8. Parts Manufacturing

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8.1. Supplier Selection

The main criterion for supplier selection was quality. Although the process used "soft" tools and lasers, the contract required production representative parts. Therefore, it was decided to identify companies that specialize in one or more of the following system groups:

- Front End Structure
- Floor Panels and Body Side Inner
- Body Side Outer
- Rear Structure
- Roof and Roof Side Rails

Extensive discussions took place with approximately 30 suppliers on a worldwide basis to identify the sources for the ULSAB program. The criteria used to rationalize the final selections were:

- Supplier must have major OEM quality rating or ISO 9000
- Must be a system supplier to a major OEM
- Must be prepared to enter simultaneous engineering prior to contract release
- CAD/CAM systems compatible with CATIA
- Program management system established
- Experience in match metal checks
- Cost competitive

Based on the foregoing, the following companies were selected:

- Front End Structure – Stickel GMBH, leading supplier to Porsche AG
- Floor Panels and Body Side Inner – Peregrine FormingTechnologies, supplier to GM, Chrysler and Ford
- Body Side Outer – AutoDie International, leading Body Side supplier to Chrysler, also supplying Ford and GM
- Rear Structure – Fab All Manufacturing, commodity supplier to Ford
- Roof and Roof Side Rails – Schaefer Hydroforming

Company Name	Address	Number of Employees
Autodie International	44 Coldbrook, Grand Rapids, Michigan, USA	700+

Major products

Tools, Dies and Molds, Prototypes & Production
Automated Systems
Transfer Equipment
Welding Fixtures
Robotic Vision Systems

Other Divisions	Customers		Major Equipment
Progressive Tool	Ford	GM	Presses up to 3000 t
WISNE Design	Chrysler	Jaguar	Bed Size to 200 x 100
WISNE Design - Die Technology	Tower	BMW	4 CMM
WISNE Automation	Spartanburg	Karmax	5 Axis Control Laser
Eagle Engineering	Navistar	Haworth	1 Lamoine Machine System
Freeland Manufacuturing	Cambridge		CNC Mills
+ Others			PDGS CGS CATIA

Company Name	Address	Number of Employees
Peregrine Forming Technologies	26269 Groesbeck, Warren, Michigan, USA	160

Major products

Prototype Tooling
Stampings and Assemblies
Doors Inner / Outer
Cowls, Fenders, Deck Lids
Roof Panels and Floor Panels

Other Divisions	Customers	Major Equipment
APG - Technical Services Battle Creek Stamping Warren Stamping Warren Assembly	Ford GM Dana Tower Ogihara Honda Spartanburg	Presses up to 1500 t Bed size to 192 x 79 3 CMM 5 Axis Control Laser Foundry 3 CNC Mills PDGS CGS CATIA

Company Name	Address	Number of Employees
Fab All Manufacturers	645 Executive Drive, Troy, Michigan, USA	95

Major products

Prototype Tools
Stampings and Assemblies
Specializing in Underbody, Front Structures
and Inner Structures

Other Divisions	Customers	Major Equipment
Hubert Group Sharp Mold Engine M & T Design Services Models & Tools	GM Ford Chrylser AG Simpson Veltri Narmco	Presses up to 1700 t Bed size to 144 x 132 2 CMM 6 Axis Laser NC Machining CATIA PDGS CGS Unigraphics

Company Name	Address	Number of Employees
Stickel GmbH	Porschestrasse 2, D - 74369 Loechgau	40

Major products

Prototype Build
Prototype Tooling, Prototype Stampings
Low Volume Production Stampings and Subassemblies

Other Divisions	Customers	Major Equipment
None	Audi BMW Mannesmann Mercedes Benz Opel AG Porsche AG	Presses up to 800 t Bed sizes up to 2m x 3m 3D Laser CMM Equipment CATIA CGS

Company Name	Address	Number of Employees
Schäfer Hydroforming, Schuler	Auf der Landerskrone 2, D - 57234 Wilhelmsdorf	135

Major products

Hydroforming Presses (Development, Fabricating)
Prototype and Production Parts
Technology Development (Active Hydro Mec)

Other Divisions	Customers	Major Equipment
Tool Shop FEM Forming Simulation Hydroforming Componenets	Audi Aerosmith GM Benteler Porsche	Hydroforming presses to 3000t 10.000 t under Construction High Speed Miling Prebending Equipment

8.2 Simultaneous Engineering

In order to achieve the optimal design from a manufacturing and assembly standpoint, reviews were held with the suppliers and the assembly facility to evaluate all designs six months prior to design release.

Each supplier was represented by specialists in CAD/CAM, tool making and manufacturing. Every detail was reviewed for formability, spring back issues, aesthetic consideration, tolerance control and assembly issues. In addition to the part suppliers, steel companies also attended these sessions in order to discuss and resolve any material issues.

These reviews continued after design release, primarily in the suppliers' facilities, but in addition to the design for manufacture and design for assembly, the reviews also included the supplier maintaining quality and timing plans.

8.3. Part Manufacturing Feasibility

Introduction

At the request of the ULSAB Steel Consortium and PES, Phoenix Consulting Inc. has assisted in the investigation and documentation of the manufacturing feasibility of the ULSAB components. The study includes the following objectives.

- Demonstrate that the processes used to fabricate the ULSAB components meet the following conditions:
  - Used design intent materials.
  - Can repeatedly produce parts that meet dimensional requirements.
  - Can repeatedly produce parts that meet formability requirements.

- Demonstrate that through continuous improvement, these processes can be evolved to production capable processes.
  - Mechanisms are in place and are being followed to address manufacturing feasibility concerns.
  - Action plans have been developed to address remaining barriers to production capability.

- Demonstrate that state of the art methods and technologies have been used to develop the demonstration hardware processes, such as:
  - Forming Simulation.
  - Early Steel Involvement.
  - Dies and fixtures developed from CAD, CNC Machining and CMM Inspection.

Overall Assessment

Although the components of the ULSAB body structure certainly present a significantly greater challenge to production capability than a conventional design, we are convinced that these components can be fabricated with production capable processes under the following conditions:

1. The process of continuous improvement that has been undertaken by Porsche is continued, including additional soft die tryout and minor product revision.
2. With the use of the more sophisticated press equipment that can be made available in hard tool construction: Multiple Nitrogen Cushions, Toggle Presses and with the superior surfaces encountered in hard tooling.
3. With the implementation of further enhancements in materials, blank development and binder development.

The team assembled to fabricate these components has made excellent progress along the learning curve of fabricating with high strength steel and laser welded blanks, advancing the state of the art. The prototype processes have undergone significant continuous improvement toward production capability

Documentation Overview

The components on the ULSAB body have been classified into three levels of difficulty or criticality. Level C being the most critical, level B the next most critical and all other parts are level A. The extent of documentation provided for a given component has been determined accordingly. The purpose of these documents is to validate the objectives outlined in the introduction. These documents have been assembled into a notebook that can be provided through the ULSAB Consortium.

These documents are described below, followed by a list of B and C level parts. In the pages that follow is an example of the detailed summaries for each individual B and C level part that can found in the notebook.

Level A - Non Critical

- Material Characterization. This validates that the parts are made of material that meets structural requirements and that these materials can be worked into the forms of the respective parts.

Level B - Moderately Critical. All Level-A requirements plus the following:

- Strain Analysis (Circle Grid and or Thickness Strain): Demonstrates that a formability safety margin exists and that parts are not merely split free. The goal and conventional buy off requirement is a 10% safety margin. These Strain Analyses are the responsibility of the Steel Vendors as part of the Early Involvement Program. They should include material properties of metal used to form the evaluated panel and the associated press conditions. This information is documented in AQP Parts format.
- Process Set Up: After extensive tryout, die shops have arrived at, and documented, optimum press conditions that will repeatedly yield quality panels. These Press Conditions along with other details of die set up are documented on Set Up Sheets. These Set Up Sheets can serve as baseline for further continuous improvement to develop production capable processes.
- Part submission warrants: These certify that prototype parts meet dimensional requirements.

Level C - Most Critical: All level A and B requirements, plus the following.

- CMM Reports: Computerized measurement of dimensional integrity.
- Development Logs: Show that state of the art methods and technologies were used to develop prototype processes and that these processes are undergoing a continuous improvement of evolution toward production capable processes.
- Proposed Production Process: This is the capstone of the above efforts. It is the culmination of lessons learned in prototype tryout and a demonstration of Porsche's confidence that the next step of setting up production processes can be taken.
- Forming Simulation: Finite Element Analysis based on CAD data was used to identify formability concerns before the construction of tools.

B and C Level Parts

Part Name	Part Number	Die Shop	Level
Pan Front Floor	040	Peregrine	C
Panel Rocker Inner	042 / 043	Peregrine	C
Panel B-Pillar Inner	064 / 065	Peregrine	C
Rail Rear Inner	046 / 047	Fab All	C
Rail Rear Outer	048 / 049	Fab All	B
Panel Wheelhouse Outer	070 / 071	Fab All	B
Panel Body Side Outer	060 / 061	Autodie	C
Member Dash Front	026	Stickel	C
Panel Skirt (& Shock Tower)	096 / 097	Stickel	C
Rail Front Inner	010 / 011	Stickel	B
Rail Front Extension	012 / 013	Stickel	B
Panel Dash	021	Stickel	B
Member Kick Up	091	Stickel	B
Rail Side Roof	072 / 073	Schaefer	C
Panel Roof	085	Schaefer	B
Spare Tire Tub	050	Stickel	B

Documentation	Responsible	Format	Parts
Forming Simulation	Steel Co.	Steel Co. Report	Select Parts
Strain Analysis (Circle Grid, Thickness Strain)	Steel Co.	AQP	B & C
Material Characterization	Steel Co. and Phoenix	AQP	A, B & C
Process Set Up (Set UP Sheets)	Steel Co, Die Shops and Phoenix	Phoenix Summary & Die Shop Set Up Sheet	B & C
Proposed Production Process	Porsche & Phoenix	Process Sheet	C
Certification of Dimensional Integrity (Warrant)	Die Shops	Die Shop Form	B & C
Inspection Report	Die Shops	CMM or Checking Fixture Report	C
Development Log. Demonstrates state of the art procedures used to develop capable prototype processes & action plans for making processes production capable.	Die Shops	Die Shop Log	C
Observations and Recommendations	Phoenix	Phoenix Summary	B & C

Summaries of individual B and C level parts.

On the following pages you will find an example of the documented data. Included will be:

1. Summary page, including observations and recommendations.
2. Part diagram.
3. Documentation checklist, listing and/or summarizing required documentation.
4. Material characterization sheet.
5. Forming limit diagram (part of strain analysis).

NOTE: Complete documentation for all A, B & C level parts is contained In a separate report obtainable through the ULSAB Consortium.

Pan Front Floor - 040

Part Manufacturing Feasibility Summary

The process involves first forming the front of the panel down, then the middle of panel the down and finally the rear of the panel up. This had to be done in separate operations for several reasons. One was press bed size. Another was the fact that all these areas are on separate levels and proper control of metal cannot be obtained without a more elaborate process involving nitro cushions and dydro units.

The availability of these resources for production will enable a reduction in the number of operations, which will be necessary to reduce the total number of operations once trim and flange dies are added. Trimming and flanging is currently performed by laser and hammer form and will require cams in production due to the orientation of some of the trim and flange lines.

Marginal strains detected in tryout and GD&T (geometric dimensioning & tolerancing) issues would have to be reassessed after implementing the recommendations below.

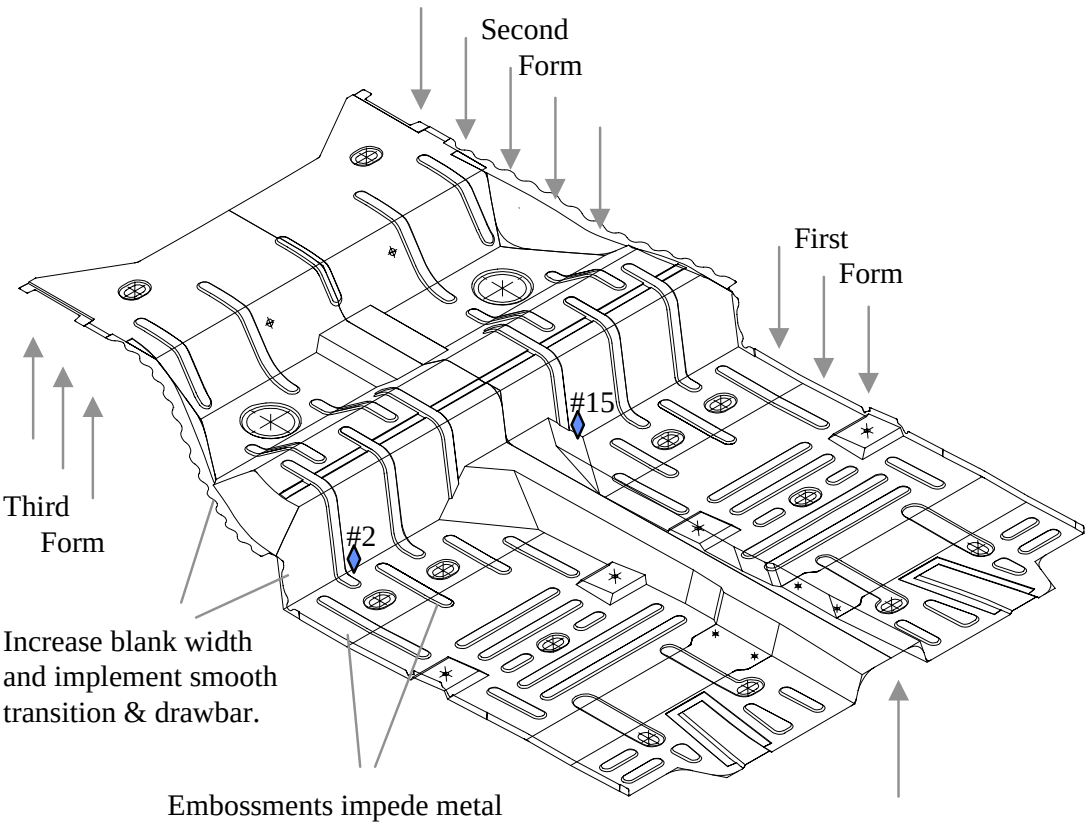
<u>Recommendations Based on Documentation Checklist</u>
Investigating grade change to a dent resistant steel that meets yield strength requirements but has a higher n-value. A dry film lube trial is also recommended.

Consider use of a wider blank. This will allow for better control of metal outside of the kickup area by adding a more gradual transition in the addendum and binder. This may also enable the use of patches of higher formability metal where they are needed the most. This exercise would be well worth the effort, considering the portion of overall weight represented by the floor pan, and the challenging forming characteristics associated with it.

Consider ways of forming embossed areas as late as possible in the process, either by using restrike die or by delayed action in draw dies, to avoid metal locking on and/or skidding over embossed area when it is required for feeding deep formations.

Forming Simulation of first draw predicted wrinkling in tunnel near kickup. This is one of the areas where wrinkling was encountered in tryout.

Marginal Forming Strains
at locations #2 and #15.



PORSCHE ENGINEERING SERVICES, INC.		
PART NAME: PAN FRONT FLOOR		
PART NUMBER: ULSAB 040	REVISION LEVEL: R04	DATE: 03 DEC 97
MATERIAL THICKNESS (MM): 0.70		
MATERIAL SPECIFICATION (MPa): 210		

ULSAB Part Manufacturing Feasibility Study Documentation Checklist

Level	Part #	Part Name	Supplier	Spc Thk	Yield Strength	Coating	Blank
C	**040**	**Pan Frt FlOOr**	Peregrine	0.7 mm	210 MPa	60G60GU	Rectangle

Document	Format	Status / Summary
Forming Simulation	Steel Co	LS-Dyna3D simulation of 1st draw predicted significant wrinkling in the step area of part near the tunnel. This is one of the areas where wrinkling was encountered in tryout. The other areas occurred mainly during subsequent operations.
Strain Analysis Material Test Press Conditions	**AQP**	**Reports 40_D1.TXF** (First Form) & **40_D3.TXF** (Third Form) Safety Margin = 3%. Dry film lube trial suggested. Marginal Strains (#2, #15) need to be re-assessed after implementing blank config, binder and die process improvements. Included in AQP. Also see Process Set Up below.
Material Test Final / Conam	**AQP**	*Samples shipped to Conam on 12/11/97*
Process Set Up	Peregrine	Peregrine **Set Up Sheet** summary: Blank Size = 1829mm x 2057mm 1) PreDraw = Three piece stretch forms tunnel and kickup 2) Draw = Single Action with Upr Binder on Nitro forms deep pocket at rear of kickup 3) Three piece stretch forms shape at rear of panel 4) Flange. Flange at kickup is hand formed. Would have to be Cam Flanged in production. All trimming is by laser. Form #1 Ram = 1000 ton Binder = 160 ton (40 cyl @ 1600 psi) Lube = Quaker Prelube Form #2 Ram = 400 ton Binder = 100 ton Lube = Super Draw Form #3 Ram = 400 ton Binder = 200 ton (toggle press) Lube = Super Draw
Proposed Production Process		1) Draw 2) 1st Trim 3) Re-strike 4) Form/Cam Form 5) Final Trim/Cam Trim
Dimensional Check	Warrant	Included
Dimensional Check	CMM Report	CMM detected points that deviated from nominal by more than +/- 0.5 mm, however all were vertical and attributable to part length and flexibility, or hammer formed flanges. No difficulty experienced in assembly.
Development Log		Simultaneous Engineering procedures were used to develop the process, and continuous improvement was implemented to evolve the process toward production capability. Supplier concerns were fed back to Porsche and product revisions were subsequently implemented. Summary of development history and log of product changes is included. Also included is sketch of part showing significant manufacturing related changes.

Material Characterization

ULTRALIGHT STEEL AUTO BODY

PART INFORMATION

Customer:	ULSAB	**Program Name:**	Phase II
Part Name:	Pan Front Floor	**Make/Model/Style:**	
Part Number:	040		

TRIAL MATERIAL

Coil Identification:		**Specification:**	
P.O. Number:		**Met. Product:**	
Material Source:		**Met. Generic:**	
Reference Number:		**Met. Quality:**	
Ordered Thickness (mm):	0.7	**Coating:**	
Measured Thickness (mm):	0.673	**Surface Treatment:**	
Ordered Blank Size (mm):	1825 x 2795	**Blank Shape:**	
Measured Blank Size (mm):	1825 x 2795		

MECHANICAL PROPERTIES

Property	L	T	D	Range Comparison
Yield Strength (MPa)	216	233	228	216
Tensile Strength (MPa)	364	373	361	364
% Elongation (Total - machine)	36.9	36.2	37	36.9
Work Hardening Exp. n Value	0.224	0.217	0.218	0.224
Plastic Strain Ratio r - bar (tensile)	1.77			1.77

Note: 1. L = Longitudinal, T = Transverse, D = Diagonal
2. Longitudinal production values are for Quarter ___ of _____ for a thickness range of _____

SURFACE PROPERTIES

Location	Ra (µm)	Pc (ppcm)	Coating Weight (gm/m²)	Coating Composition	Coating Adhesion
Top					
Bottom					

CHEMICAL COMPOSITION (%)

C	Mn	P	S	Si	Cu	Al	Cb	V	Ni	Cr	Ti	N	Mo	B
0.053	0.31	0.058	0.008	0.008	0.	0.038	0.	0.	0.	0.015	0.0025	0.0063	0.	0.0005

Forming Limit Diagram

PART INFORMATION

Customer:	ULSAB
Program Name:	Phase II
Make/Model/Style:	
Part Name:	Pan Front Floor
Part Number:	040

FLD PARAMETERS

FLD Thickness (mm):	0.7	**FLDo:**	31.5
FLD n Value:	0.199	**% Thinning @ FLDo:**	23.9
Circle Grid Diameter (mm):	5.	**FLD Status/SF:**	M / 3%

DATA

Pt	% Major Strain	% Minor Strain	Thickness Strain		Status	Label
			Thickness (mm)	% Thinning		
1	24	-9	0.623	11	S	1
2	30	-1	0.546	22	M	2
3	17	3	0.581	17	S	3
4	14	0	0.616	12	S	4
5	13	-2	0.63	10	S	5
6	20	-1	0.588	16	S	6
7	20	-10	0.651	7	S	7
8	21	-15	0.679	3	S	8
9						
10						
11						
12						
13						
14						
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16						
17						
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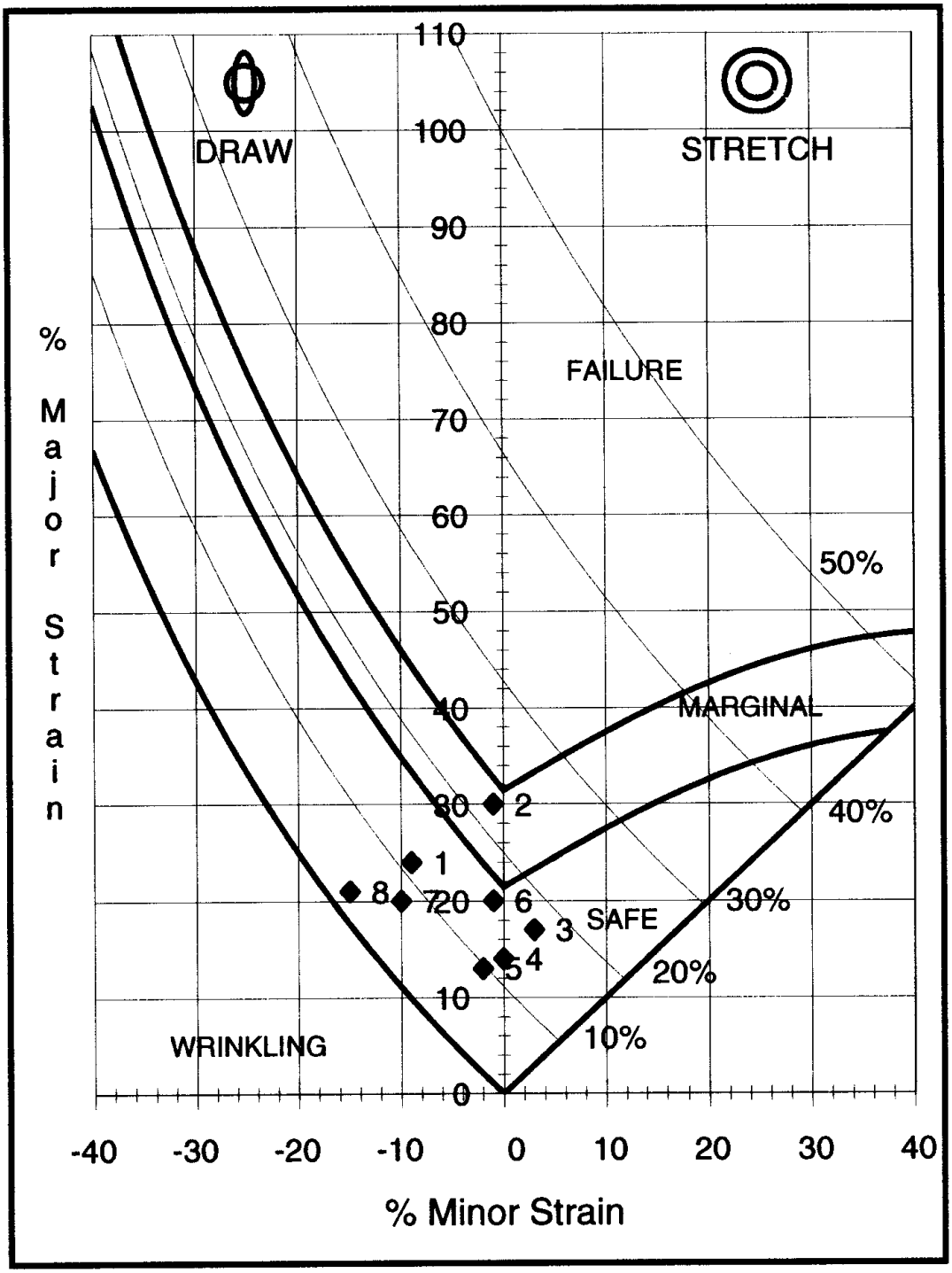
22						
23						
24						
25						

Note: 1. Thickness and % Thinning values are calculated from the % Major and % Minor Strains.
2. S = Safe, M = Marginal, F = Failure, W = Potential Wrinkling/Thickening



Note: 1. Marginal Zone (% Major Strain) = 10
2. Potential Wrinkling/Thickening Strains are plotted as squares.

8.4. Quality Criteria

The quality assurance system utilized on the ULSAB project followed the same standards as normal automotive practices. The key elements of control were:

- Material
- Engineering levels
- Process control
- Dimensional accuracy
- Parts submission

Material: All material received was checked for dimensional accuracy by the part suppliers, the steel suppliers provided the material characterization data which was verified by an independent laboratory. Additionally, Porsche checked the material for weldability.

Engineering Levels: A strict engineering change control system was implemented for this program. At each weekly review meeting all product levels were checked against the design status to insure compatibility. Suppliers were not allowed to implement any change without the authorization of PES.

Process Control: As previously stated, the components were produced to production intent standards. Therefore, to insure this occurred, regular audits of the process were undertaken.

Dimensional Accuracy: For each component, automotive standard checking fixtures were produced. These fixtures were used throughout the development process to provide verification of dimensional accuracy. Additionally for all major parts, the contract with the suppliers called for two fully CMM checked samples. As further assurance, where possible, match checks were undertaken to insure fit and function for the assembly process.

Parts Submission: The approval process was based on PPAP (Production Part Approval Process) as outlined in QS 9000 guidelines. Before any part was shipped, the supplier had to provide documentation that showed all material, engineering, process and dimensional controls had been completed and met with the specifications set within the program.