Porsche Engineering Services, Inc.

9 Materials and Processes

Throughout the material selection process in ULSAB-AVC, the goal was to optimize for manufacturing feasibility, performance and cost.

9.1 BACKGROUND

It was demonstrated by the ULSAB Program, which was completed in 1998, that the extensive use of both High Strength Steels (HSS) and Ultra High Strength Steels (UHSS) could contribute significantly to achieve mass reduction. HSS were defined as steels with yield strengths from 210 - 550 MPa. Isotropic (IS), Interstitial-Free (IF), bake hardenable (BH) and high strength low alloy (HSLA) grades were used most frequently in this group. UHSS were defined as steels with yield strengths greater than 550 MPa.

9.2. New Steel Grades (AHSS)

The goals for the ULSAB-AVC program are focused on the development of steel-intensive concepts that could be introduced from 2004. Therefore, it was appropriate to consider, to a large extent, the application of new types of high strength steels, the so-called "Advanced High Strength Steels" (AHSS). These grades, a few of which were used in the ULSAB Program already, exhibit higher rates of work hardening than conventional steels and therefore, have the potential for higher crash energy absorption. In combination with their good press formability these steel grades can contribute significantly to project objectives.

AHSS are multiphase steels, which contain martensite, bainite and/or retained austenite in quantities sufficient to produce unique mechanical properties. All these grades, which overlap the range of strength between HSS and UHSS are showing high strain hardening capacities as a result of their lower initial yield strength (YS) to ultimate tensile strength (UTS) ratio.

The multiphase AHSS family includes dual phase (DP), transformation induced plasticity (TRIP) and complex phase (CP) steels. Stretch Flangeable (SF) steels used in suspension components of ULSAB-AVC, are a subset of the DP products, but contain bainite instead of martensite in a ferritic matrix. The AHSS family also includes the martensitic steels (MART), which offer the highest tensile strengths up to 1500 MPa UTS.

Since ULSAB-AVC is a concept program, the portfolio of steels available for selection was expanded to include those steels that are currently under development and will be commercially available by 2004. This limited the grades selected to those with a significant commercial potential. Additionally, because the program required high strain rate properties for conducting crash simulations, steel grades considered were further limited to those for which these properties were available.

9.3. ULSAB-AVC Steel Nomenclature

Because methods used to classify steel products vary considerably throughout the world, the ULSAB-AVC Consortium, adopted a classification system that defines both YS and UTS for all steel grades. In this nomenclature, steels are identified as “XX aaa/bbb,” where:

XX = Type of steel
aaa= Minimum YS in MPa
bbb= Minimum UTS in MPa

The steel type designator uses the following classification as shown in Table 9.3-1.

Table 9.3-1 Steel type designator

Designator	Steel Type	Designator	Steel Type
Mild	Mild Steel	DP	Dual Phase
IF	Interstitial Free	SF	Stretch Flangeable
BH	Bake Hardenable	TRIP	Transformation Induced Plasicity
CMn	Carbon Mangenese	CP	Complex Phase
HSLA	High Strength Low Alloy	Mart	Martensite
IS	Isotropic	MnB	Hardenable Mangenese Boron

As an example of this classification system, DP 500/800 refers to dual phase steel with 500 MPa minimum yield strength and 800 MPa ultimate tensile strength.

An exception to this nomenclature is the material used for the exhaust system, which is named according to international standardization because the selected grades are widely available. This selection was mainly driven by forming and/or heat resistance requirements for different components of the system. Details of the material selection for the exhaust system are described in Section 9.6

9.4. Material Description

The fundamental metallurgy and mechanical behavior of conventional high strength steels are generally well known. The metallurgy, processing, and mechanical behavior of AHSS reflect more recently-introduced strip steel processing technologies. Details are described in the Consortium document "Technical Transfer Dispatch 6" (TTD#6) which was edited by the Material Working Group (MWG) of the Consortium.

9.5. Material Selection Process

In contrast to the ULSAB program, where manufacturing feasibility was assured by using conventional materials with known formability, a new material selection approach was utilized for the ULSAB-AVC program. Since this project was likely to feature the selection of a wide range of new AHSS and the body structure design process was to be based on the use of strain rate compensated mechanical properties, the selection of steel grades was carried out in close cooperation of PES engineers and steel company specialists working together as the ULSAB-AVC Material Working Group.

The initial steel selection was made by PES based upon static strength requirements and experience. Then, using a Simultaneous Engineering Approach, the MWG determined the ultimate grade of steel to best satisfy manufacturability and performance requirements of each component. For the more complex components, forming feasibility was assessed through the use of one-step forming simulations. The formability of some of the more challenging parts, which were designed to use tailor welded blanks or hydroforming, and all outer panels, were further subjected to incremental FEA simulations. During all these assessments, opportunities to utilize higher strength, lower thicknesses and/or lower costs were continuously evaluated.

The assessment of forming behavior should be carried out as early as possible in the concept design phase. For those components where critical strains were predicted in the initial forming assessment, iterative changes in material and/or geometry were made until all components were considered to show acceptable forming behavior.

By doing these early forming simulations, the initial indication was that the superior formability of TRIP steels was unnecessary to manufacture most of the ULSAB-AVC components. Detailed design, which would be performed later in a vehicle development program, could increase the geometric complexity of some components and may require the more extensive use of TRIP steels.

The absence of press hardening (or hot forming) steels – which may be of interest especially for those components with a complicated shape but requiring ultra high strength levels – can be similarly explained. In this concept phase, those components are made of martensite grades which do not require hot forming.

Throughout the material selection process in ULSAB-AVC, the goal was to optimize the manufacturing feasibility, performance and cost. The materials presented in this Report are, of course, specific only to the C-Class or PNGV-Class design requirements, but are not the absolute or unique solution nor is the material selection appropriate for every possible design.

As anticipated, the proportionate distribution of steel grades – shown later in Chapter 9 – is significantly different from that used in ULSAB. This distribution, utilizing a large amount of AHSS, provides a probable indication of future automotive design trends. AHSS are an enabler for future crash performance requirements in combination with mass efficient design.

Steels for other applications like fuel tank or applique were chosen by experience from similar applications. Due to their simplicity in shape no forming simulation was performed.

The material selection for the seat structure -which is not included in the crash calculation model- was made with input and experiences from both suppliers of seats and members of the Material Working Group.

The first step in the material selection process for the suspension parts was to choose a steel type and grade by engineering judgement taking the expected loads into account. A CAE calculation was performed in order to verify material selection. The assessment of forming behavior was performed later and iterative changes in geometry were made until all parts were considered to show acceptable forming behavior.

9.6. Material Properties / Master Material List

It is well known that steel displays positive strain rate dependency. This means that at higher rates of strain – typically associated with crash events – steel displays an increase in strength. It was confirmed in preliminary ULSAB-AVC engineering studies that the utilization of this phenomenon could assist in mass reduction. Taking this experience into consideration, it was decided to use dynamic true stress-strain curves (which describe stress-strain behavior over a wide range of strain rates) for the crash calculation model. The master material list shown in Table 9.6-1 shows the static mechanical properties of the steels selected for the ULSAB-AVC body structure, closures, ancillary parts, suspension and wheels. Dynamic stress-strain curves for the body structure steels can be found in the previously mentioned TTD#6 which was edited by the MWG

Table 9.6-1 Master Material List

Product	YS (MPa)*	UTS (MPa)*	Total EL (%)*	n-value (5-15%), if applicable	r-bar*	Application Code
Mild 140/270	140	270	38-44	0.23	1.8	A,C,F
BH 210/340	210	340	34-39	0.18	1.8	B
BH 260/370	260	370	29-34	0.13	1.6	B
IF 260/410	260	410	34-38	0.20	1.7	C
DP 280/600	280	600	30-34	0.21	1.0	B
IF 300/420	300	420	29-36	0.20	1.6	B
DP 300/500	300	500	30-34	0.16	1.0	B
HSLA 350/450	350	450	23-27	0.22	1.0	A,B,S
DP 350/600	350	600	24-30	0.14	1.1	A,B,C,W,S
DP 400/700	400	700	19-25	0.14	1.0	A,B
TRIP 450/800	450	800	26-32	0.24	0.9	A,B
HSLA 490/600	490	600	21-26	0.13	1.0	W
DP 500/800	500	800	14-20	0.14	1.0	A,B,C,W
SF 570/640	570	640	20-24	0.08	1.0	S
CP 700/800	700	800	10-15	0.13	1.0	B
DP 700/1000	700	1000	12-17	0.09	0.9	B
Mart 950/1200	950	1200	5-7	0.07	0.9	A,B
MnB**	1200	1600	4-5	na	na	S
Mart 1250/1520	1250	1520	4-6	0.07	0.9	A

Application Code: A = Ancillary Parts, B = Body Structure, C = Closures, F = Fuel Tank, S = Suspension/Chassis, W = Wheels

**) Note: Flat sheet as shipped properties*

***) Properties in heat treated condition; YS/UTS = 280/450, EL=21% before hardening*

As mentioned in section 9.3-1 the nomenclature of the steels chosen for exhaust system is somewhat different from what is shown in Table 9.6-1. Therefore all materials used for exhaust system are listed in Table 9.6-2.

Table 9.6-2 Exhaust Material List

Component	European Material Identification	Euro.-Code	US.-Code	Jap.-Code	Type
Exhaust Manifold	X 15 CrNiSi 20 12	1.4828	309	SUH 309	Austenitic
Reinforcements	X 5 CrNi 18 10	1.4301	304	SUS 304	Austenitic
Connectors (Front End)	X 5 CrNi 18 10	1.4301	304	SUS 304	Austenitic
Tubes (Front End)	X 2 CrTiNb 18	1.4509	441	SUS430J1L	Ferritic
Catalyst Housing (Inlet/Outlet)	X 2 CrTiNb 18	1.4509	441	SUS430J1L	Ferritic
Muffler (Inner parts)	X 2 CrTiNb 18	1.4509	441	SUS430J1L	Ferritic
Tubes (Rear End)	X 6 CrTi 12	1.4512	409	SUS 409	Ferritic
Catalyst Housing (Middle Area)	X 6 CrTi 12	1.4512	409	SUS 409	Ferritic
Muffler (Inner Parts)	X 6 CrTi 12	1.4512	409	SUS 409	Ferritic
Connectors (Rear End)	St 1203	1.0330	A 366	SPCC	Ferritic
Muffler (Outer Shell)	St 1203 (aluminized)	1.0330	A 366	SPCC	Ferritic

Table 9.6-3 Body Structure Tube Material List

Steel Grade	YS* (Mpa)	UTS* (Mpa)	Total EL (%)**	n-value (5-15%)	r-bar	Application Code
DP 280/600	450	600	27-30	0.15	1.0	B
DP 500/800	600	800	16-22	0.10	1.0	B
Mart 950/1200	1150	1200	5-7	0.02	0.9	B

Application Code: B = Body Structure
** YS and UTS are minimum values, others are typical values*
*** Total EL % - Tubes tested with A5 method (flat sheet tested with A50 or A80)*

9.7. Material Distribution

9.7.1. Material Distribution - Body Structure

In the exploded views (Figures 9.7.1-1 and 9.7.1-3), all components of the ULSAB-AVC body structure are shown and designated by the three last digits of their part number. Their steel grades are represented by colors. The same color coding is used in Figures 9.7.1-2 and 9.7.1-4 which show the proportion of each grade in the body structure. Detailed parts lists are located in the Appendix of this Engineering Report.

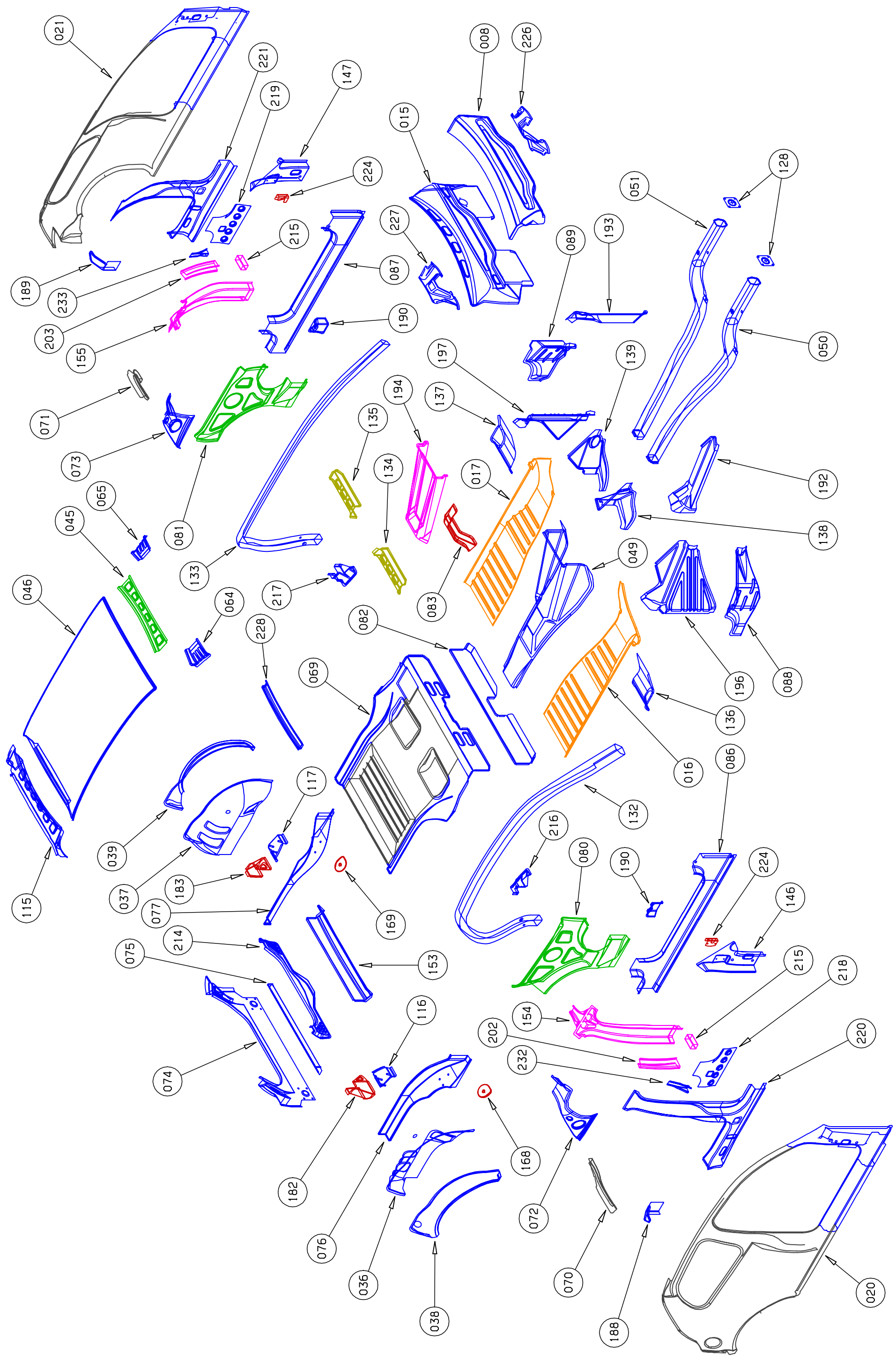
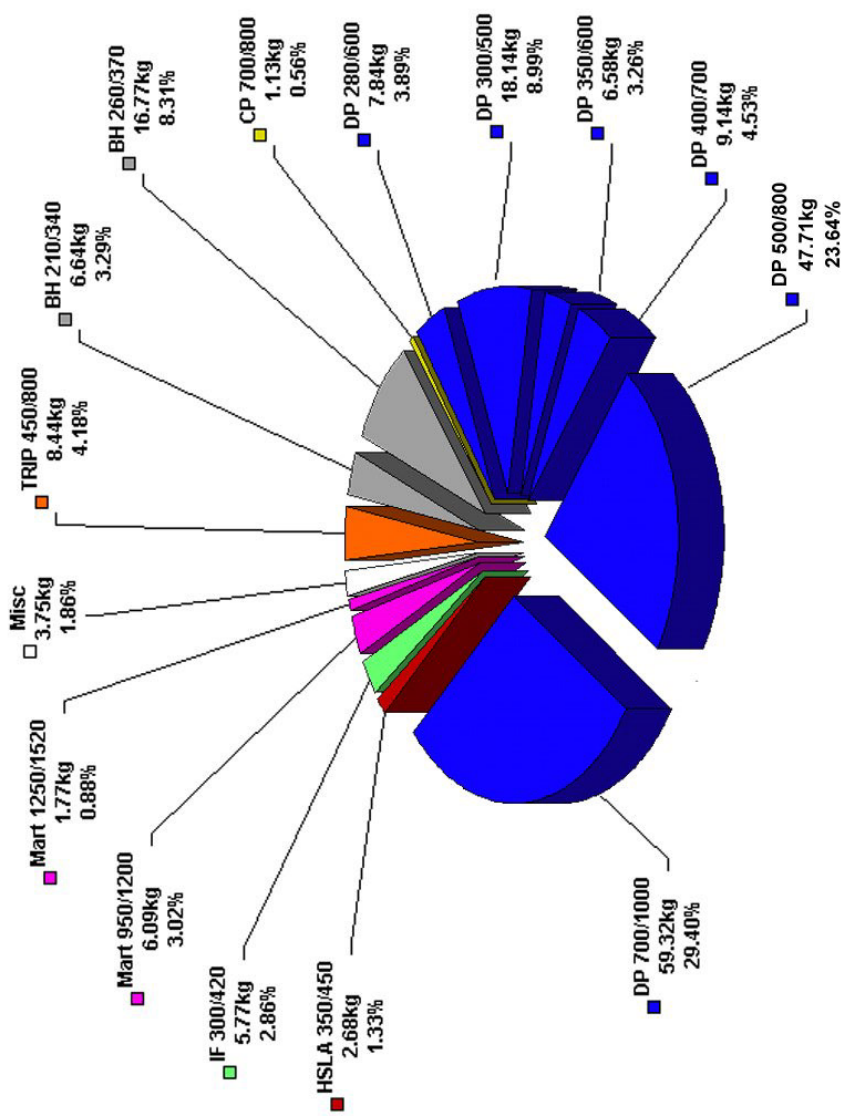


Figure 9.7.1-1 Exploded view C-Class body structure illustrating steel grade



BH	210/340
BH	260/370
CP	700/800
DP	280/600
DP	300/500
DP	350/600
DP	400/700
DP	500/800
DP	700/1000
HSLA	350/450
IF	300/420
Mart	950/1200
Mart	1250/1520
TRIP	450/800
Misc	

Material Type	Mass [kg]
BH	23.42
CP	1.13
DP	148.73
HSLA	2.68
IF	5.77
Mart	7.86
TRIP	8.44
Misc	3.75
Total	201.78

Figure 9.7.1-2 C-Class body structure steel/grade distribution

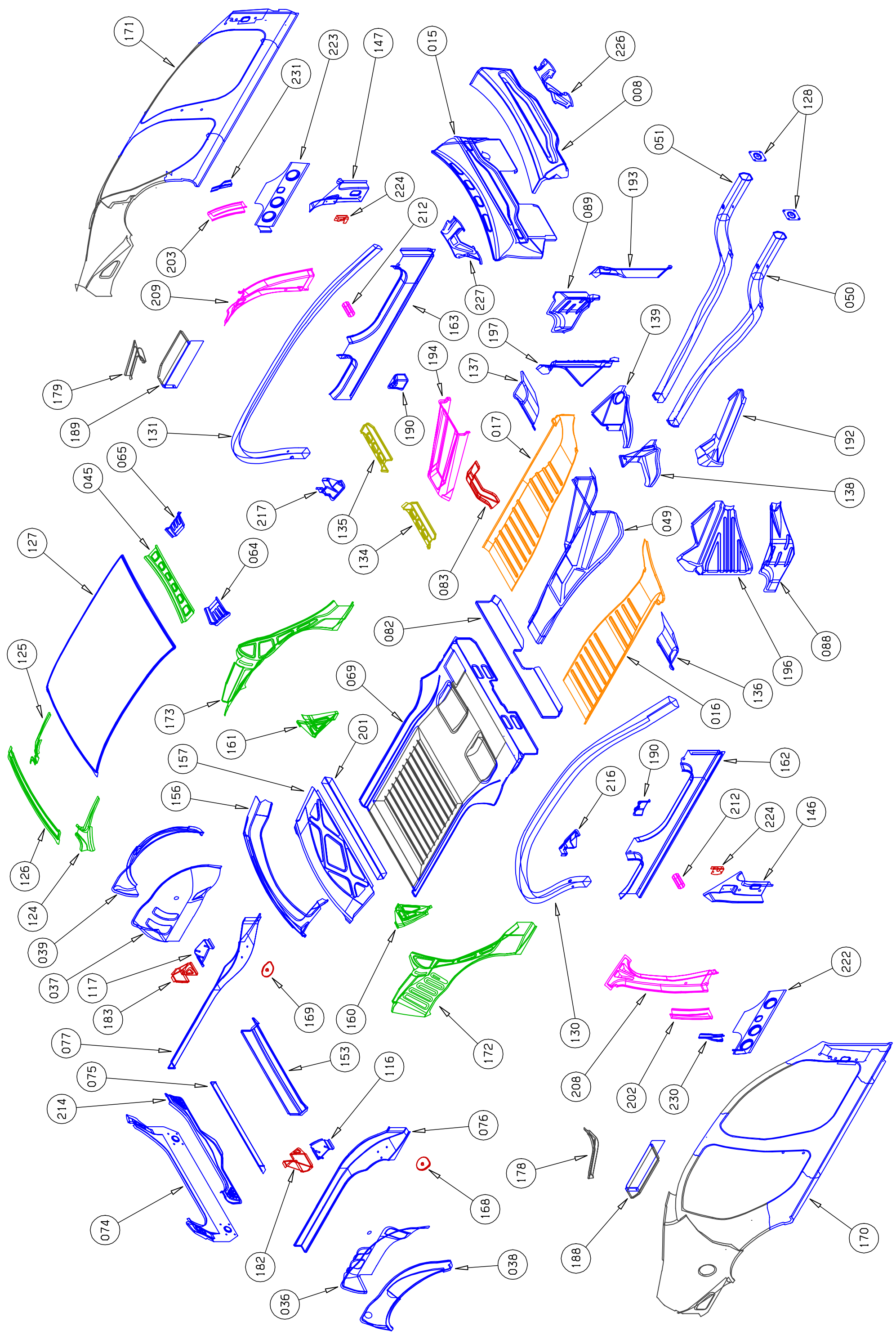


Figure 9.7.1-3 Exploded view PNGV-Class body structure illustrating steel grade

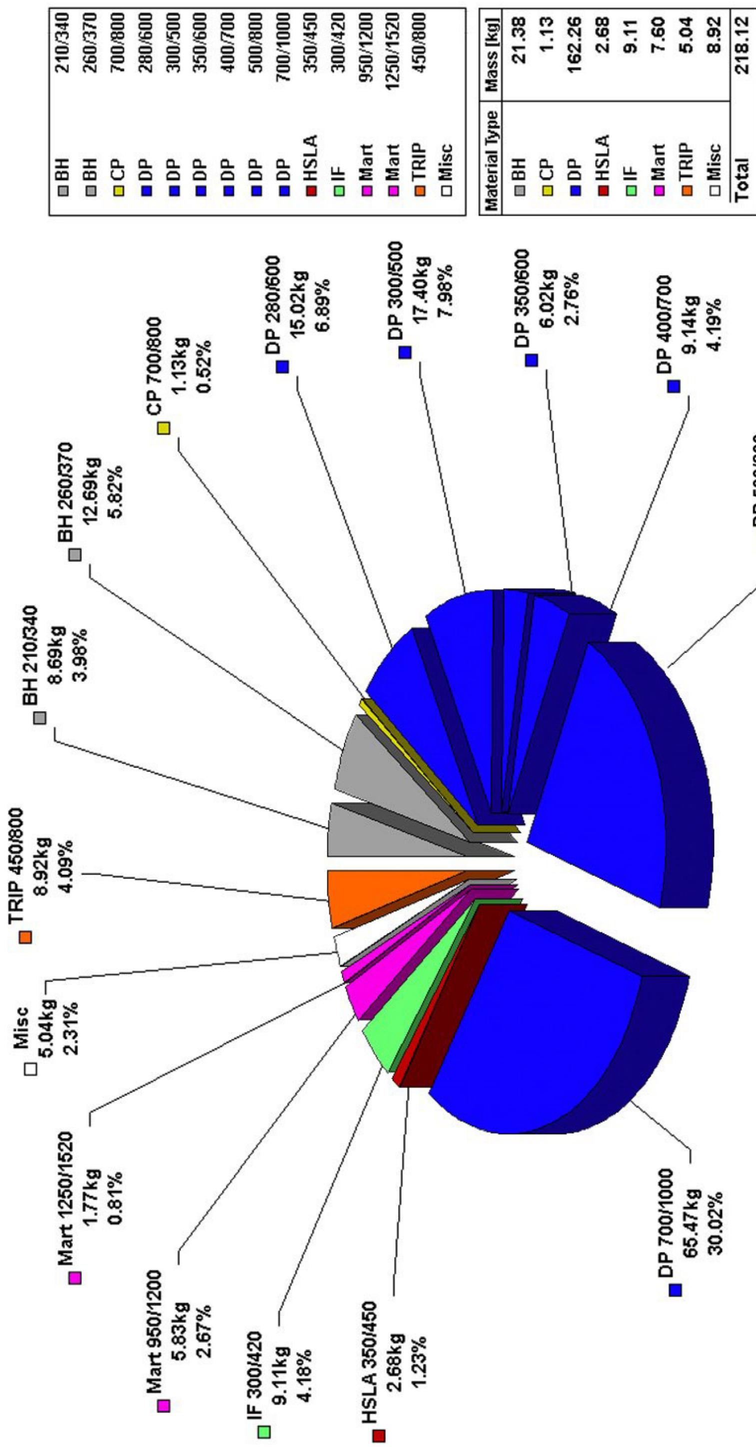


Figure 9.7.1-4 PNGV-Class body structure steel/grade distribution

The ULSAB body structure used a large amount of conventional High Strength Steel. For body structure of ULSAB-AVC, mild steel is no longer used. The percentage of conventional High Strength Steel is reduced to about 15% for both vehicles the C-Class and PNGV-Class. The AHSS grades represent about 82% of the body structure mass, of which 74% are DP grades, 4% are TRIP and the grades with the highest strengths available – CP and martensite steels – account for the remaining 4% .

9.7.2. Material Distribution - Closures

The exploded view Figure 9.7.2-1 shows the C-Class vehicle closure structures and includes Doors Front, Hood and Liftgate. The exploded view 9.7.2-3 shows the PNGV-Class vehicle closure structures Doors Front and Rear, Decklid and Hood. Their steel grades are represented by colors as shown in Figure 9.7.2-2 and 9.7.2-4, which also show the steel grade distribution.

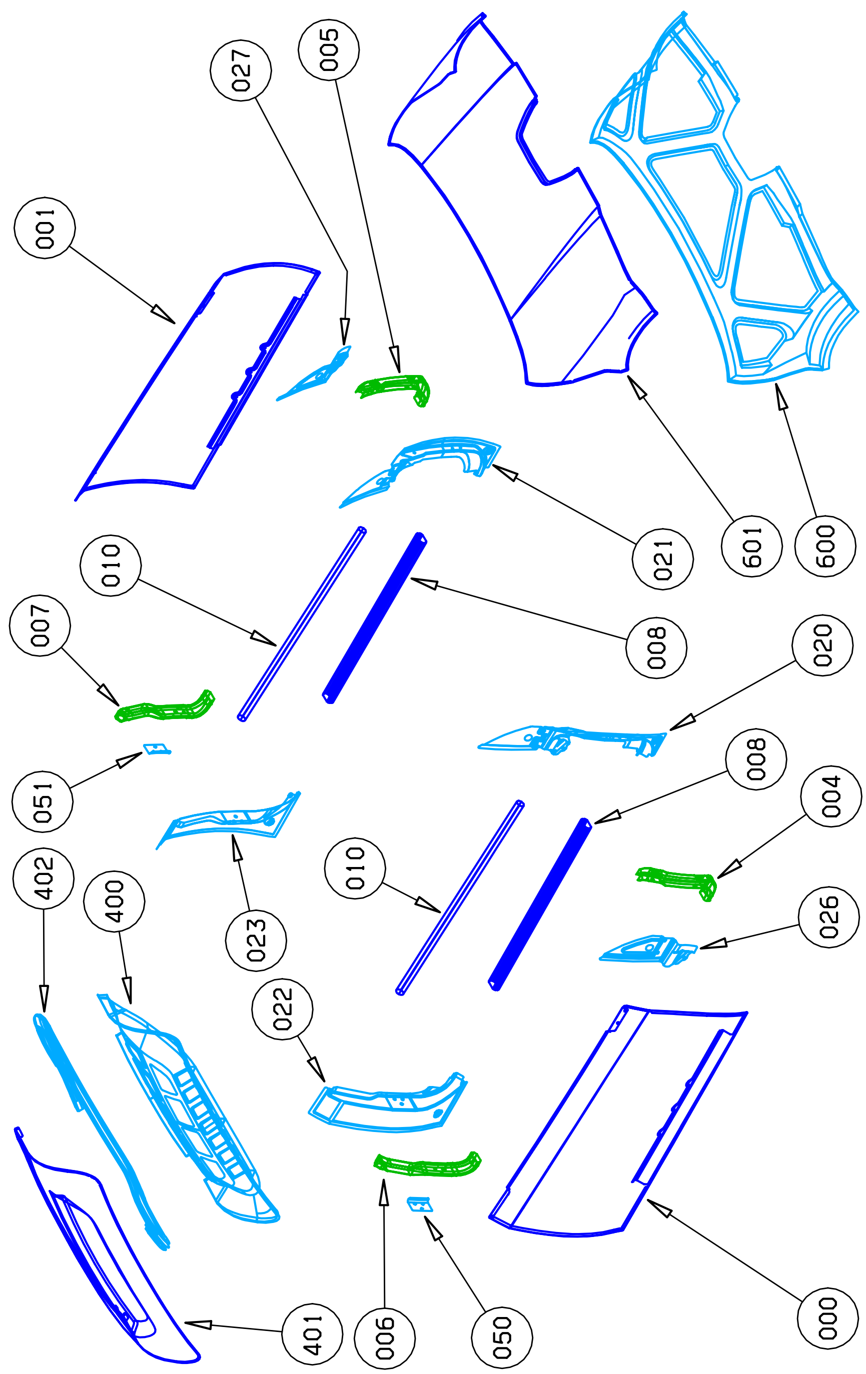
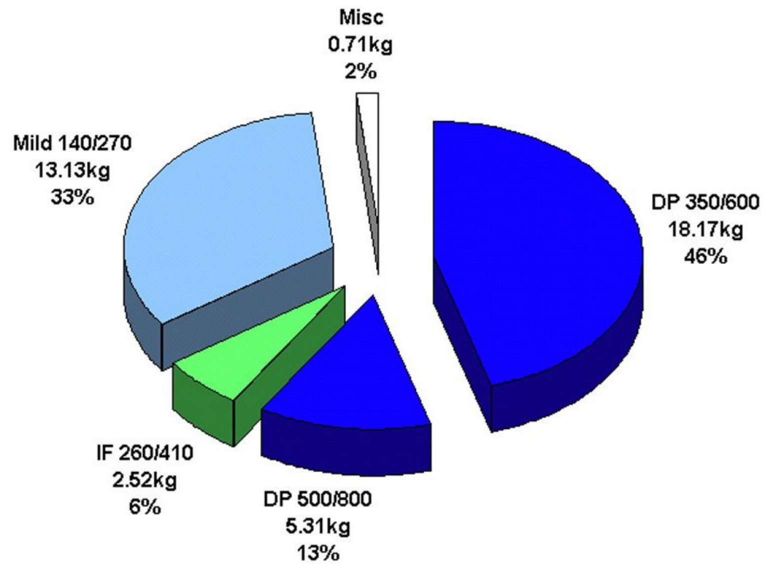


Figure 9.7.2-1 Exploded view C-Class vehicle closures illustrating steel grade



DP	350/600
DP	500/800
IF	260/410
Mild	140/270
Misc	

Material Type	Mass [kg]
DP	23.48
IF	2.52
Mild	13.13
Misc	0.71
Total	39.84

Figure 9.7.2-2 C-Class vehicle closures steel/grade distribution

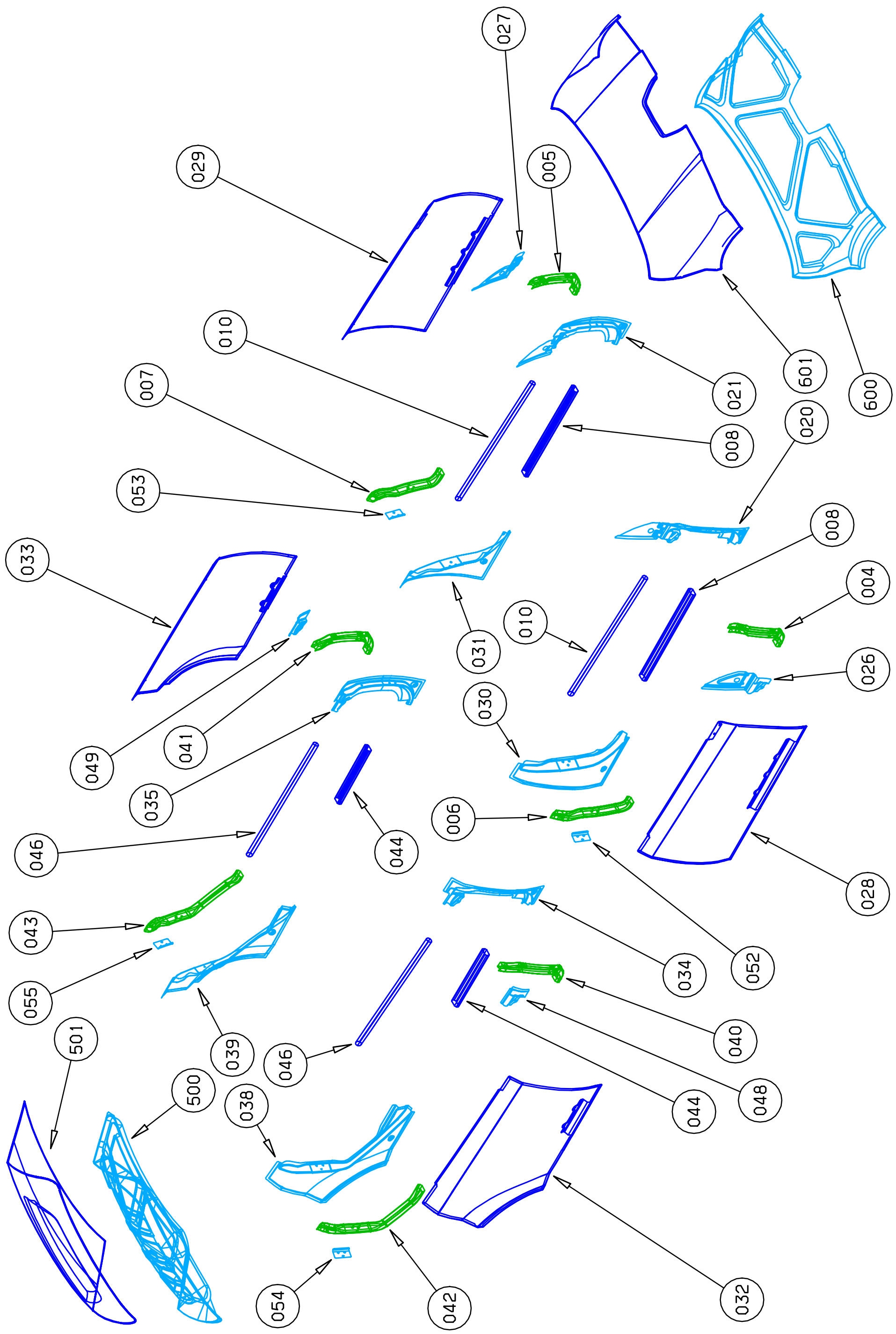
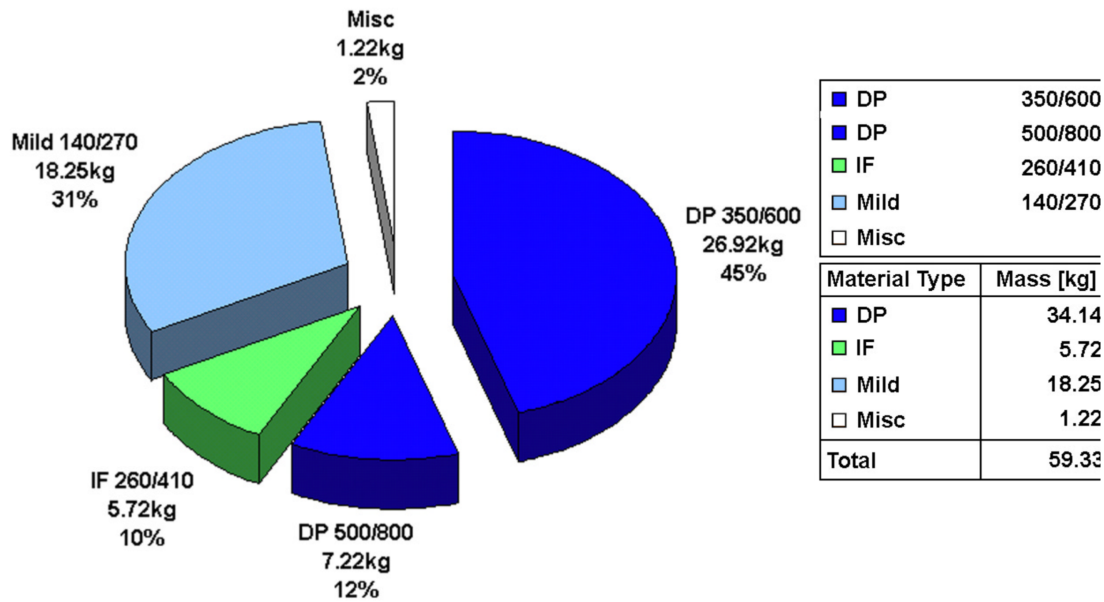


Figure 9.7.2-3 Exploded view PNGV-Class vehicle closures illustrating steel grade



Material Type	Mass [kg]
DP	34.14
IF	5.72
Mild	18.25
Misc	1.22
Total	59.33

Figure 9.7.2-4 PNGV-Class vehicle closures steel/grade distribution

9.7.3. Material Distribution - Ancillary Parts

9.7.3.1. Ancillary Parts – Body Structure

The ULSAB-AVC ancillary body structure parts are defined as:

- Seat Structure Front and Rear
- Instrument Panel Beam
- Bumper Beam Structure

All components of the seat structure are shown in Figure 9.7.3.1-1 and 9.7.3.1-2. Their steel grades are represented by colors again. The same color coding is used in Figure 9.7.3.1-3, which also shows the proportion of each material in the seat structure.

All components of the instrument panel beam are shown in Figure 9.7.3.1-4. Their steel grades are represented by colors again. The same color code is used in Figure 9.7.3.1-5, which also shows the proportion of each material.

All components of the bumper beam structure are shown in Figure 9.7.3.1-6. Their steel grades are represented by colors again. The same color code is used in Figure 9.7.3.1-7, which also shows the proportion of each material.

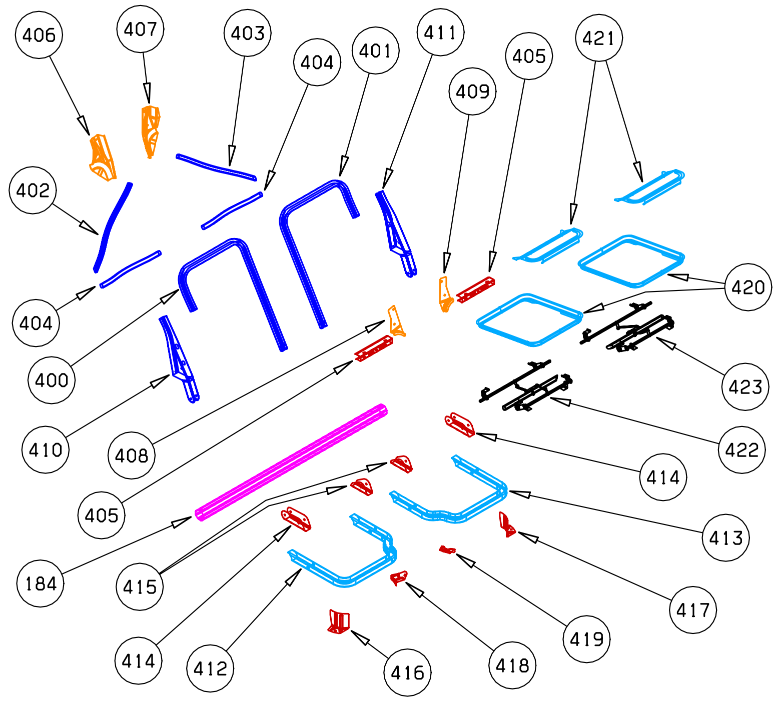


Figure 9.7.3.1-1 Exploded view Front Seat structure illustrating steel grade

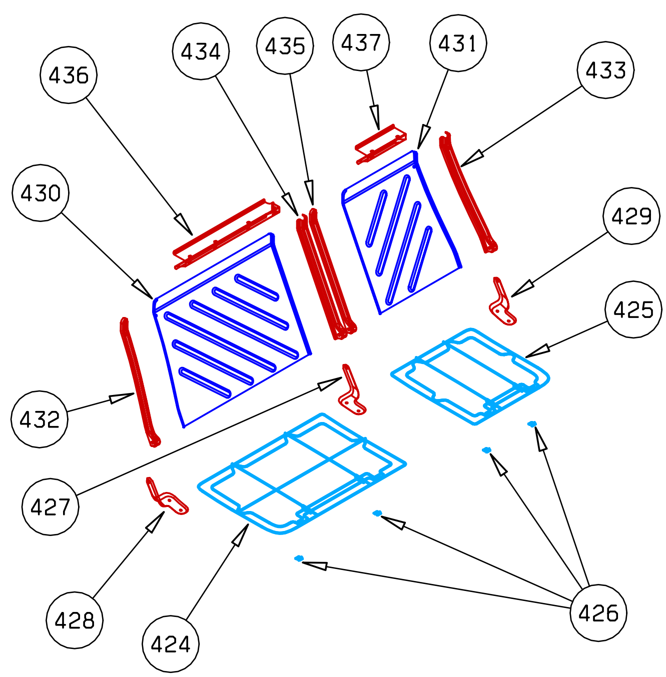
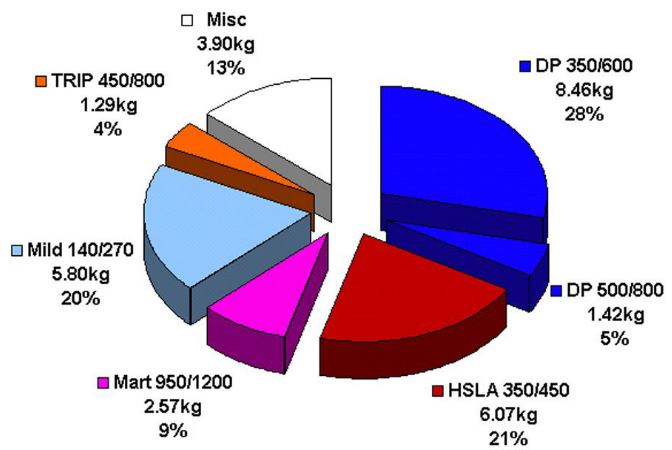


Figure 9.7.3.1-2 Exploded view Rear Seat structure illustrating steel grade



DP	350/600
DP	500/800
HSLA	350/450
Mart	1950/1200
Mild	140/270
Trip	450/800
Misc	

Material Type	Mass [kg]
DP	9.88
HSLA	6.07
Mart	2.57
Mild	5.80
Trip	1.29
Misc	3.90
Total	29.51

Figure 9.7.3.1-3 Front and Rear Seat Structure steel/grade distribution

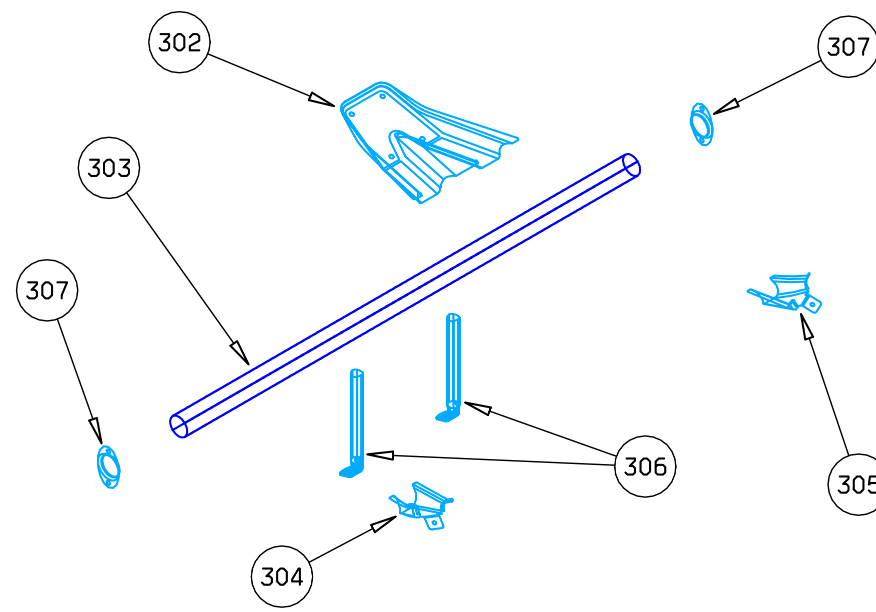
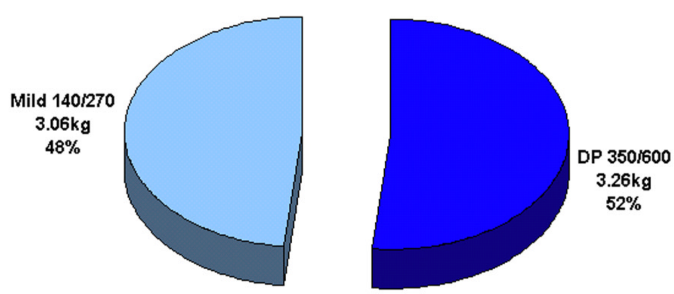


Figure 9.7.3.1-4 Exploded view Instrument Panel Beam illustrating steel grade



DP	350/600
Mild	140/270

Material Type	Mass [kg]
DP	3.26
Mild	3.06
Total	6.26

Figure 9.7.3.1-5 Instrument Panel Beam steel/grade distribution

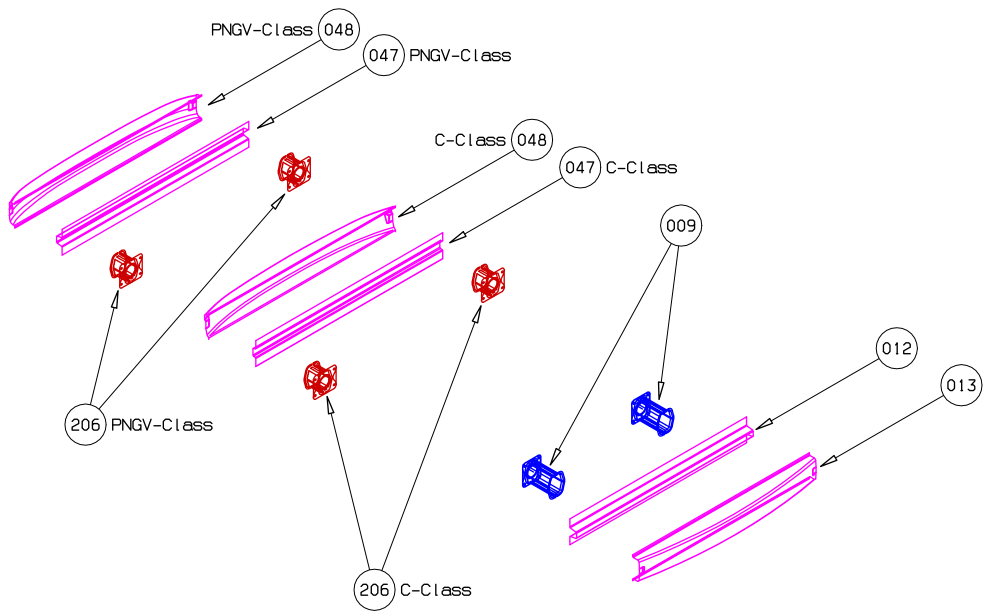


Figure 9.7.3.1-6 Exploded view Bumper Beam Structure illustrating steel grade

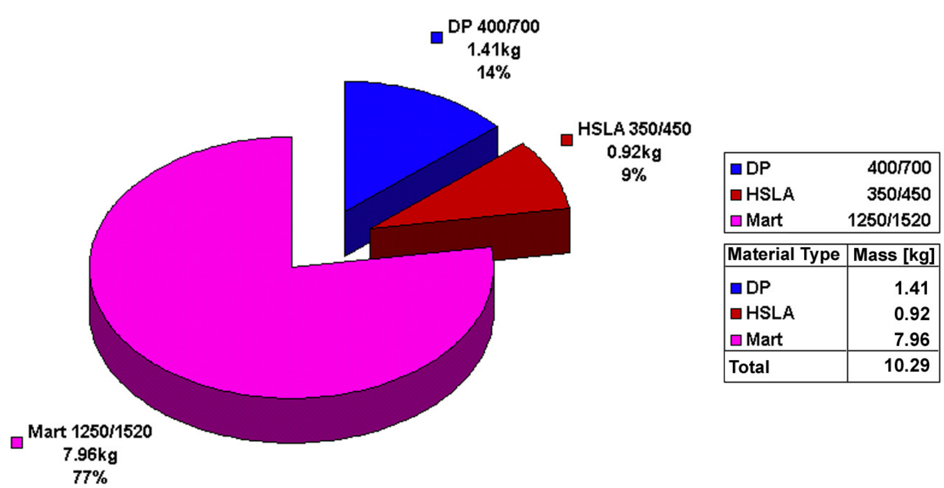


Figure 9.7.3.1-7 Bumper Beam Structure steel/grade distribution

9.7.3.2. Ancillary Parts – Outer Panels

The ULSAB-AVC ancillary outer panel parts are defined as:

- Fenders
- Fuel Filler Decklid
- Service Decklid
- Applique Roof Side Rail

All components are shown in Figure 9.7.3.2-1. Their steel grades are represented by colors shown in Figure 9.7.3.2-2 and Figure 9.7.3.2-3 which also show the proportion of each material and use the same color coding. The same color code is used in Figure 9.7.3.1-7, which also shows the proportion of each material.

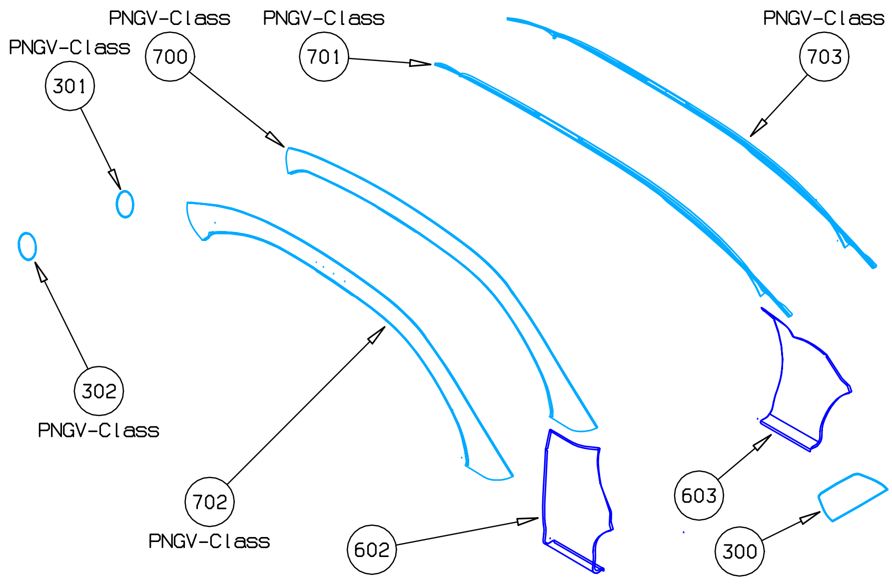


Figure 9.7.3.2-1 Exploded view ancillary outer panels illustrating steel grade

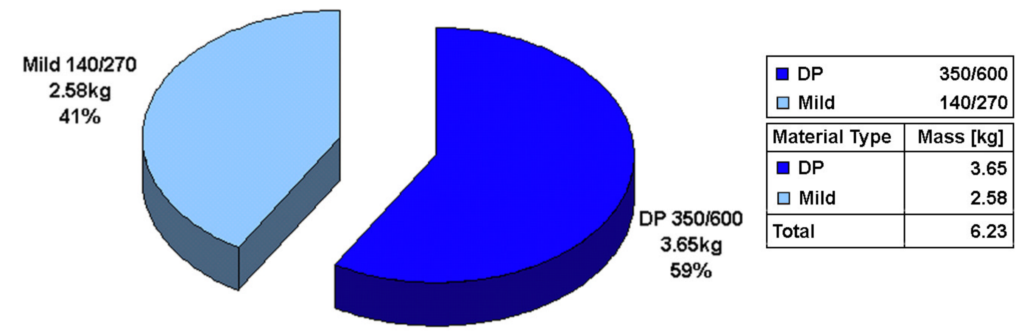


Figure 9.7.3.2-2 C-Class ancillary outer panels steel/grade distribution

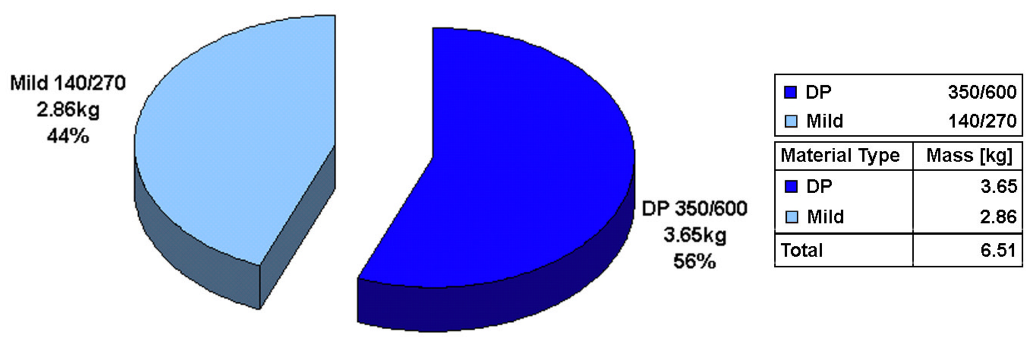


Figure 9.7.3.2-3 PNGV-Class ancillary outer panels steel/grade distribution

9.8. Tube Material

Due to the specific design of the ULSAB-AVC body structure and closure structures, a range of tubular steel products was used for hydroforming (HFS or HFS/TWT) or as straight or shaped tubes (ST). Additional information on the hydroforming of single thickness or tailor welded tubes is presented in section 9.9.2. Due to the fact that tubes used for ULSAB-AVC are made from flat sheet material, the mechanical properties are influenced by the tube forming process (rolling, welding and calibration). An additional effect may occur from a second forming operation where a round tube is formed later e.g. into square or octagonal shape. Therefore in general an increase of YS and UTS can be observed in conjunction with a decrease of elongation due to the mentioned forming operations. But due to the fact that high strain rate data were available for flat sheet material only these values were taken into consideration for crash calculation.

All tubes used in the ULSAB-AVC body structure, closures and ancillary parts are shown in Figures 9.8-1 and 9.8-2. Additionally, this hydroformed parts, which were made from tubes are used in the chassis area as well (not shown here). Details are described in Chapter 7 – Chassis. In Table 9.8-1 all tubes used for ULSAB-AVC are listed together with their steel type/grade, thickness, (initial) diameter or cross section and designed length. All tubes were considered – as in ULSAB and ULSAC – as laser or high frequency welded products.

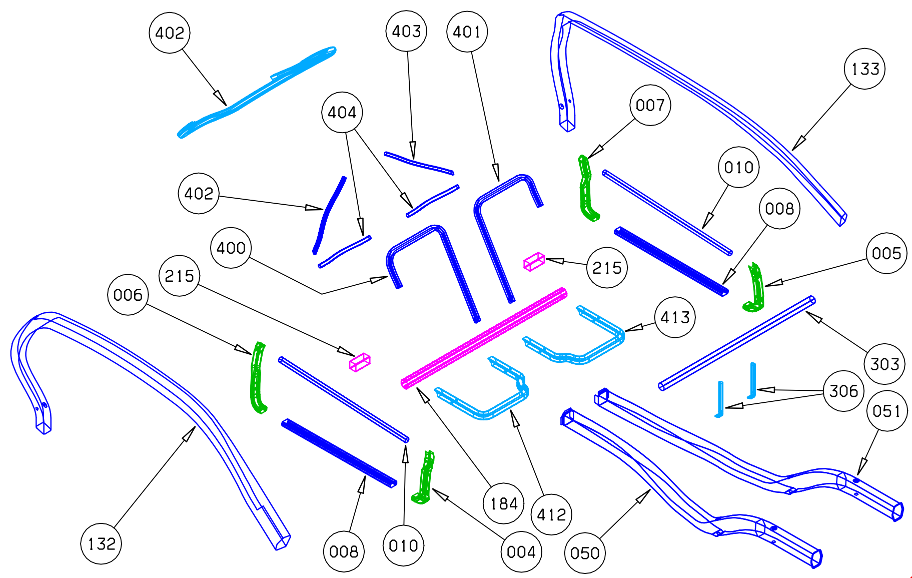


Figure 9.8-1 Exploded view C-Class tubes (chassis parts not shown)

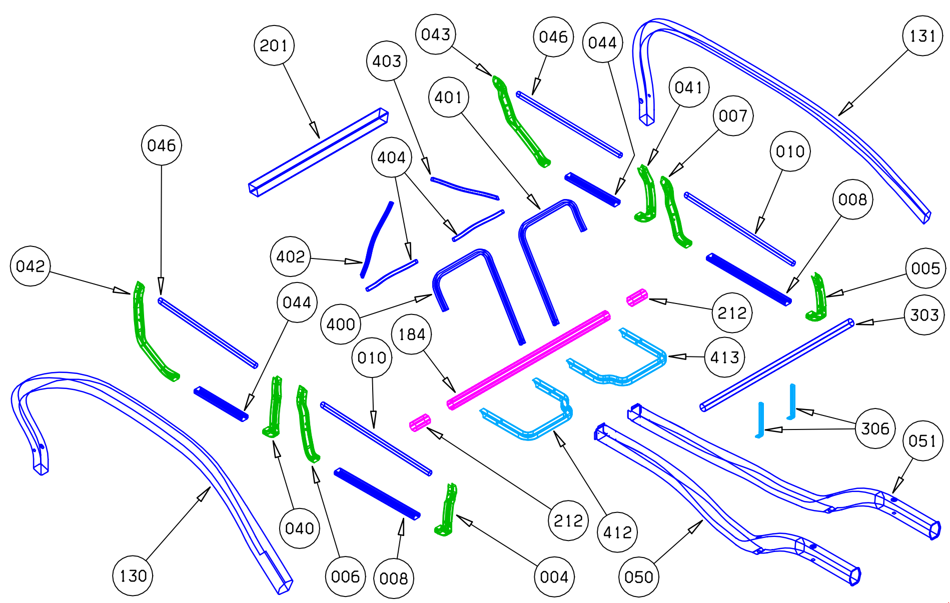


Figure 9.8-2 Exploded view PNGV-Class tubes (chassis parts not shown)

Table 9.8-3 Tube criteria list

Revision Level: A07 Date: 18 JUL 01

Part Number			Part Name	Manuf. Process Code	Material				Dimensions (mm)	
					Gage (mm)	Type	Grade (MPa)		Cross Section	Designed Length
							Yield Strength	Tensile Strength		
AVC	1	1184	Crossmember Support Front Seat Rear	ST	1.20	Mart	950	1200	60 x 60	1388
AVC	1	1303	Crossmember Instrument Panel	ST	2.00	DP	350	600	∅ 50	1320
AVC	1	1306	Brace Crossmember Inst Panel Support (x2)	ST	2.00	Mild	140	270	∅ 25	289
AVC	1	1400	Frame Member Back Support Front Seat RH	ST	1.00	DP	350	600	30 x 30	1388
AVC	1	1401	Frame Member Back Support Front Seat LH	ST	1.00	DP	350	600	30 x 30	1388
AVC	1	1402	Diagonal Member Back Supt Front Seat RH	ST	1.00	DP	350	600	20 x 20	536
AVC	1	1403	Diagonal Member Back Supt Front Seat LH	ST	1.00	DP	350	600	20 x 20	536
AVC	1	1404	Crossmember Back Support Front Seat (x2)	ST	1.00	DP	350	600	20 x 20	446
AVC	1	1412	Frame Member Seat Support Front Seat RH	ST	0.70	Mild	140	270	40 x 40	1192
AVC	1	1413	Frame Member Seat Support Front Seat LH	ST	0.70	Mild	140	270	40 x 40	1192
AVC	1	2004	Hinge Tube - Front Door RH	HFT	1.20	IF	260	410	∅ 48	440
AVC	1	2005	Hinge Tube - Front Door LH	HFT	1.20	IF	260	410	∅ 48	440
AVC	1	3135	Subframe	HFT	2.00	DP	350	600	∅ 66	2067
AVC	1	3233	Twist Beam	HFT	2.50	MnB	1200	1600	∅ 90	1351
AVC	1	3237	Trailing Arm (x2)	HFT/TWT	3.00 2.20	DP DP	350 350	600 600	∅ 76	427 158
AVC	2	1050	Member Rail Front RH	HFT/TWT	1.50 1.30	DP DP	500 500	800 800	∅ 100	500 1981
AVC	2	1051	Member Rail Front LH	HFT/TWT	1.50 1.30	DP DP	500 500	800 800	∅ 100	500 1981
AVC	2	1132	Member Body Side Inner RH	HFT	1.00	DP	500	800	∅ 85	3312
AVC	2	1133	Member Body Side Inner LH	HFT	1.00	DP	500	800	∅ 85	3312
AVC	2	1215	Extension C-Member Kick-Up (x2)	ST	1.20	Mart	950	1200	55 x 55	122
AVC	2	2006	Latch Tube - Front Door RH	HFT	1.00	IF	260	410	∅ 48	506
AVC	2	2007	Latch Tube - Front Door LH	HFT	1.00	IF	260	410	∅ 48	506
AVC	2	2008	Lower Tube - Front Door (x2)	ST	1.50	DP	500	800	55 x 30	943
AVC	2	2010	Outer Belt Reinforcement - Front Door (x2)	ST	1.00	DP	500	800	∅ 34	1105
AVC	2	2402	Member Aperture - Liftgate	HFT	0.70	Mild	140	270	∅ 60	2172
AVC	3	1050	Member Rail Front RH	HFT/TWT	1.50 1.30	DP DP	500 500	800 800	∅ 100	500 2066
AVC	3	1051	Member Rail Front LH	HFT/TWT	1.50 1.30	DP DP	500 500	800 800	∅ 100	500 2066
AVC	3	1130	Member Body Side Inner RH	HFT	1.00	DP	500	800	∅ 85	3284
AVC	3	1131	Member Body Side Inner LH	HFT	1.00	DP	500	800	∅ 85	3284
AVC	3	1201	Crossmember Package Tray	ST	1.00	DP	280	600	72 x 72	1172
AVC	3	1212	Extension C-Member Supt Front Seat Rr (x2)	ST	1.20	Mart	950	1200	60 x 60	121
AVC	3	2006	Latch Tube - Front Door RH	HFT	1.00	IF	260	410	∅ 48	508
AVC	3	2007	Latch Tube - Front Door LH	HFT	1.00	IF	260	410	∅ 48	508
AVC	3	2008	Lower Tube - Front Door (x2)	ST	1.50	DP	500	800	55 x 30	686
AVC	3	2010	Outer Belt Reinforcement - Front Door (x2)	ST	1.00	DP	500	800	∅ 34	960
AVC	3	2040	Hinge Tube - Rear Door RH	HFT	1.20	IF	260	410	∅ 48	574
AVC	3	2041	Hinge Tube - Rear Door LH	HFT	1.20	IF	260	410	∅ 48	574
AVC	3	2042	Latch Tube - Rear Door RH	HFT	1.00	IF	260	410	∅ 48	710
AVC	3	2043	Latch Tube - Rear Door LH	HFT	1.00	IF	260	410	∅ 48	710
AVC	3	2044	Lower Tube - Rear Door (x2)	ST	1.50	DP	500	800	55 x 30	429
AVC	3	2046	Outer Belt Reinforcement - Rear Door (x2)	ST	1.00	DP	500	800	∅ 34	886

Code	Manufacturing Process
HFT	Hydroformed Tube
HFT/TWT	Hydroformed Tube / Tailor Welded Tubes
ST	Straight or Shaped Tube

9 Materials and Processes

9.9. Manufacturing Processes

9.9.1. Tailor Welded Blanks

Tailor welded blanks were used extensively in the ULSAB Program. The advantages of this type of design are well accepted by the automotive industry.

The ULSAB-AVC design also uses tailor welded blanks, utilizing the previous experience from ULSAB. For example, the body side outer design principle was realized again in a similar blank layout, but in addition, it was made utilizing AHSS for some areas of the body side outer. Results from the simulation indicated feasible forming behavior.

Forming simulation was performed on all tailor welded blank parts. These simulations showed all tailor welded blanks were feasible to form or could be made feasible through normal detailed design and die development processes, which are beyond the scope of the present concept design activity. The blank layouts for all tailor welded blank parts (body structure and closures) are shown in Figures 9.9.1-1 to 9.9.1-14.

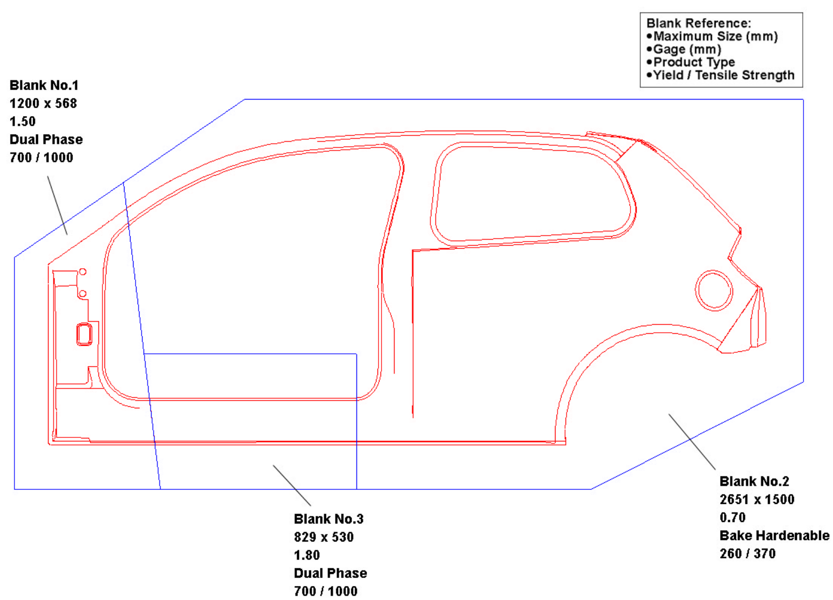


Figure 9.9.1-1 AVC 21020/21 Body Side Outer RH/LH

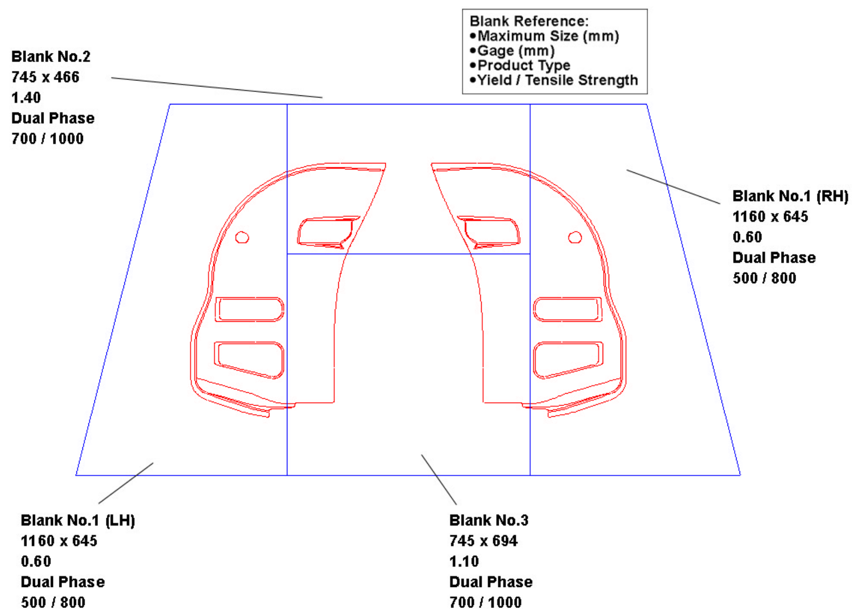


Figure 9.9.1-2 AVC 21036/37 Wheelhouse Inner RH/LH

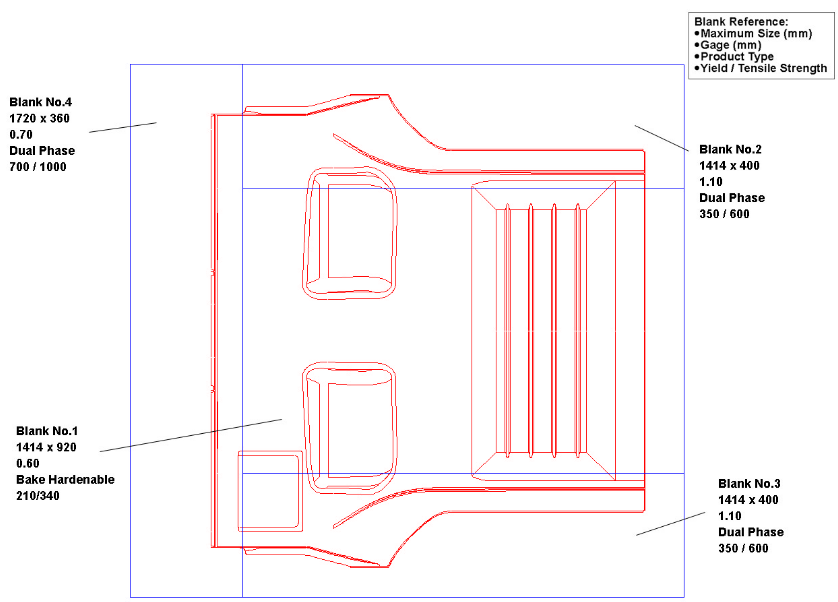


Figure 9.9.1-3 AVC 21069 Floor Rear

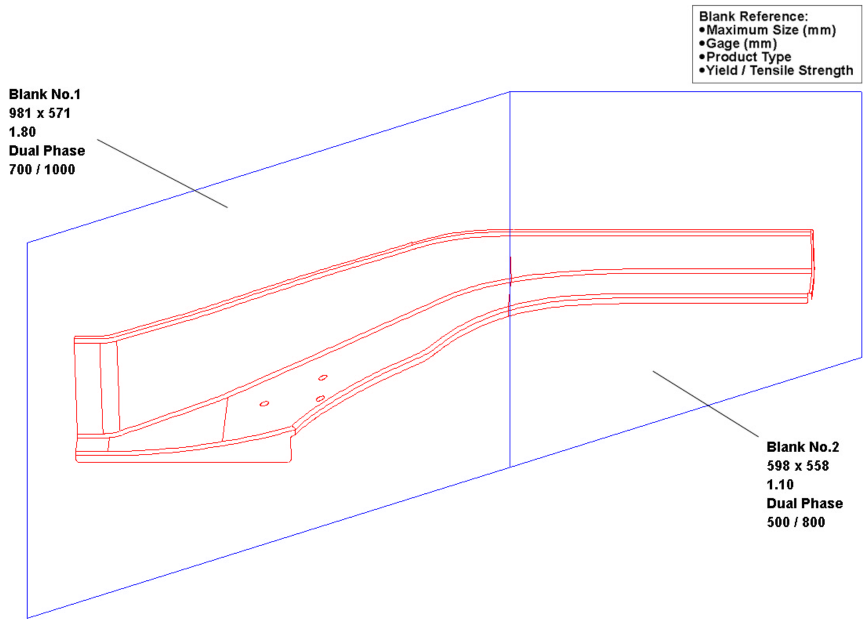


Figure 9.9.1-4 AVC 21076/77 Rear Rail RH/LH

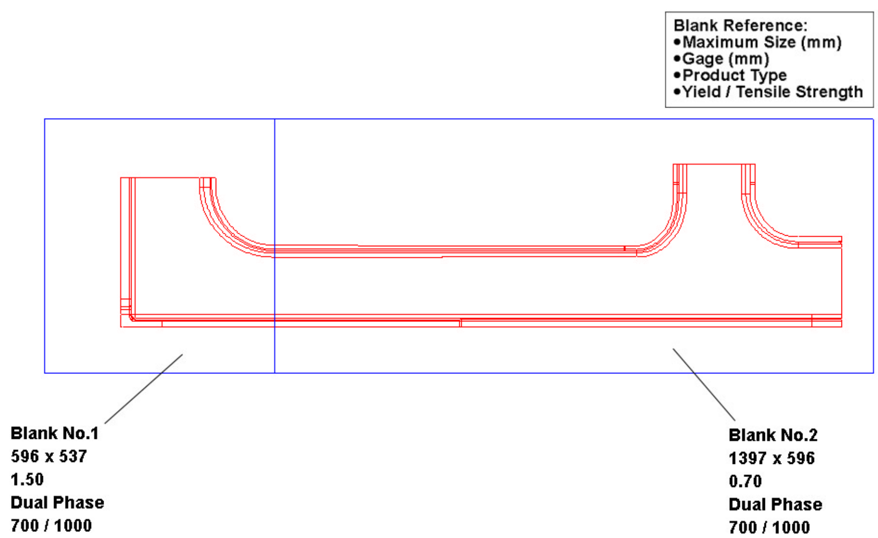


Figure 9.9.1-5 AVC 21086/87 Rocker Inner RH/LH

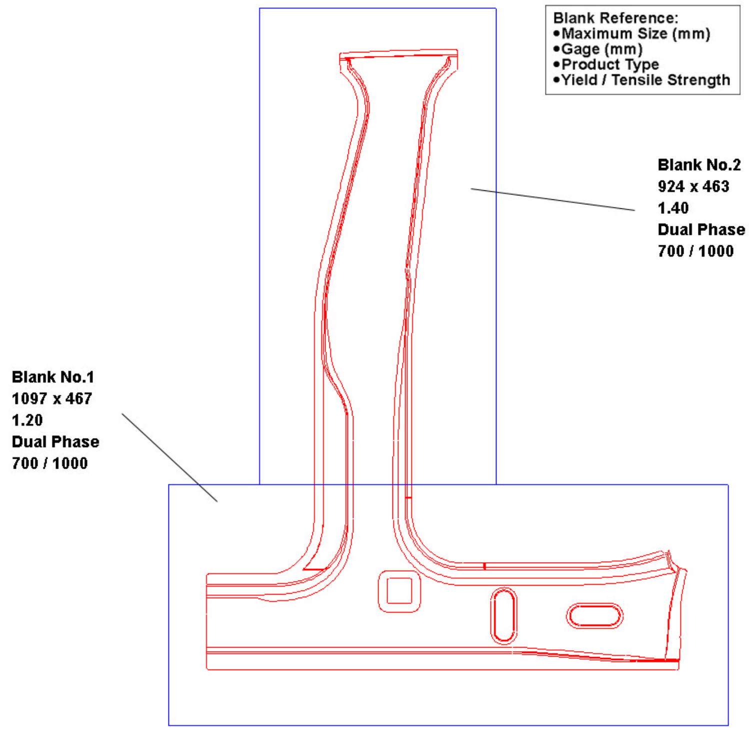


Figure 9.9.1-6 AVC 21220/21 Reinforcement B-pillar Rocker Rear RH/LH

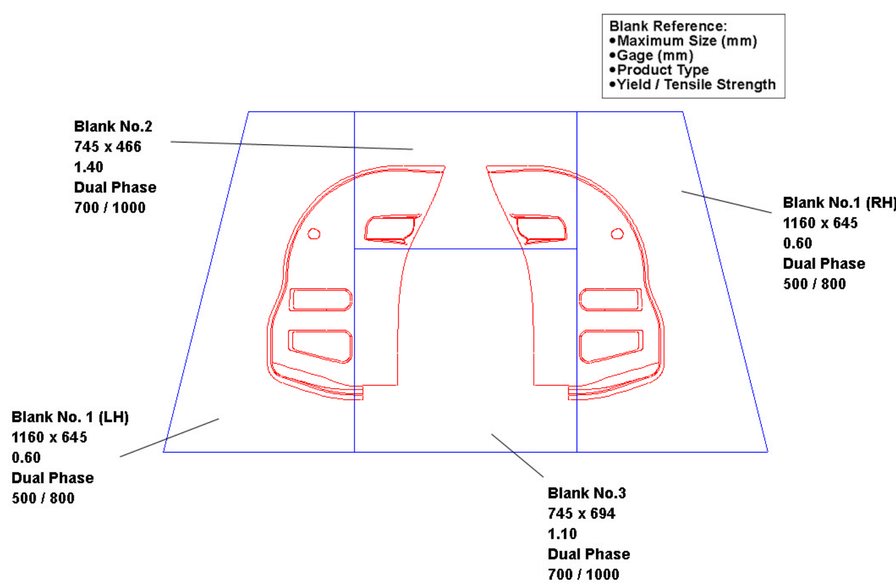


Figure 9.9.1-7 AVC 31036/37 Wheelhouse Inner RH/LH

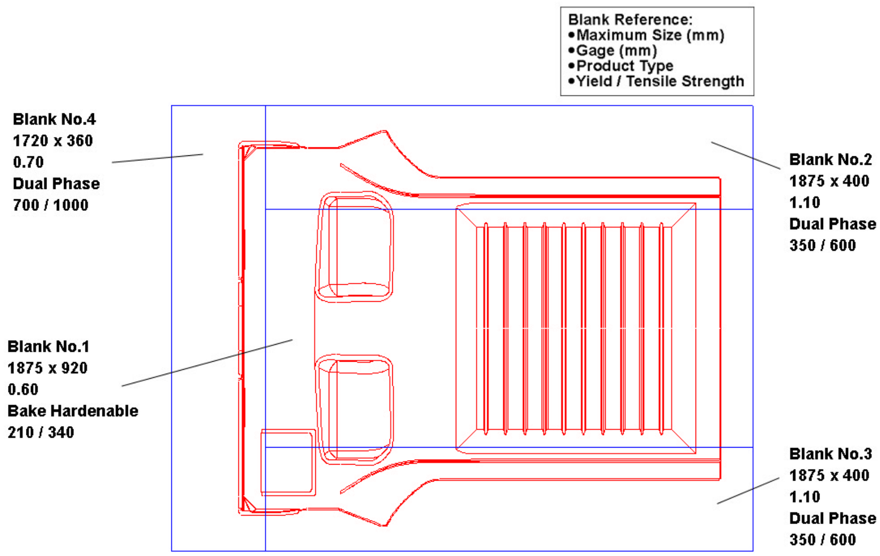


Figure 9.9.1-8 AVC 31069 Floor Rear

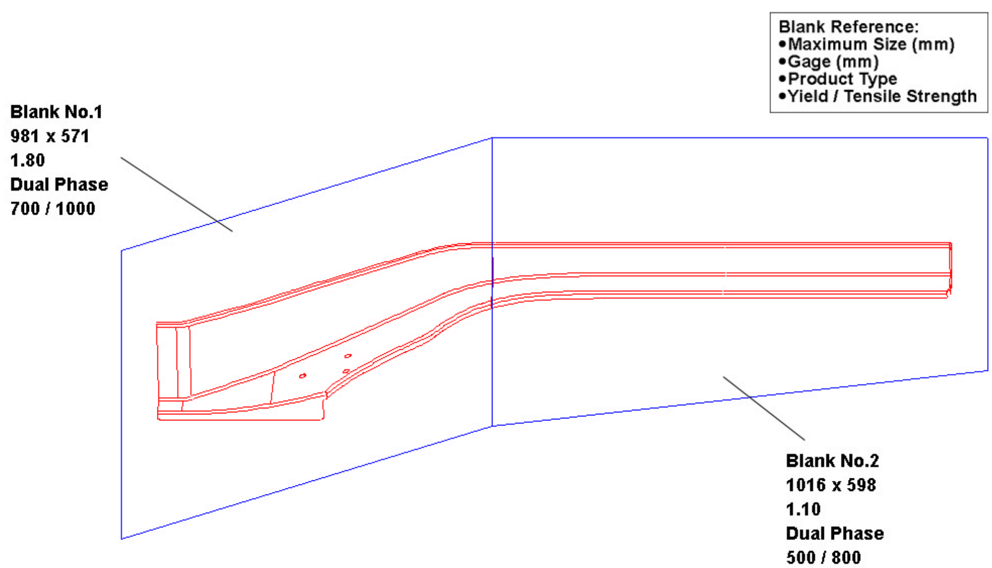


Figure 9.9.1-9 AVC 31076/77 Rail Rear RH/LH

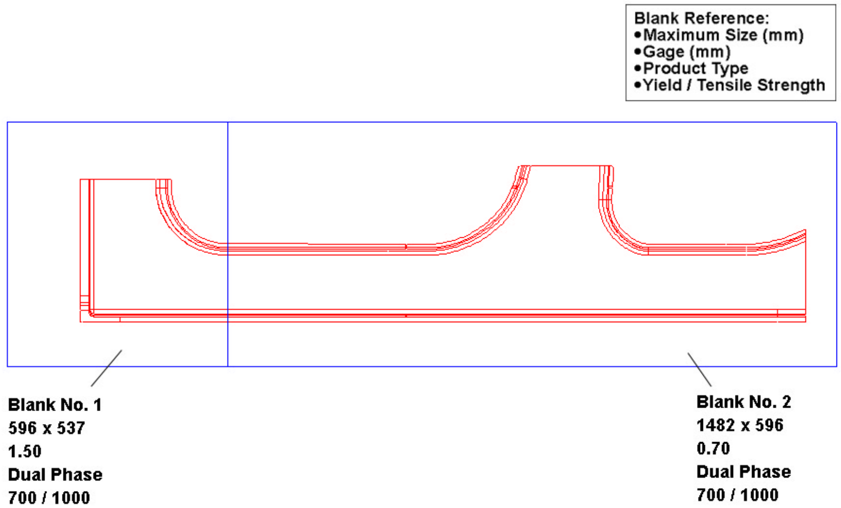


Figure 9.9.1-10 AVC 31162/63 Rocker Inner RH/LH

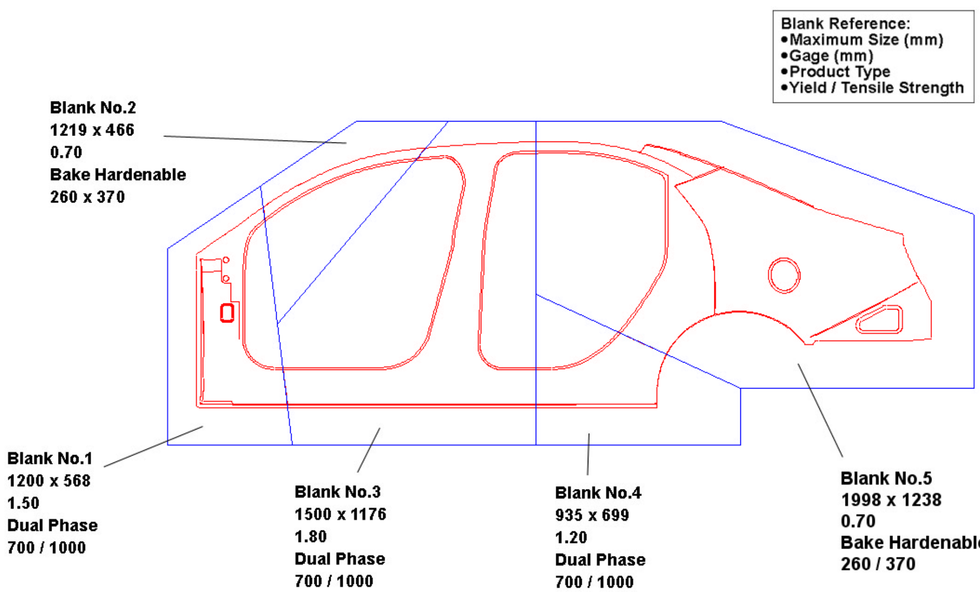


Figure 9.9.1-11 AVC 31170/71 Body Side Outer RH/LH

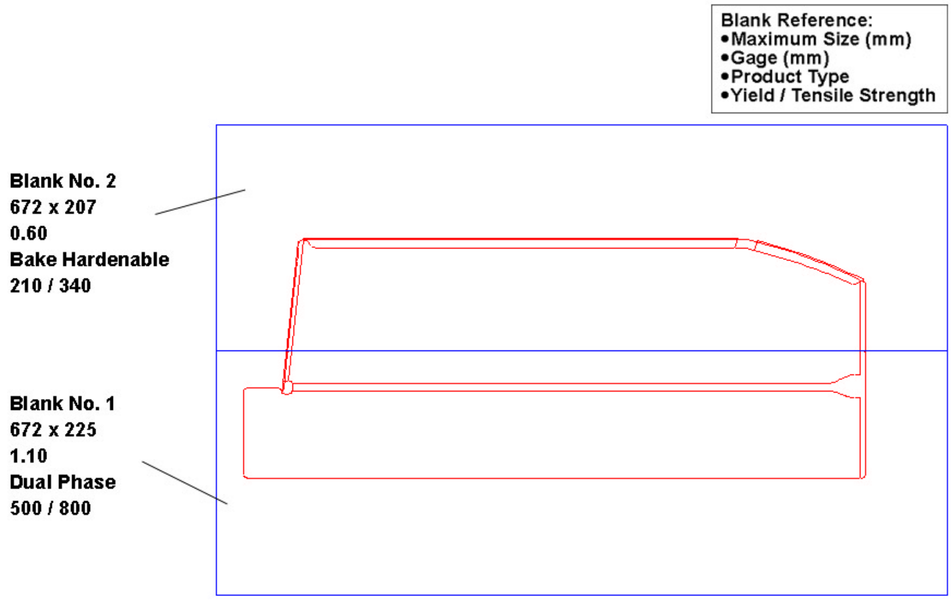


Figure 9.9.1-12 AVC 31188/89 Rail Rear Outer Floor Extension RH/LH

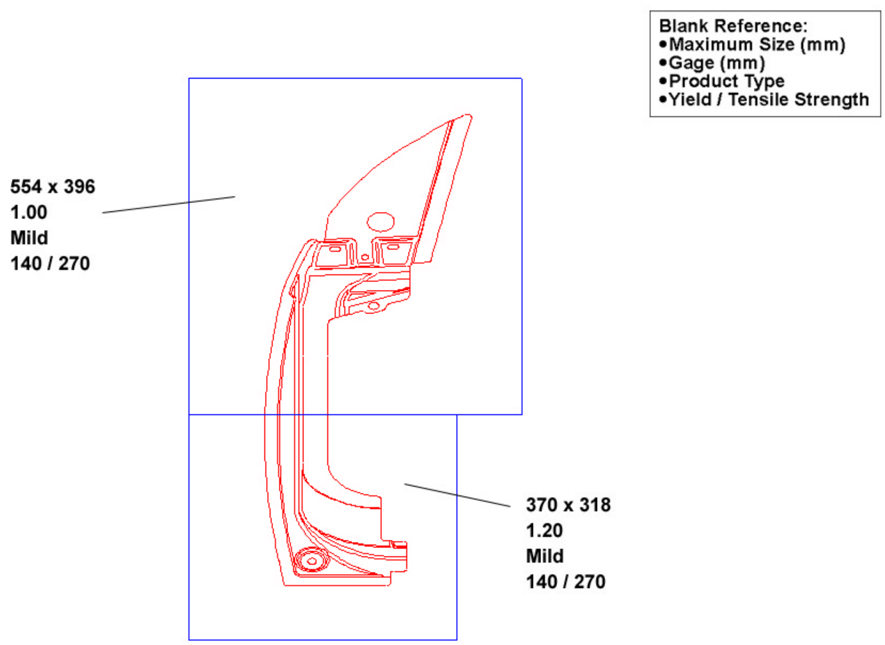


Figure 9.9.1-13 AVC 12020 Front Door Inner Front RH/LH

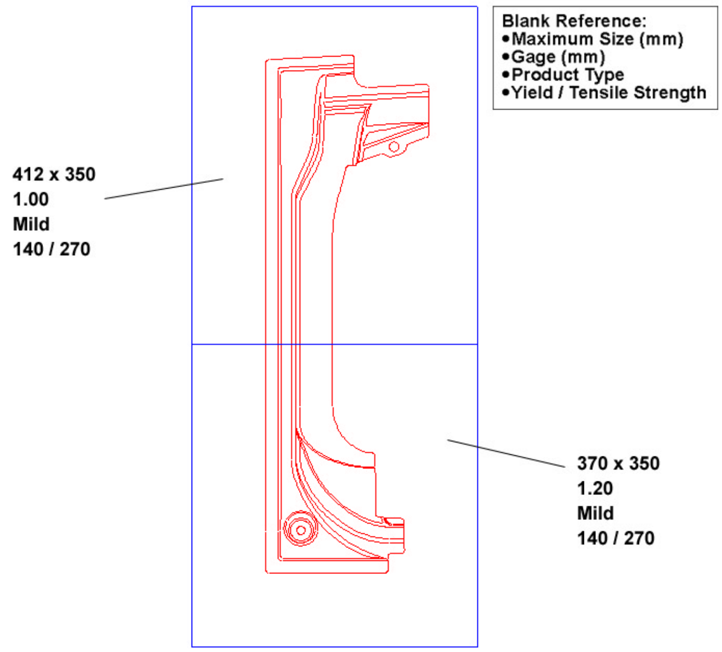


Figure 9.9.1-14 AVC 32034 Rear Door Inner Front RH/LH

Unique to ULSAB-AVC, tailor welded blanks were chosen for specific chassis components. The suspension's upper and lower wishbones were designed in this way for mass optimization. Details of these suspension parts can be found in Chapter 7 - Chassis and Suspension Concepts.

9.9.2. Hydroforming

9.9.2.1. Tubular Hydroforming

Valuable experience was gained with tubular hydroformed parts on the ULSAB side roof rail and on ULSAC (hinge and latch tubes). These applications have shown high structural efficiency and structural members made from hydroformed steel tubes have now gained acceptance as enablers for optimized load flow.

The ULSAB-AVC front rails (see Figure 9.9.2.1-1) are designed as hydroformed parts. The structural efficiency of these AHSS hydroformed components was enhanced by using tailor welded tubes (TWT), that is tube sections made of the same grade and diameter, but different thicknesses.

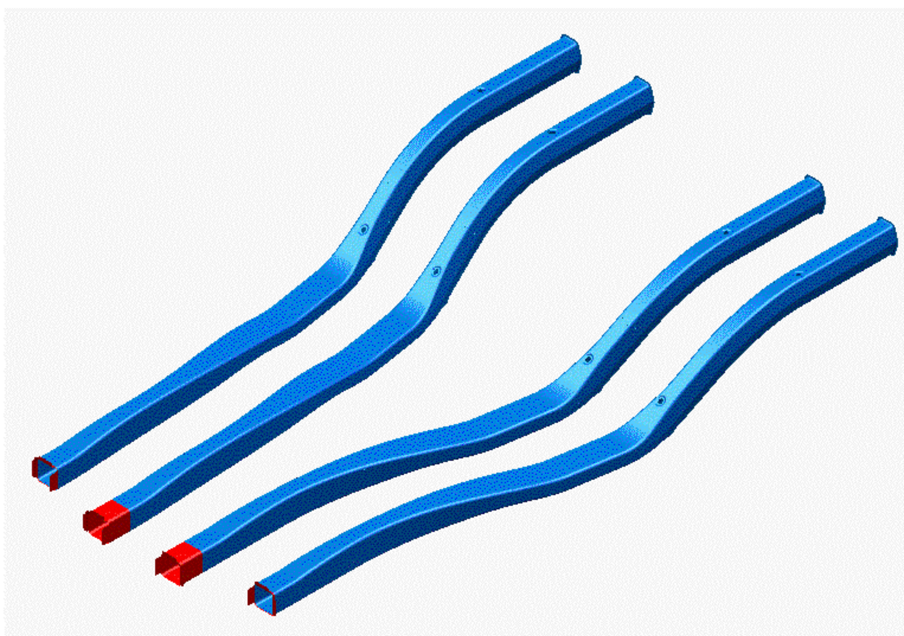


Figure 9.9.2.1-1 Members rail front (RH/LH)

In Section 9.8, Figures 9.8-1 and 9.8-2, all tubular parts on the ULSAB-AVC –except for the chassis area- were shown already.

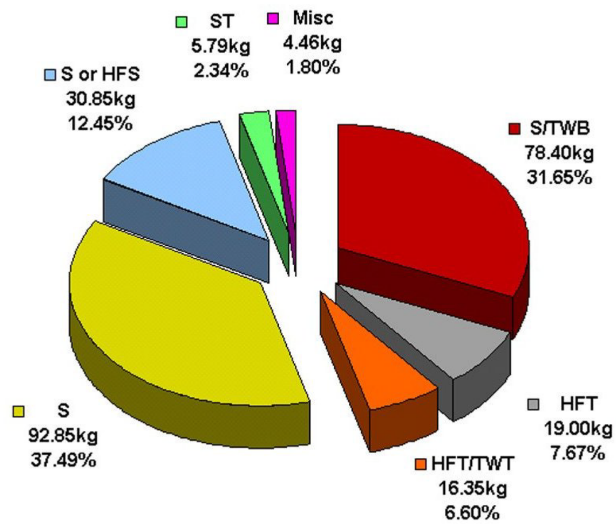
Furthermore hydroforming – both single thickness and tailor welded tubes – was used for subframe, trailing arm and twist beam rear axle. Detailed descriptions of these components can be found in Chapter 7 - Chassis Concepts.

9.9.2.2. Sheet Hydroforming

The Active Hydromechanical (AHM) sheet hydroforming process, as already described in the ULSAC Engineering Report, was considered as an alternative to conventional stamping for the manufacture of the closure panels and all outer panels on the body structure (except the rear quarter panel). This emerging process allows for material thickness reduction with the application of AHSS (DP 350/600) to realize the desired dent resistance and oil canning performance. However, since there is no guarantee that this process will have matured to the stage of development compatible with cost effective, high volume manufacture by 2004, conventional stamping was also considered using AHSS. Consortium members (MWG) performed additional forming simulations to confirm that the closure panels and other outer body panels with the selected material thickness could be manufactured using conventional stamping techniques with DP350/600 grades. These incremental FEA simulations showed that > 1.5% major strains can be developed in the stamped parts with the given design. These strain levels are considered by the MWG to be satisfactory to provide the desired dent resistance and oil canning performance.

9.9.3. Summary of Manufacturing Processes

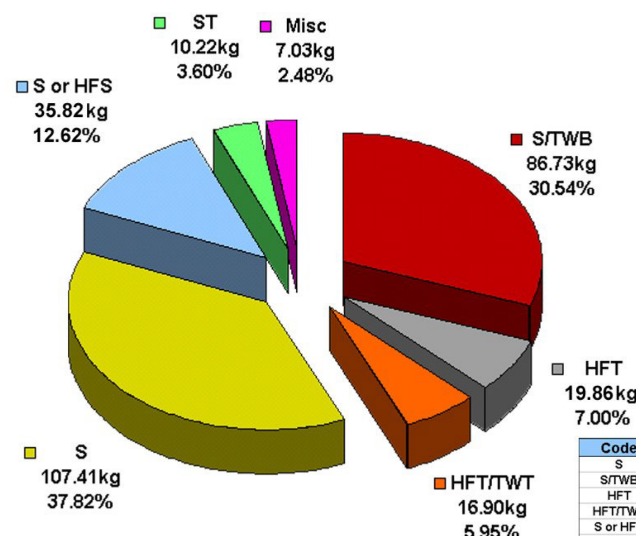
A breakdown of the manufacturing processes used for the ULSAB-AVC body and closure structures is shown in Figure 9.9.3-1. From this diagram, it is clear that in ULSAB-AVC there is a large proportion (> 30%) of tailor welded blanks. The percentage of tubular hydroformed parts, along with the relatively new use of tailor welded tubes for hydroforming applications amounts to approximately 7%. The percentile distribution of the manufacturing processes is very similar for C-Class and PNGV-Class.



Material Type	Mass [kg]
S/TWB	78.40
HFT	19.00
HFT/TWT	16.35
S	92.85
S or HFS	30.85
ST	5.79
Misc	4.46
Total	247.70

Code	Manufacturing Process
S	Stamped
S/TWB	Stamped / Tailor Welded Blanks
HFT	Hydroformed Tube
HFT/TWT	Hydroformed Tube / Tailor Welded Tubes
S or HFS	Stamped or Hydroformed Sheet
ST	Straight or Shaped Tube
Misc	Miscellaneous

Figure 9.9.3-1 Manufacturing Processes used on C-Class body structure and closures



Material Type	Mass [kg]
S/TWB	86.73
HFT	19.86
HFT/TWT	16.90
S	107.41
S or HFS	35.82
ST	10.22
Misc	7.03
Total	283.97

Code	Manufacturing Process
S	Stamped
S/TWB	Stamped / Tailor Welded Blanks
HFT	Hydroformed Tube
HFT/TWT	Hydroformed Tube / Tailor Welded Tubes
S or HFS	Stamped or Hydroformed Sheet
ST	Straight or Shaped Tube
Misc	Miscellaneous

Figure 9.9.3-2 Manufacturing Processes used on PNGV-Class body structure and closures

For the body structure only, the distribution of manufacturing processes is shown in Figure 9.9.3-3 and 9.9.3-4.

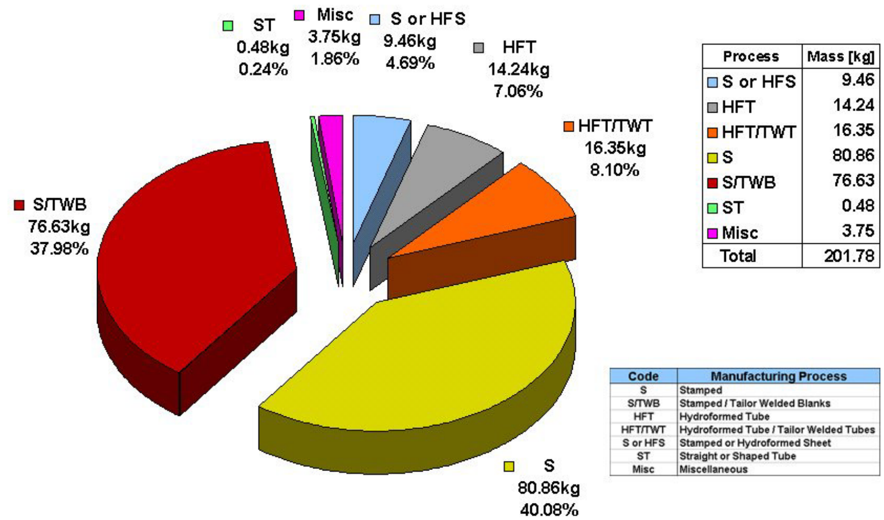


Figure 9.9.3-3 Manufacturing Processes used on C-Class body structure

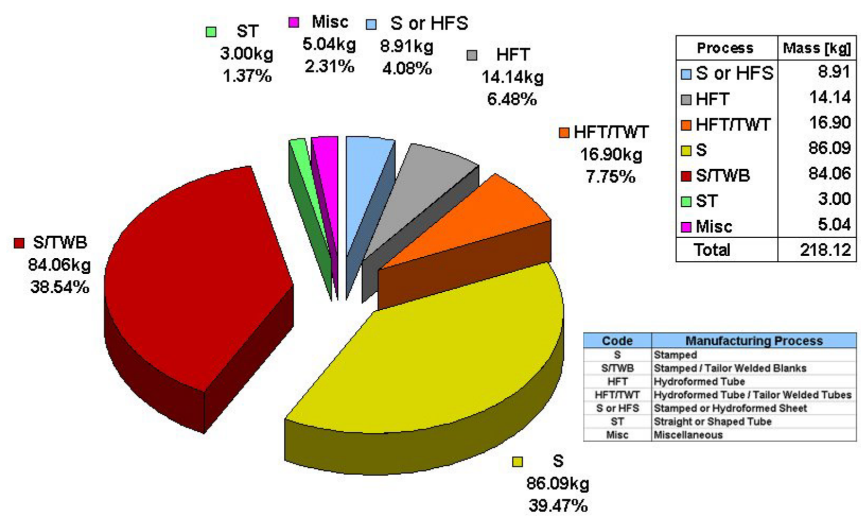


Figure 9.9.3-4 Manufacturing Processes used on PNGV-Class body structure

9.10. Joining Technologies

ULSAB-AVC relies on established arc-, spot-, and laser-welding technologies. Laser assembly welding, as demonstrated on both ULSAB and ULSAC, provides good structural performance and the ability to join components where only one side is accessible (such as joining stampings to tubes). Such technologies become essential when incorporating hydroformed parts or other closed sections in the vehicle structure. Only conventional laser welding was used on ULSAB-AVC. There may be a future potential for using the so-called "Remote Laser Welding" process, the first application of which has already been introduced by various OEMs. An additional advantage of this process will be that there is no movement of a robot or other similar device (e.g. gantry). This results in savings of manufacturing time and also reduces current limitations concerning accessibility for the laser head. On the other hand, this process requires that more effort and investment is assigned to clamping devices for accurate part alignment.

In the ULSAB-AVC body structure, the number of spot welds for each subassembly of the body structure is shown in the assembly process sheets (see Appendix). The total length of laser assembly welds on the C-Class body structure is 114 m and 100 m on the PNGV-Class, which is high when compared with present-day standards, but is required because of the high use of structural tubular parts where only single-side weld access is available. Significant laser welding also leads to a more effective use of weld stations.