Purpose
To provide guidelines for casting galvanic anodes.

References
1. Flowchart – Manufacture (in Management Manual)
2. Standard – Australian Standard AS3679.1 (current version)
3. Standard - NACE SP0387 (current version)
4. Standard – Australian Standard AS2239 (current version)
5. Procedure - Alloy Additions
6. Form – Heat Sheet
7. Procedures – Spectrometer Operation
8. Furnace Instruction Manual (Inductotherm)
9. Furnace Operator Course notes (Inductotherm)

Procedure
The "Manufacture" flowchart (ref 1) in the Management Manual provides a summary of the manufacturing process. This procedure provides an overview of what is required when manufacturing anodes. It is not specific to any piece of equipment.

1. Pre Casting Set-Up

Preparation of Moulds

Prior to casting, moulds must be thoroughly cleaned to remove loose oxides. This can be done with a wire brush. Grinding or blasting may be used if required.

Some moulds may require a coating of releasing agent to allow anodes to slide easily out of the mould. This is applied when the existing coating appears thin. It is applied with a brush or spray.

Just prior to casting, heat the moulds to around 125degC to evaporate any moisture. Heat small moulds for 5 minutes and large moulds for up to 15 minutes. If this step is not carried out, the water vapour may cause a molten metal explosion as moisture tries to escape from the bath of molten metal, or the water may turn to vapour and get trapped within the casting, causing undesirable voids.

Preparation of Ladles

For hand casting, ensure that ladles are in good condition. If they are showing excessive signs of wear either repair them or replace them. Prior to casting you may need to coat the ladles with a coating/barrier agent.

Anode Inserts

Steel inserts must be fabricated according to the catalogue or technical drawing. All steel is supplied with some degree of mill scale. This is a natural oxide that forms as part of the steel making process and the only way that it can be removed properly is through abrasive blasting.

For general casting, all steel should be received from suppliers in clean condition, free from any rust bloom, oxides or oils. It should be supplied in a condition that is suitable for casting.

Some customers request that all steel inserts be abrasive blasted just prior to casting. If this is the case, ensure that it is carried out according to the Australian or international standard specified by the customer.

Reference standards: For Australian made hot rolled bars and sections, refer to AS3679.1 (ref 2) or equivalent standard for hot rolled bars and sections not made in Australia. For pipe inserts, refer to NACE SP0387 (rev 3) for relevant standards.

Creating the Alloy
For AS2239 (ref 4) alloys Z1, A1, A2 and A6 the alloy composition is weighed according to the percentages listed in the "Alloy Additions" procedure (ref 5). The job details and alloy percentages are then written onto the Heat Sheet (ref 6).

For other alloys, obtain a copy of the alloy composition (usually on the technical drawing) and calculate the weight of specific alloy additions accordingly.

Loading the Furnace
Before loading the furnace, ingots are checked for surface moisture. If there is any moisture, the ingots are set aside until they are dry. Only dry ingots are to be loaded into the furnace.

The addition of the other elements (alloying) always takes place when the entire primary ingot per heat is melted. This is because:

1. In Aluminium, the ingot melts at 660 deg C. Some of the alloys have melting points of around 400 deg C and lower. These alloys can and will burn (oxidise) and therefore if the alloys are in contact with the crucible surface at approximately 900 deg C the operator risks a loss of alloy addition by weight calculation. Refer to the Alloy Additions procedure (ref 5) for further information.

2. In Zinc, the additional elements are added using the Z1 Master Alloy at a ratio of 1 Master Alloy Slug to 1 SHG Zinc Ingot. Refer to the Alloy Additions procedure (ref 5) for further information.

Melting Ingots

	Alloying Temperature	**Casting Temperature**
Aluminium	750degC	720degC
Zinc	550degC	500 to 510 degC

Temperature is determined by using a k-type thermocouple probe and displayed to the operator via a digital handheld display.

Analysing Alloys
Aluminium Anodes
Once the ingots and additional elements are molten and have been thoroughly stirred (manually, in gas fired furnaces, automatically in electric induction furnace), the disc samples are clearly labelled with the batch number, they can then be analysed on the spectrometer in the laboratory (ref 7).

If the analysis meets the desired alloy composition, proceed. If not, re-stir the furnace and take a second sample. If this sample shows similar results to the first sample a mathematical calculation by the Spectrometer operator will determine the required alloy additions needed to bring the heat into specification. Then re-alloy the molten metal accordingly and check the analysis on the spectrometer again. Do not proceed until the analysis complies with the specification.

Zinc Anodes
Anode samples are taken from each batch of Zinc alloy cast, the batch number is **clearly** transcribed onto the sample. The disc samples are then placed in the storage bucket located on the factory floor. Each bucket is clearly labelled with the start date and once it is full it is clearly labelled with the end date. The buckets are stored in sequential order on the lab roof for easy retrieval. These samples are kept on site for a minimum of 5 years and then remelted.

Spectrographic testing is carried out on zinc anodes when requested by customers. A minimum of 10% of zinc anode samples are randomly analysed on the spectrometer.

Personal Protective Equipment

While casting, ensure that the following safety clothing is worn:

- Long pants (no holes)
- Long sleeve shirt (no holes)
- Safety glasses and/or visor
- Ear plugs
- Leather gloves
- Leather apron
- Safety boots
- Spats (optional)

Note: Heat/Splash proof Hood to be used when we get a batch of Zinc that may have moisture. Ingots to be heated to minimise moisture.

2. Anode Casting

Once the above steps have been completed, casting can commence.

Furnace Operation

We use the following types of furnaces:

1. Crucible furnace for casting by hand with a ladle
2. Electric Induction furnace (ref 8 and 9) for casting directly into a mould via launder or via transfer ladle.
3. ERBO Electrical Resistance Bale Out Furnace

3. Post Casting

Removing Anodes from Moulds

Ensure anodes remain in moulds until solidification complete. Then remove anodes to allow the dies to cool.

Traceability

Aluminium Anodes

Aluminium anodes are traceable via the heat number, which is hard stamped on the face of the anode. This heat number is also recorded on the disc sample, which links it to the spectrometer analysis (ref 7) and the customer job number.

Zinc Anodes

We hold large stock volumes of Zinc anodes so that we can react quickly to customer's demands. Some zinc anodes are not hard stamped with a heat number, primarily due to their small size and the large volume.

Standard Casting Tolerances

Anodes are cast to comply with the following weight, dimensional and straightness tolerances:

Anode Gross Weight	
0 - 1kg	+/- 10%
1 - 50kg	+/- 5%
50kg +	+/- 3%*

*As per NACE SP0387 (ref 3)

Anode Dimensions	
Anode mean length	+/-3% of the nominal length or +/-25mm whichever is smaller*
Anode mean width	+/-5% of the nominal width*
Anode mean depth	+/-10% of the nominal depth*
Anode straightness	No more than 2% of the anode nominal length from the longitudinal axis of the anode*.

*As per NACE SP0387 (ref 3)

4. Casting Defects

The following photographs are examples of poor quality casting, which are to be avoided.

Shrinkages and Voids

As the alloy starts to cool, it shrinks away from the hottest point, which is where the molten metal enters the mould. As cooling takes place, the void where the molten metal is shrinking away from must be filled before the metal begins to solidify. If this is not done, large voids may be present inside the anode or a depression may occur on the casting surface.

To reduce the chance of shrinkages and voids, keep the casting temperature under tight control and feed the void using top up metal with an elevated temperature to ensure that the top up metal bonds with the primary anode material, this also prevents the anode from solidifying too quickly. Keeping the mould very hot during casting also assists. Refer to SP0387 (ref 3) section 3.9.1 and 3.9.2 for acceptance criteria.

Bending

The primary cause of bending is the difference in contraction rates of metals. For example, Carbon Steel has a contraction rate of up to 2.0% against Aluminium of 1.3%. This causes a mechanical force exerted by the steel on the Aluminium alloy, which bends the combination of anode material and steel insert upon solidification or during cooling to ambient temperature.

Sharp Edges

It is best practice to cast without having any sharp edges on the casting. If this is not possible, all sharp edges are to be removed.

Cracking

Cracking is caused by a combination of the nature of the alloy, casting temperature, the size of the anode and the insert. NACE standard SP0387 (ref 3) states:

> **3.10.1** With the exceptions stated in Paragraphs 3.10.2 through 3.10.4, anode cracks shall not be cause for anode rejection because of the fact that, even with good foundry practice, particular compositions of cast galvanic anode alloys (notably aluminum-based) suffer a degree of cracking that does not affect performance.[22]

Metals naturally contract as they cool/solidify. If you cast an Aluminium anode 1.5m long into an open mould with no steel core, it would contract about 20mm (about 1.3%). When you add the steel insert, the alloy grips to the steel core as it cools. A large steel insert with a comparatively small amount of alloy surrounding it is prone to causing cracking as the alloy at the ends of the mould cool and solidify, while the alloy in the middle is still molten. This gives the cooling alloy nowhere to go but to crack away from the hottest area towards the cooler ends. This is a known cause of full circumferential cracking in the 'Hot Zone'. Refer to SP0387 (ref 3) section 3.10 for acceptance criteria.

Cold Folds/Shuts

Cold folds are caused by a cold mould and/or a delay during casting, where the lower part of the alloy has solidified, before the upper portion has been cast. Cold folds can be avoided by casting at the correct temperature and at a controlled constant rate of metal flow into the mould cavity. Refer to SP0387 (ref 3) section 3.9.5 for acceptance criteria.

Inclusions

This is foreign material entering the body of the anode while it is molten. Inclusions can be in the form of dirt or grit (from poor factory practices), moisture (from poorly heated moulds) or foreign materials, such as tools being knocked into the molten metal during casting. Refer to SP0387 (ref 3) section 3.9.4 for acceptance criteria.

5. Rejects

Rejected goods prior to dispatch

Anodes can be rejected for the above reasons as well as for incorrect alloy composition, incorrect weight or incorrect dimensions or straightness.

Anodes found to be rejects can be re-melted. This is usually only done when anodes meet the chemical analysis, but do not comply with weight or dimensional tolerances.

Anodes can be remelted if the cause of the rejection is poor chemical composition, but it must be done under carefully controlled parameters to ensure that the quality of the new melt is not compromised.

Remelting or reclaiming an anode of any size is achieved by suspending the anode section into the molten bath of metal and depending on anode mass, the anode would be suspended by means of hand tongs or by suspending the anode into the furnace by overhead crane on anodes of larger mass.

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