SYLATECH

DESIGN | ENGINEERING | MANUFACTURING

Engineering your future

Aerospace | Defence | Space

Design Guide

For the Casting Process

Contents

Design Guide

Precision Investment Casting Process

This guide will enable the designer to take advantage of the technical and commercial benefits offered by the Sylatech casting process. Design ideas and considerations are included to help stimulate the design process.

Sylatech continues to develop its process to meet the ever more exacting market challenges. For any aspect not covered by this guide, please contact our Sales Engineers who will share their experience, offer advice and assist in the design of your components.

Since 1964 Sylatech has refined its techniques for excellence in the production of copper and aluminium alloy investment castings. Sylatech combines its impressive investment casting technology with best practice CNC machining, so allowing many of the constraints placed on engineering design to be overcome. This is all carried out within the BSI AS9100 Quality System.

Why use the Sylatech Casting Process

- Reduce overall costs by Designing for Manufacture: simplify an assembly by combining a number of parts, eliminate joining processes and reducing the part count whilst improving the integrity of the finished product.
- Reduce time to market through the use of Rapid Prototyping technology and obtain casting, machining, assembly and packaging from one source. Finished metal parts can be delivered from concept in under four weeks.
- Design flexibility, with quick modifications to tooling that costs 90% less than for a pressure die casting, whilst maintaining economic batch quantities of up to 150,000 parts per annum.
- High quality finish, detail and specification.

What the Sylatech Process can deliver

- Thin walls as fine as 0.2 mm (0.008”), typically 1-3 mm (0.04” – 0.12”).
- Light weight components, weighing as little as 1g can be produced using techniques to minimise material usage whilst retaining component integrity.
- Ideally a maximum size of 190 mm x 160 mm x 160 mm (8” x 6” x 6”). A length of 250 mm (10”) is possible providing no other dimension exceeds 100mm (4”). Larger sizes can be considered on a case by case basis.
- Complex detail on internal and external features.
- Super-fine surfaces with 0.8 micrometres (32 micro inches) being the “as cast” finish. Zero draft angle.

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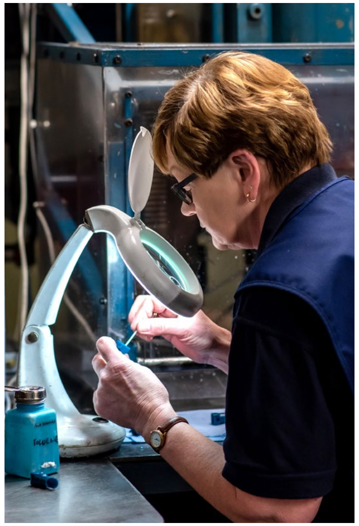
Design Considerations

2.1 Casting Tolerances

Tolerances depend on the geometry of each part, but the following tolerances are suggested as a guide to designers.

Lengths including hole diameters, held to:

mm		inch	
Length	Tolerance	Length	Tolerance
0 – 15	±0.08	0.0 – 0.6	±0.003
15 – 25	±0.13	0.6 – 1.0	±0.005
25 – 50	±0.25	1.0 – 2.0	±0.010
50 – 75	±0.37	2.0 – 3.0	±0.015
75 – 100	±0.50	3.0 – 4.0	±0.020
100 – 125	±0.60	4.0 – 5.0	±0.025
125 – 250	±1.00	5.0 – 10.0	±0.040



Flatness

Generally held to ±0.13mm (0.005") per 25 mm (1.00") square.

Straightness

Generally held to ±0.1 mm (0.004") max per linear 25 mm (1.00").

Squareness and Angularity

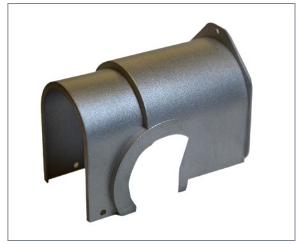
±0.5 degree
Note: Angular tolerances are affected by irregular geometries.

When tolerancing, use of a central feature as a datum may allow detail to be cast that would otherwise carry too large a tolerance. Where a mechanical interface feature is required on a surface, it helps to use the centre of the feature as a datum.

2.2 Wall Sections

Constant section thin walls are preferred but large changes of section can be accommodated through critical analysis of the component design and special tooling design features.

Size (cubed)	Suggested Wall thickness
up to 10mm (0.4")	0.2mm – 1.0mm (0.008" – 0.04")
25mm (1.0")	0.5mm – 1.5mm (0.02" – 0.06")
75mm (3.0")	1.0mm – 3.0mm (0.04" – 0.12")
100mm (4.0")	1.5mm – 3.0mm (0.06"– 0.12")
above 100mm (4.0")	2.0mm (0.08") upwards



Cast example of 1mm (0.040") wall thickness throughout

Cast example of thick and thin wall sections

Cast example incorporating ribs to improve flatness and rigidity

Wall thickness and flatness over large surfaces are better controlled if through-holes and ribs are incorporated in the design.

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Design Considerations

Wall Section Tolerances:

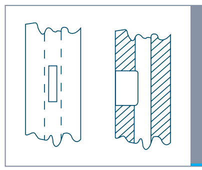
mm		inch	
Section	Tolerance	Section	Tolerance
up to 0.5	±0.10	up to 0.020	±0.004
0.5 – 1.0	±0.15	0.020 – 0.040	±0.006
1.0 – 2.0	±0.20	0.040 – 0.080	±0.008
2.0 – 4.0	±0.25	0.080 – 0.160	±0.010
4.0 – 8.0	±0.30	0.160 – 0.320	±0.012

Cast example incorporating holes to improve flatness and reduce weight

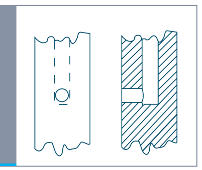
2.3 Cast Holes

The mould material used by the Sylatech casting process is applied as a slurry and is easily removed by water jets. This enables fine through holes of up to 0.8mm in diameter to be cast.

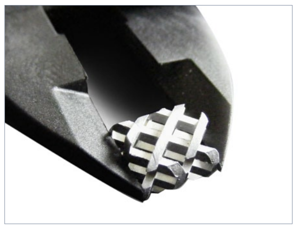
Long through holes may be cast if crossholes are provided to support the mould core during casting.



Examples of support using a slot



Examples of support using a side hole



This casting is a maze of holes. Its perfect surface is due to easy mould removal.

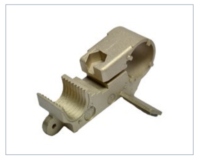
2.3 Cast Holes

Blind Holes

Blind holes can be cast provided the depth to diameter ratios do not exceed 3:1. Holes of under 0.5 mm (0.020") diameter are often cast.

Elongated Holes

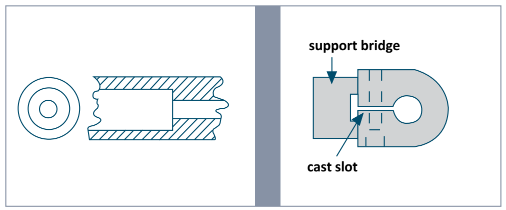
Elongated holes can easily be cast allowing the take up of tolerances within an assembly.



Threads

Threads are best not cast but provision of a hexagonal cavity around a bolt hole allows the use of a captive nut or bolt, removing the need to tap a hole.

Holes can also be cast which are suitable for self-tapping screws.



Examples of support using a counter bore

To reduce cost and improve accuracy a cast counter bore can be used in through hole applications where a tight tolerance is rarely needed over the full length.

Drill starts can be incorporated to aid drilling in cases where blind holes may be too long to cast.

Where a component is to be clamped to a shaft, a clamping slot can be cast, rather than machined. To make reaming of a through hole easier and more accurate a removable support bridge should be included.

Design Considerations

2.4 Daft Angles

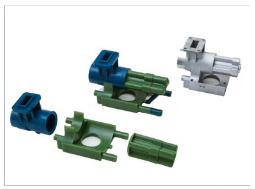
The Sylatech casting process does not normally require draft angles as the wax has a relatively low injection pressure, is self lubricating and has minimal shrinkage.

However, if investment casting is being employed to develop a component, which may eventually be produced in very large quantities as a pressure die casting, then draft angles can be incorporated to simulate those which will eventually be needed.

2.5 Special Features

Soluble Cores

Complex internal features such as swept bends can be formed by the use of soluble cores (orange wax). Tolerances however may require relaxing.



Wax Assembly

Tooling for a complex component can sometimes be simplified by joining two or more patterns together at the wax stage. This enables the requirement for brazing after casting to be eliminated.

Cast Gears and Teeth

Components requiring teeth for gripping or gear applications may be impossible to produce by machining. The definition achieved by the Sylatech process is ideal for these applications.

Integrally cast rivets can be peened over to give an economic, strong and permanent joint.

2.6 Surface Finishes

As Cast

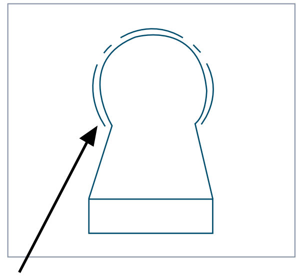
"As cast" - parts removed directly from the mould have a surface finish equal to or better than 0.8 micrometres (32 micro inches); this finish may show variable colour.

Chip Rumbling

Removes any sharp edges left after linishing, leaving a surface suitable for most subsequent "finishing" processes

Shot Blasting

Using stainless steel shot, is generally suitable for brass components and gives a slightly polished surface.



An example of highlighting a drawing to show important cosmetic surfaces

Glass Bead Blasting

Produces a more highly polished surface finish and is most suitable for aluminium parts.

Special Surface Effects

Such as textures and knurling can be incorporated within the Sylatech casting process.

Automatic Grit Blasting

Gives a uniform matt finish, suitable for most subsequent finishing operations.

Design Considerations

2.7 Integrated Labelling

It is possible to include many types of permanent product identification which can eliminate further need for labelling. Logos and text may be produced with minimum cost if the design ensures that detail is in the line of draw of the wax from its die.

Ideally, cast labels should use raised lettering on the casting face (engraved into the wax tool). Where such information must be below a functional surface, it can be sited on a pad sunk into the cast face.

Preferred depth of engraving:
0.25 mm – 0.50 mm
(0.010" – 0.020")

Types of Labels
Logos
Names
Numbers
Lettering
Direction
Instructions
Product ID
Part No.
Issue No.
ID for version traceability
Date code
Graduations
Raised pad for engraved serial no.
Label recess

Raised lettering/instructions

Label recess

Drg. no. and issue on sunken pad

Graduation markings

Sunken Lettering

Logo, no., date raised on sunken pad

2.8 Applied Surface Treatments

The following treatments can be applied:

Alocrom1200/1000/Chromate Conversion

Surtec 650 Roche complaint processes which provide corrosion resistance to aluminium parts whilst providing an electrically conductive surface.

Anodising

For protective purposes can be carried out on aluminium alloy castings but cast alloys do not readily accept decorative anodised finishes due to the silicon content.

Plating

Can be applied to most alloys.

Hipping (Hot Isostatic Pressing)

Is used to improve the mechanical properties of aluminium castings by sealing internal voids.

Impregnation

Can be carried out on "as cast" or machined parts where pressure tightness is essential.

Paint/Powder Coating

For protection or visual purposes.

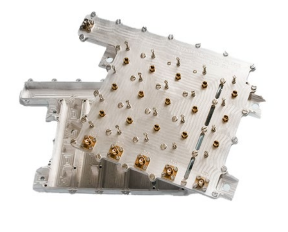
2.9 Heat Treatment

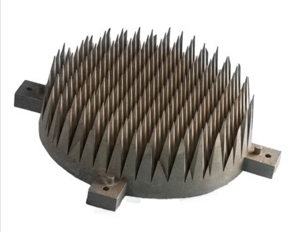
Various heat treatments can be applied to harden components. This is carried out generally to aid subsequent machining and enhance component stability.

Suffixes to the material grade are used to denote the heat treatment carried out: UK and equivalent USA and EN suffixes are shown below:

Treatments	UK	USA	EN
As cast/manufactured	M	F	F
Solution heat treated and stabilised	TB7	T4	T4
Artificially age hardened	TE	T5	T5
Solution heat treated and artificially age hardened	TF	T6	T6

Gallery


Microwave Filter Machined in Invar

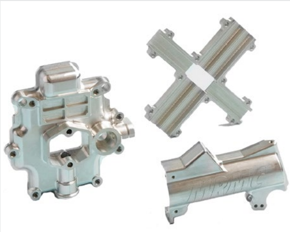

RF Component


Satellite 4 Port Horn


Railway Catenary Component


Baggage Carousel Component


Automotive Air Vent Fascia


Carburettor part, Microwave Filter & Camera Pedestal


90^{0} Conduit Bend Aerospace Sector


Automotive Light Housing


Timing Belt Adjuster


90^{0} Connector Bend Mining Sector


Model Aircraft Engine

- Our gallery demonstrates a range of quality components that we have created through our unique investment casting and machining capability
- We deliver a world-class product to our global customers
- Contact our sales engineers for expert advice on your engineering requirements.

bsi. AS/EN 9100 Series Aerospace

Nadcap Administered by PRI ACCREDITED

SHARING IN GROWTH

Metal Specifications

4.1 Aluminium Alloys

Mechanical Properties

Metal	UTS		0.2% Proof		Elong	BHN	Density
	N/mm²	TPSI	N/mm²	TPSI	%		
LM25M	130 150	8.0 10.0	80 100	5.0 6.5	2.0 3.0	55 65	2.68
LM25TF	230 280	15.0 18.0	200 250	13.0 16.0	0.0 2.0	90 100	2.68
LM25TB7	160	10.0	80 110	5.0 7.0	2.5	65 75	2.68
EN1706 ENAC 42000 T6	220	13.4	180	11.1	1	75	2.68
EN1706 ENAC 42000 F	140	8.6	80	4.9	2	50	2.68
2L99	230	14.8	185	12.0	2.0	80	2.68
A356T6	234	15.0	166	10.8	5.0	70 100	2.68
356F	130	8.4	120	8.0	2.0	55	2.68
356T6	207	13.3	138	8.9	3.0	70	2.68
356T7	214	13.8	126	8.1	3.0	75	2.68
356T51	159	10.2	110	7.1	3.0	60	2.68
356T71	172	11.1	124	8.0	3.0	60	2.68
C355.0 T6	240	14.8	175	10.8	3	80	2.71
40E	215	13.9	170	11.0	4.0	60 100	2.80
712	224	14.4	172	11.1	4.0	75	2.80
LM31	215	13.9	170	11.0	4.0	60 100	2.68

Comparison with International Specifications

BSI1490	ISO	France	Germany	USA	Aerospace
LM25	AlSi7Mg	A-S7g	G-AlSi7Mg	A356	BS2L99 BSL173 BSL174

Comparison of LM25 physical properties with 6061 & 6082 wrought aluminium

	LM25	6061	6082
Thermal Conductivity (% IACS)	38.4	39.6	43.7
Coefficient of linear expansion (20-100° C)	22×10^{-6}	24×10^{-6}	23×10^{-6}
Electrical Conductivity (%IACS @ 20°C)	39	43.1	43.7
Hardness (Brinell)	60 – 105	60 – 100	60 -100
Modulus of Elasticity	71	69	69

Please note that further alloys are available on request.

Standard Aluminium Alloys

Silicon Magnesium Series

These alloys are the best general purpose high strength cast alloys available and can be supplied with a variety of heat treatments. They also have good salt water corrosion resistance and can be anodised to produce a thick black colour. Decorative anodising is not possible due to the metallic silicon content.

A356 – An American specification that is is generally made available to meet the requirements of the American Military.

LM25 – Our most commonly used cast aluminium alloy and can be supplied as cast or heat treated.

2L99 – This is a more tightly controlled version of LM25 for aerospace applications.

Zinc Magnesium Series

These alloys are less easy to cast because of their high viscosity in the liquid state.

40E – This alloy is particularly suitable for castings which require flame or dip brazing. Components using this material should have uniform wall sections. To achieve corrosion resistance an additional surface treatment such as anodising or chromatic conversion is necessary. The material machines very well and is self-aging at room temperature, therefore hardening and strengthening over about three weeks.

712/LM31 – These alloys are similar to 40E and are often specified for defence and space applications.

Aluminium and copper alloys are non-magnetic whilst retaining excellent thermal and electrical conductivity. This is becoming of increasing importance in numerous applications.

Metal Specifications

4.1 Copper Alloys

Some modern copper alloys have properties equal to or better than the more commonly specified steels. In respect of corrosion resistance copper, gun metal or aluminium bronze is often superior to stainless steel particularly in low oxygen environments. Certain high specification aluminium bronzes have extremely high wear resistance and good anti-galling properties.

Mechanical Properties

Metal	UTS		0.2% Proof		Elong	BHN	Density
	N/mm²	TPSI	N/mm²	TPSI	%		
Silicon Brass MB1	479	31	200	13	25	70 100	8.5
Aluminium Bronze AB2	640	41	250	16	13	140 190	8.3
Manganese Bronze HTB1	470	30	170	11	18	150	8.4
Manganese Bronze HTB3	740	48	400	26	11	190	8.4
Die Casting Brass DCB3	290	19	90	6	15	60 70	8.4
Silver Bronze SB1	450	30	180	11	5	100 130	8.7

MM Spec.	BS1400	France	Germany	USA
MB1	-	-	-	ASTM B584 & C87500
AB2	AB2	-	DIN1714	ASTM B148
HTB1	HTB1	-	DIN1709	ASTM B147
HTB3	HTB3	-	DIN1709	ASTM B147
DCB3	DCB3	NF A 53-703	69	-

Please note that further alloys are available on request.

Copper Alloys

Silicon Brass-MB1

The most commonly cast copper alloy. It offers high wear resistance particularly in well-lubricated conditions. Silicon aids fluidity during the casting process, increases the tensile strength by approximately 50% compared with normal copper-zinc alloys, and promotes resistance to dezincification. MB1 is a viable alternative to mild steel for many applications.

Aluminium Bronze-AB2

This alloy is noted for its corrosion resistance, good tensile strength, and retention of its properties at higher temperatures. The oxide film which forms on the liquid material requires the use of relatively high cost pouring systems.

Manganeze Bronze-HTB3

A highly alloyed brass which offers higher tensile strength and loadings than MB1, but lower elongation. The tendency to produce zinc dross, when in the liquid state, leads to a lower surface finish than MB1.

Manganeze Bronze-HTB1

A medium strength alloy suitable for soldering. It offers good machineability.

Die Casting Brass-DCB3

A low strength material also suitable for soldering. It offers good machineability.

Silver Bronze-SB1

This unusual silver coloured material is an alloy of copper/nickel/manganese, with high resistance to salt water corrosion and erosion. The alloy is difficult to handle and should only be specified in premium applications and after consultation.

Tooling

A tool body is made from aluminium. Moving parts in the tool are produced in brass or steel to prolong their life and maintain accuracy. Design changes can be made quickly, particularly when material is added to the component, as metal is removed from the die.

- Try to specify quantity requirements at the enquiry stage so that the number of impressions and the degree of automation is considered at the outset.
- If the design is not finalised, the production of a rapid prototype part or a prototype single impression tool will help to establish the design prior to going to more complex tooling for high volume.
- Tooling can normally be produced in 2-5 weeks.

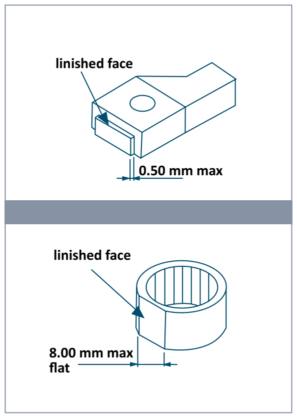
Reduce tooling costs by keeping as much detail as possible in the line of draw.

5.1 Gate Witness

"In-gates" are required where the metal feeds into the component.

The part should ideally be fed in an area where the gate can be removed by linishing to leave a witness of up to 0.5 mm (0.020") which does not affect the functionality of the component.

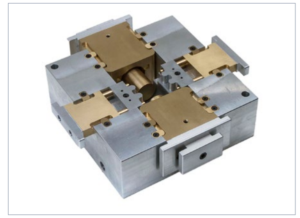
On machined castings, this witness may be removed during the machining process but the position and size of the witness should be agreed.



5.2 Types of Tools

Manual Tooling

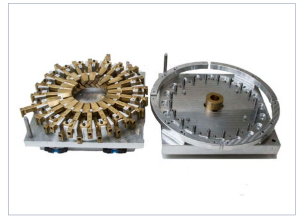
Where volumes are unlikely to exceed 1000 off per annum, manual tooling will normally be used. Tooling cost is minimised without compromising on quality.



Manual tool

Automatic Tooling

This type of tooling is useful for parts where high quantities are needed. Automatic core operation and ejection of the wax from the die ensures rapid production and repeatability throughout the life of the part.



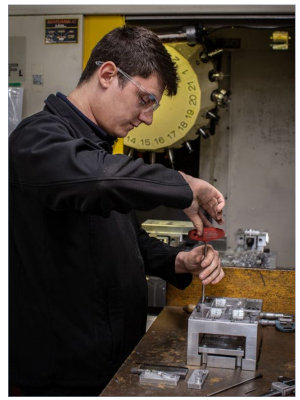
Collapsible multi-part core

Multi-Part Coring

Internal features can be produced in manual tooling by using split cores. Complex parts of this type may run to quantities in excess of 5000 per annum.

Multi-Impression Tooling

Smaller items may be ordered in quantities from 50,000 per annum upwards. The use of automatic tooling with multiple impressions enables parts to be made quickly and economically, without sacrificing detail.

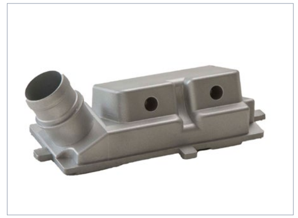


Machining

The machining of castings requires a different approach to the machining of wrought metal components. Castings are never totally flat, square, round or straight. A secondary datum system may be required to define the machining requirements.

When a flat face is required, add material to the casting to give a machining allowance.

When fixtures are necessary to hold the part for machining, the target datum points (see Datum Systems) will be used to set the casting to establish start points for machining.



Holes may be cast to provide location points

Renishaw Probes

Sylatech's machining centres are fitted with Renishaw probes. Probing establishes the position of detail prior to machining. Cast datums have to be established from "touch points" and probing those points produces accurate machining, repeatable from component to component.

Reaming

Due to the lead angle on reamers, blind holes cannot be reamed to full depth. Holes with full depth tolerance will need boring, which usually adds cost.

De-Burring

Where castings require machining on faces, bosses or any type of raised edge, chamfers cast round the periphery help to minimise de-burring operations and so reduce cost. This also applies to feed gates which are to be removed by machining. Setting them on a pad 0.5 mm (0.020") high with chamfers minimises the need for de-burring.

On parts with no obvious location areas for machining, machined lugs should be added for holding the casting. These can be removed completely with a secondary machining operation.

Tapping

Cast holes can be tapped without pre-machining. Lead-in chamfers on cast holes aid tapping.

Rapid Prototyping

Sylatech uses 3D printing to produce sample metal prototype parts for its customers, allowing them to test their designs without having to invest in tooling ahead of investment casting. This yields significant time and cost savings as fewer tooling modifications are necessary.

Our 3D prototyping capability, coupled with our investment casting process, delivers high accuracy castings with ultra-fine detail and a smooth surface finish. Rapid prototype components can also be CNC machined as required.

Benefits of 3D Printing

- Flexibility in the product design lifecycle
- Accelerated placement of tooling orders
- Reduced level of tooling modifications
- Time and cost savings

Working with STL or SLC models, it is possible to deliver a physical metal cast prototype part to our customers within 72 hours. This affords designers and engineers the ability to have actual components to test and validate their design fit.

Inspection/Quality Assurance

Sylatech Limited is approved to AS9100C.
Certificate # - FS642580
Nadcap Welding. Certificate - #FS 642580

8.1 Control Techniques

- Inspection techniques and metal fault criteria can be agreed with the customer at the development stage.
- A well designed casting will meet AMS 2175 Grade B or C dependent on wall thickness and variation in sections.
- Leak testing can be carried out as necessary.
- Dye penetrant testing is carried out to customer requirements by operators trained to PCN GEN ISS 10 2014, (British Institute of Non Destructive Testing).
- Fully automatic co-ordinate measuring machine (CMM) with statistical process control (SPC) software.
- Mechanical/destructive testing carried out to suit relevant material standards.

8.2 Inspection Criteria

- We can specify suitable machining/measurement co-ordinate datum systems where necessary (see Appendix: Datum systems).
- Ensure that key characteristics (and method of measurement) are agreed prior to production commencing.
- Agree control measurements for production.
- Agree touch points for machining and co-ordinate measuring machine.

Supply of Design Information

Electronically

Drawings or files can be taken on Solid Works or other and compatible CAD packages via e-mail. These can be modified and returned with suggestions. Solid model or 3D wire frame information is preferred.
Files can be accepted in different formats but the most widely used are IGES and DXF.

Hard Copy

2D drawings can be used, these will be converted to CAD as the need arises.

Sketch/Sample

Sketches or samples can be used to give budget prices and allow discussion on design changes to make the parts suitable for our process.

For more information or enquiries you can contact us here.

E: engineer@sylatech.com

T: +44 (0) 1751 432 355

Appendix: Datum Systems

A datum is a theoretically exact geometric reference such as an axis, plane or straight line, etc, to which tolerance features are related (BS8888). A group of two or more datums used as a reference for a toleranced feature is referred to as a datum system.

For the unambiguous manufacture and subsequent inspection of a part, there must be a system of measurement co-ordinates, defined by a datum system agreed between the customer and Sylatech prior to manufacture.

A co-ordinate system with 3 mutually perpendicular axes controls six degrees of freedom, X origin, Y origin, Z origin, roll (X rotation), pitch (Y rotation) and yaw (Z rotation), by the following datums:

- A datum plane – say the X-Y plane, which defines the Z origin, pitch and roll.
- A datum line – in the X-Y plane along Y to define the X origin and yaw.
- A datum point – along the Y axis to define the Y origin.

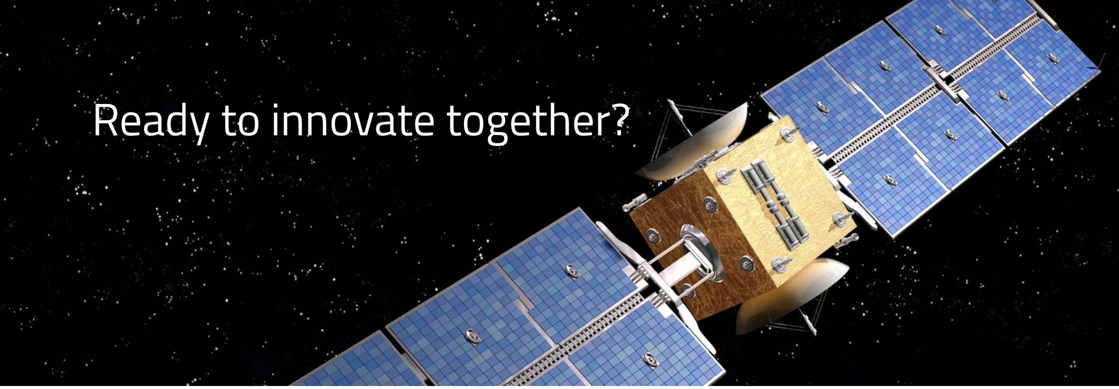
Establishing the Datums

A datum feature is a real feature of a part (e.g. an edge, a flat or a cylindrical surface) which is used to locate a datum. Any datum feature has a dimensional variation and depending on the required part tolerance, accurate measurements may not be possible. Cast surfaces exhibit such variation and to minimize this datum targets are required. A datum target may be a point, a line or a localised area, usually a few mm across. They are the key touch points for machining jigs and inspection equipment, and provide a co-ordinate system as follows:

- The datum plane is defined by three datum targets (touch points), spaced as widely as possible.
- The datum line is defined by two datum targets (touch points) again well spaced.
- The datum point is defined by one datum target (touch point).

Datum targets should be chosen to be accessible, to avoid fillets, split lines or other potential casting defects, and may be incorporated as deliberately cast features.

Where new datums are machined for subsequent operations, it must be clear as to whether these form a system which is subsidiary to the original master set and related to it, or whether they will form a new (unrelated) master set.



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To engineer the future of our team and customers, through the delivery of world-leading precision engineering solutions, assemblies and components.

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Sylatech is home to a committed team who hold a shared sense of purpose and are focused on working together to deliver to our customers. Maintaining the spirit of teamwork is at the heart of everything we do, and we encourage involvement to make a difference and achieve success.

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