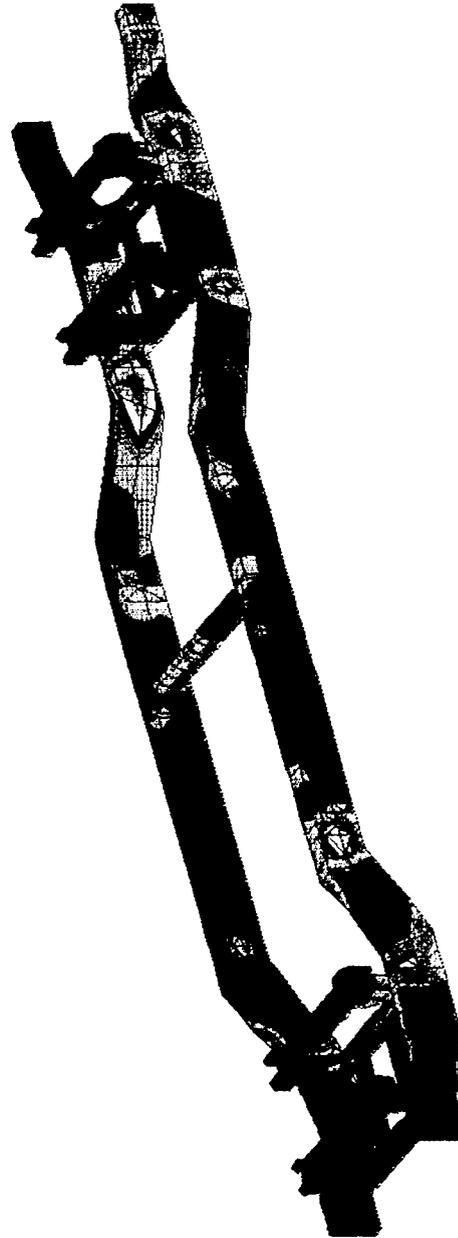
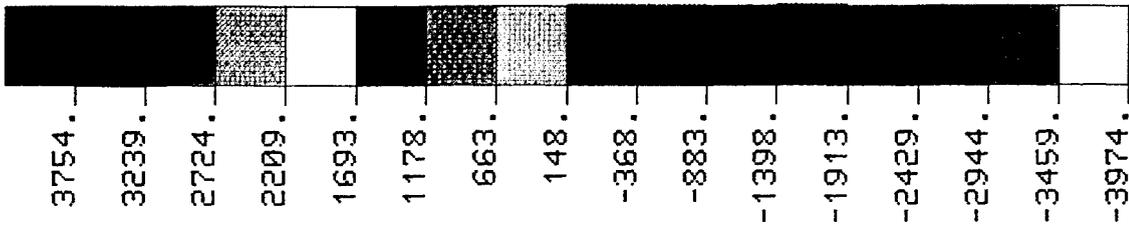
HMMWV FRAME WITHOUT DRAIN HOLES

MAX SHEAR STRESS (PSI)



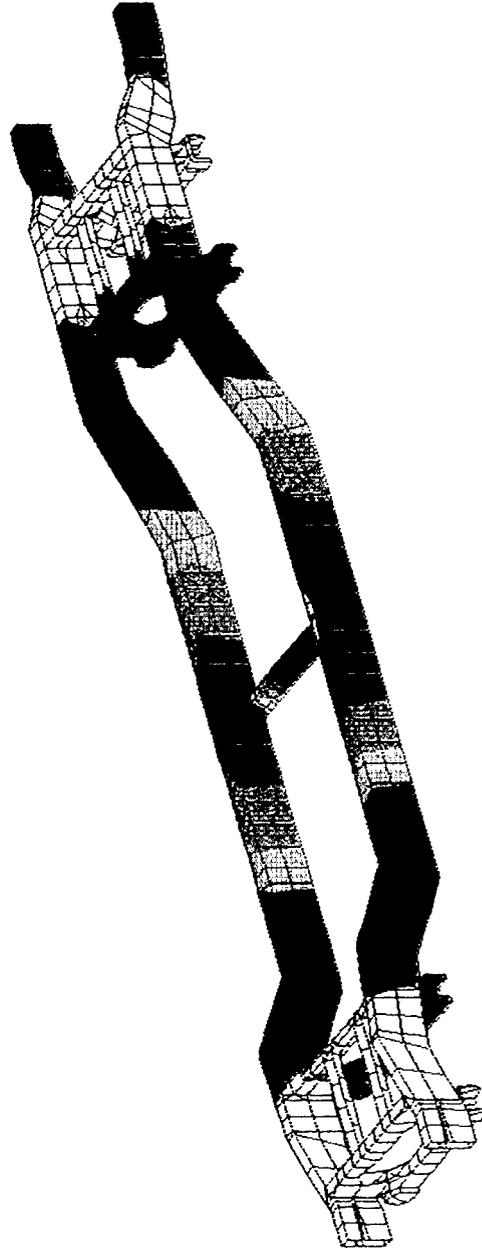
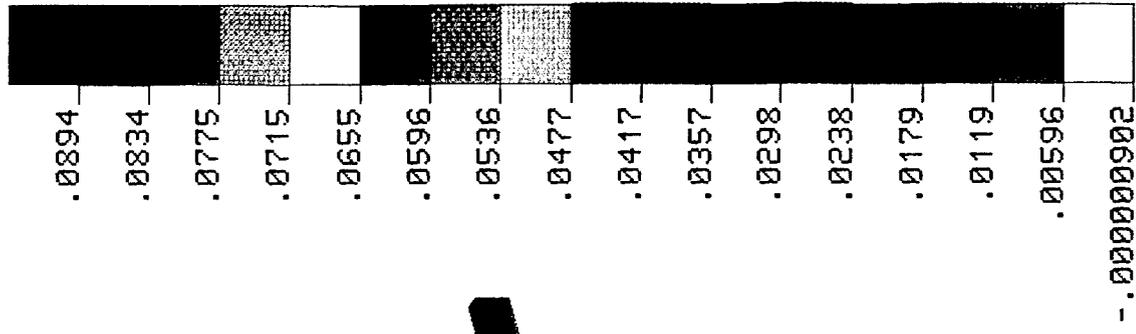
HMMWV FRAME WITHOUT DRAIN HOLES

MAX SHEAR STRESS (PSI)



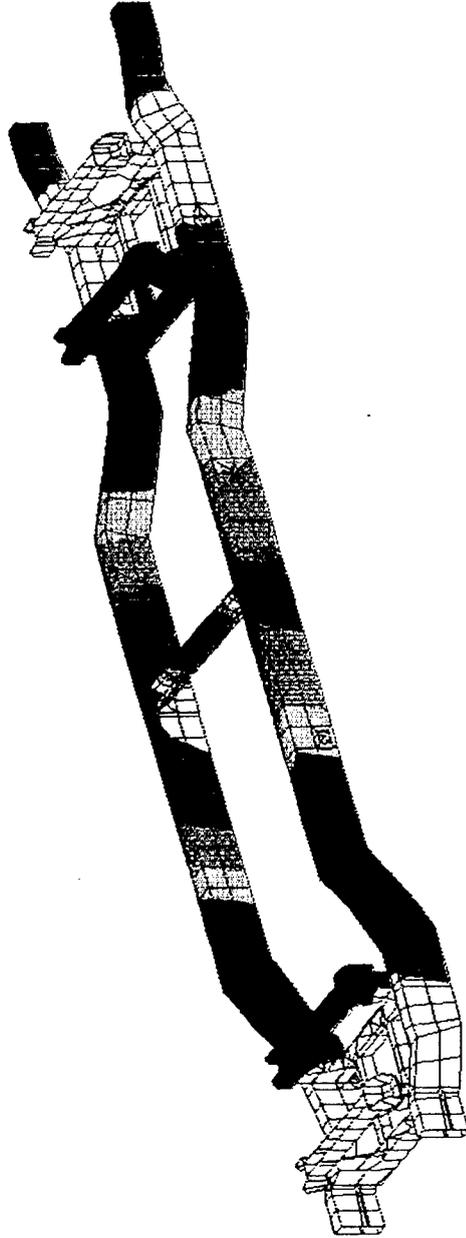
HMMWV FRAME WITHOUT DRAIN HOLES

TOTAL DISPLACEMENT (INCH)

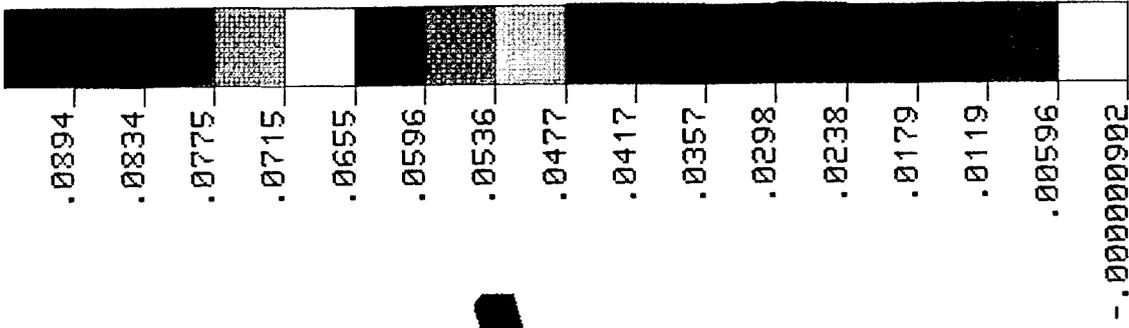


HMMWV FRAME WITHOUT DRAIN HOLES

TOTAL DISPLACEMENT (INCH)



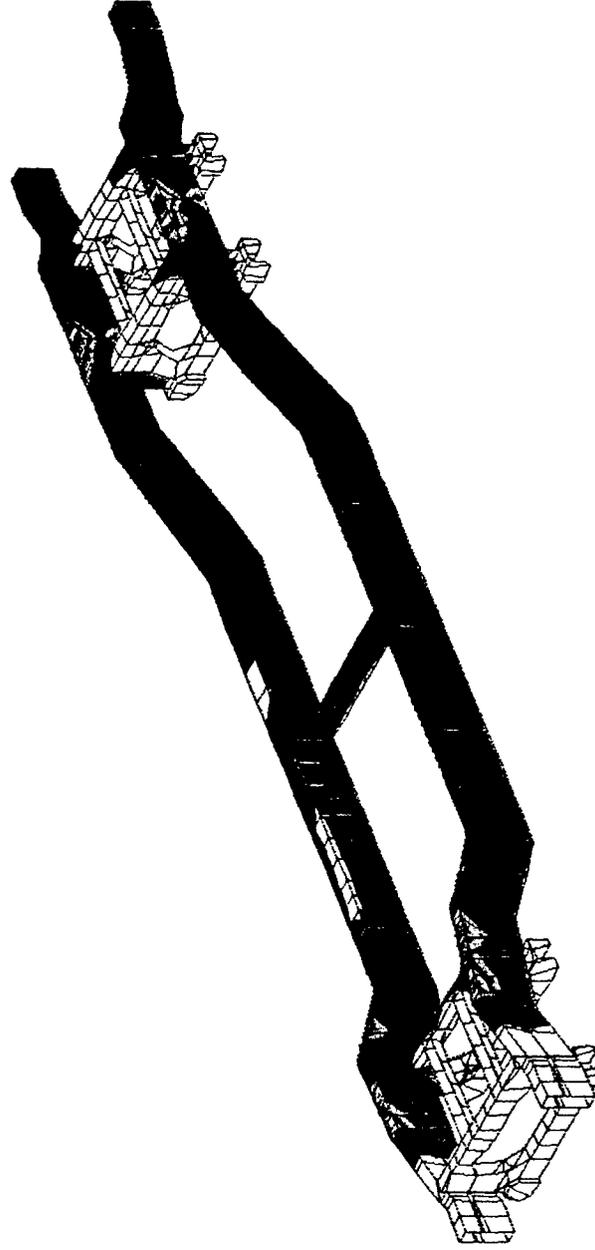
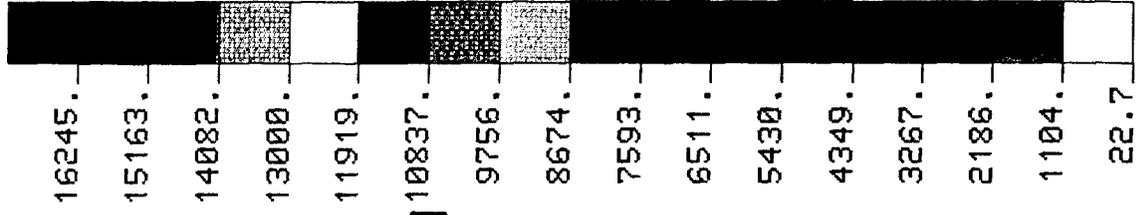
HMMWV FRAME WITHOUT DRAIN HOLES



APPENDIX B

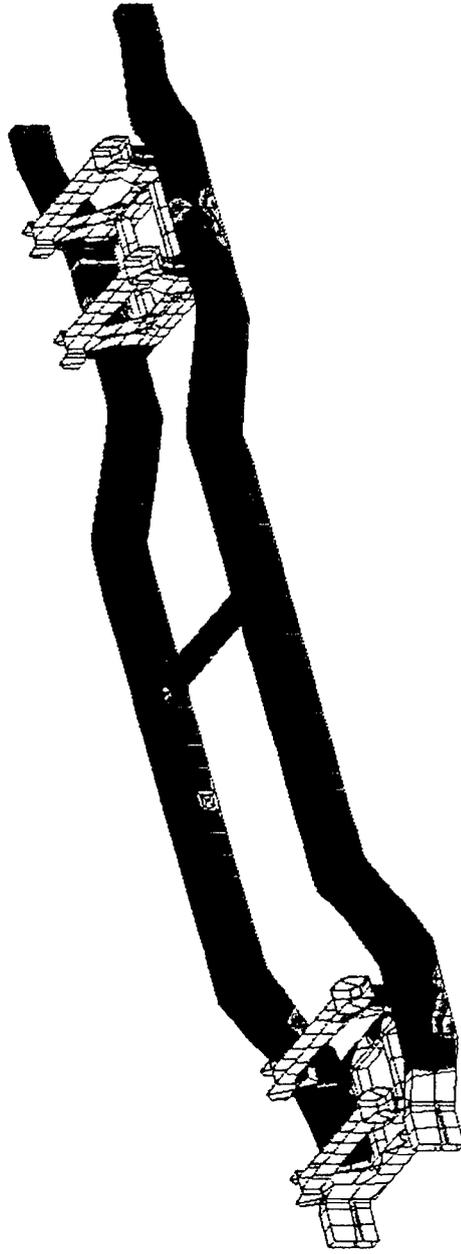
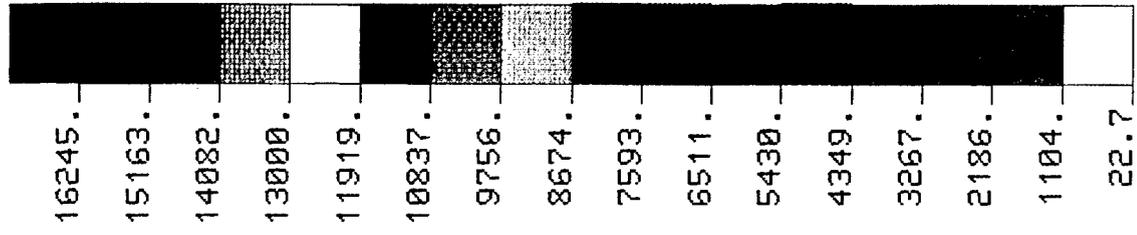
Result Plots of Frame with Drain Holes

VON MISES STRESS (PSI)



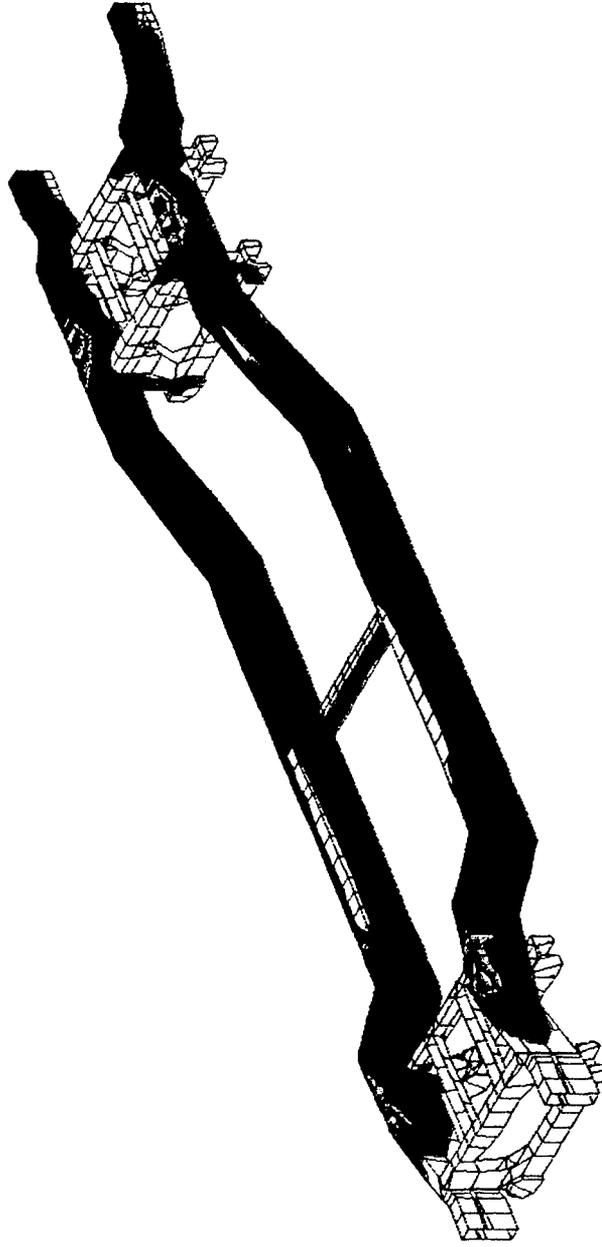
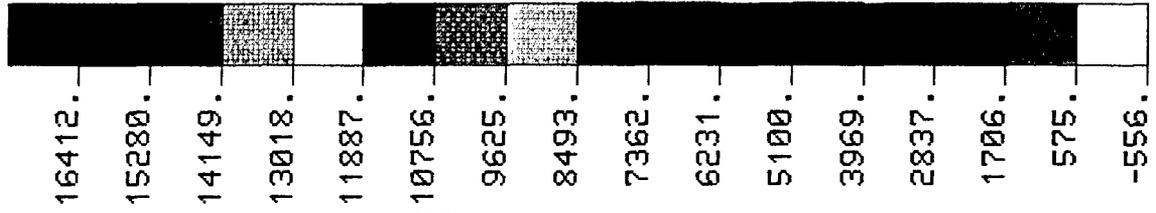
HMMWV FRAME WITH 0.5 INCH DRAIN HOLES

VON MISES STRESS (PSI)



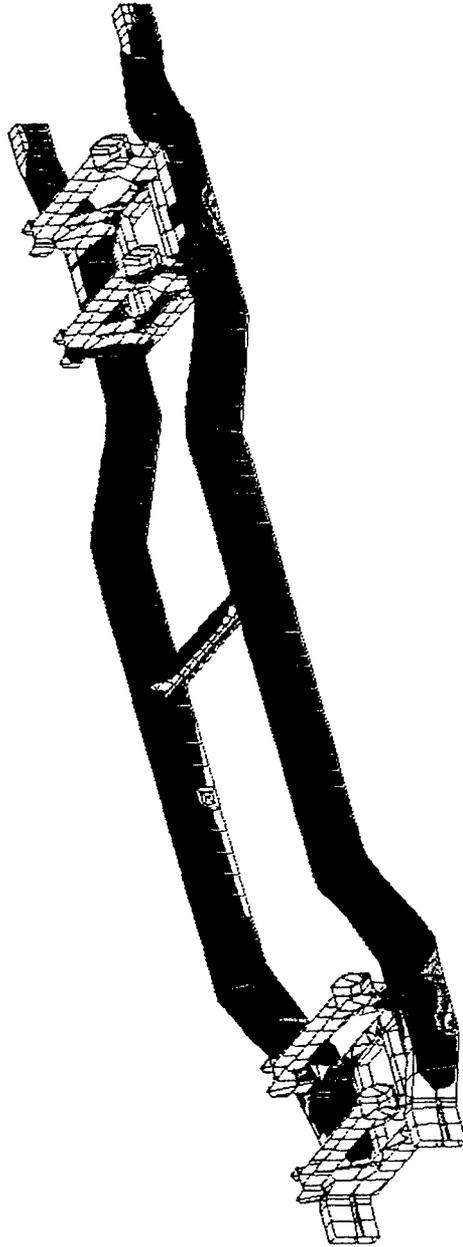
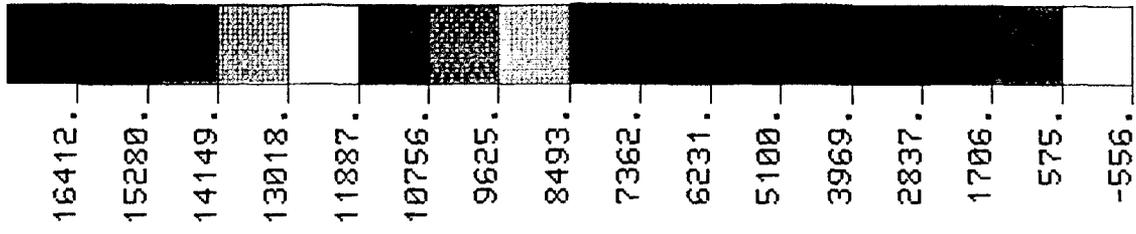
HMMUW FRAME WITH 0.5 INCH DRAIN HOLES

MAX PRINCIPAL STRESS (PSI)



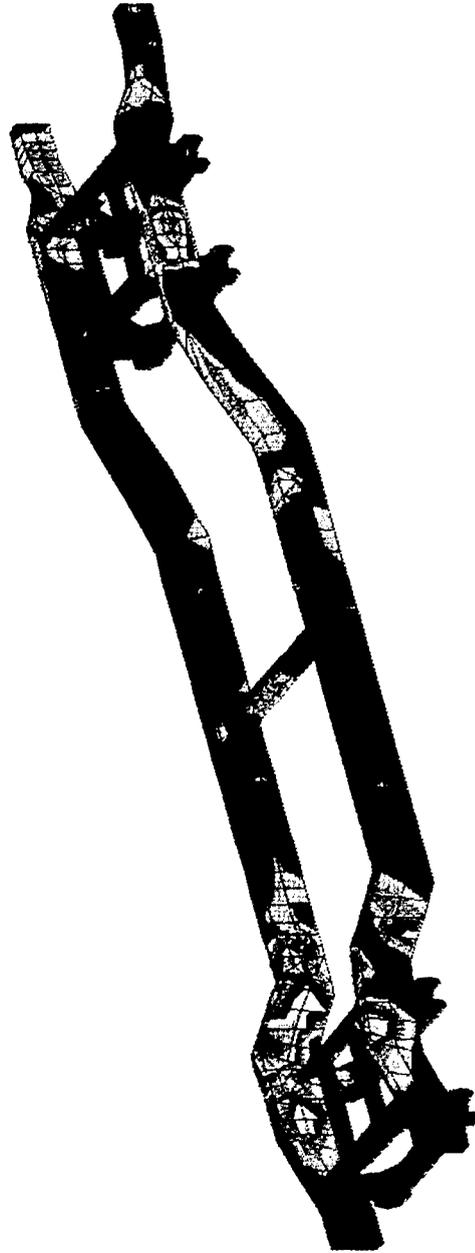
HMMWU FRAME WITH 0.5 INCH DRAIN HOLES

MAX PRINCIPAL STRESS (PSI)

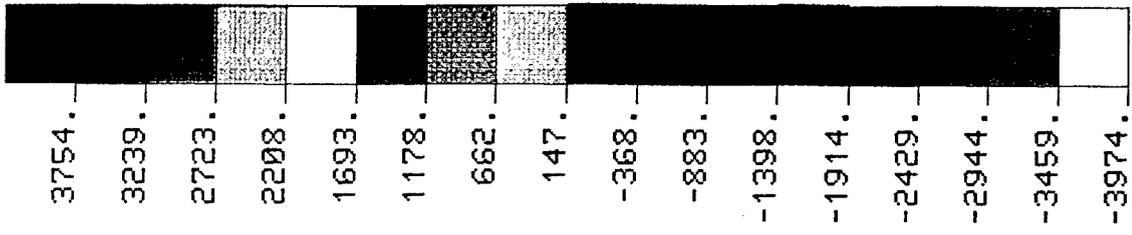


HMM1UJ FRAME WITH 0.5 INCH DRAIN HOLES

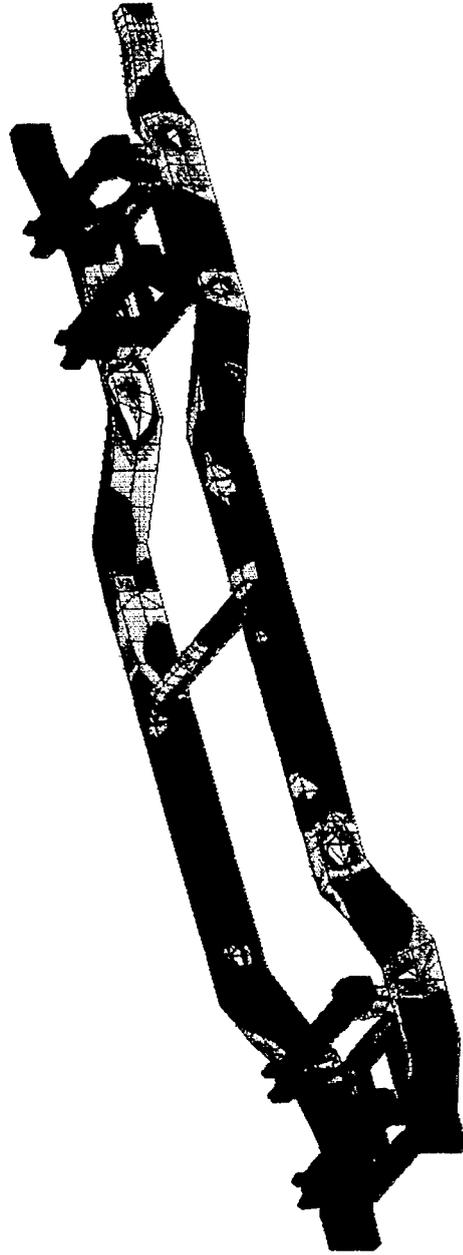
MAX SHEAR STRESS (PSI)



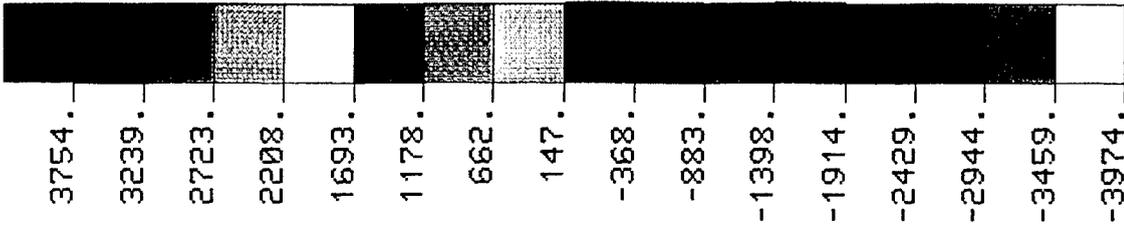
HMMWV FRAME WITH 0.5 INCH DRAIN HOLES



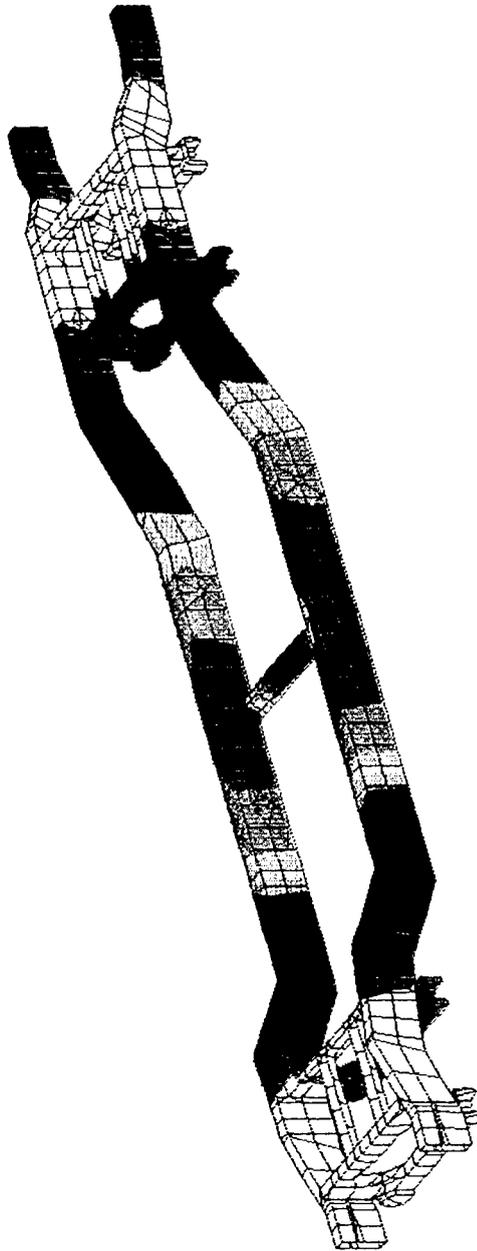
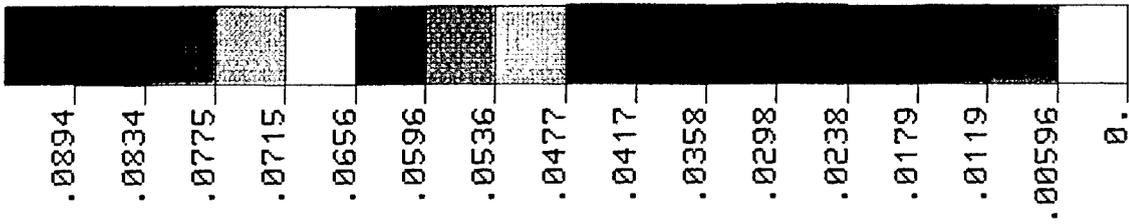
MAX SHEAR STRESS (PSI)



HMMUJ FRAME WITH 0.5 INCH DRAIN HOLES

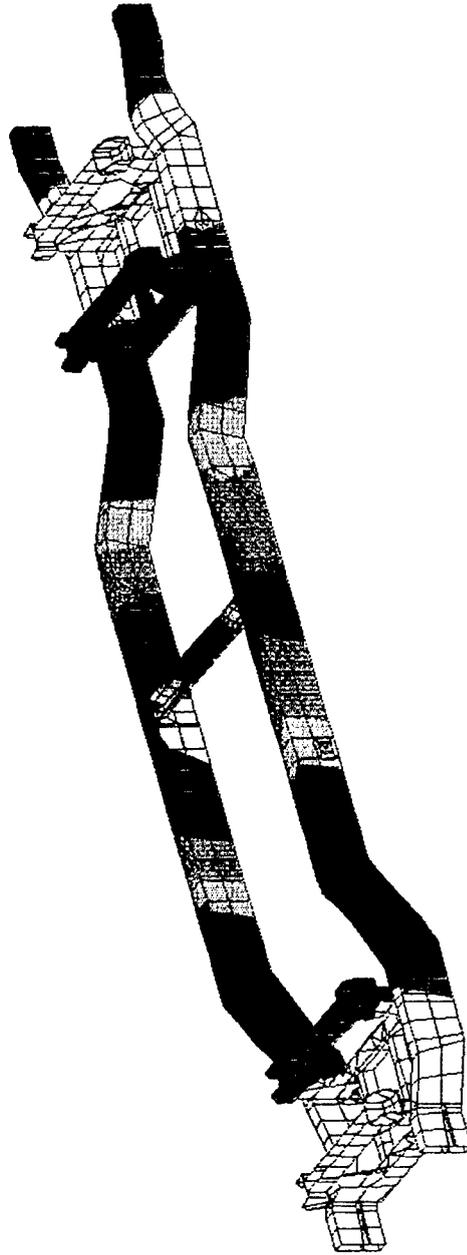
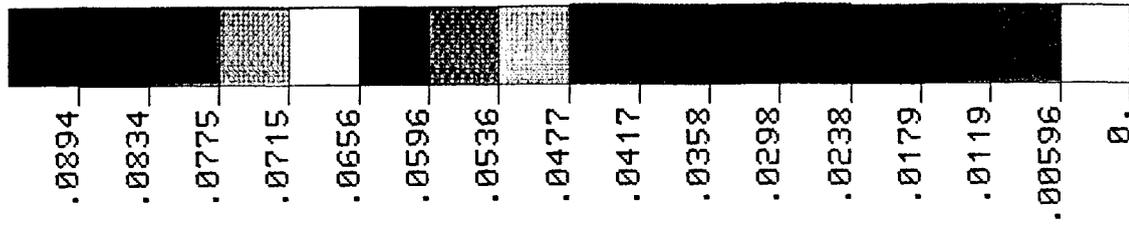


TOTAL DISPLACEMENT (INCH)



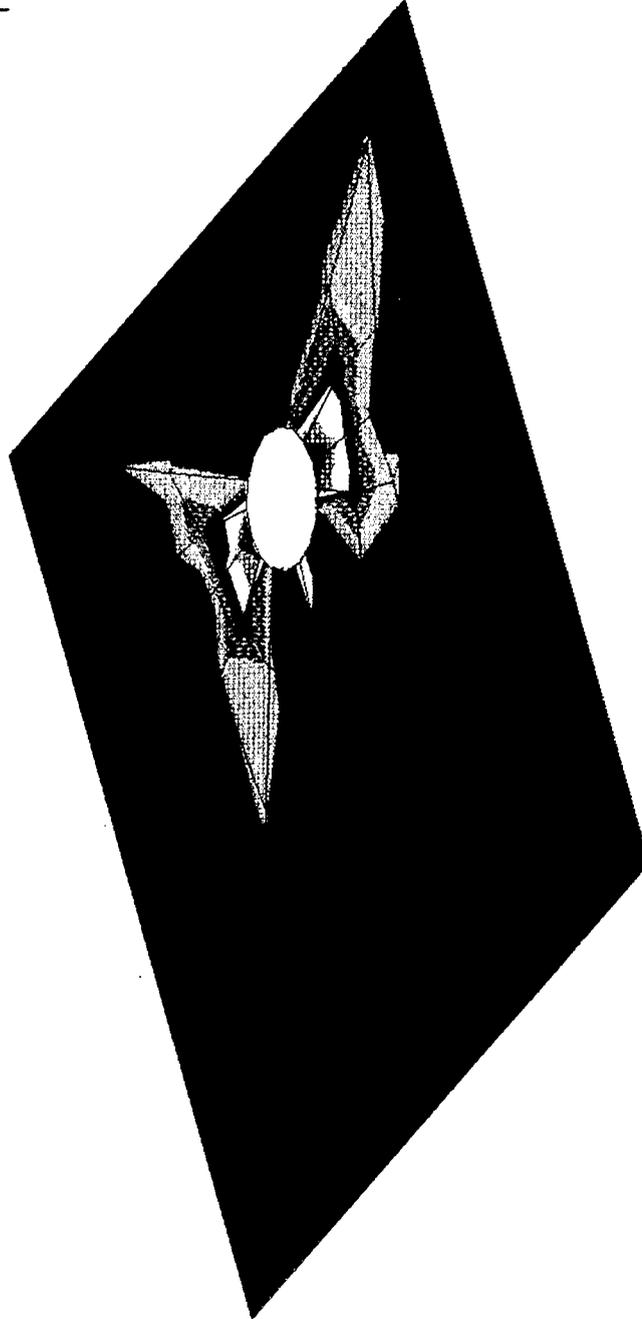
HMMUJ FRAME WITH 0.5 INCH DRAIN HOLES

TOTAL DISPLACEMENT (INCH)

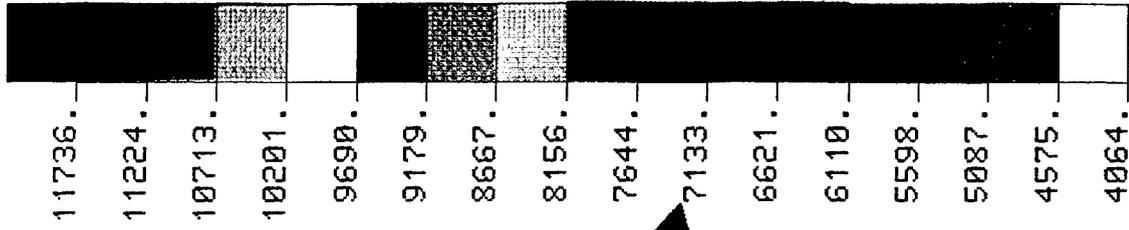


HMMWV FRAME WITH 0.5 INCH DRAIN HOLES

VON MISES STRESS (PSI)



LEFT FRONT DRAIN HOLE



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