Troubleshooting Manual

Installation, Care and Use of Crucibles

CANADIAN THERMIX Inc.

Distributors of Foundry Products

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Recommended Foundry Practices for *CRUCIBLE MELTING* Gas Fired and Electric Resistance Furnaces

Introduction

Foundry practices utilizing crucible melting can vary widely from foundry to foundry depending upon melting practices. The following discussion is based on information and data collected from customers and crucible manufacturers. The information is designed to provide foundry personnel with the basic guidelines to maximize crucible life and thereby increase productivity.

Although technology has brought changes to the industry such as electric resistance melting, iso-statically pressed crucibles with denser walls, corrugated walled crucibles, the development of low temperature/specialty glazes and binder systems, the basics of crucible melting have not changed.

For simplicity, this discussion is based mainly on bale-out and tilt furnaces.

Crucibles

1) Selection

- Select the proper crucible for the application.
- Consult with your crucible supplier, as the proper selection will be based on a variety of factors.

The chart below is a basic guide for crucible selection:

Furnace	Alloy	Temperature Range	Crucible
Gas	Aluminum	750-1200ºC	SiC
	Aluminum	620-750ºC	SiC & low temp. glaze
	Brass/Bronze	1000-1400ºC	SiC
	Gold/Silver	1000-1600ºC	Clay/Graphite
	Gold/Silver	1000-1600ºC	SiC
	Zinc	400-600ºC	SiC & low temp. glaze
Electric Resistance	Aluminum	All	SiC & low temp. glaze
	Zinc	All	SiC & low temp. glaze

2) Size

- A general rule of thumb is that approximately 10% of the diameter of the crucible is needed between the crucible and the top of the furnace lining to maintain uniform heat throughout the entire crucible body (gas fired).
- For electric resistance, the distance between the heating elements and the crucible wall range from 65mm (2 1/2") to 100mm (4"). The crucible should be kept within the heating elements, it should never extend outside the length of the elements.

3) Base block

- The crucible should rest on a stand made of the ***same*** material as the crucible.
- The stand should be of the correct ***height*** to allow for proper burner alignment (See Fig. 1 – Pg. 24).
- The stand should be the ***same*** size or ***slightly larger*** in diameter than the crucible base.
- The stand ***should not*** be smaller in diameter than the crucible base.
- ***Do not*** bind or cement the stand to the furnace floor.
- It is good practice to use a new stand with a new crucible as the stands also oxidize and become fragile. Base blocks provide the crucible base with uniform heat (reducing thermal stresses) and support. They also aid in maintaining proper burner alignment as they heat up and expand at the same rate as the crucible.

4) Handling and storage

- Store crucibles in a ***warm dry*** area on pallets.
- ***Do not*** store crucibles on a concrete floor.
- ***Do not*** stack crucibles.
- ***Do not*** roll a crucible on it's edge or chine, this may cause glaze damage.
- If the glaze is damaged, touch-up the area prior to installation and pre-heat.
- If tongs are used, ensure they are fitted properly (See Fig. 4 – Pg. 24).
- ***Never*** grip the crucible near the rim, always lift from a lower point on the body to spread the stresses more evenly throughout the body (See Fig. 4 – Pg. 24).
- ***Always*** "Ring Test" a crucible prior to installation. A sound crucible will exhibit an audible bell like ring when rapped on the inside of the rim. If a deadened sound is heard, the crucible may have hair line cracks. Crucibles are ***Hygroscopic*** and will therefor pick up moisture easily even from high humidity.

5) Installation (gas fired/bale-out furnace)

- Install stand and crucible ***centrally*** within the furnace chamber.
- The cover bricks should be at the ***same*** height as the crucible rim leaving room for expansion and to allow heat up to the top rim (See Fig. 1 – Pg. 24).
- Lay a 25mm layer of insulating blanket across the refractory and onto the top rim of the crucible bridging and expansion gap (See Fig. 1 – Pg. 24).
- ***Do not*** pack the insulation between the crucible and furnace wall.
- ***Do not*** fully compress the insulating blanket. It is an expansion cushion for the crucible and insulates the top plate(s).

Installation (electric resistance/bale-out furnace)

- As per above installation.
- Ensure elements are in good condition.
- ***Always*** use a crucible with ***Low Temperature C11-Glaze***.
- Usually a cover ring is installed to avoid any metal splash onto the electric panels, ***always*** provide an expansion gap between the cover ring and the inside of crucible (See Fig. 1 – Pg. 24).

Tilt Furnaces

- As per item 5 above.
- Tilt crucibles ***must*** be supported by either the 2 or 3 grip brick method of installation (See Fig. 2 – Pg. 24). Front 2 bricks are set to 60º each side of spout, 3rd brick is opposite the spout end.
- ***Always*** ensure proper expansion gap of 1/4" minimum between grip bricks and under the crucible spout (See Fig. 2 – Pg. 24).

6) Pre-heat (SiC Crucibles)

a) Gas Furnace

- To ***ensure*** there is no risk of the crucible being damp, pre-heat the crucible for 15 to 20 minutes at approximately 250ºC.
- Finish the curing by ramping the temperature ***as fast*** as the furnace will allow, until the crucible is *bright red* throughout (at least 800ºC, max 400ºC/hr.).
- Recommended times for pre-heat:

Up to 65 lbs.	(Al)	35 minutes
Up to 210 lbs.	(Al)	45 minutes
Up to 530 lbs.	(Al)	60 minutes
Up to 710 lbs.	(Al)	90 minutes
Up to 1000 lbs.	(Al)	120 minutes

b) Electric Resistance Furnace

- As per above, however, electric furnaces (metallic elements) often take longer to reach operating temperature, therefore the recommendation of low temperature C11-glaze.

6-A) Pre-heat (Clay Graphite Crucibles)

- Clay graphite crucibles are ***much less*** resistant to thermal stressing.
- Pre-heat times above ***should*** be increased by at least 50%.

c) Transfer of Molten Metal

- When transferring molten metal to a crucible, ***always ensure*** that the crucible is at the same temperature or slightly above the temperature of the molten metal.

7) Charging

- Charge ***immediately*** once the crucible has reached *red heat* all over.
- Charge light scrap first (See Fig. 3 – Pg. 24).
- Charge larger scrap and ingots using the light material as a cushion.
- Charge ingots and large pieces ***vertically***.
- Use ***tongs*** to charge ingots and larger pieces.
- ***Do not*** pack the metal in the crucible, allow space for metal expansion.

  Aluminum has an expansion rate of about 7 times that of the crucible.

8) Fluxing

- ***Do not*** over flux. Use the minimum amount to clean the melt.
- Use the proper flux for the application (cover, drossing, wall, refining, etc.).
- Use the flux according to the manufacturers recommendations i.e. proper temperature.
- ***Never*** add flux to the bottom of an empty crucible, ***only*** to molten metal.
- ***Do not*** hold melts treated with flux for extended periods.
- ***Do not*** leave flux on top of the melt for extended periods.
- ***Do not*** super heat the melt.

Crucibles are porous at elevated temperatures and flux can migrate through the walls.

9) Cleaning

- ***Always*** keep the side walls and bottom of the crucible free of dross and slag.
- Clean the walls of the crucible ***daily and/or between*** melts while the crucible is *red hot*.
- ***Always*** scrape the walls of the crucible vertically.
- Use tools that have the same curvature as the crucible walls and that are hoe-shaped and blunt.
- Where possible (tilter), scrape crucible in the horizontal position.
- ***Do not*** chip at the crucible walls to remove build-up.
- If using wall flux, follow manufacturers recommendations.
- Do not allow a heel to freeze in the crucible bottom, if shutting down, ***completely*** bale-out or pour-out the crucible.

Build-up (dross and oxides has an expansion rate of about 5 times that of the crucible.

Furnace

- Furnace lining ***must*** be circular in shape, similar to the curvature of the crucible.
- The refractory walls should be as ***even*** and ***smooth*** as possible.
- Keep the furnace floor ***clean*** and ***free*** of debris and refractory slag.
- Keep the drain hole area ***clear*** and ***sealed*** (very important in electric resistance).

Burner

- ***Ensure*** proper burner alignment, center-line of the burner should be level with the base of the crucible and fire midway between the crucible and the furnace lining (See Fig. 1 – Pg. 24).
- The flame ***should not*** fire above the stand.
- The flame ***should not*** fire directly onto the crucible body.
- ***Maintain*** proper air/fuel mixture, use a slightly oxidizing flame (slightly green tips), too oxygen rich (deep green flame) will contribute to crucible oxidation.
- ***Maintain*** burner and keep clean. Have exhaust gas analyzed periodically to ensure proper burner efficiency.
- ***Ideally*** the flame should swirl around the crucible in a helical pattern to the top providing even heating to all parts of the crucible.

Melting Practices

- ***Keep*** the crucible as full as the process will allow.
- Melt as ***quickly*** as possible.
- ***Do not*** superheat the melt. ***Always*** melt at the lowest temperature the casting process will allow.
- Pour the metal ***as soon*** as it is ready, ***do not*** allow the metal to simmer or stew for prolonged periods of time.
- Clean out the crucible after each melt while *hot*.
- ***Never*** allow any molten metal to solidify in the crucible.
- Re-melt as ***quickly*** as possible on subsequent heats.
- ***Avoid*** charging large pieces into a small molten bath (chill back).
- If shutting down, ***seal*** the furnace and ***cover*** the crucible to keep air out.

Common causes of shortened crucible life

1) Mechanical damage.
2) Thermal shock.
3) Chemical attack (flux and slag).
4) Oxidation-burning out of carbon bond within crucible body. ***Do not*** allow the temperature to remain in the 800ºF to 1000ºF (400ºC to 540ºC) range.

1) Mechanical damage

- Possible results of a crucible being rolled on the floor – damaging glaze and or crucible:

Unglazed area	oxidation	cracking.
Rolling of heavier crucibles		hairline cracking.

- Possible results of an Insufficient Expansion Gap:

Grip bricks	cracks.
Cover bricks	cracks.
Tight furnace cover	cracks.
Under spout	cracks.

Mechanical Damage Continued

- Possible results of Improper Charging:

Wedging ingots	cracks.
Tightly packed charge	cracks.
Dropping heavy pieces	cracks and holes.
Sliding sharp material down sidewall	abrasions and/or cracks.

- Frozen heel re-melted   cracks.
- Poorly fitted tongs   cracking around top rim.
- Poor cleaning techniques   damage to interior walls/erosion and oxidation.
- Dross and oxide build-up   expansion cracks.
- Rocking lift-out crucible on stand   cracks.
- Improper base block (stand), stand smaller than crucible base will cause distortion and sagging of crucible bottom leading to cracking.

2) Thermal Shock

- Base block of material other than that of crucible body: Insulating blanket.
  Refractory cement.
- Placing hot crucible on cement floor.
- Minimize cold start-ups (crucibles prefer to remain hot).
- Crucibles should be hot prior to molten transfer.
- Improperly adjusted burner, i.e. a short hot flame.
- Flame impingement will cause localized overheating.

3) Chemical Attack

- Flux products with high levels of fluorides and chlorides are particularly aggressive, as they will react with clays and SiC and glazes.
- Flux left on molten metal surface for extended periods, if this is necessary, ensure a proper cover (liquid) flux is used or use a charcoal cover.
- Do not overheat the melt, as the rate of flux attack will increase with increased temperature.
- Refining flux products are particularly aggressive – use only recommended amounts.
- Flux attack is characterized by a foamy looking glaze, usually green in colour found on the outside walls.

NOTE: Flux attack moves from the inside walls to the outside walls, this is due to the crucible porosity and the fact that flux products will gravitate to the hottest point which is the combustion chamber.

- Oxide/slag build-up   expansion   cracking.
- Slag deposits can contain entrapped flux   flux attack.

4) Oxidation

- Improper burner adjustment, too oxygen rich will contribute to oxidation.
- Flame impingement, protective glaze is burned off exposing crucible wall.
- Improper crucible installation.
  – Insulation allowed between crucible wall and furnace lining.
- Improper crucible start-up.
  – Crucible not cured up to top rim, not enough heat to activate the glaze.
- Keep crucible as full as possible to avoid temperature difference between the top and bottom halves, the empty inside wall will be overly exposed.
- Improper handling, damaged glaze oxidation.
- Furnace leaks, open drain hole drafts oxidation.
- Not using special Low Temperature C11-Glaze.

A Summary of Good Foundry Practices

Storage

All crucibles must be stored in a dry warm environment and stacked on pallets. A hardboard spacer should be placed between stacked crucibles.

Handling

Always use a mechanical aid for handling heavy crucibles. Small crucibles can be transported with hand trucks. If fork lift trucks are used, ensure that the forks are wrapped in a suitable material to protect the crucible from damage.

Setting

General

All crucibles should be supported in the furnace by a crucible stand with similar thermal characteristics to the crucible. The stand should provide complete support over the whole crucible base. The crucible and the stand should be set centrally within the furnace chamber.

Bale-Out Furnaces

The top cover bricks should be set with a chamfer on the underside and the flat top set to the same level as the top edge of the crucible. An expansion gap of at least 5mm should be allowed all round the crucible top edge and the cover bricks. A 25mm layer of insulating blanket should be laid across the top of the refractory and carried across the top edge of the crucible. After the metal cover plates have been set into position, the metal top cover ring is set. The flange of the top cover ring should fit loosely within the crucible, leaving a gap of approximately 9mm all round to allow for expansion.

Tilting Furnaces

Special provision should be made to hold the crucible firmly during the tilting operation. Grip bricks are used to centralize the crucible in the chamber. The first grip brick should be positioned at the back of the furnace opposite the pouring spout and two in the front, set at approx. 120 degrees to the rear grip brick. A gap of at least 5mm should be left between bricks and crucible to allow for expansion.

Preheating

All crucibles should be uniformly preheated to an even red heat (about 800°C/1475°F) prior to charging with metal.

Charging

As soon as the crucible has been correctly preheated, place the metal charge in the crucible and melt immediately. The crucible should be charged in the vertical position with light metal scrap being put in first to form a cushion for the heavier metal. Tongs should be used to charge ingots or other large pieces of metal to avoid impact damage to the crucible and ingots should be placed vertically to avoid bridging or wedging across the crucible. Ingots must never be tightly packed in the crucible or dropped. Sufficient space should be allowed between the metal charge and the crucible to provide room for the metal to expand. Once the melt is finished, the crucible should be cleaned out thoroughly before starting the next melt.

Tongs

Always ensure that the tongs are a good fit and are able to lift a crucible fully charged with molten metal, safety (See Fig. 4 – Pg. 24).

Thermal Shock

Thermal Shock occurs when uneven heating of the crucible results in stress being generated within the structure of the crucible. Ensure that the crucible is heated evenly and the flame direction is correct. Ensure that a crucible is preheated to red heat all over before pouring in molten metal.

Chemical Attack

Many of the fluxes and chemical agents used during melting readily attack the crucible. Therefore the minimum quantity should be added at the latest possible stage in keeping with good metal quality. Refining fluxes are particularly aggressive as they migrate into the crucible wall causing bloating and cracking. Rapid erosion of the external surface can occur due to the much higher temperatures present. Cleaning fluxes, added before the charge, melt before the metal and cause internal erosion in the base and lower walls.

Oxidation

“Perishing by oxidation” is the oxidizing or burning of the carbonaceous materials in the crucible. Do not over-insulate the top of the crucible and make sure the furnace is not operating with an oxidizing flame. Ensure that the furnace has good combustion conditions.

Guidelines for *Good Foundry Practice*

- ✓ Store crucibles in a warm, dry place and on pallets, never directly on the floor.
- ✓ Handle with care to avoid damage to the glaze.
- ✓ Preheat evenly to obtain correct maturing of the glaze.
- ✓ Charge with care to avoid mechanical damage.
- ✓ Don't allow metal to freeze in the crucible.
- ✓ Avoid direct flame impingement and thermal stress conditions.
- ✓ If fluxes/modifiers are being used, ensure the correct type is added in the minimum quantity at the correct stage in the process.

REDUCE OPERATING COSTS
BY USING CRUCIBLES CORRECTLY

Canadian Thermix Inc.

Cracks caused by *Handling Damage*

Problem

Bottom edge crack or vertical crack from top edge appears after a very short time in use.

Checklist

Is crucible sitting on an unsuitable stand?

Are improper furnace conditions in evidence?

Are there any signs of oxidation?

Are there any signs of dross or salt precipitation?

Are there signs of irregularities in the flame area?

If none of the above apply, then...

Diagnosis

Crack must have been caused by mechanical damage through pressure, impact, improper storage or during installation into the furnace.

An example of fault caused initially by damage due to incorrect handling.

Cracks caused by *Unsuitable Stand*

Problem

Crack appears in the chine area or glaze/body deterioration occurs due to flame impingement caused by unsuitable stand.

Possible Causes

Is the stand material different from the crucible material?

Is the stand too small/too big/too tall or too short?

Is the flame firing above the stand and onto the crucible body?

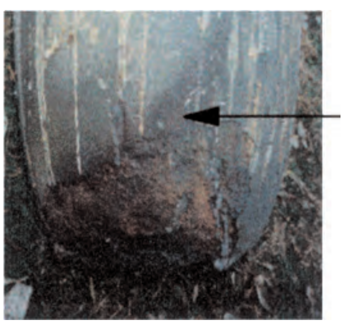
Is the stand surface uneven (i.e.: not flat)?

Is the stand positioned off centre below the base of the crucible?

If any of the above apply, then...

Diagnosis

The cracks or deterioration have been caused by the use of an unsuitable stand.



Mark left by flame.

Damage caused by flame impingement due to poor fitting stand.

Example of brick being used instead of a stand.

Severe crucible body deterioration caused by flame impingement as a result of a poor fitting stand.

Cracks caused by *Parting Agents*

Problem

Cracks at the bottom of the crucible.

Possible Causes

If powder is used, is the spread over the stand uneven?

Is the force of the flame in the furnace blowing the powder away?

Is the powder moistened during installation, thus causing the moisture to pass into the crucible base?

The use of ceramic fibre between crucible and stand will produce an insulating effect such that the crucible base may remain relatively cold whilst the walls reach red heat. The temperature difference will result in thermal stress which can lead to crack formation.

If any of the above apply, then...

Diagnosis

The cracks have been caused by the parting agent.

Crack caused by the incorrect use of parting agents.

Cracks caused by *Metal Charge*

Problem

Cracks or holes appearing anywhere in the crucible base or wall.

Possible Causes

Are the ingots wedged transversely or crossways causing contact with the wall of the crucible?

Are the ingots being wedged in an inclined position against the wall of the crucible?

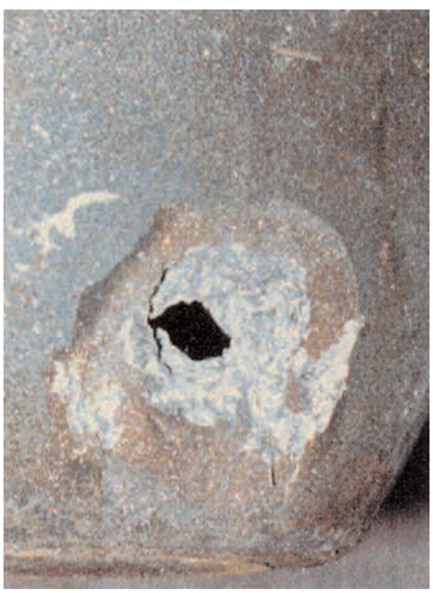
Are the ingots being dropped into the crucible rather than placed?

Are the ingots being forced into the crucible thus becoming tightly packed?

If any of the above apply, then...

Diagnosis

The cracks are caused by incorrect charging procedure.



Hole caused by an ingot being thrown into the crucible.

A "shield" shape crack caused by an ingot being wedged against the side of the crucible wall.

Cracks caused by *Air Entering the Emergency Drain Port*

Problem

Localized deterioration around the area of the crucible adjacent to the emergency drain port possibly with cracks running away from the flaw.

Possible Causes

Is the emergency port opening during melting or during tilting?

Is the waste gas exhaust off centre?

Are there any design faults in the furnace which allows cold air to pass over a heated crucible for extended periods of time?

If any of the above apply, then...

Diagnosis

The cracks or deterioration have been caused by cold air entering the area around the crucible.

Cold air coming into contact with a hot crucible will result in cracks similar to these.

Cracks caused by *Poor Flame Direction*

Problem

Areas of the crucible where glaze has run off, oxidized and stress cracks may have developed.

Possible Causes

Are there any uneven areas or obstructions on the base or the wall of the furnace where the flame could be throttled or deflected?

Is the burner incorrectly aligned?

Are there signs of burner deterioration?

Are there any deposits on the fuel jet, dust build up in the air nozzle or the blower which may be causing a disturbed flame?

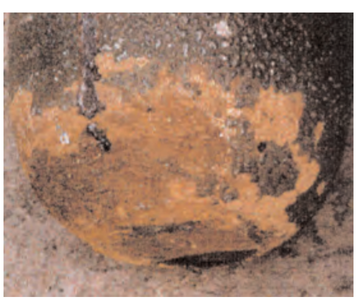
Is the flame firing around the bottom of the crucible only and not passing around the crucible in a helical pattern?

In oil furnaces, is poor atomization and incomplete combustion causing unburned oil to spray onto the crucible, forming coke and then disrupting the flame pattern?

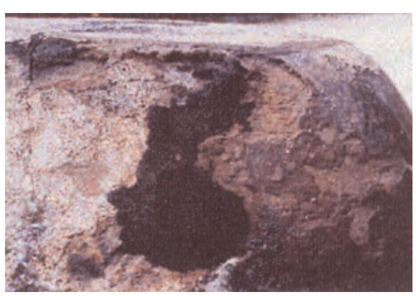
If any of the above apply then...

Diagnosis

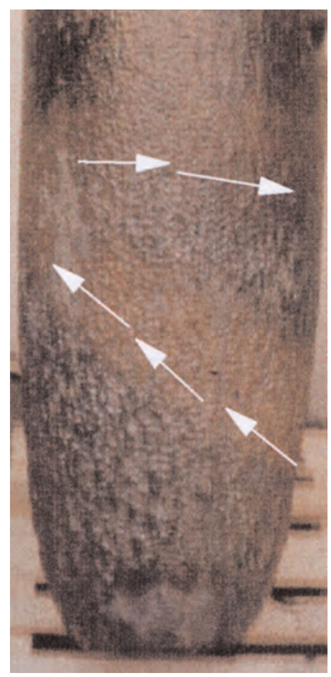
The cause of the crack was poor flame direction.



Severe oxidation caused by poor flame direction.



Extreme case of flame being fired directly at the base of the crucible causing carbon build up and oxidation of the surrounding area.



Arrows show direction of flame. Poor flame direction clearly indicated by reddish flame path. The flame was not travelling around the crucible in a helical direction.

Cracks caused by *Oxidation*

Problem

Porous and brittle layer of a crucible which begins to flake and spall off – possibly leading to cracks.

Possible Causes

If the crack is at the top of the crucible –
Has the crucible been set in the furnace with insulation material between the cover bricks and crucible wall thus causing cool spots and subsequently preventing glaze maturity?

If the crack is at the bottom of the crucible –
Is there any sign of a blocked nozzle causing poor flame direction?

Was the crucible subjected to bad handling before installation?

Has the crucible been subjected to damp, causing the glaze to flake off and thus leading to oxidation of the unglazed area?

Is air entering the furnace? No drain hole plate/flap or poor fitting plate/flap.

If any of the above apply, then...

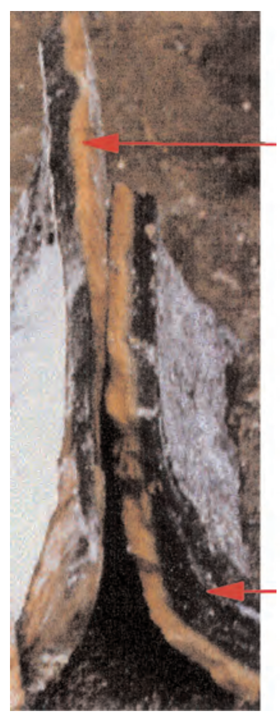
Diagnosis

The crucible has become oxidized.

Damage of the crucible chine followed by oxidation in use.

Cracking near top edge from bad setting followed by oxidation.

Oxidation of clay graphite crucible.



Layer of oxidation.

Unaffected material.

Cracks caused by
Crucible Tongs and Carrying Shanks

Problem

Crush marks appear around the top edge of the crucible and may lead to crack development.

Possible Causes

Are the tongs or shanks too small for the crucible?

Are the tongs or shanks incorrectly positioned on the crucible?

If either of the above apply, then...

Diagnosis

The cracks have been caused by ill fitting tongs or shanks.

Incorrect use of tongs to lift crucible. The tongs are too high up the body and this causes crushing of the crucible wall.

Correct positioning of crucible tongs.

Cracks caused by *Dross Build-Up*

Problem

Cracks appearing in the wall, rim or base.

Possible Causes

The presence of a layer of metallic oxides in the base and on the walls of the crucible can lead to bursting cracks. These dross build-ups become extremely hard with subsequent heating. The expansion of this material can be up to ten times the expansion rate of the crucible. Dross deposits also have a heat insulating effect.

If the above applies, then...

Diagnosis

The crack was caused by dross build-up.

Dross accumulation in the base of the crucible.

Cracks caused by *Flux Attack*

Problem

Deterioration of the crucible wall followed by random cracking.

Possible Causes

Are fluxes and other chemical agents being overused?

Is the crucible being used to hold metal treated with fluxes for long and unnecessary periods of time?

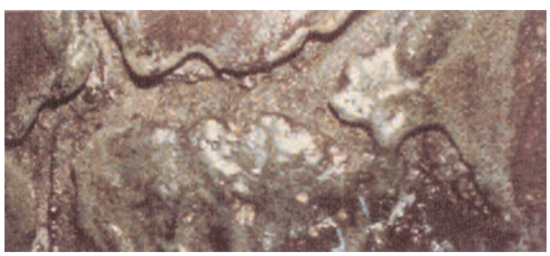
Are the fluxes being used at a higher temperature than is necessary to melt the metal?

Are the fluxes being allowed to sit on top of the charge rather than being stirred in?

If any of the above apply, then...

Diagnosis

The deterioration and cracking were caused by Flux attack.



Green, glassy type surface is a clear indication of flux attack.

Another good indication of flux attack are the "moon surface craters" as a result of the corrosive effect of the chemicals used.

Flux attack at the top of this crucible has probably occurred because the flux material has been allowed to remain on the surface of the charge whilst the crucible has been holding metal.

Cracks caused by *Metal Expansion*

Problem

Crack anywhere in the crucible wall or crucible breaking apart.

Possible Causes

Was the charge allowed to solidify in the crucible?

Had the crucible been left at the end of the week without being cleaned out properly?

If either of the above apply, then...

Diagnosis

The crack/breakage was caused by metal being allowed to solidify and then subsequently re-heated. As the metal will expand at a far greater rate than the crucible material, a bursting crack in the crucible will release the pressure.

Cracking after subsequent expansion of frozen charge.

Bursting type crack from frozen heel of metal.

Cracks caused by
Improper Installation into the Furnace

Problem

Crack appears around the top edge of the crucible rim, or around the spout of a spouted crucible.

Possible Causes

Is the furnace cover too close to the crucible rim leaving insufficient room for expansion?

Is too much packing or mouldable being used?

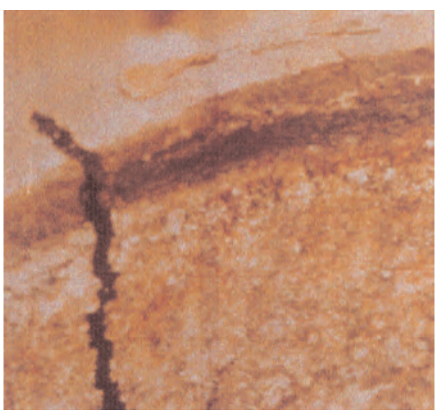
Does the packing material around the spout prevent the material from expanding?

If used, are the grip bricks tightly packed against the crucible?

If any of the above apply, then...

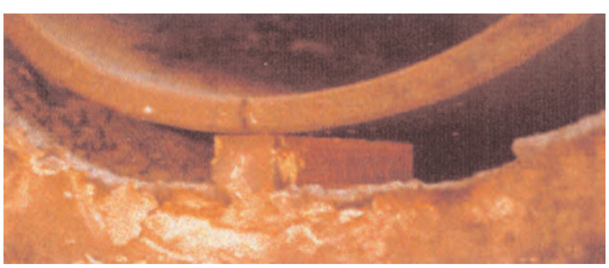
Diagnosis

The cracks have been caused by improper installation into the furnace.



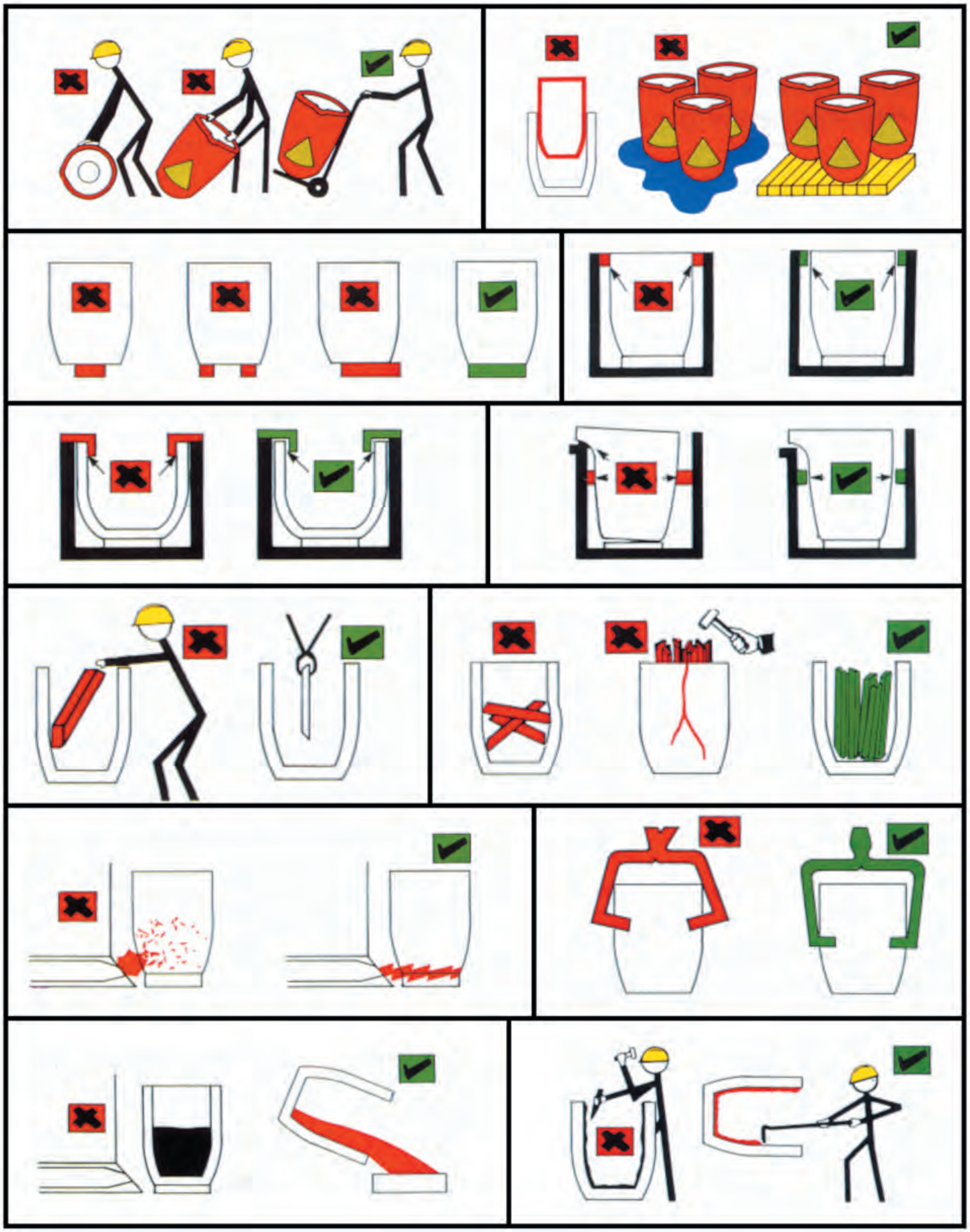
Top edge cracking due to tightly fitting top cover ring.

Top edge vertical cracking due to tight fitting grip-brick.



Crucible with cracking showing grip-brick too tight.

Proper Storage, Care and use of Crucibles



Illustrations of Figures 1-4