VENTING: A CONTINUING NEED FOR AN OLD ART

The need to vent cores and low-permeability molds to produce acceptable castings has been recognized for many years. Methods and materials are discussed here, and the technical literature is reviewed to provide criteria for determining the adequacy of vents.

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The desirability, if not necessity, of venting cores and low-permeability molds to assure acceptable quality castings has been recognized for many years. As stated in 1940 by Biringuccio in the Pirotechnia:

Summarizing, the more vents you make on your molds and the wider the entrances [gates], the sure you will be of a good result in your casting, if you have melted well. I neither know nor am able to say any more about this.

The basic function of a vent is to allow the gases trapped and evolved within the core or the mold during the casting process to exist within or, preferably, to exit the mold without being forced into the liquid metal or solidifying casting.

While venting is required for both, generally the need is greater with cores than molds, since a major fraction of the core's surface area is in direct contact with the cast metal, and the area through which gases may escape from the core is generally limited. This paper primarily addresses the venting of cores, although much of the information is also applicable to molds.

A variety of techniques and materials are available for venting cores. The five basic types of vents and venting systems used include:

1. Rod- or plate-formed vents
2. Textile tubing
3. Coke, slag orinder
4. Wax
5. Rope

Rod- or Plate-Formed Vents

There are a number of methods available for introducing channels or open passages within cores with rod, wire or plates. The rods are generally metal, although other rigid materials will suffice. The core is either formed around the rod, as with ram-up vents, or the rod is inserted into the formed but uncured core, as with plug vents. The rod is then removed, leaving an open channel (the vent) in the core. When the core is made in parts, vent plates may be used to form a channel along the parting plane of the core parts, such that when the core halves are assembled, a channel or vent will exist.

The vents formed with rods are simply holes or passages that extend through the core. Venting with rods is one of the most common techniques used by the foundry industry. The process is relatively simple, inexpensive and, unlike the other venting systems to be described, does not involve any consumable non-core material as part of the vent.

Rod-formed vents are generally straight, cylindrical channels (of slightly larger diameter than the rod) within the core, since removal of the rod or wire from one-piece cores imposes restrictions on the allowable path configuration of the vent. Thus, rod-formed vents are most often used with straight, cylindrical cores. Cross-vents and more intricate venting patterns may be formed by using straight rods disposed at angles to each other and intersecting within the core.

A basic concern with the rod-formed vents is that the formed channel must remain open over its entire length, up to and through use of the core. Since there is no internal support of this vent, core material may collapse and fill the vent passage at various sites, thereby severely limiting the functioning of the vent.

Textile Tubing

Textile tubing was initially developed in Europe as an all-purpose venting material that could be used with baked and no-bake binders. The textile tubing is placed in the core during core production, where it remains to provide an internal passage for gas to escape. The tubing generally consists of three fibers (two cellulose and one thermoplastic) woven together to produce an integral, porous, tubular product. The fibrous materials are selected to provide flexibility, high structural strength, and low gas evolution.

The textile make-up insures flexibility to fit horizontally...
around corners or vertically into deep pockets in complex cores and molds. The permeable and porous nature of the sintilites allows gases to flow easily into the tubing. The weave of the textiles is tight enough to prevent grains of sand from entering the tubing, and it is stiff enough to prevent the tubing from flattening out when exposed to reasonable hand or machine ramming. Since the textile tubing is hollow, it does not have to be baked out to leave a vent, as does wax. It is therefore ideally suited to vent cores or molds made with nooks and knockers. It is easy to work with and is virtually unaffected by cold, heat or moisture. Textile tubing is available in a variety of diameters and lengths.

Coke, Slag or Cinder Vents

Relatively large cores may be vented by providing a dry and permeable coke, slag or cinder pocket in the interior of the core. A continuous passageway from the interior of the core (the coke, slag or cinder bed) to the outside of the core via the mold or core print must also be provided. In baked cores, coke, slag or cinder interiors may also aid in reducing baking time.

Coke, slag or cinder bed type venting is generally limited to larger cores. It is frequently difficult to adequately vent deep cores or all sections of complex-shape cores with this technique. Also, an additional section of vent such as textile tubing must be provided connecting the cinder bed to the core print or mold. It is somewhat difficult to design this type of vent system, since the permeability of the bed may be a variable from site to site due to variations in coke, slag or cinder particle size and packing density.

Wax Vents

In a manner somewhat similar to the lost wax molding process, vents may be formed in cores by placing wax preforms within the core material and then melting the wax preform to leave an open vent passage in the core. Wax for this application is available from the foundryman in the form of small diameter solid rods, flat oval ribbon, or hollow tubing. Solid vent wax is generally used. There appears to be limited production and usage of hollow vent wax.

The relative flexibility of the vent wax forms allows the formation of rather intricate vents in cores. In cores, the wax melts to leave an open passage; however, a major portion of the melted wax generally remains in the core material. The melted wax which diffuses or flows into the core material may affect the physical properties of the core and is a contributor to gas evolution within the core during the casting operation. Wax vents are best suited for use with core materials that are baked or heated during curing so that the removal of the wax does not require an additional energy-intensive operation.

The wax should be kept at a temperature of about 15-25°C (59-77°F) in order to exhibit appropriate flexibility and strength for forming the vents.

Rope Vents

The introduction of rope or permeable fibrous materials into cores for venting has been used for centuries. (Biringuccio describes the use of hemp tow or rope as part of core lubrication for cannon casting.) The core material is impacted around the rope, and generally the rope is left intact in the final core. The rope should be of significantly greater permeability than the core material.

As with any art, there are a number of venting variations found in foundries which involve these and other similar materials and techniques.

Technical Literature

While the need for using vents in molds and cores is noted in a number of technical articles, only a few authors have quantitatively addressed the basic questions given below concerning vent use. These basic questions include:

1. How does the need for venting depend on the nature and composition of the mold or core material?
2. How is the need for venting influenced by the size (dimensions) of the core and the core placement in the mold?
3. What are the necessary vent dimensions and placement within the core that will eliminate gas-associated defects and yield sound castings?

The papers of May,12 Caine and Toepke,13 Fesham4 and Woman and Nieman14 address these and related questions. May12 performed experiments which showed that the permeability of molds and cores could be increased via venting, particularly when the vents were close (0.12-0.25 in.) to the mold or core surface. He also showed that venting was successful in preventing the formation of scabs on casting faces when the mold was of relatively low permeability or had high water content. May summarized that, to be effective, vents should be formed as near as is practical to the mold or core face, and the vents should have a free access path to the atmosphere.

Caine and Toepke13 showed that gas pressures could be reduced to low values (less than 0.5 psf) if vents were properly placed so that the gas forming at the heated face could travel a short distance to an unobstructed vent for passage through the core print and out the mold. The placing of vents so that the generated gases do not have to travel more than one inch from the heated area to an open vent was preferred.

Fesham4 noted that in many cases the venting of molds and cores was relatively ineffective because of poor design or improper care of the vents. Thus, while foundries may introduce vents, they do little to allow for the adequate escape of evolved gases. This ineffective use of vents is attributed to such factors as: closure of the vent prior to use due to vent collapse, filling with mold coating, or penetration of liquid metal into the vent (generally at or near the core print). Fesham also stated that it was important to consider the total gas evolved within the core to design the appropriate venting system. He indicated that the permeability of the mold or core could be significantly increased if the vents are within 3-5 mm (0.12-0.19 in.) of the mold or core surface and have free access to the atmosphere.

Woman and Nieman14 present a mathematical procedure to calculate the pressure associated with the core gas evolution for any given core configuration and, in turn, to evaluate whether or not a core gas defect will occur for the casting. This paper essentially addresses and answers the three basic vent design questions previously listed. The
Mandrels in this edge-blow corebox produce excellent vents while lightening the cores and reducing sand and binder use.

A basic equation used by Worsman and Nienau is:

\[ P = K \left( a_c - a_m \right) g d c \]

where:
- \( P \) = pressure due to core gas (psi)
- \( K \) = unit conversion factor; \( K = 0.0185 \) psi cm\(^2\) for the units given.
- \( g \) = gas flow (cc/sec)
- \( d \) = core density (g/cc)
- \( c \) = percent core decomposed (%)
- \( p \) = core permeability (cm^2 x sec)

Note that the pressure developed within the core depends on the total amount of gas generated and the freedom of the gas to escape (i.e., the extent of venting through the core gas escape area). The core gas escape area, \( a_c \), is the cross-sectional area of the core prints plus the total surface area of the vents. Once the core gas pressure is calculated for a given core material and casting system, one can compare that pressure with the metal flow; pressure to ascertain if the gas will report to the liquid metal or remain within the core.

Nienau and Worsman's formulation (Equation [1]) can be used to obtain a venting design criterion:

\[ a_c > a_m (1 - A - a_p) \]

where:
- \( a_c \) = cross-sectional area of the vents (cm\(^2\))
- \( a_m \) = core-metal contact (surface) area (cm\(^2\))
- \( a_p \) = cross-sectional area of the core prints (cm\(^2\))
- \( A \) = metal filling percentage
- \( p \) = remaining core gas pressure

where:
- \( p_{metal} \) = density of liquid metal (g/cm\(^3\))
- \( p_{core} \) = density of core/mold material (g/cm\(^3\))
- \( P \) = permeability of core/mold material (cm^2 x sec)
- \( Z \) = distance between the top of the core and the top surface of the molten metal (cm)
- \( K' \) = unit conversion factor = 2.166 cm^2/sec for the units given
- \( g \) = gas evolution of the core/mold material (cc/g)
- \( c \) = fraction of core/mold material decomposed (gaseous)

Equation [2] enables the foundryman to calculate the vent size needed to eliminate the occurrence of typical gas-related defects. To demonstrate the application of Equation [2], consider the venting required for the following examples:

- \( p_{metal} = 7.0 \text{ g/cm}^3 \) (density of iron)
- \( p_{core} = 2.5 \text{ g/cm}^3 \)
- \( P = 1.5 \text{ g/cm}^2 \cdot \text{sec} \)
- \( K' = 2.166 \text{ cm}^2 / \text{sec} \)
- \( g = 25 \text{ g/cm}^2 \cdot \text{sec} \)
- \( c = 1.0 \) (fully decomposed core)

and the core-metal surface area, \( a_m \), is 150 cm\(^2\) and the core print area, \( a_p \), is 20 cm\(^2\). For such cores placed at three depths in the casting cavity, \( Z = 5 \text{ cm} \), \( Z_2 = 10 \text{ cm} \) and \( Z_3 = 20 \text{ cm} \) respectively; the parameter \( A \), and the required vent area are given in Table 1.

<table>
<thead>
<tr>
<th>Core Depth, cm</th>
<th>( A )</th>
<th>Calculated Vent Area (cm^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.388</td>
<td>71.8</td>
</tr>
<tr>
<td>10</td>
<td>0.770</td>
<td>15.6</td>
</tr>
<tr>
<td>20</td>
<td>1.55</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Thus, a vent or vents with a cross-sectional area in excess of 71.8 cm\(^2\) is required for the shallow (\( Z = 5 \text{ cm} \)) placed core, while no additional venting is required for the deeper (\( Z = 20 \text{ cm} \)) placed core in this example. Equation [2] is consistent with the intuitive expectations that the need for venting increases with increasing gas evolution of the core/mold materials and decreases with increasing core permeability. Note that \( A \) approaches zero as the core permeability diminishes (i.e., \( A = 0 \) for \( p = p_0 \)) and the venting design criterion becomes:

\[ a_c > a_m (1 - a_p) \]

Conclusions

The ancient art of venting remains a much-needed practice in today's foundries. The increasing use of resin binders may even make venting more needed than with past molding practices. The art of venting has not advanced much relative to the position cited in 1540 by Birringuzzo, that is, the more vents used, the greater the probability of producing sound castings.

Based on the technical literature, venting should fulfill the following requirements:

1. Vents should be positioned as close to the core-metal interface as practical (i.e. typically within 1/4-inch of the core or mold-metal surface).
2. Vents should remain open over their entire length throughout the casting and solidification period.
3. Vents should be adequately connected to the mold and atmosphere to allow easy escape of gases.

The general design rules coupled with the venting design criteria presented herein (Equation [2]) essentially constitute the science of venting.

In practically all cases, it is simpler and less expensive to introduce adequate venting of cores and molds than to suffer the consequences of increased surface repairs of castings and increased scrap rates.

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References

8. C. C. Foundry Practice, American Foundrymen's Society, 1980, pp. 53-60.