REVIEW and INTRODUCTION:

A. Problem Analysis:

1. Review of errors associated with indirect restorations:
   a. Impressions = 0
   b. Casts and Dies = 0
   c. Wax-up = 0
   d. Investing = +1.5%
   e. Casting = −1.5%
   f. Finishing, Polishing = 0
   g. (Porcelain Application) = ?
   h. Cementation = 0

B. Requirements for Casting Investments:

1. Expansion: 1.2-2.2% compensation for alloy shrinkage
   a. Gold alloy expansion: 1.4-1.7%
   b. Base metal alloy expansion: 2.0-2.3%
2. Accuracy: Resistance to distortion during setting
3. Strength: Resistance to casting forces and high temperatures
   a. Refractory: Material with high mp that resistant to high temperature

C. General Formulation for Investment Materials:

1. Refractory FILLER: [66%] = Quartz, Cristobalite
2. BINDER (Matrix): [33%] = Gypsum, Phosphate, Silicate
3. ADDITIVES (Modifiers): [ 1%]

D. Dimensional Changes in Investment and Casting:

1. Setting Reaction: Chemical Reaction (Formation) = [-]
   Physical Reaction (XI Growth) = [+] 
2. Hygrosopic Reaction: Physical Reaction (XI Growth) = [+]
3. Thermal Reaction: Chemical Reaction (Decomposition) = [-]
   Physical Reaction (Thermal Expansion) = [+]
   Physical Reaction (Thermal Inversion) = [+]
4. Casting Shrinkage: Physical Reaction (Thermal Contraction) = [-]

TOTAL: = [0]
ANALYSIS OF INVESTMENT REACTIONS:

A. Setting Reaction:

1. Chemical reaction involves minor contraction
2. Crystallization involves crystal impingement and expansion

B. Hygroscopic Reaction:

![Graph showing expansion over time for different conditions]
C. **Thermal Reactions:**

1. Review of Phase Changes for Solid Phases:
   a. **Reconstructive Phase Transformation:**
      (Equilibrium transformation)
      (New crystal structure; Long range diffusion required; Very SLOW)
   b. **Displacive Phase Transformation:**
      (Non-equilibrium transformation= INVERSIONS)
      (Distorted crystal structure; No diffusion required; Very FAST)

2. Review of Equilibrium and TTT Diagrams for SiO₂:

3. Silica Filler:
   a. Exists as 4 forms (3 undergo displacive transformations and inversions)
   b. Unique thermal expansion coefficients for each form

<table>
<thead>
<tr>
<th>Fused Silica:</th>
<th>Cristobalite:</th>
<th>Tridymite:</th>
<th>Quartz:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Non-Crystalline, Glass)</td>
<td>(Crystalline)</td>
<td>(Crystalline)</td>
<td>(Crystalline)</td>
</tr>
<tr>
<td>Expansion</td>
<td>1.7% from RT to 600 °C</td>
<td>0.9% from RT to 600 °C</td>
<td>1.5% from RT to 600 °C</td>
</tr>
</tbody>
</table>

---

**THERMAL EXPANSION CURVES FOR SILICA**

- Cristobalite
- Quartz
- Tridymite
- Fused Silica (Amorphous)

---
A.D.A. SPECIFICATIONS FOR INVESTMENTS:

A. Specification #2:
   1. Type I: Inlays, Crowns: Thermal Expansion Types (0.0-0.6%)
   2. Type II: Inlays, Crowns: Hygroscopic Types (1.0-2.0%)
   3. Type III: Partial Dentures: Thermal Expansion Types

ANALYSIS OF INVESTMENT MATERIALS:

A. Gypsum Bonded Investment, GBI: (Low Temperature Investment)

1. Chemical Composition:
   a. Binder: 25-45% alpha calcium sulfate hemihydrate
   b. Filler:
      (1) Quartz, or
      (2) Cristobalite
   c. Modifiers
      (1) Colorants:
      (2) Reducing Agents:
      (3) Shrinkage Controllers: Boric Acid, NaCl

2. Setting Reaction:

   \[ \text{CaSO}_4 \cdot (1/2)\text{H}_2\text{O} + (3/2)\text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot (2)\text{H}_2\text{O} \]

3. Dimensional Changes:
   a. Contraction due to the chemical reaction
   b. Expansion due to impinging crystal growth
   c. Expansion facilitated by hygroscopic technique
   d. Contraction due to calcium sulfate dehydration (~200°C)
   e. Contraction due to calcium sulfate de-sulfonation (~700°C)
   f. Expansion due to thermal expansion of fillers
   g. Expansion due to thermal inversions fillers
   h. Contraction due to cooling of casting alloy

4. Applications: Gold casting alloys

B. Other investment materials (PBI and SBI) will be discussed later.
MULTIPLE CHOICE STUDY QUESTIONS:

1. What are the error limits overall for indirect dental procedures?
   a. 0.2 %
   b. 0.5 %
   c. 1.0 %
   d. 1.5 %
   e. 2.0 %

2. What is the overall range of casting shrinkage that must be compensated for by the investment?
   a. 0.2 - 0.5 %
   b. 0.5 - 1.0 %
   c. 1.0 - 1.2 %
   d. 1.2 - 2.2 %
   e. 2.2 - 3.0 %

3. What is the typical range of casting shrinkage that is associated with gold alloys?
   a. 0.2 - 0.5 %
   b. 0.5 - 1.0 %
   c. 1.0 - 1.2 %
   d. 1.4 - 1.7 %
   e. 1.7 - 2.3 %

3. How much filler is there in a typical investment composition?
   a. 20%
   b. 45%
   c. 66%
   d. 75%
   e. 94%

4. During the setting reaction of investment materials, the chemical reaction generates which one of the following dimensional changes?
   a. No change
   b. Contraction
   c. Slight expansion
   d. Large expansion
   e. Expansion and then contraction

5. Hygroscopic expansion of investment materials occurs by:
   a. Facilitated crystal impingement producing expansive forces
   b. Production of more reaction products
   c. Production of a secondary reaction product
   d. Absorption of water by the filler phase
   e. Slowing the reaction during setting

6. Thermal expansion of investment materials occurs by:
   a. Chemical reaction in the filler phases
   b. Chemical reaction in the binder phase
   c. Thermal expansion and Inversion of the filler particles
   d. Allotropic phase transformation
   e. Dehydration of the binder

7. Which one of the following filler phases undergoes the most expansion per unit of temperature?
   a. Fused Quartz
   b. Quartz
   c. Tridymite
   d. Cristobalite
8. What is the difference between quartz and cristobalite?
   a. The water content of the phases
   b. They are different inversions of the same phase
   c. They are different allotropic phases
   d. They are different chemical compositions
   e. They represent different amounts of crystallinity

9. Inversion of cristobalite occurs:
   a. Slowly over a range of temperature
   b. Slowly over a narrow range of temperature
   c. Rapidly over a narrow range of temperature
   d. In direct proportion to the temperature change

10. ADA specifications for Type II investment refer to materials that involve:
    a. Only hygroscopic expansion
    b. Only thermal expansion
    c. Both hygroscopic and thermal expansion
    d. No expansion

11. Gypsum bonded investments are generally used for:
    a. Gold casting alloys
    b. Ni-Cr casting alloys
    c. Titanium casting alloys
    d. Co-Cr casting alloys
    e. Ag-Pd casting alloys

12. The maximum usable temperature for gypsum bonded investment is about:
    a. 650 C
    b. 800 C
    c. 1000 C
    d. 1100 C
    e. 1400 C

13. Gypsum bonded investment normally does NOT contain which of the following?
    a. Calcium sulfate hemihydrate
    b. Quartz
    c. Tridymite
    d. Cristobalite
    e. Boric Acid

DISCUSSION STUDY QUESTIONS:

1. What is the purpose of an investment ring liner?
2. What is the effect of air bubble incorporation into the investment materials before setting on the final casting?
3. How long can an invested pattern be stored before casting?
4. What is the effect of the water temperature for hygroscopic expansion on the degree of expansion?

© 2004, Stephen C. Bayne, Chapel Hill, NC 27514