GOODWIN STEEL CASTINGS LTD
Registered Office:
Ivy House Foundry, Hanley, Stoke-on-Trent, ST1 3NR, England
Tel +44 (0)1782 220000 Email castings@goodwingroup.com

Steam Turbine Castings

Components for coal fired steam turbine applications have to endure arduous high stress and temperature environments. These castings within the pressure barrier of the turbine have to exhibit predictable behavior at high temperature under extreme pressure conditions, while maintaining good oxidation resistance for up to 30 years of service life.
Materials under constant stress, at temperatures of >30% of their melting point, and held prolonged periods of time, experience creep phenomena.
Creep is the tendency of a solid material to slowly move or deform permanently under the influence of stresses. It occurs as a result of long-term exposure to high levels of stress that are below the yield strength of the material.

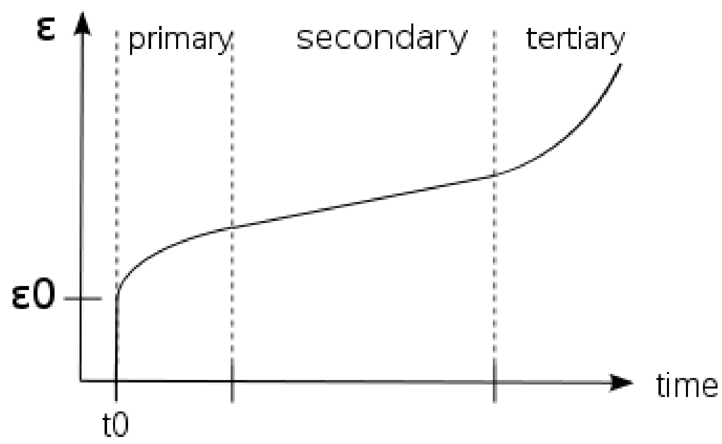

Fig 1

Fig 1. In the initial stage, or primary creep, the strain rate is relatively high, but slows with increasing strain.

These are the exact conditions found within the steam turbine, and therefore, all castings materials in these zones are required to possess good creep properties. Their ability to withstand cyclic stress from stop start operations is also important, while being readily weldable to aid fabrication during manufacture and installation.

Steam Turbine High Temperature and Pressure rated Castings:
Table 1 details typical stream turbine cast components produced in a variety sizes and materials depending on Mega Watt rating of the turbine, and steam temperature and pressure rating of the zone of operation.

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Table 1: Typical Steam Turbine cast Components		
HP Inner Casings	Re Heat Steam Valves (RSV)	Regulators (ICV)
IP Casings	Valve Covers	Diffusers
Main Stop Valves (MSV)	Bends	Inserts
Control Valves	Elbows	Flanges

9.5% Cr Steel Machined castings for a 800MW Power Station in India
Produced by Goodwin Steel Castings Ltd

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Set of RSV-ICV Castings 9.5% Cr Steel

Produced by Goodwin Steel Castings Ltd

Casting Materials Grades:

At present, current power station efficiencies range from 38 to 46% using conventional ferritic steels. Generally the operating temperature range of these materials is from 565'C to 610'C with a maximum main steam operating pressure of 275bar. This range of temperature and pressure is referred to as Super Critical (SC) and Ultra Super Critical (USC) respectively. The table below details some typical steel grades for both SC and USC applications:

Table 2 Typical Valve and Casing Material Grades.

Steel Grade	C	Si	Mn	S	P	Ni	Cr	Cu	Mo	V	Nb	Other
Super Critical Materials												
G17CrMoV5-10	0.17	0.45	0.70	0.015x	0.020x	0.4x	1.35	0.30x	1.0	0.25	-	Al <0.025
G17CrMo9-10	0.17	0.50	0.70	0.020x	0.020x	0.4X	2.25	0.30x	1.0	0.02	-	Al <0.025
Ultra Super Critical Materials												
G-X12CrMoVNbN9-1	0.12	0.30	0.60	0.010x	0.020x	0.4x	9.50	0.10	1.0	0.25	0.06	N2:0.05
G-X12CrMoWVNb10-1-1	0.12	0.25	0.75	0.010x	0.020x	0.50	10.0	0.10	1.0	0.25	0.06	W:1; N_2:0.05
GX-13CrMoCoVNbNB9	0.12	0.29	0.86	0.010	0.020	.20	9.5	0.10	1.5	0.2	0.06	B:0.012 $N_2$0.02

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The more conventional super critical materials can be produced by a variety of melting techniques, including electric induction melting, electric arc furnace and ladle furnace.
For the USC series of materials, these require secondary refinement such AOD, VOD or ladle furnace refining. This is due to the much tighter chemical control required and lower residual gas and cleanliness levels necessary to produce successful castings.

Heat Treatment:
The heat treatment of all steam turbine cast components is of vital importance. Super Critical grades 2.5%Cr;1%Mo Steel and 1.25%Cr;1%M;0.25%V Steel types require typically an austenitisation treatment, followed by a rapid forced air quench. After this initial hardening treatment, the castings are tempered to improve ductility and to obtain the optimum microstructure. This final structure is of tempered bainite with < 5 to 20% proeutectoid ferrite, depending on exact material grade.
9% Cr Steels Castings again are austenitised usually at above 1050'C, followed by a rapid forced air quench, and then receives a double temper treatment. This is required to ensure any retained austenite remaining after rapid cooling is transformed to tempered martensite.
The MF (*Martensite Finish*) temperature is very low for 9% Cr steels, and cooling to below this temperature is essential after each heat treatment stage, to ensure transformation is complete.
For optimum heat treatment, surveyed heat treatment furnace are required, with often contact thermocouples being employed to ensure through section heating. Adequate force air-cooling is necessary to ensure fast cooling to prevent ferrite formation in heavy sections.
Ferrite is much weaker than bainite or martensite, and has a detrimental effect on component long-term service life.

Non-Destructive Examination
The industry standard techniques for NDE of power generation valve and casing castings are detailed in the table 3.

Table 3 Technique	Inspection	Coverage
Radiography	Volumetric	Weld Ends Only
Magnetic Particle Inspection	Surface	100% of all accessible areas
Ultrasonic Examination	Volumetric	100% of all accessible areas
Visual Inspection	Surface	All areas

These techniques are well known and are used to determine the castings integrity during processing. Acceptance criteria is stipulated by the turbine manufacturer, and defects which are not acceptable are upgraded by weld repair. Weld repairs are then post weld heat-treated and the weld areas are re inspected to ensure the acceptance criteria is met.

Radiography of a 7,500kg Valve Casting using an 8.5 MeV Linear Accelerator at Goodwin's Site

Fabrication:
Often casings are fabricated to produce larger assemblies. There can be many reasons for opting for fabrication rather than single piece, and they can include, inspection accessibility, simplification of cast geometry and maximum single piece weight considerations. The welding techniques used for fabrication vary depending on material type, component geometry and section size of weld to be produced. Typical welding techniques employed are TIG, FCAW, SMAW and SAW

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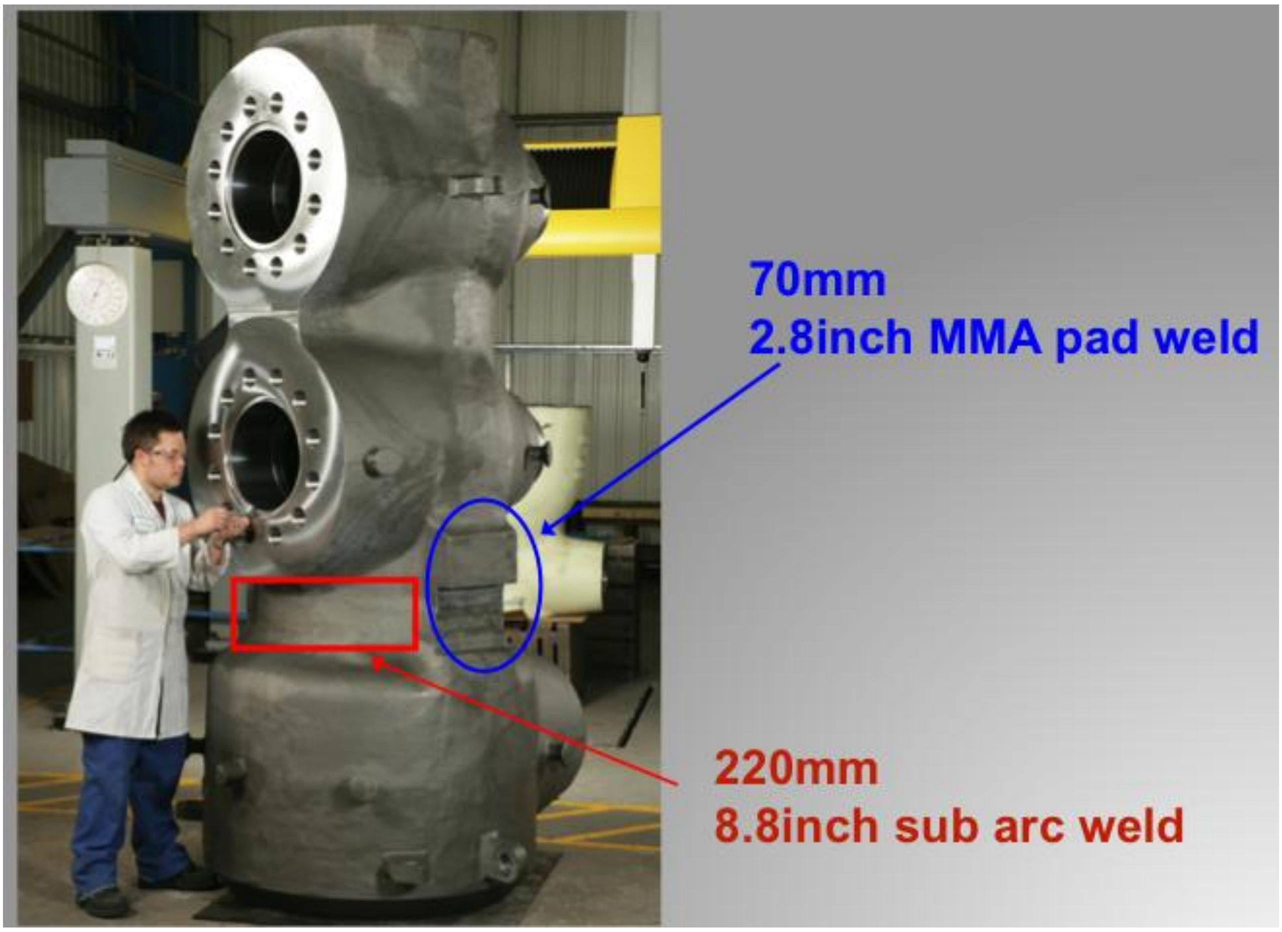

600MW MSV Body fabricated from two Castings (14,970kg)

9.5% Cr Steel GX12CrMoWVNbN - Produced by Goodwin Steel Castings Ltd

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1000MW MSV and CV RH and LH Assembly produced from 8 castings (49,895kg)

9.5% Cr Steel GX12CrMoWVNbN - Produced by Goodwin Steel Castings Ltd

Increased Efficiency:

To facilitate increase power station efficiency, steam temperatures and pressures have to be increased. To achieve increased efficiencies of above 50% would require main steam temperatures in excess of 700'C. Such temperatures are categorised as Advanced Ultra Super Critical (A-USC). For operating temperatures above 700'C, most steels will not have enough strength and oxidation resistance to facilitate their use. In this higher temperature environment, Nickel Alloys possess the best-desired combinations of properties for cast components.

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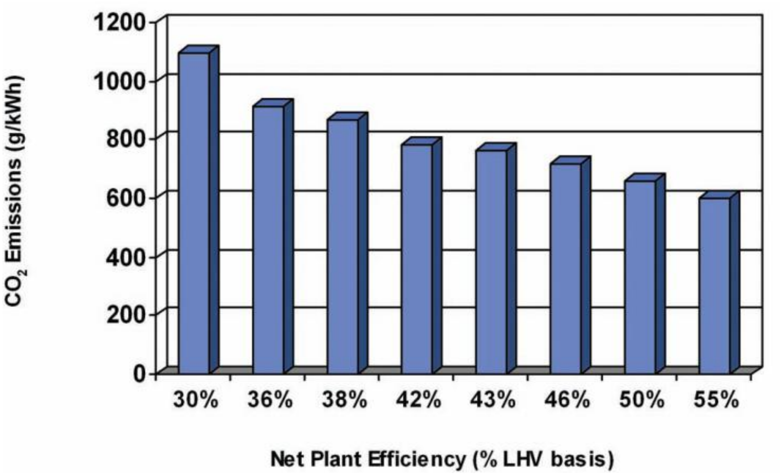

Fig.2

Fig: 2 shows the relationship between power plant efficiency and carbon dioxide emissions. As efficiency increases, specific carbon dioxide emissions decrease from 1100g/kWh at 30% net plant efficiency to 650g/kWh at 50% efficiency. This equates to a reduction in carbon dioxide emissions of 41%. Coal consumption is similarly reduced and clearly illustrates the benefits of efficiency increase with regard to potential environmental protection.
Fig: 3 Shows that as the steam temperature and pressure rises, the need for higher alloy content materials increases. The melting techniques listed in Fig 3, are those used for the production of the particular material grades at Goodwin Steel Castings.

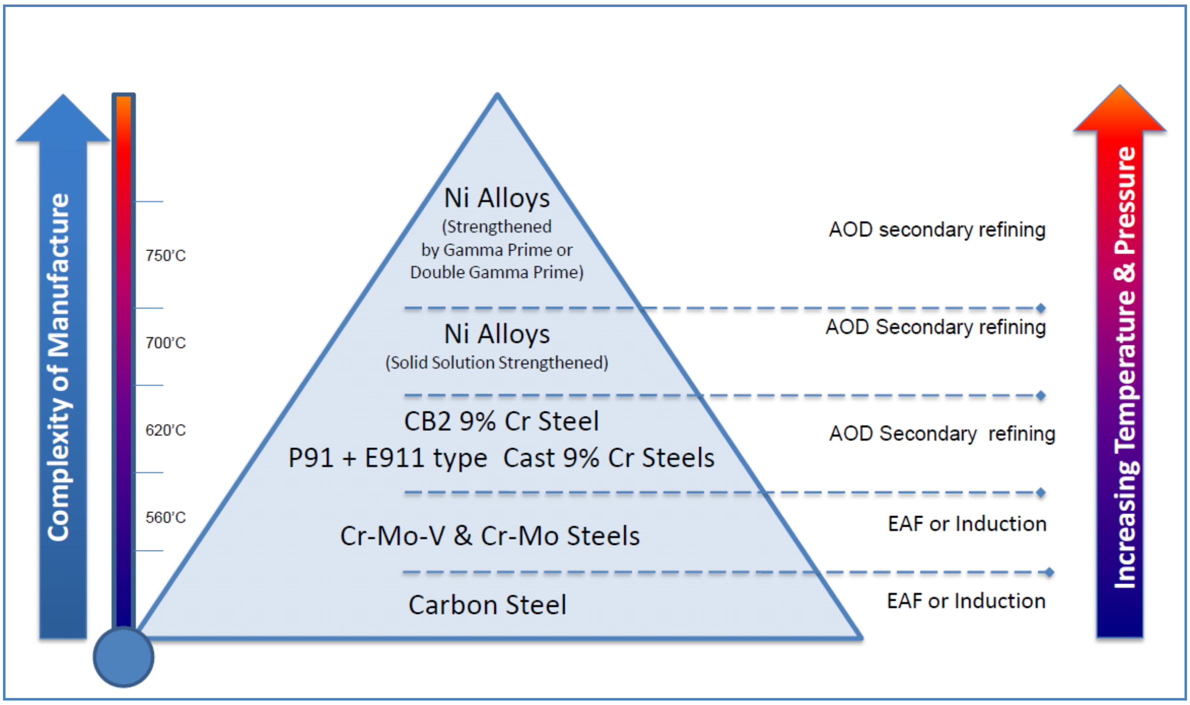

Fig 3. Turbine Material Evolution with increasing Steam temperature and Pressure

Increase in steam temperature comes hand in hand with enhanced difficulty of manufactured and technical competence requirements to facilitate successful casting manufacture.

Ni Alloys for 700'C + Applications (A-USC)

At present, no PF steam power station in the world is operating at 700'C, as the first demonstration plant is yet to be built. However, work around the world is being carried out to bridge the technology gap in heavy section advanced materials to ensure this will be reality in the near future.

GE Alloy 625 Steam Gland for 720ºC operation. Fully machined and fabricated (Gas Turbine Application)
Produced by Goodwin Steel Castings Ltd

For cast materials it's likely that there will be a demand for Ni alloys. Typical alloy types could include those detailed in Table 4.

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Table 4: Nominal Compositions

	Ni	Fe	Cr	Mo	Co	Nb	Ti	Al
cast 625	Bal	3.0	22	9.0		3.8	0.2	0.2
cast 617	Bal	2.0	22	9.0	13		0.5	1.1
cast 740	Bal	0.7	25	0.5	20	2.0	1.8	0.9

Ni alloys present the casting manufacturer with particular technical challenges that are not valid for steel castings, especially when heavy section sizes are required.

Solidification prediction, melting and refining, non-destructive testing, fabrication welding, post weld heat treatment, and machining are all more technically difficult then required for conventional steels, and therefore, the manufacturer requires an increased level of experience with these alloys to ensure successful manufacture, and to avoid costly mistakes.
Goodwin Steel castings has been involved in Ni Alloy development programs world wide with regard to A-USC programs for steam turbines and has resulted in the largest Ni alloy castings in the world being produced.

S.Roberts (Technical Director)
Goodwin Steel Casting Ltd