4. Assessment of Risk

Background

Many foundry environments operate processes which evolve significant quantities of fume, dust and other emissions. A zinc alloy casting foundry is not in this group. Zinc is a very ‘clean’ metal to melt, alloy with other metals, cast and otherwise process. Molten zinc has an extremely low vapour pressure and evolves no fumes. The Brock Metal foundry does not require any local exhaust ventilation and our regularly monitored occupational exposure levels are always a small fraction of the relevant Workplace Exposure Limits.

Temperatures used in the zinc alloying processes do not exceed 680°C and are most typically down at 490°C. Within the metals processing sector zinc alloy production is low temperature.

The alloying process produces approximately 1% waste, referred to as ‘dross’. This is a solid waste, approximately 75% zinc with iron making up most of the remainder along with very small quantities of alloying elements such as aluminium, copper and magnesium. The dross is re-processed off-site by specialist businesses. Any manufactured product that is out of specification, either in terms of alloy composition, or dimensional accuracy, can be gradually re-introduced into the process.

Water is used for cooling moulds during casting, and then for further cooling the solid ingots. Process water usage is minimal as the high-volume production plants (ingots and blocks) now have ‘closed’ systems which recirculate the cooling water through chiller units. In the event of extended breakdown on the new ingot plant the old ingot casting track is temporarily used. This puts a very small volume of cooling water to drain, but it has simply been sprayed on the underside of cast iron ingot moulds so it is uncontaminated. Similarly, very small volumes of cooling water runs ‘mains to drain’ on the low volume Technigalv and Bullet plants.

Crucibles have a finite service life. They will ultimately fail, almost invariably through cracking. Crucibles are therefore managed by a regime of regular visual inspection (lifting the crucible from the furnace well so that its furnace-facing side can be seen) and turning in the furnace well to spread the effect of any hot spots. When crucibles reach a defined lifetime limit they are sacrificed even if they are showing no signs of failure. In this way the number of instances where crucibles fail in service is minimised.

Should a crucible fail in service the environmental consequences are not severe. Most failures in service begin with small beads of zinc emerging through a crack onto the furnace-facing surface of the crucible. This zinc is rapidly oxidised to zinc oxide by the burner which changes the characteristic of the exhaust gases from the furnace giving them a slight mistiness. This is immediately evident to the furnace operator so the melt can either be stopped or cast immediately. In the rare instances where significant quantities of molten metal leak into the furnace well, it will exit the well through a run-out hole at the base of the furnace onto the concrete floor of the foundry. Foundry sand can be used to help control any such flow and the metal is allowed to solidify on the floor from where it can be lifted and returned to the process.

The environmental risks associated with the Brock Metal process are thus very small and the site has always been considered as being at the lowest risk end of the sector spectrum by our COMAH Officer.

Description and Assessment of Environmental Risk Associated with Proposed Developments

It is considered that the developments described in 1), 2) and 3) of the Non-Technical Summary will not change the environmental risks associated with our process.

This is because the larger capacity crucibles described in 1) and 2) will use the same technology, the same materials, the same design principles and the same operational control methods as the current crucibles. They will not therefore fundamentally change the process.

The reservoir described in 3) will add an additional step to the process (see '*Brock Metal Process Flow Chart*') but will not add additional environmental risk because of the nature of its design, use and operational control measures.

The detailed rationale behind these assertions is given in sections a) and b) below.

It should be clearly stated that the increase in melting capacity described in this application is proposed in order to create more production capacity at Brock Metal to facilitate further business growth. Therefore, in assessing any changes to environmental risk levels it is helpful to distinguish the *risk per tonne of product produced* from the *total risk* associated with producing increased production volumes. Using the 6 tonne crucible as an example, and based on performance data gathered to date, we can say with some confidence that the 6 tonne crucible has the same service life as the 5 tonne crucible measured in terms of the number of melting cycles. Since each melting cycle produces 20% more alloy in a 6 tonne crucible than in a 5 tonne crucible the larger crucible is capable of producing 20% more product *with the same risk of failure.* The development therefore *reduces* environmental risk per tonne and it *reduces* total risk up to and until the point at which total annual plant output has increased by 20%. Beyond this point the total risk must be considered as increasing purely on the basis of increased plant activity levels.

a) Increased Capacity Crucibles

Both the 6 tonne and the 6.5 tonne crucibles will be made in the same grade of cast iron used for the 5 tonne crucible by the same foundries who supply Brock Metal the 5 tonne crucible. They will have the same hemispherical shape as used on the 5 tonne crucible, but with small increases to the internal radius to give the extra capacity as shown in Table 1 below.

Crucible Capacity	5.0 tonne	6.0 tonne	6.5 tonne
Internal radius	734mm	758mm	774mm

Table 1: Crucible capacity and internal radius

Their wall thickness will follow the same structural design principles as used on the 5 tonne crucible to keep both meridional and longitudinal wall stresses constant. This means that for each crucible design the wall thickness at the bottom of the crucible will be 1.5 times that at the top (see Note 1 for explanation of why this is so). Whilst this ratio will be retained the actual wall thicknesses for each capacity design will be increased according to the appropriate formulae for stress to ensure that the wall stresses in the larger, heavier crucibles are no greater (or slightly less) than those in the 5 tonne crucible.

6 tonne capacity crucibles have been in use in a number of furnaces for over half a year now. Whilst data will continue to be gathered, the results to date indicate that their service lifetime (measured in terms of number of melting cycles) is comparable to the 5 tonne crucible. This is good practical evidence that the design aim has been achieved that they are not subject to any greater demands in terms of stress than the 5 tonne crucible.

The larger capacity crucibles will be managed through the same approach of regular visual inspection and turning in the furnace, coupled with sacrifice at defined limits, as successfully deployed with the 5 tonne crucibles.

b) Reservoir

The reservoir will have an 18 tonne capacity. Once melts prepared in 6 tonne crucibles have been tested for compositional accuracy and are ready for casting, they will be pumped into the reservoir and cast from there. The reservoir creates a ‘buffer’ holding capacity and allows the crucibles emptied into it to be reloaded and their next melting cycle commenced earlier than if it had been necessary to wait for them to be cast. It will be installed within the line of furnaces feeding the ingot casting and stacking plant (see *‘Site Plan’*)

The reservoir is constructed as an open-top cube. It uses a steel shell with appropriate stiffening members welded externally to meet the structural engineering requirements for stiffness and strength. It is lined with 20mm of very high-performance insulation against the steel followed by a layer of castable refractory material to a depth of 280mm at the bottom and 150mm against the walls. This leaves a void of approximately 1.5m x 1.5m x 1.5m in the centre to contain 18 tonnes of molten zinc alloy.

This type of construction has been successfully employed in this application for many years by our parent company, NFM Alloyz. Experience with refractory-lined furnaces at Brock Metal suggests that even if a crack were to propagate all the way through the refractory lining, its thickness is such that the thermal gradient will ensure that any molten zinc permeating along the crack reaches its solidification temperature well before it contacts the high-performance insulation.

The risk of zinc leaking from the reservoir is therefore considered to be extremely low. Additionally, the reservoir will be installed in a shallow pit (approximately 500mm deep) in the floor which will both offer some bund capacity and reduce the volume of molten metal above floor level which could conceivably leak outwards along the floor.

Part of the operating procedure for the reservoir involves having contingency for the possibility that the ingot casting and stacking plant suffers an extended breakdown. In this event it is important that the contents of the reservoir are not allowed to solidify in the reservoir. To this end there are two contingencies. Firstly, the reservoir will have the facility to apply some top heating through 2 burners directed down onto the surface of the molten zinc. Secondly, there will be a sufficient number of old 1 tonne block moulds stored near the reservoir to allow its entire contents to be rapidly pumped out into them in the event that it cannot be cast. This means that in the highly unlikely event of a leak developing in the reservoir the entire contents can be rapidly pumped out into block moulds.

Note 1

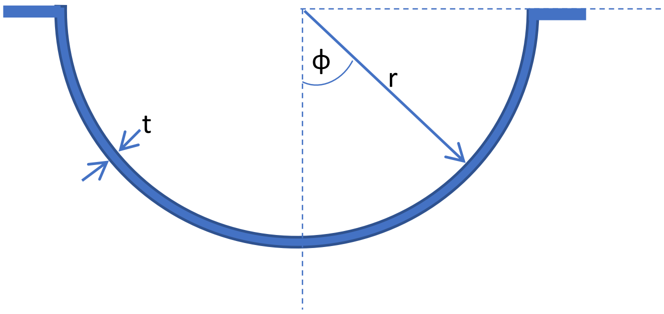
1. Consider a hemispherical crucible containing liquid simply supported around its top edge flange.

The membrane theory of shells gives:

$$\sigma_\phi = \frac{\Upsilon\, r^2}{3\,t}\left[1 + \frac{\cos^2(\phi)}{1 + \cos^2(\phi)}\right]$$

And:

$$\sigma_\theta = \frac{\Upsilon\, r^2}{3\,t}\left[2\cos(\phi) - \frac{1}{1 + \cos(\phi)}\right]$$



Where:

r = radius of hemispherical container

t = thickness of container wall

Υ = specific weight of liquid

Φ = angle between vertical through bottom of hemisphere and radius from centre of hemisphere

Thus:

When $\phi = 0°$, $$\sigma_\phi = \frac{\Upsilon\, r^2}{3\,t}\left[1 + \frac{1^2}{1 + 1^2}\right] = \frac{\Upsilon\, r^2}{2\,t}$$

When $\phi = 90°$, $$\sigma_\phi = \frac{\Upsilon\, r^2}{3\,t}\left[1 + \frac{0^2}{1 + 0^2}\right] = \frac{\Upsilon\, r^2}{3\,t}$$

This means that the stress at the top of the pot is two thirds that at the bottom of the pot. Hemispherical pots are therefore designed with an upper wall thickness which is two thirds the lower wall thickness to avoid stress concentrations.

For any given pot capacity and radius ‘r’, the wall thickness ‘t’ may be chosen to keep the wall stresses σ_ϕ and σ_θ constant from one crucible size to another.