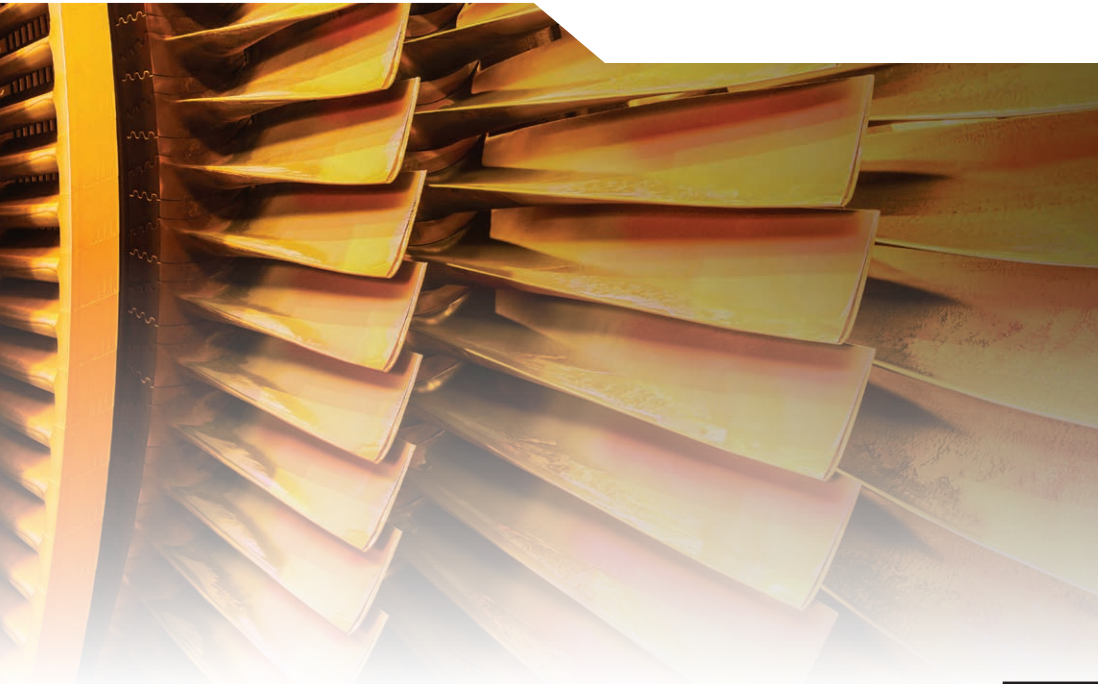


---

# SUPER-NICKEL ALLOY CASTINGS

---

THE MOST SOPHISTICATED MATERIALS  
FOR HIGH TEMPERATURE APPLICATIONS



GOODWIN STEEL CASTINGS LTD

ESTABLISHED 1883



## NICKEL ALLOY CASTINGS

Goodwin has been a highly regarded producer of nickel alloy castings for over 30 years and has a supply record of over 5,700 tonnes of nickel alloy castings, ingot and revert material. Consequently, both our customers and end users benefit from our proven technical expertise providing on time, to specification components at highly competitive pricing from our manufacturing base in central England.

The traditional market for nickel alloy castings has been principally the petro-chemical industry. Nevertheless power generation is a significant and growing sector where Goodwin is a world leader in research and production of super nickel alloy castings. Projects in this sector have included the manufacture of very heavy section castings for advanced high efficiency gas turbines, full scale demonstration steam turbine castings for advanced ultra-super (A-USC) critical steam plant, and CO<sub>2</sub> pilot plant components.

Goodwin has been responsible for the manufacture of A-USC technology test loop nickel alloy components for both the European and the Japanese national projects where heavy section castings were produced and operated at service conditions and evaluated.

**“Customers and end users will benefit from our proven technical expertise in providing on time, to specification components at highly competitive pricing.”**

Alloy 625  
Steam Gland  
produced from  
two castings and  
fabrication of  
associated pipe  
work and filter;  
(weight 3,000kg)





## STEAM GLAND CASTING

**Material:** Alloy 625

**Application:** GE 9H high efficiency gas turbine - one half of the steam gland casting during dimensional inspection.

Fire Point

[www.goodwinsteelcastings.com](http://www.goodwinsteelcastings.com)





Our collaboration has extended to all leading European and Asian nickel alloy casting development projects, where castings have been successfully produced in both solid solution strengthened and precipitation hardened nickel alloys with enhanced creep rupture life.

Successful manufacture of nickel alloy castings and cast assemblies present very different technical challenges compared to the production of steel castings. These include understanding solidification characteristics and segregation, under riser stress cracking phenomena, processing technology, welding and machining, all of which differ greatly in complexity and difficulty when compared with conventional steel casting manufacture.

For heavy section nickel alloy castings, Goodwin utilises an advanced induction feeder technology, which controls alloy solidification and subsequent cooling to prevent under riser cracking. This system has been used to successfully produce some of the world's largest and thickest section alloy 625 and 617 castings.

**“Our collaboration has extended to all leading European and Asian nickel alloy castings development projects.”**



#### TEST CAN CASTING

**Material:** Alloy 625

**Largest Section Size:** 100mm

**Weight:** 900kg

**Application:** Castings for the Japanese A-USC national project test loop.

#### NET POWER CASTINGS

**Material:** Alloy 625 and Toshiba TOS-3X\*

**Largest Section Size:** 150mm

**Weight:** 2,500kg each

**Application:** Exhaust casing castings for the 25MW Toshiba/Net Power CO<sub>2</sub> Turbine.



\*TOS-3X is a proprietary material of the Toshiba Corporation



GG35175  
617  
TG 2



### NOZZLE BOX CASTINGS

**Material:** Alloy 625 and 617

**Weight:** 1,500kg

**Application:** Japanese National A-USC Project – castings used for material characterisation.

[www.goodwinsteelcastings.com](http://www.goodwinsteelcastings.com)





## GOODWIN NICKEL ALLOY RESEARCH & DEVELOPMENT

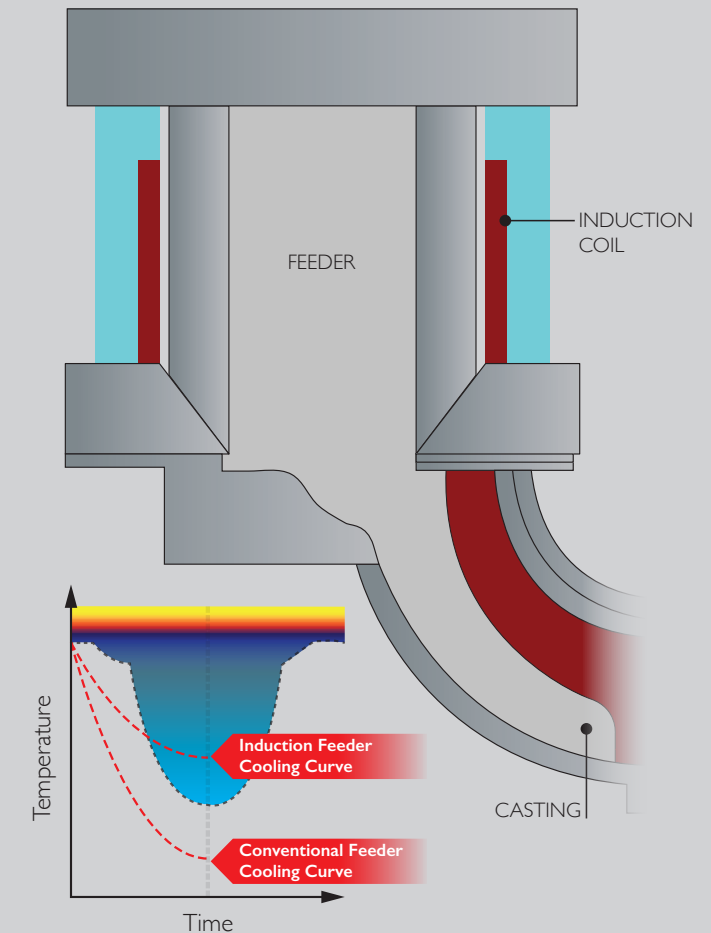
Goodwin has collaborated within many of the world's leading advanced turbine projects (A-USC technology), which has resulted in the manufacture of some of the largest nickel alloy castings for applications that include A-USC steam power plant, gas turbine and more recently the world's first CO<sub>2</sub> turbine pilot plant.

For the successful production of heavy section nickel alloy castings Goodwin has developed and patented innovative technology called the induction feeder system, where an induction coil can be positioned around casting feeders and is used to control cooling and subsequent solidification stresses.

By the controlled cooling of the casting feeders, the induction system reduces stress concentrations which result from temperature differences across the feeder's section, which is exaggerated in nickel alloys due to their poor thermal conductivity. Without such a system, the stresses result in unacceptable under feeder cracking defects.



Use of the Induction Feeder System.



Schematic of the Goodwin Induction Feeder System



TM3030  
Tabletop Microscope

HITACHI

Scanning Electron Microscope up to  $\times 30,000$  magnification. Equipped with EDX facility for both matrix and pin point chemical analysis.

[www.goodwinsteelcastings.com](http://www.goodwinsteelcastings.com)





Upscaling nickel alloy casting section sizes while maintaining acceptable metallurgical properties and casting quality requires a high level of technical foundry and metallurgical competence.

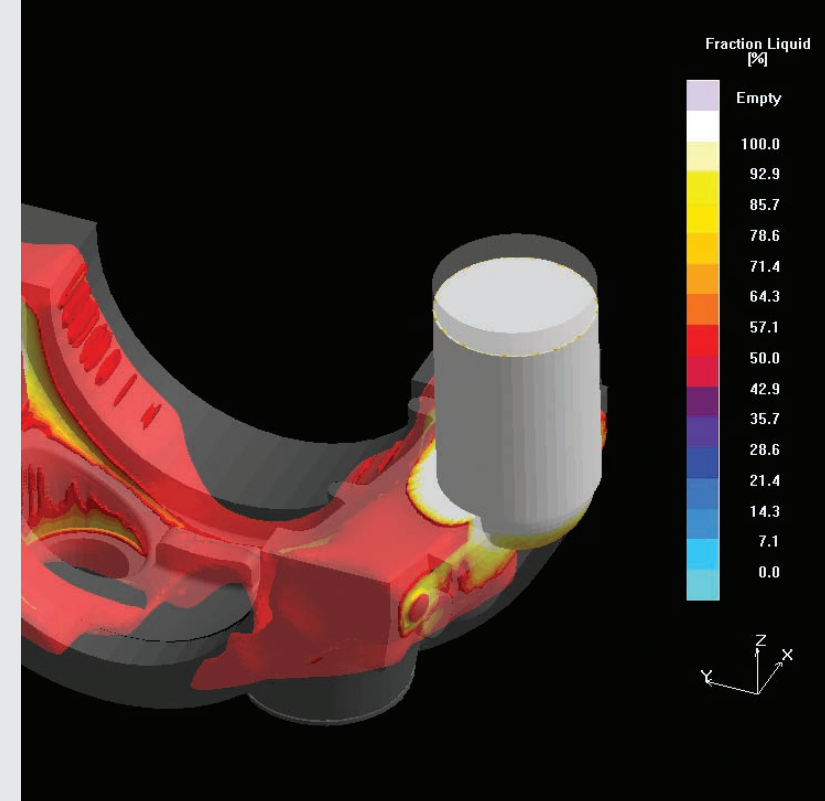
The techniques used for the production of small thin section castings are very different from the special disciplines required for successful heavy section casting manufacture.

This 10,500kg high pressure turbine casing featured opposite is the heaviest section nickel alloy casting poured to date and was produced using the induction feeder system where the solidification of the casting and subsequent solid state cooling is carefully controlled.

This technique is essential for castings of this scale to ensure acceptable casting quality.

Volumetric non destructive testing is performed by x-ray as ultrasonic inspection cannot be used for nickel alloy castings. For sections above approx 100mm, only radiographic techniques which involve high energy radiation can be utilised.

Solidification Simulation using Magmasoft™



10,500kg Alloy 625 HP Casing during quality heat treatment.





**LARGE STEAM TURBINE  
HIGH PRESSURE CASING**

**Material:** Alloy 625

**Largest Section Size:** >425mm

**Weight:** 10,500kg

**Application:** Casting for the Japanese A-USC national project.



Welding of nickel alloys is known to be more difficult than welding of conventional steels such as carbon, low alloy and stainless steels.

However, in general solid solution strengthened nickel alloys are easier to weld than precipitation hardened nickel alloys.

Goodwin has vast experience of welding nickel alloys in both light and heavy section via various techniques such as SMAW, SAW, and GTAW.

Dissimilar joints combining heavy section nickel alloy welds to steels have been produced, and nickel overlays to dissimilar materials are routinely performed.

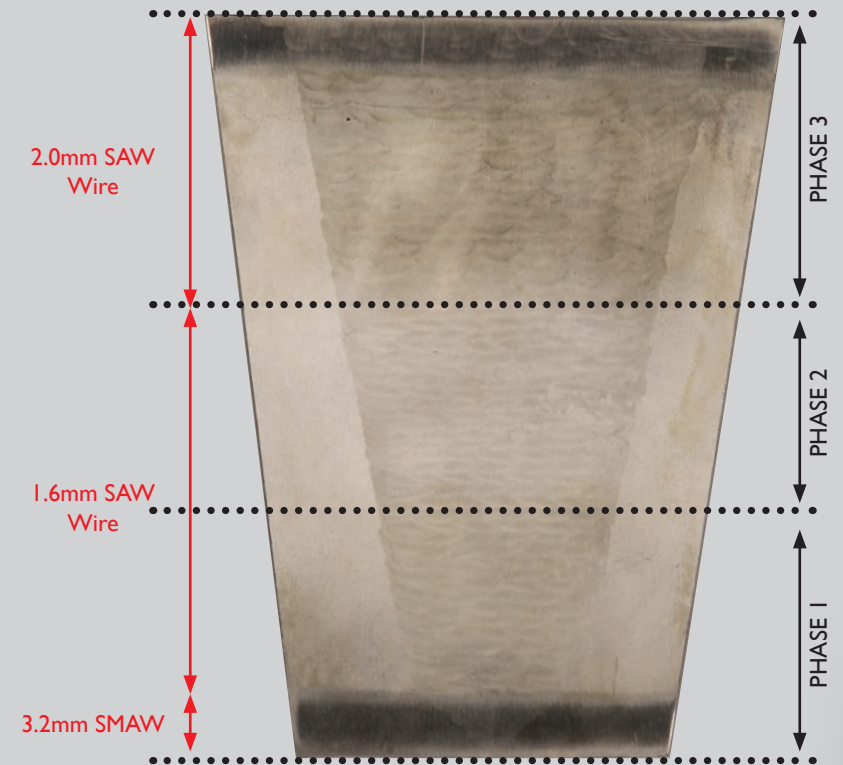
Studies of non destructive testing sensitivity to defect shape, size and orientation have been performed.

#### Example of Weld Combinations Completed

Weld Type	Comment	Material	Section Size	Techniques
Fabrication of Transition piece to Control Valve	Development work	Alloy 625 to Alloy 625	≤200mm section	GTAW Root SAW Fill
Fabrication of 2 x transition pieces	Development work	Alloy 625 to Alloy 625	≤200mm section	GTAW Root SAW Fill
Simulated Fabrication of a Steel Component to Nickel Casting	Development work	Alloy 625 to Cr/Mo/V	≤200mm section	GTAW Root SAW Fill
Welding of Control Valve Seats	Multiple Production welds completed	Alloy 625 to 9% Cr Steel	Overlay welding	GTAW
Development of Repair Procedures	Development work	G130 to G130	50mm	GTAW
Fabrication of 617 pipework to Alloy 625 casting	Multiple production weld completed	Alloy 617 to 625	20mm	GTAW



Sub arc welding of Alloy 625



#### SECTION OF A NI ALLOY WELD

Section Size: 200mm  
 Parent: Alloy 625  
 Filler: Alloy 625

Root 0-5mm: GTAW  
 5-20mm: GTAW  
 20-200mm: SAW



## DEMONSTRATION CASING

**Material:** Alloy 625

**Weight:** 3,500kg

**Application:** Casting manufactured for feasibility study and material characterisation.



## GOODWIN ALLOY G130

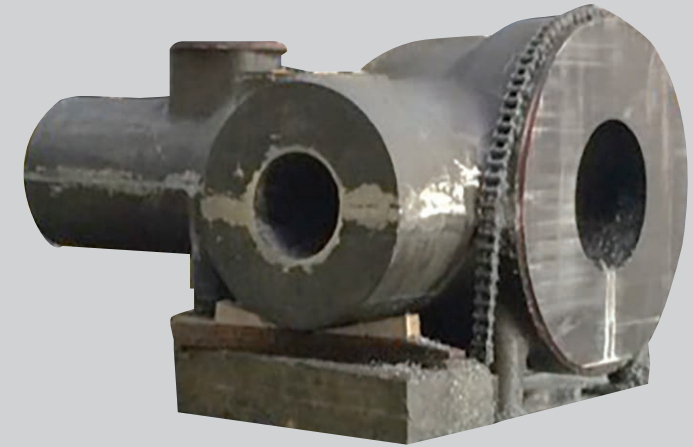
The need for higher creep strength nickel alloys that can be welded and cast in thick section has resulted in the development of the Goodwin Alloy G130. This material has a creep strength much greater than Alloy 625 and 617 while maintaining good castability in heavy section unlike many other precipitation hardened nickel alloys.

### ALLOY DESCRIPTION:

G130 is nickel based Ni/Cr/Co alloy specifically designed for heavy section castings operating at high temperature and pressure where high creep strength and outstanding steam oxidation resistance is required. The alloy is strengthened by a gamma prime precipitation during a two step heat treatment resulting in a cast material with an exceptional balance of strength and ductility, while maintaining excellent creep resistance and microstructural stability. Target application temperatures are 680°C to 750°C typically in advanced super critical (A-USC) environments. The alloy is highly castable compared with other gamma prime strengthened alloys, and has good weldability properties using suitable nickel base filler materials.

### APPLICATIONS:

Used for high temperature application cast turbine components. Examples include casings and valve bodies, operating in A-USC environments in fossil fuel power plant, or high temperature gas turbine components, such as exhaust castings.



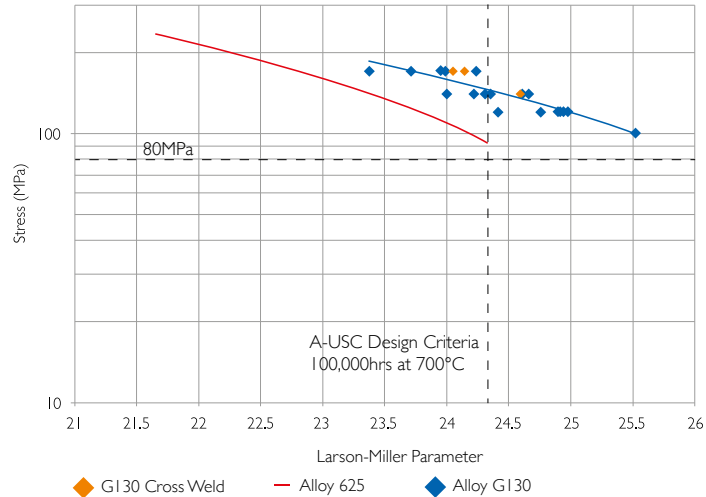
G130 turbine casting during processing

- Superior castability and casting integrity compared to other cast nickel precipitation hardened alloys
- Alloy designed for low segregation tendency, ensuring good through section properties
- Good microstructural stability
- Higher creep strength than cast 625 and 617
- Excellent weldability & ductility
- Excellent corrosion resistance due to high chromium content



# GOODWIN ALLOY G130

## G130 STRESS RUPTURE PROPERTIES



## Typical Melt Chemistry

	C	Si	Mn	Ni	Cr	Co	Al +Ti	Other
Typical	≤0.015	≤0.40	≤0.50	BAL	24.5	19.5	2.8	Mo + Ta + B

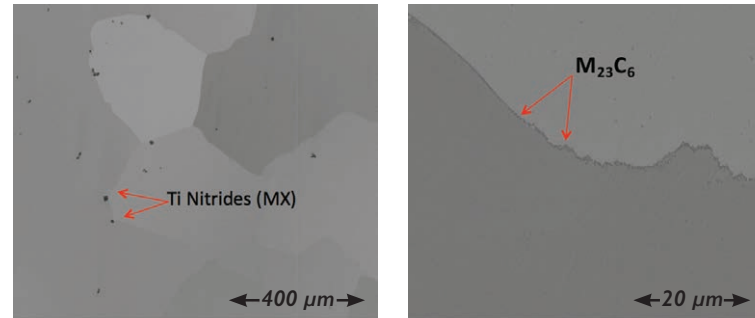
## Typical Room Temperature Mechanical Properties

UTS (N/mm <sup>2</sup> )	0.2% Proof Stress (N/mm <sup>2</sup> )	Elongation (%)	Hardness (HBN)	Avg. Charpy Impacts (J)
600 – 700	400 – 450	20	200	100

## Typical Elevated Temperature Mechanical Properties

Temp (°C)	UTS (N/mm <sup>2</sup> )	0.2% Proof Stress (N/mm <sup>2</sup> )	Elongation (%)	R of A (%)
700	550	390	30	22
800	445	340	16	35

## SCANNING ELECTRON MICROSCOPE (SEM) IMAGES OF THE G130 MICROSTRUCTURE



The G130 microstructure consists of gamma grains with M<sub>23</sub>C<sub>6</sub> carbides evenly precipitated along the grain boundaries which aids boundary coherence. MX carbide precipitation is reduced to a minimum by compositional control. Random titanium nitrides (dark) can be seen dispersed in the left hand image. The alloy is strengthened by aging to precipitate gamma prime (γ') Ni<sub>3</sub>(Al,Ti). The microstructure of G130 is designed to be stable after high temperature service aging with good resistance to deleterious phase precipitation.

## Typical Elevated Temperature Mechanical Properties

Condition: Post Weld Heat Treated

Weld Thickness: 30mm

Filler Metal: Inconel® 740H®

G130 Parent Thickness: 50mm

Cross Weld Tensile Mid section (Transverse)		Average Charpy Impact Properties (J) Location			Hardness (HV10) Location	
UTS (N/mm <sup>2</sup> )	Elongation (%)	Weld C/L	Fusion Line	HAZ	Weld	HAZ
745	16	51	160	137	310-325	210-245

All the information contained in this data sheet is based on the results of research and development carried out by Goodwin Steel Castings Ltd (GSC). The information does not represent a guarantee of specific properties. GSC reserve the right to update information without notice.

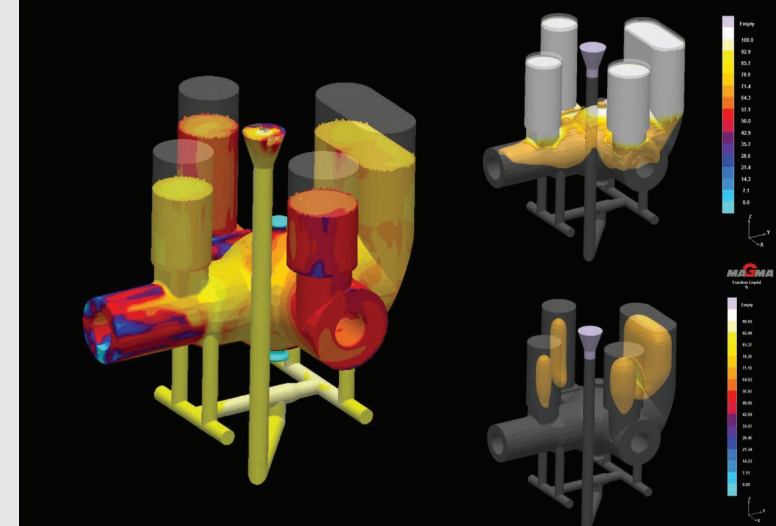




## FOUNDRY FACILITIES & CAPABILITY

- Casting Solidification:
  - Fluid flow and stress analysis packages MAGMASOFT™
- Melting & Analysis:
  - Primary electric arc and induction furnace melting.
  - AOD secondary refining vessel with oxygen, argon and nitrogen injection
  - Pouring capacity of 65,000 kg
  - Thermofisher 4460 33 channel, direct reading optical emission spectrometer.
- Heat Treatment:
  - 2 x High temperature water quench furnace (10,000 kg / 50,000 kg)
  - Gas fired low thermal mass bogie hearth furnace (50,000 kg)
  - 3 x Gas fired low thermal mass top-hat furnaces (20,000 kg)
- Riser Removal:
  - Large 3.5m CNC Gantry Saw
- Radiographic Inspection:
  - Varian M9a 9MeV Linatron in a 10m x 8m x 9m Bay with a 70 tonne overhead crane
  - Raytech Super-X 8.5MeV Linac
- Mechanical Laboratory (UKAS accredited to BS EN ISO 1705):
  - In-house inspection (Charpy V-notch, tensile, corrosion & metallography)
- Machine Shop:
  - Extensive CNC Machining facility

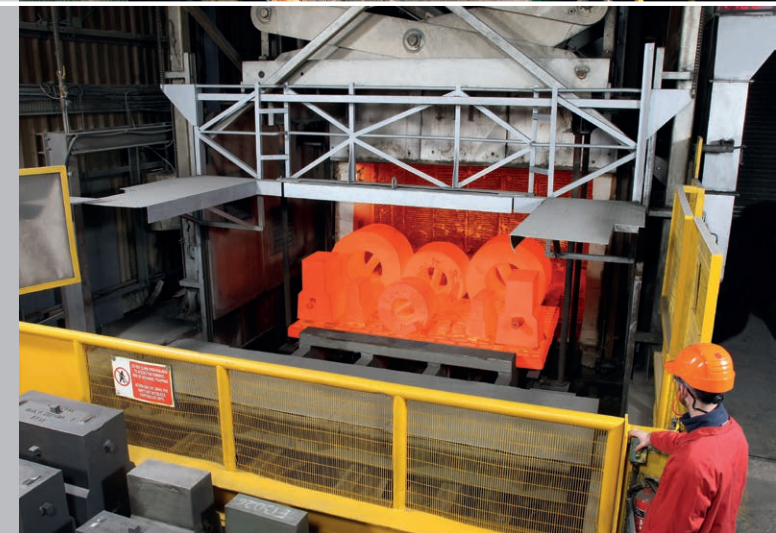
MAGMASOFT™  
Solidification  
Simulation



AOD  
Secondary  
Refining



Automated Heat  
Treatment &  
Water Quench  
Facility



# IVY HOUSE SITE OVERVIEW

Main Foundry Facility

Pattern Shop & Storage

Heat Treatment Furnace & Quench Facility

Material Testing Centre

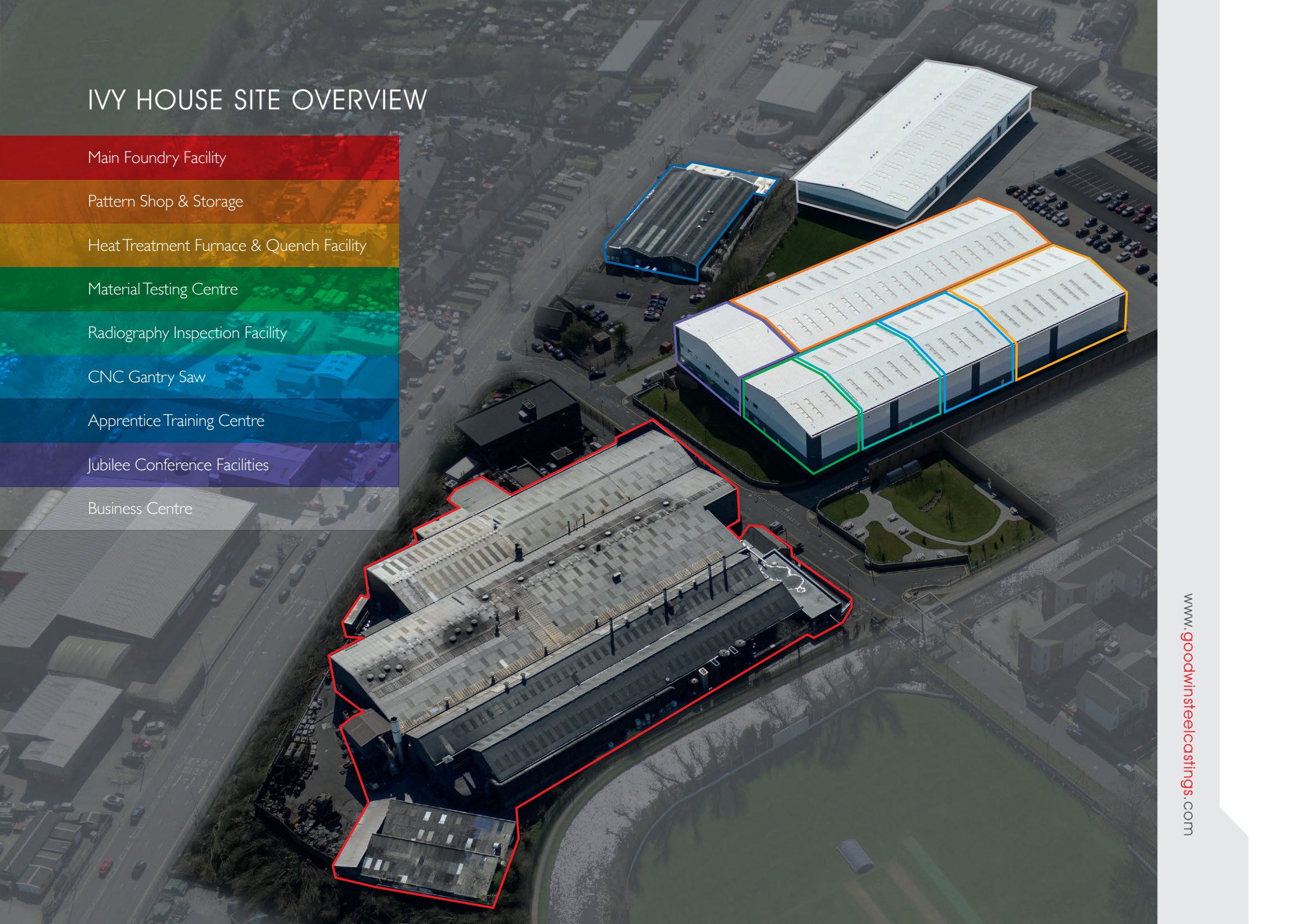
Radiography Inspection Facility

CNC Gantry Saw

Apprentice Training Centre

Jubilee Conference Facilities

Business Centre





GOODWIN STEEL CASTINGS LTD  
HEAVY SECTION STAINLESS STEEL AND NICKEL ALLOY FOUNDRY

Goodwin Steel Castings Ltd  
Ivy House Foundry  
Hanley, Stoke-on-Trent  
ST1 3NR  
United Kingdom

Tel +44 (0)1782 220000  
Fax +44 (0)1782 208060  
Email [castings@goodwingroup.com](mailto:castings@goodwingroup.com)

[www.goodwinsteelcastings.com](http://www.goodwinsteelcastings.com)