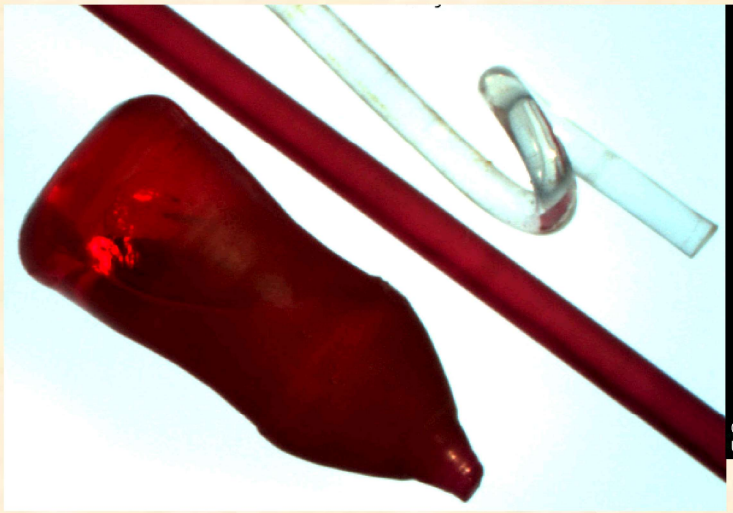
Quiz

- The first synthetic gems were rubies produced in _____(year)
- Mass production of synthetic rubies began in _____(year)
- The first synthetic diamonds were produced in _____(year) by the _____ company
- The first synthetic diamonds were produced by the _____ technique
- The yearly World production of synthetic diamonds is _____ carats
- Natural quartz gems (amethyst and citrine) are too inexpensive to support a synthetic gemstone market (True or False)
- The first commercially successful synthetic emeralds were made by Carroll C. Chatham in 1939, when he was 25 (True or False)
- Synthetic, gem-quality diamonds are still years from being commercially available.

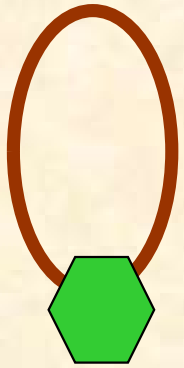
Gemstone Synthesis

Paul F. Hlava
Access to Gems & Minerals



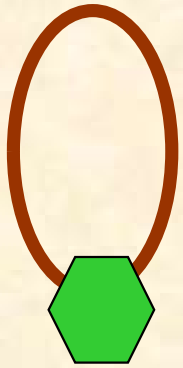
In The Beginning…..

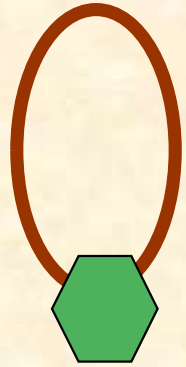
- **Day One - Aag found a very pretty piece of rock and tied it around his neck with a piece of string. (Gemstones were born.)**



In The Beginning…..

- Day One - Aag found a very pretty piece of rock and tied it around his neck with a piece of string. (Gemstones were born.)
- **Day Two - Envious Oog couldn't find a piece of the "real" stuff so he made something to look like it. *Simulated* gemstones were born. (Why not synthetic?)**





As I was Saying…….

By Pliny's time, counterfeiting gems was big business

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...Moreover, I have in my library certain books by authors now living, whom I would under no circumstances name, wherein there are descriptions as to how to give the color of smaragdus [emerald] to crystallus [rock crystal] and how to imitate other transparent gems: for example, how to make a sardonychus [sardonyx] from a sarda [carnelian, in part sard]: in a word to transform one stone into another. To tell the truth, there is no fraud or deceit in the world which yields greater gain and profit than that of counterfeiting gems.

Pliny [23-79 AD], from Ball, 1950, p. 19

As I was Saying…….

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Nothing has changed!

Goals/Purpose/Outline

- **Definitions**

Goals/Purpose/Outline

- Definitions
- **The Keys to Success**

Goals/Purpose/Outline

- Definitions
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- **History of Ruby Synthesis**
  - **Flame Fusion or Verneuil**
  - **Czochralski**
  - **Flux Growth**

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  - **Early Attempts**
  - **High Pressure Synthesis**
  - **Recent Developments**

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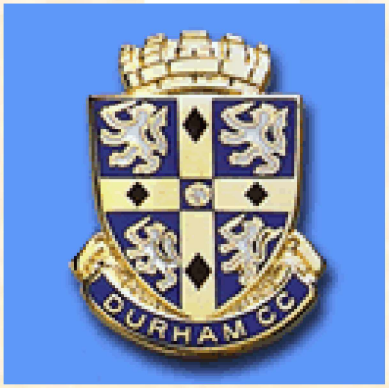

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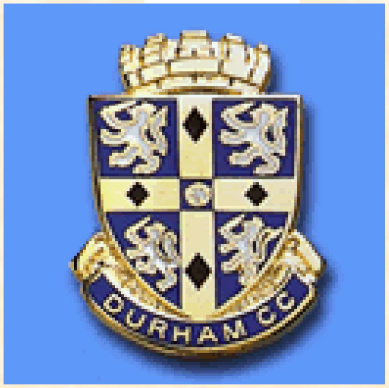
- **Jewel** - a object made of precious metal and enamel and/or gems used for ornamentation.
- **Gemstone** - a naturally occurring material that is desirable for its beauty, valuable in its rarity, and durable and stable enough to give lasting pleasure when worn as an ornament.



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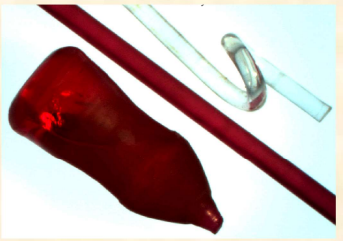

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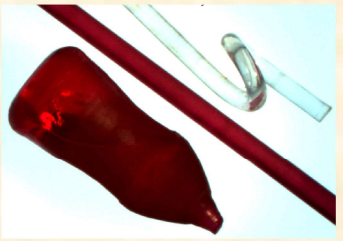

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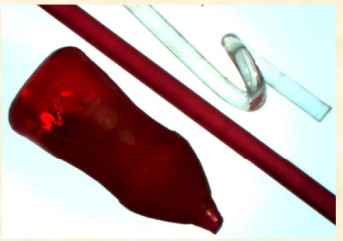
  - **Simulants** - any material with the wrong chemistry and physical properties masquerading as a gemstone. (plastic, glass, other minerals)



Key #1 - Analytical Chemistry

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- **Advances in the science of chemistry by the end of the 18th century revealed the constituent elements and coloring impurities of many gems and their proper proportions. (diamond, 1797; emerald, 1798; ruby, by 1800)**

Other Keys

- **Heat - required development of potent torches and furnaces**
  - **Rubies and sapphires made at 2200°C (4000°F)**
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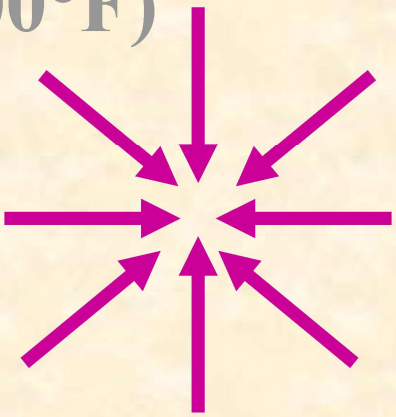

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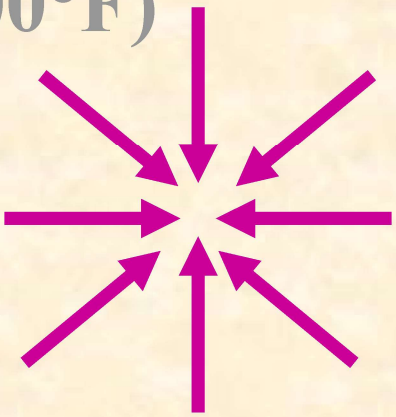
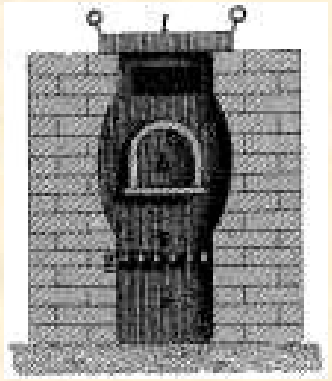


- **Pure starting materials**
  - **Ruby from alum**

Synthetic Rubies - Early Work

- **Nassau lists over 2 dozen people who worked on ruby synthesis in the early 1800's.**



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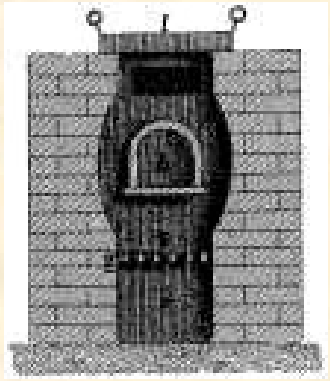

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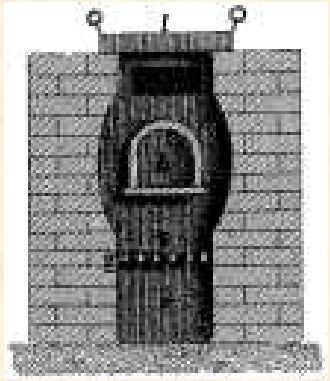
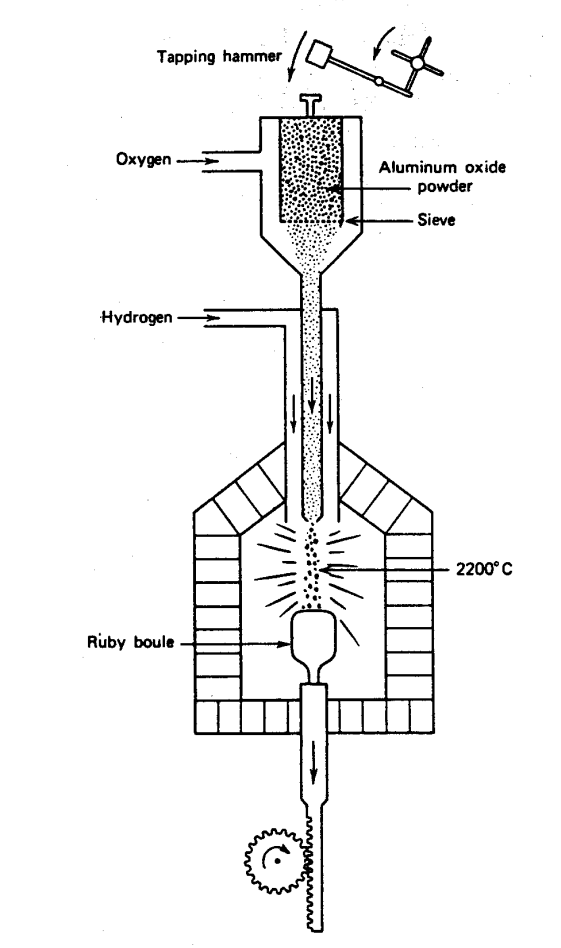
- **Frémy, 1877 - large crucibles, Pb-oxide flux, small but commercial quality - too expensive to compete with naturals.**

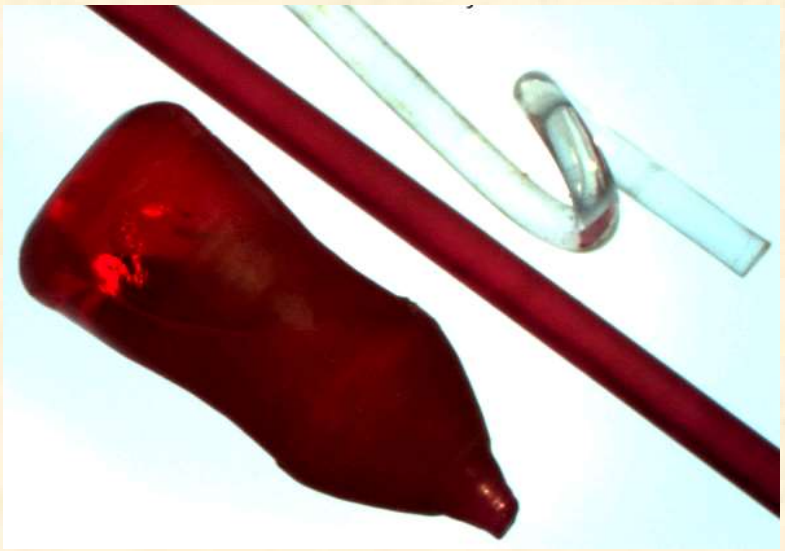


Verneuil Succeeds

- **Verneuil (student of Frémy) perfected a viable furnace to make ruby, and later sapphire somewhere between 1888 and 1891. Commercial, mass production began in 1902. The technique is called Flame Fusion or the Verneuil Process.**



Verneuil Furnace and Boules



The small attachment neck is crucial to reducing stresses.

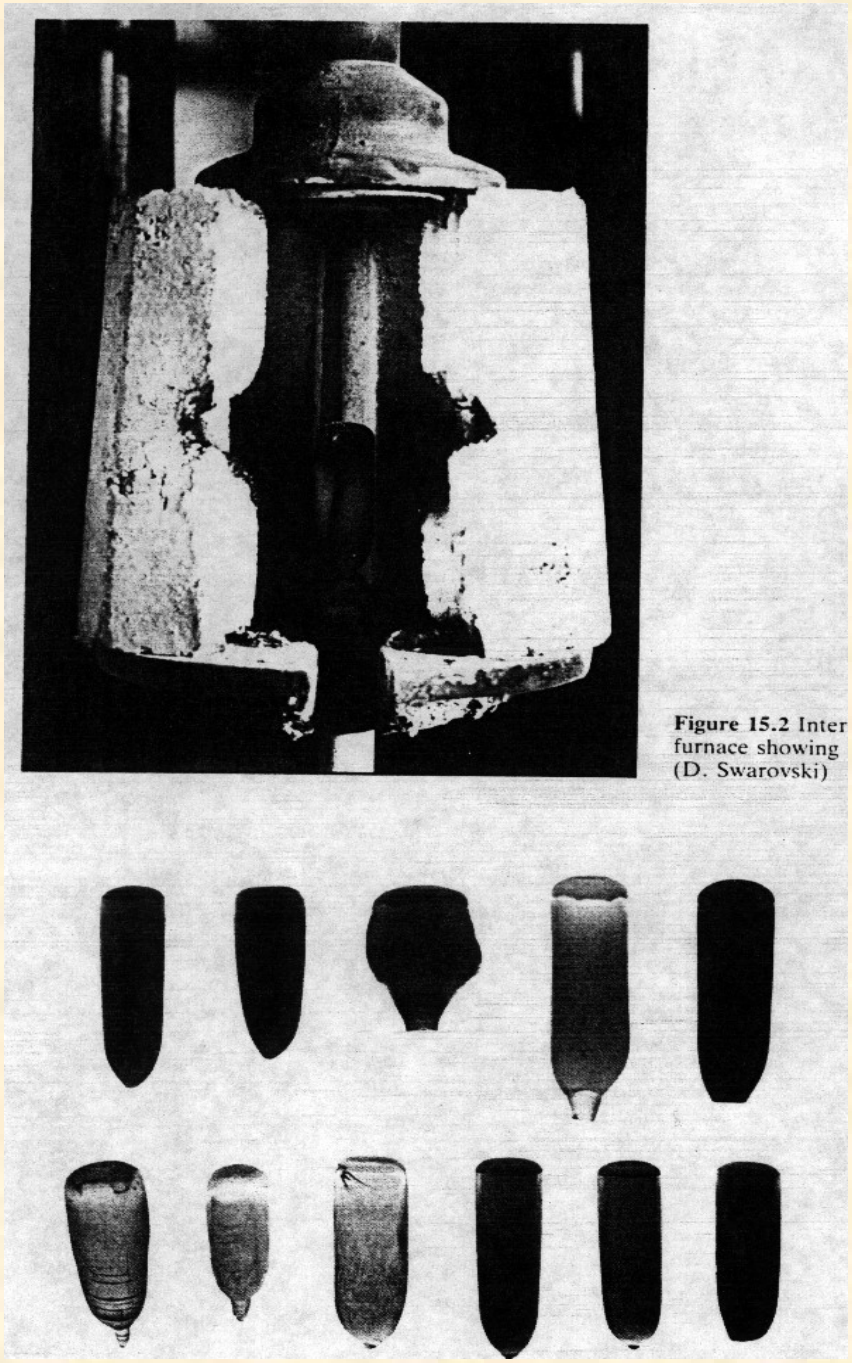


Figure 15.2 Inter
furnace showing
(D. Swarovski)

Mass Production

- **Fla[illegible] Fusion or Verneuil process**
  pr[illegible] and
  sp[illegible]

Mass Production

- Flame Fusion or Verneuil process
  pr and
  sp
- Al less)

Mass Production

- Fla… Fusion or Verneuil process
  pr… and
  sp…
- Al… less)
- **Hu…**
  pr… c
  ge…

Mass Production

- Fla
  pr
  sp
- Al
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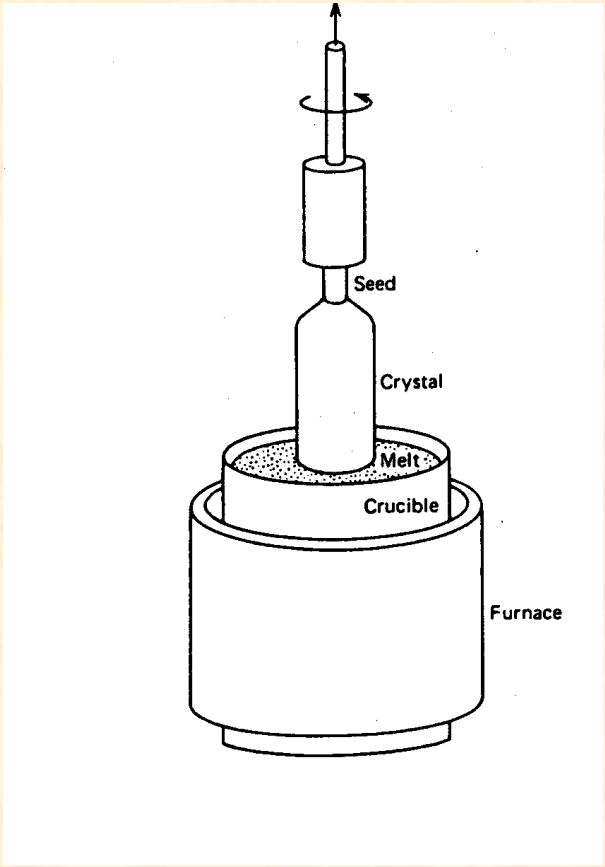
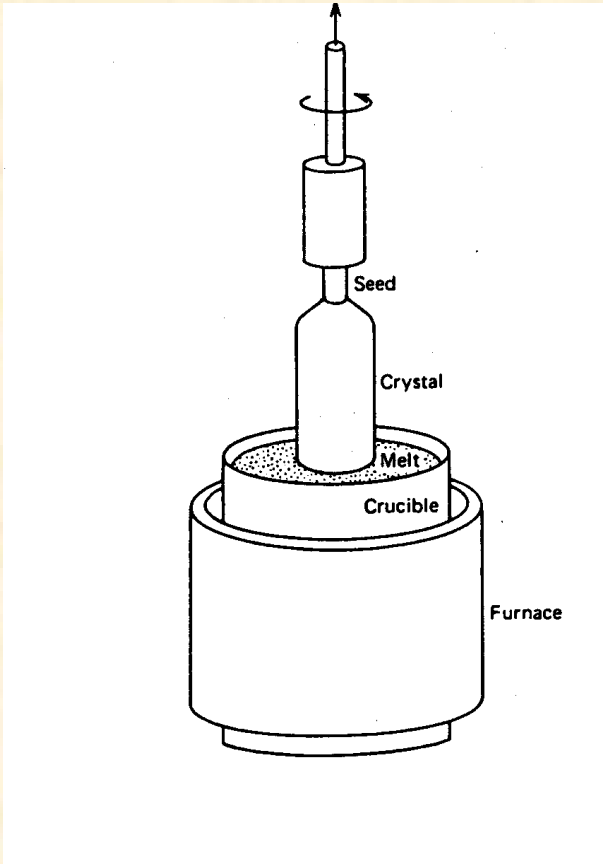
- Co

Czochralski Crystal Pulling



A variation used to produce better quality and larger sizes of boules.

Czochralski Crystal Pulling



- **A small seed on a rotating rod is dipped into a pool of molten ruby.**

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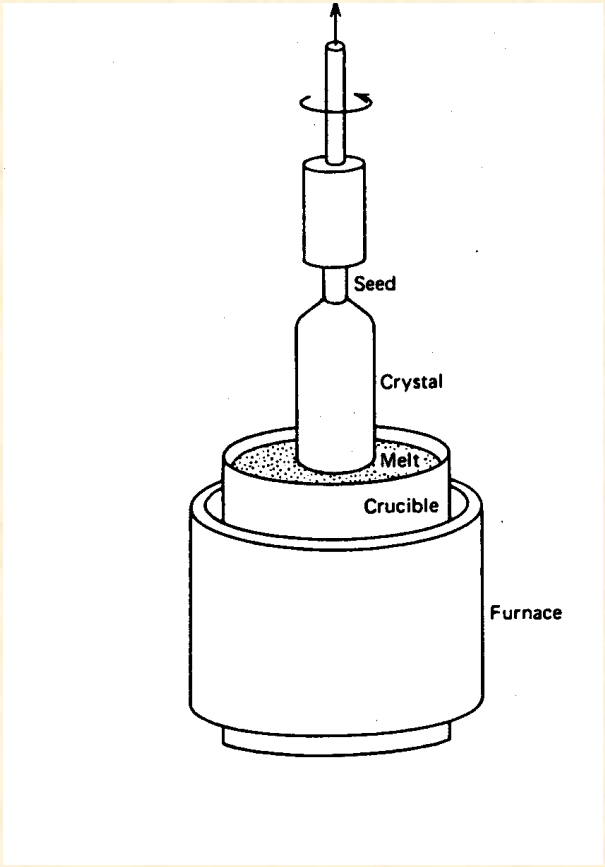

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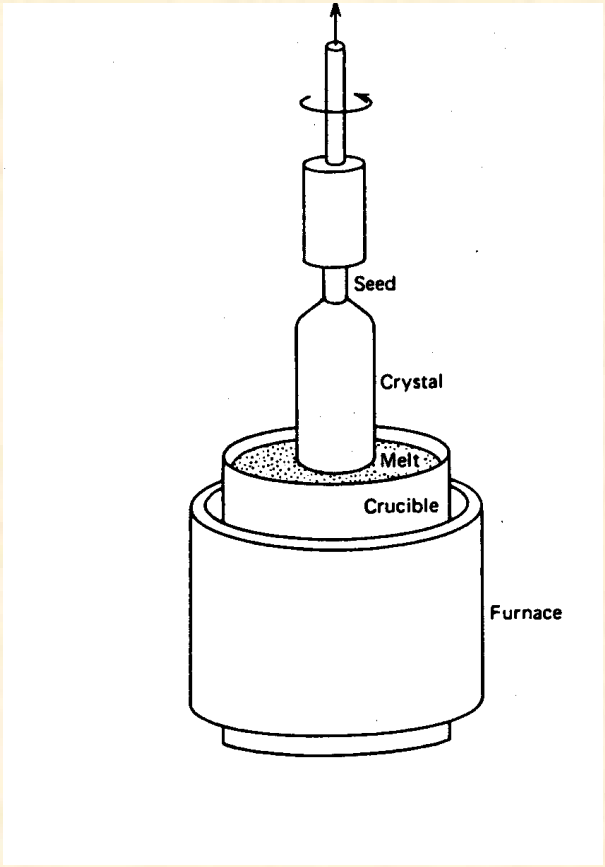

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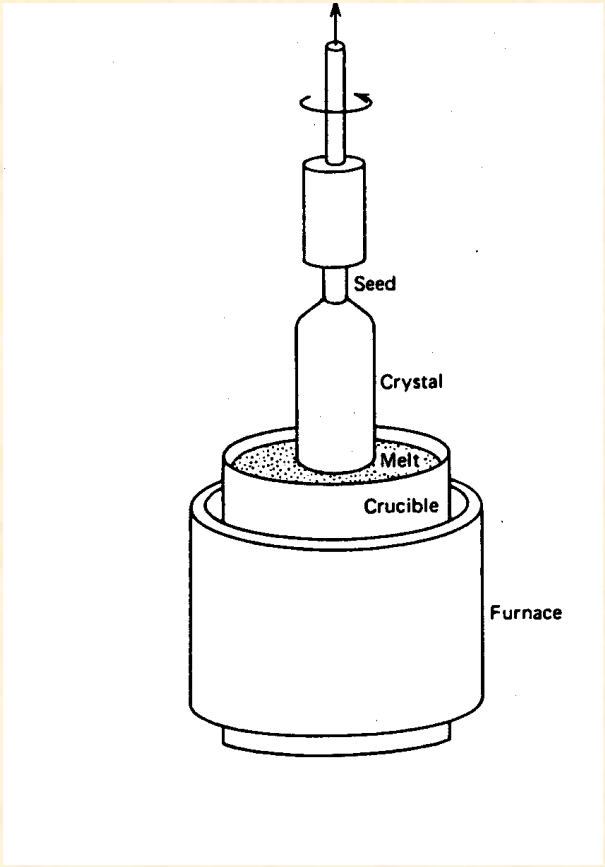
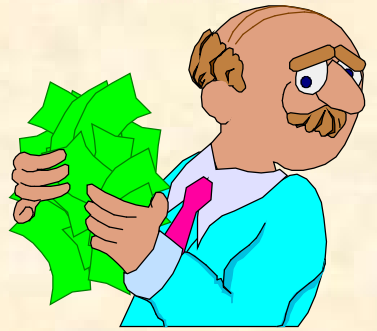


- A small seed on a rotating rod is dipped into a pool of molten ruby.
- The rod is pulled up as the crystal grows.
- The end crystals are very high quality.
- **Product more expensive because technique is touchy and requires expensive Ir crucible.**

A variation used to produce better quality and larger sizes of boules.



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- Emeralds melt and crystallize incongruently (They decompose into other compounds before they melt or form these upon cooling from a melt.)
- The Verneuil technique does not work.
- **They have to be crystallized from some solution or flux.**

Flux Growth History

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- **Nacken - 1916-1928**

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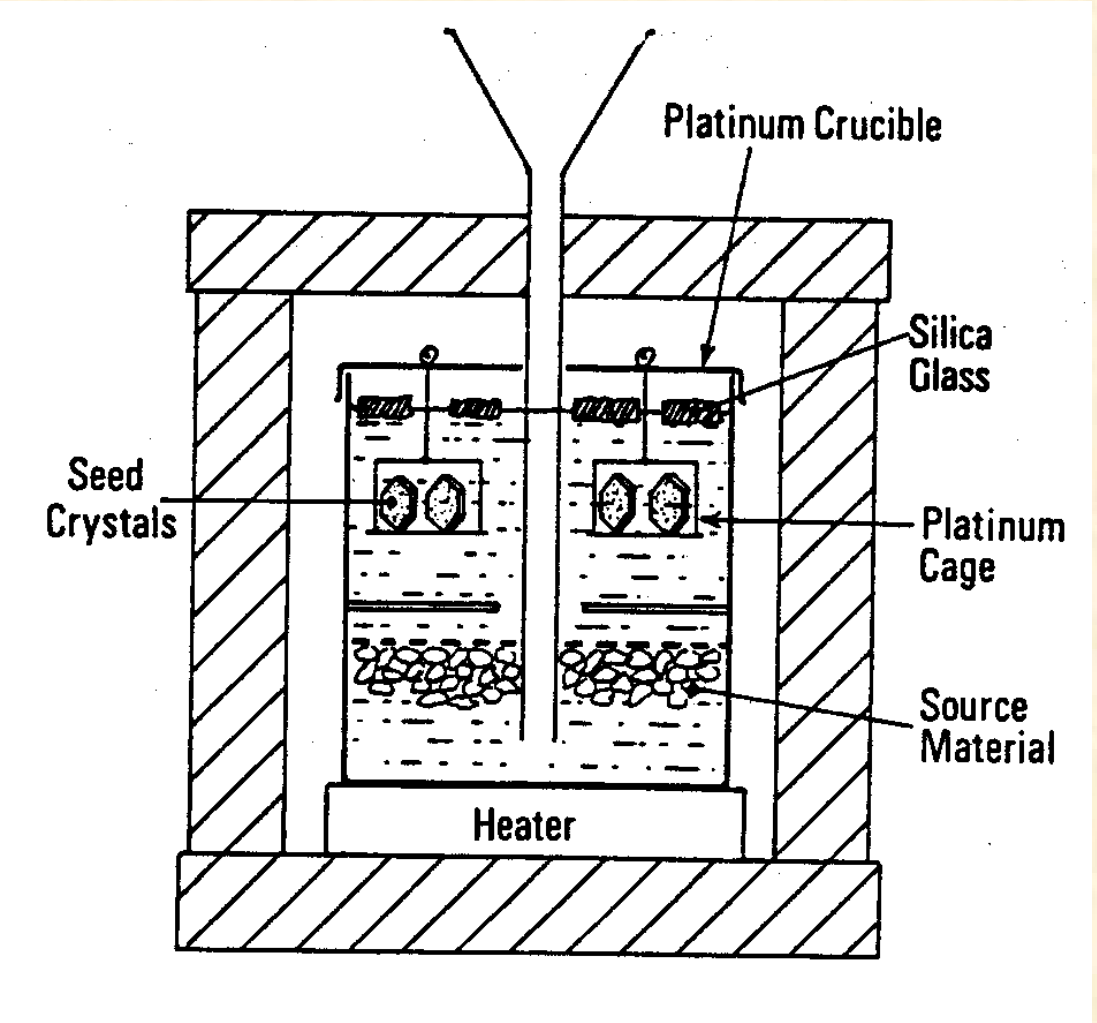
- **Gilson - 1964 - seeds, heterogeneous nucleation**

Flux-Reaction Grown Emeralds

- **First successes with high temperature solvents called fluxes**



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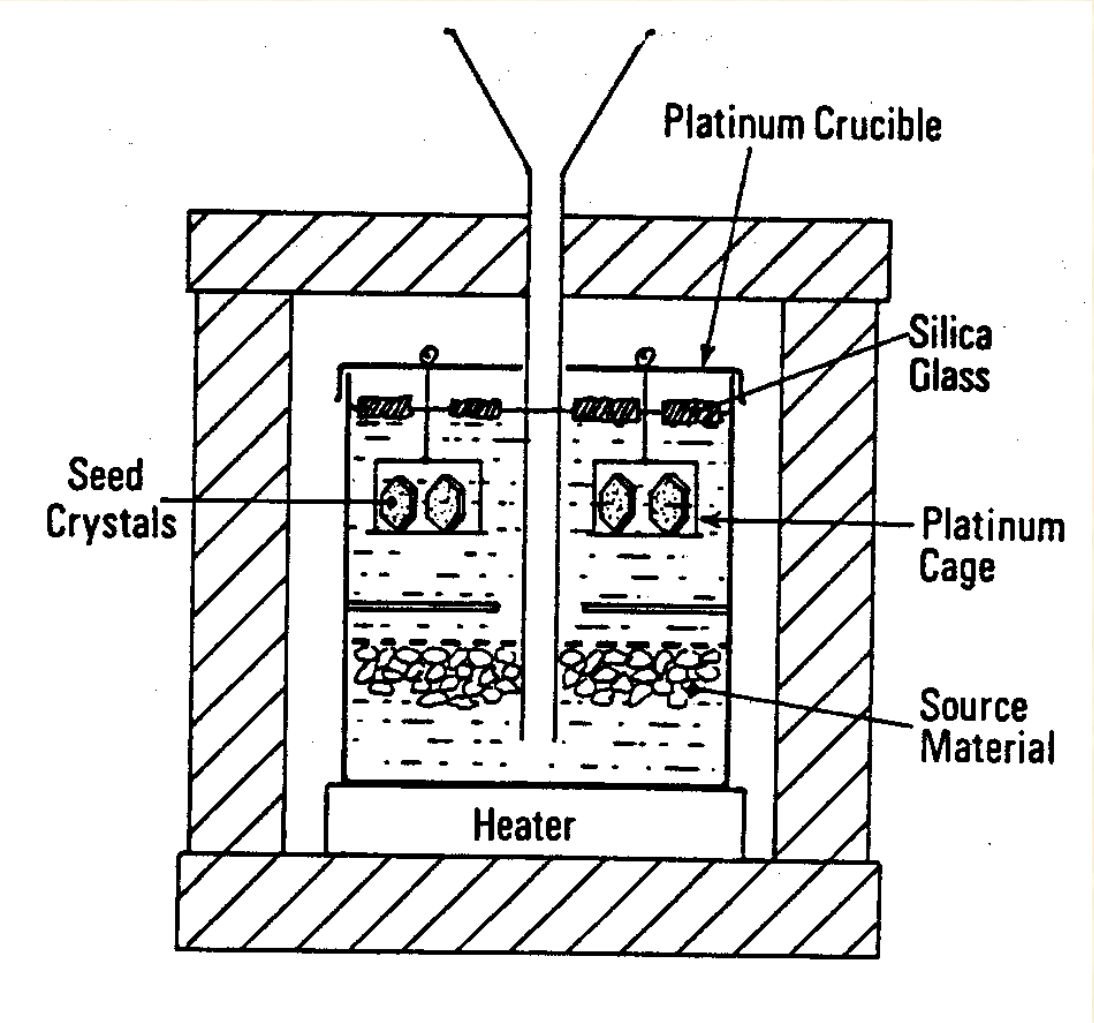

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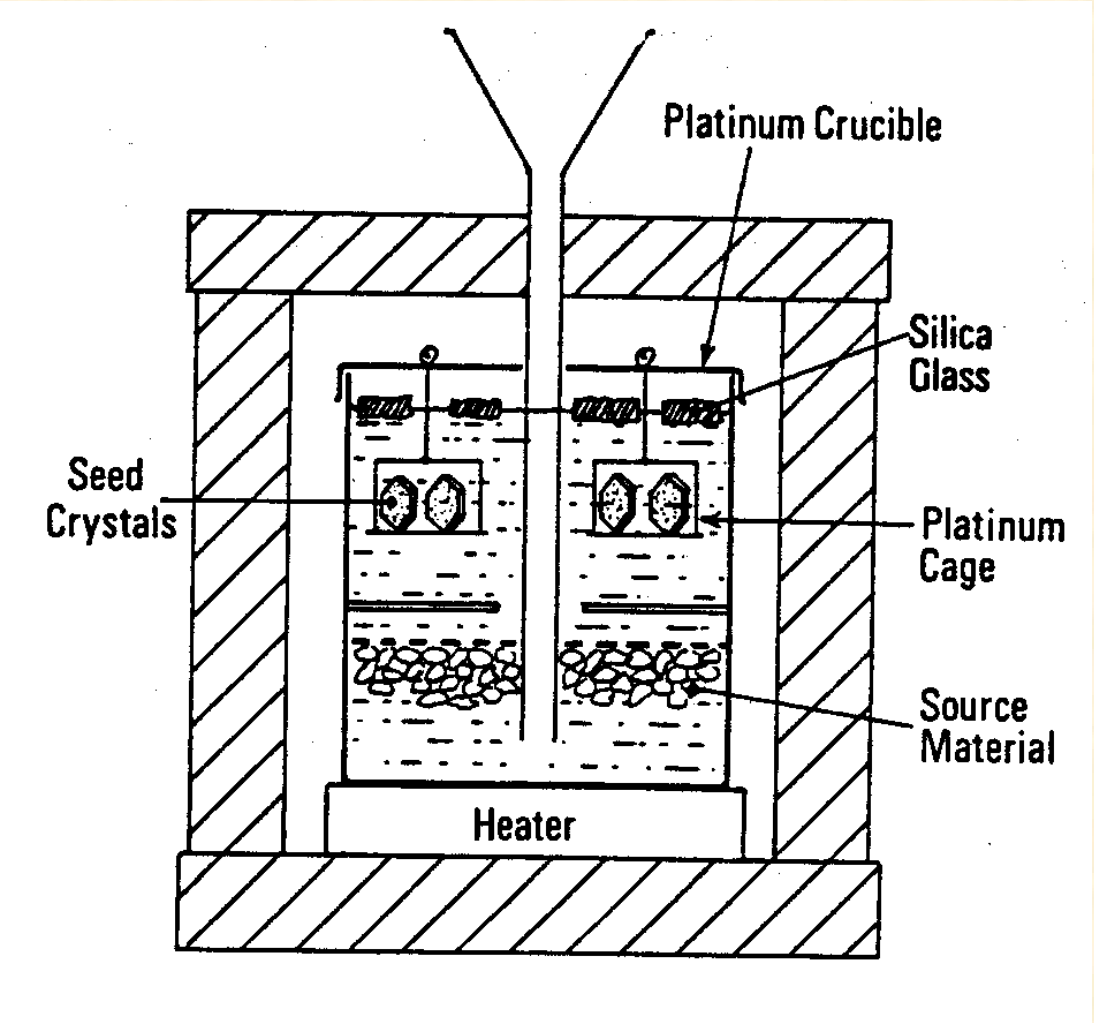
- **May or may not use seed crystals.**



Flux Growth Problems

- **Flux grown gem crystals require**
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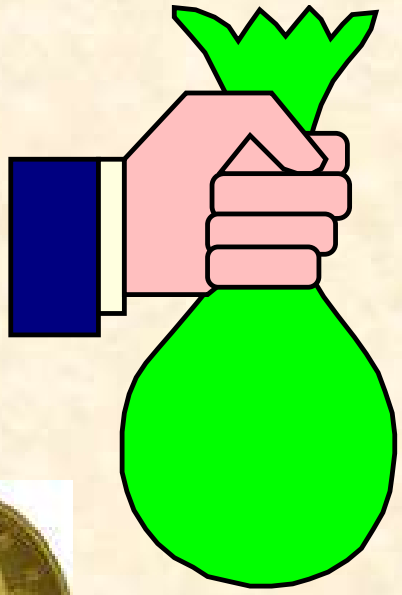

Flux Growth Problems

- Flux grown gem crystals require
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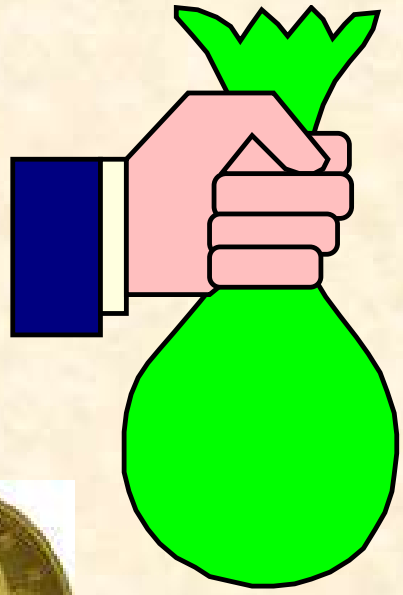

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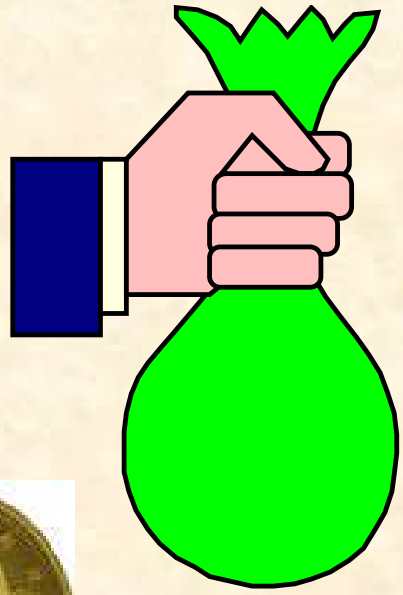

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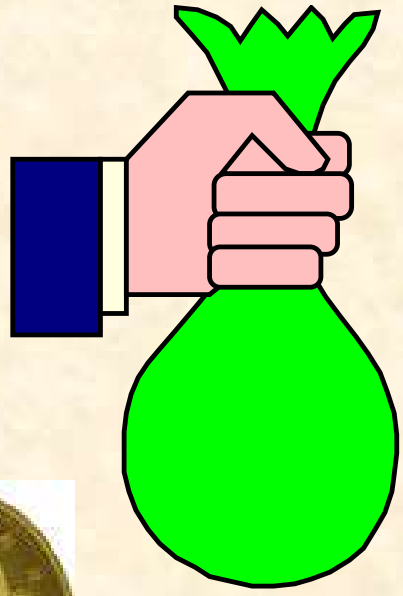
    - **About one year**



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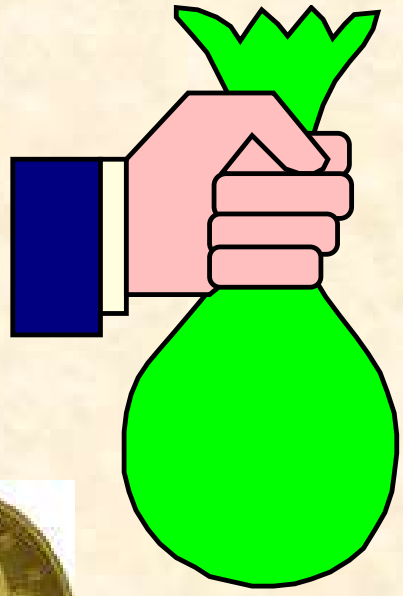

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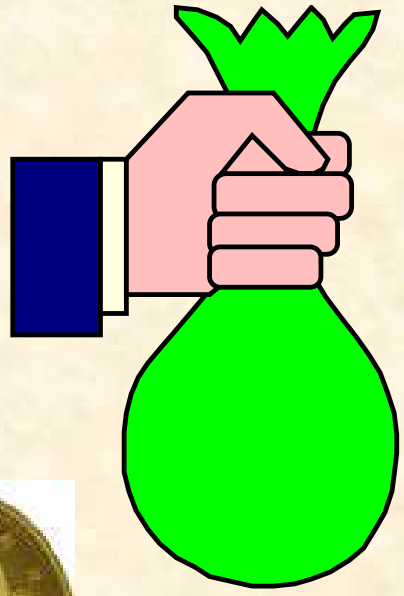
    - Lots of electricity
- **All of these are expensive**



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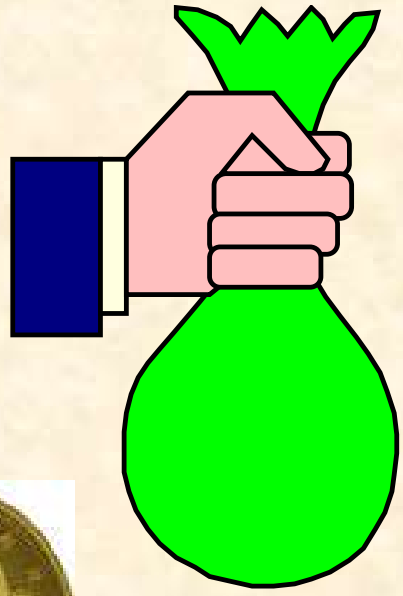
  - Pt crucibles
  - Careful controls
  - Long times at temperature
    - About one year
    - Lots of electricity
- All of these are expensive
- **Product is pricey but excellent quality**



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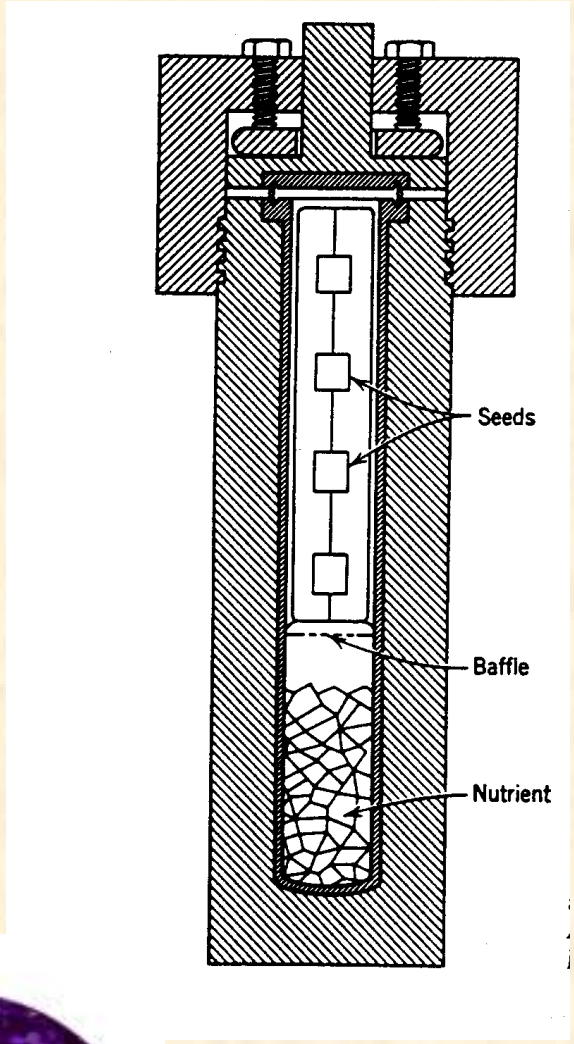
- **USA and Britain - WW2 many successful, commercial processes by 1950.**

Hydrothermal Quartz

- **Quartz synthesis requires an alkaline (NaOH), aqueous solution, modest temperatures (just a bit over 300°C)and pressures (1700 bars), a modest temperature gradient (~40°C) and pure feed for about 33 days.**



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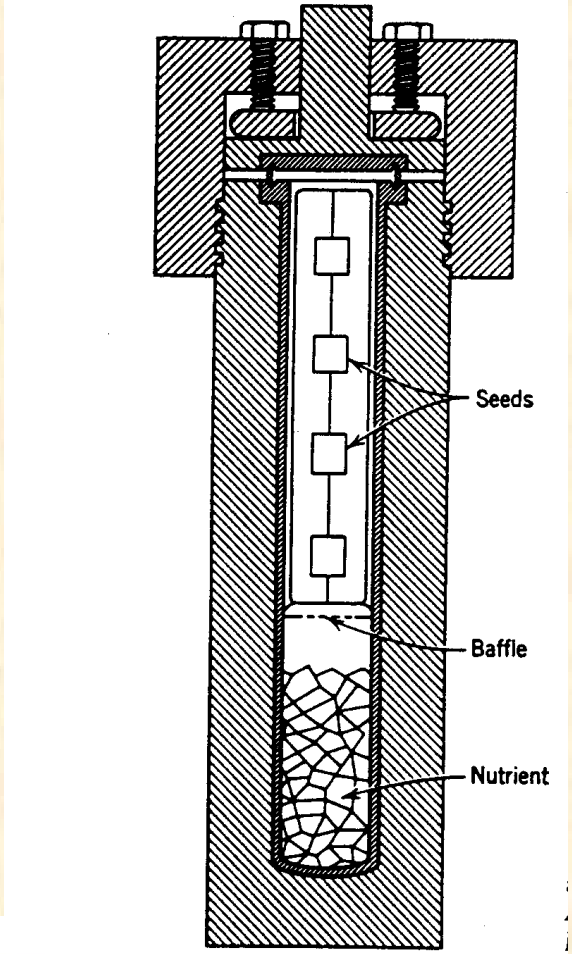

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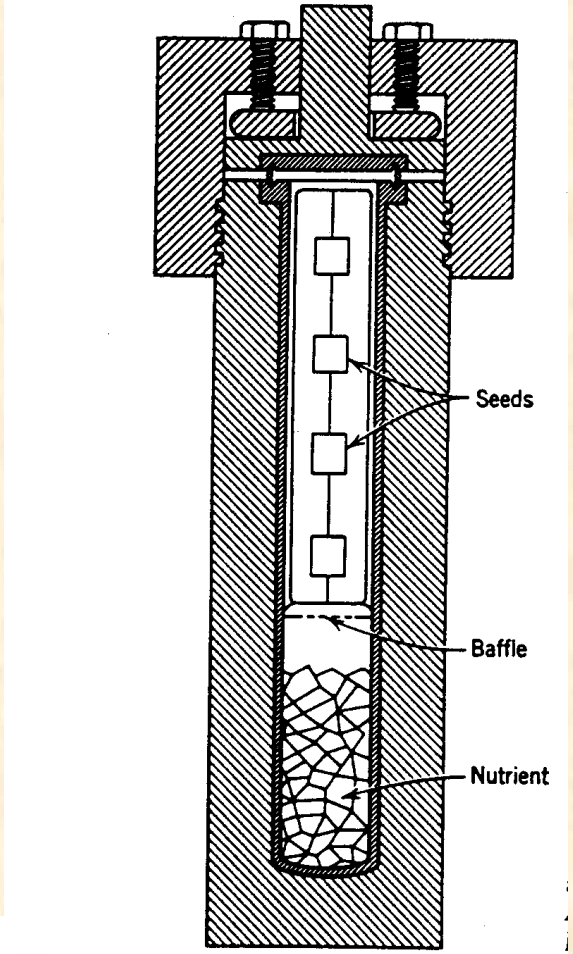
- **Part of this is smoky quartz, citrine, and amethyst**



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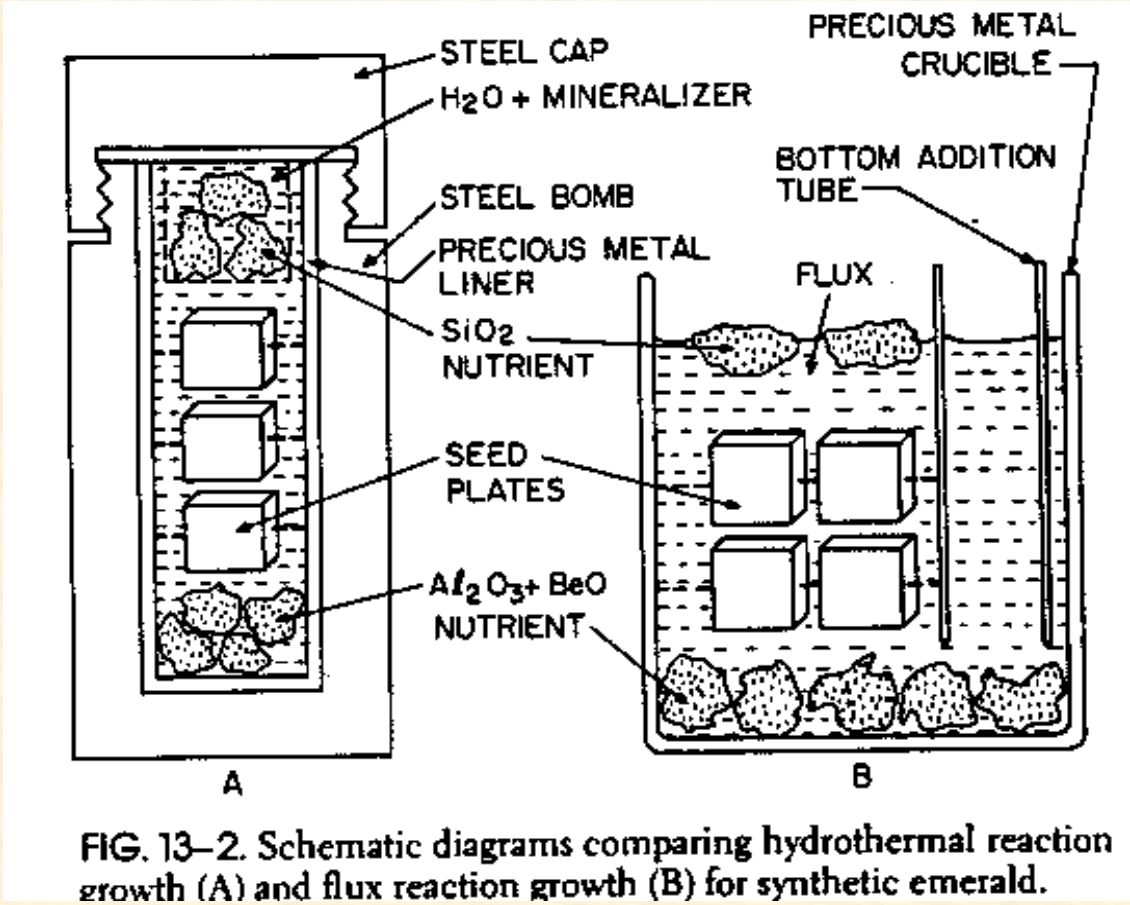
- **Now - a number of companies**

Linde Process

- **Hydrothermal-reaction process**



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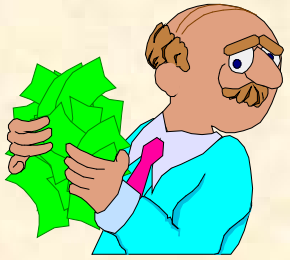

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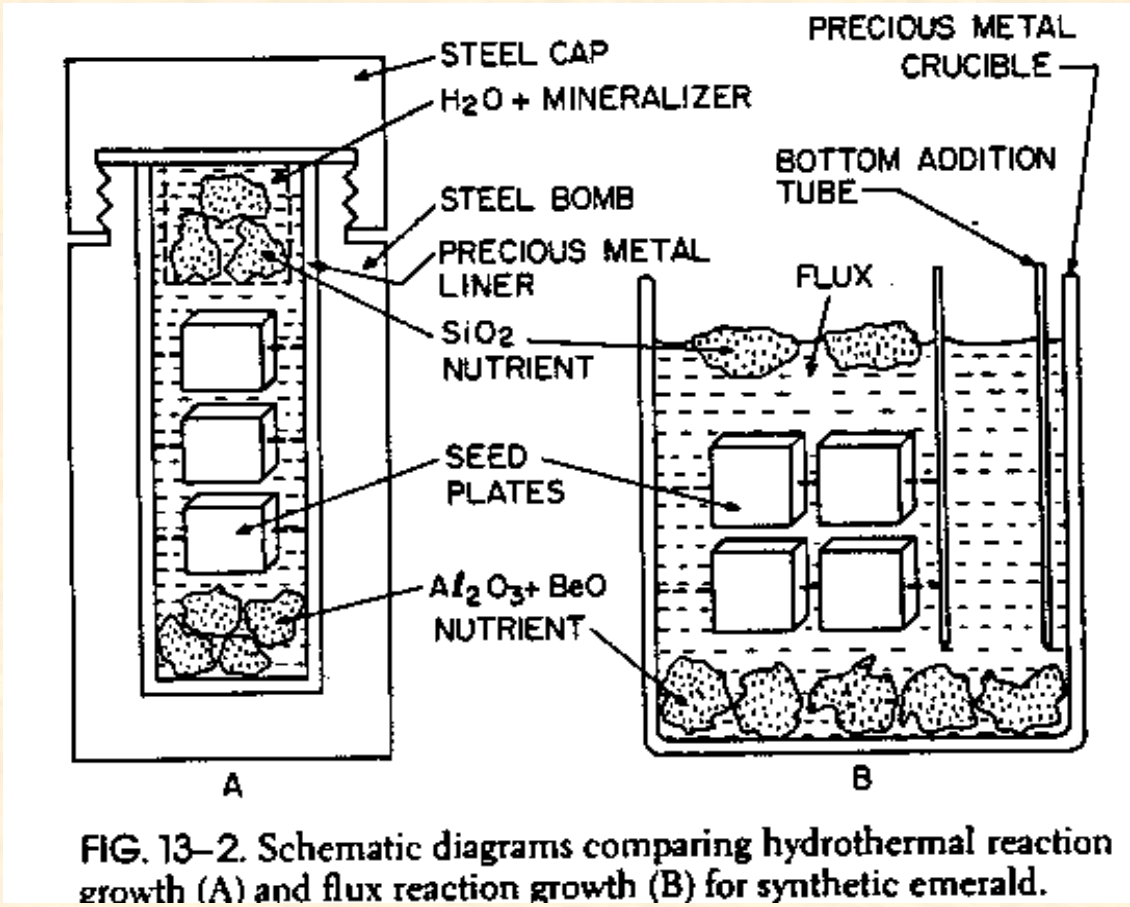

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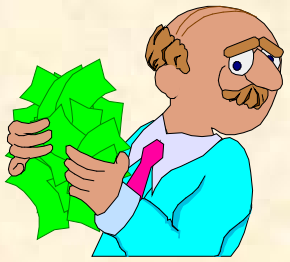

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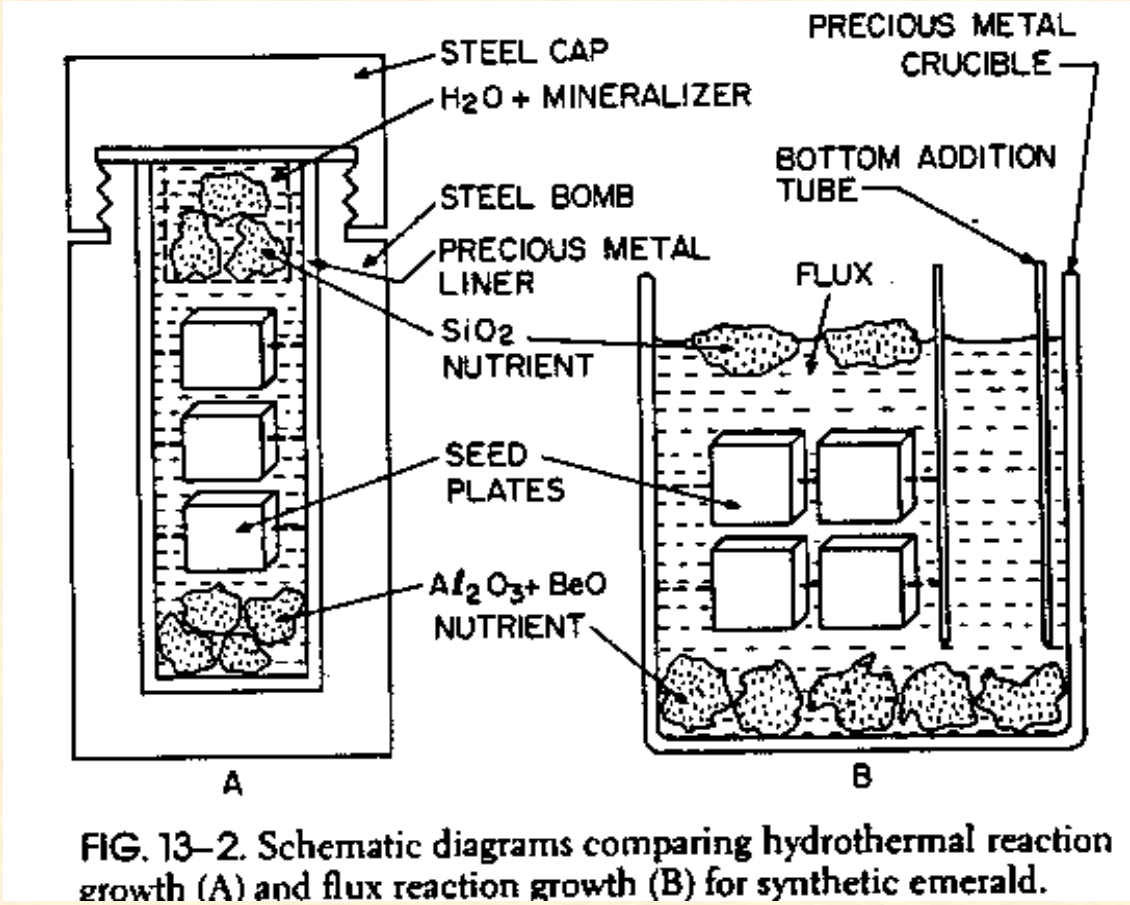

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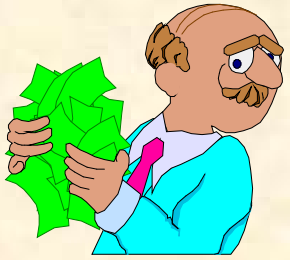

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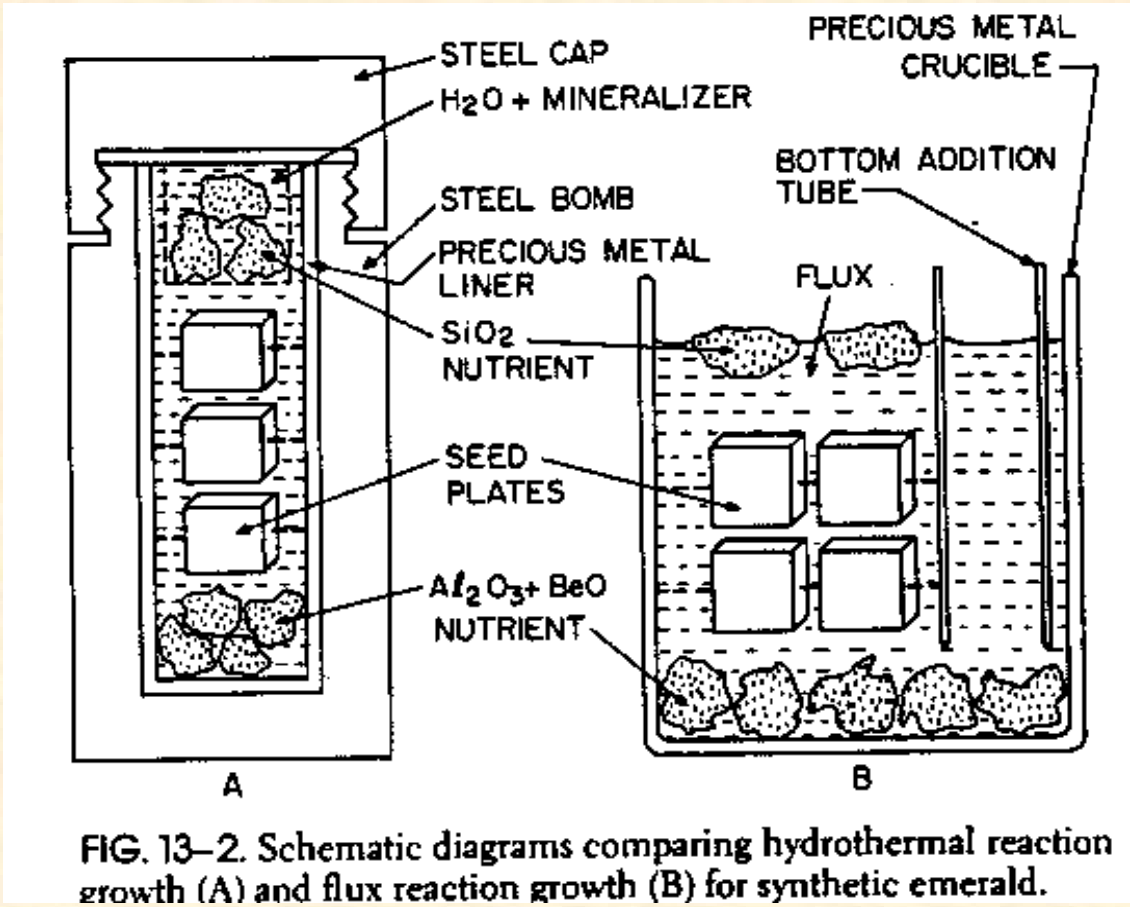

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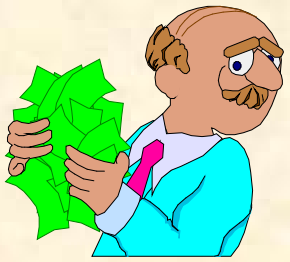

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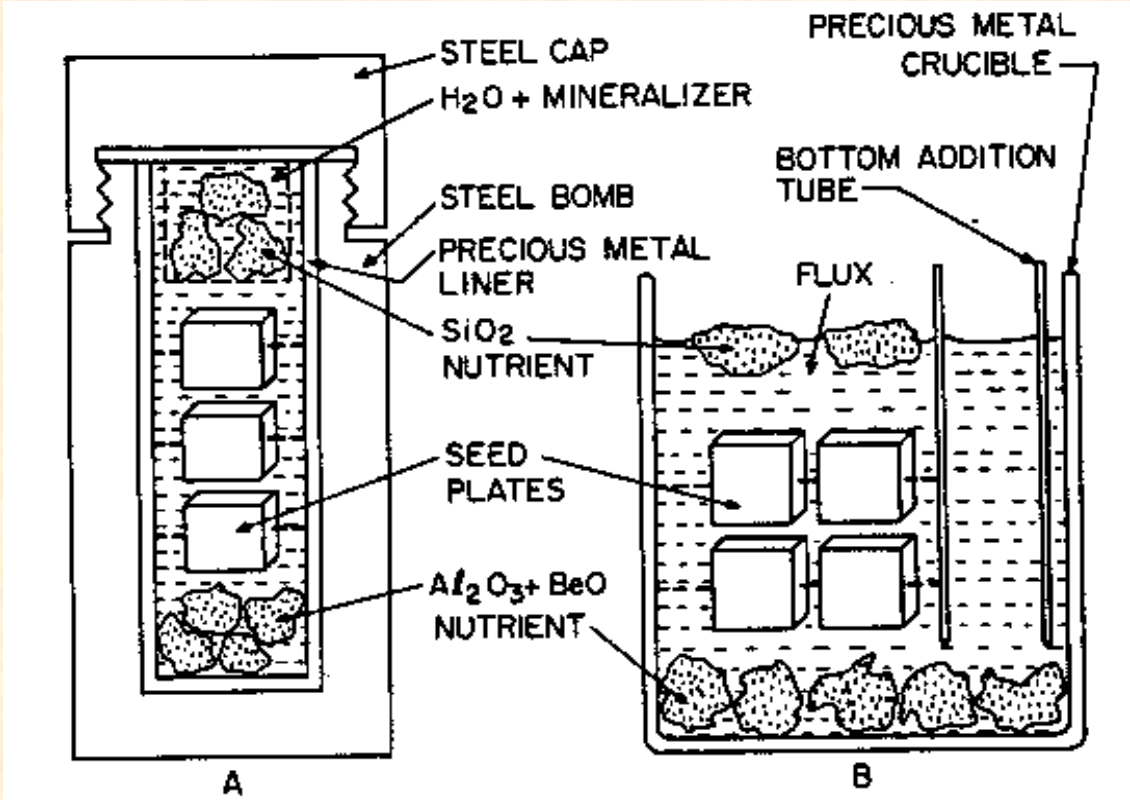

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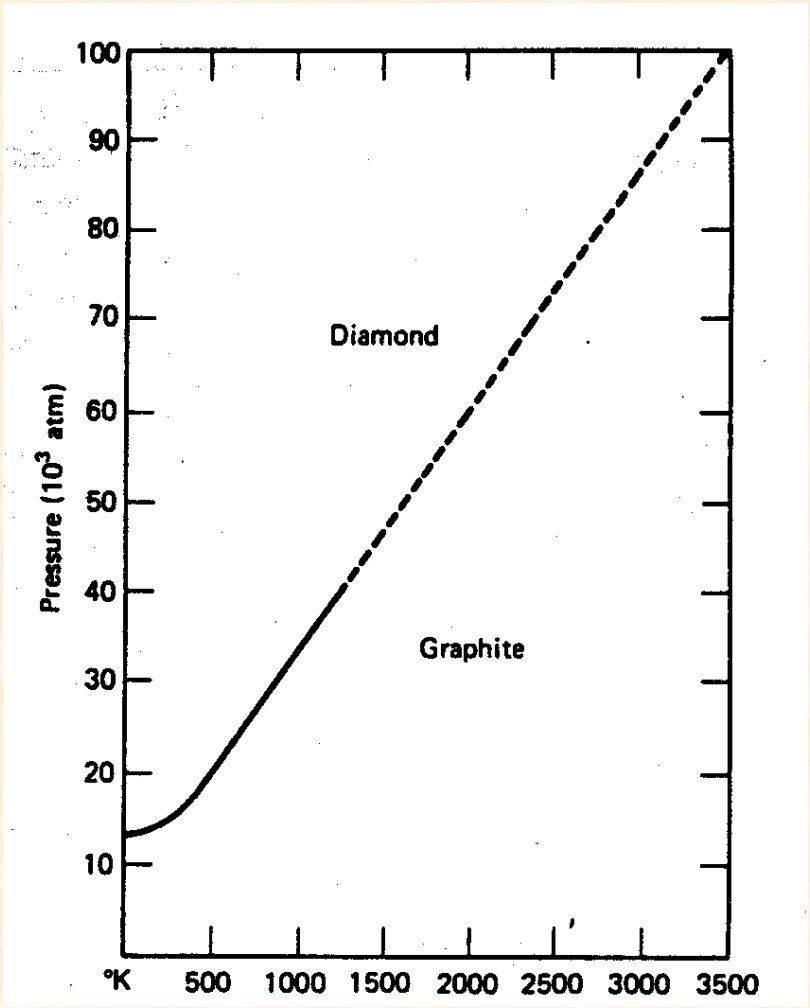
Diamond Synthesis Problem

- **Diamonds need more than heat to grow, they need tremendous pressures and a solvent.**



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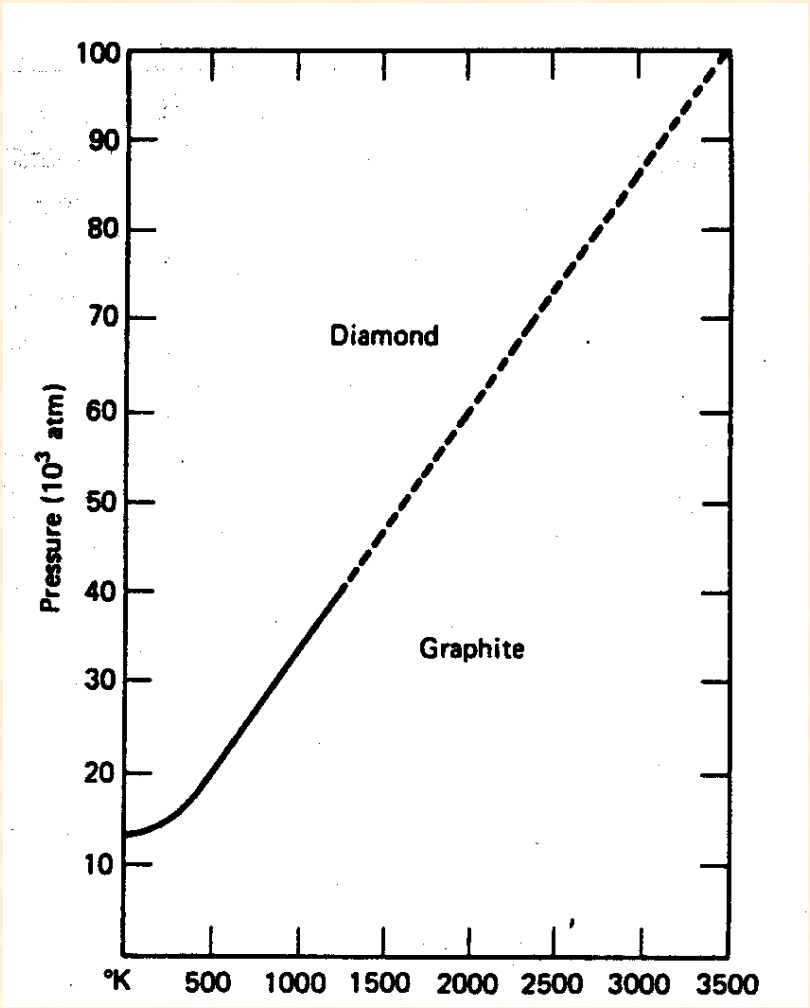

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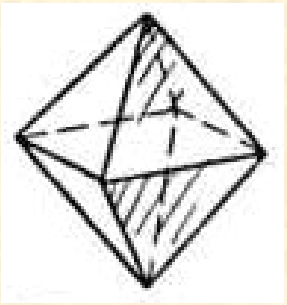

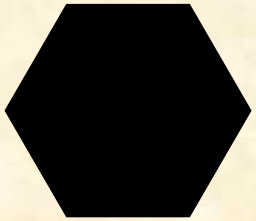

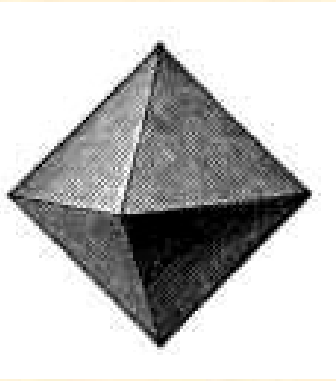

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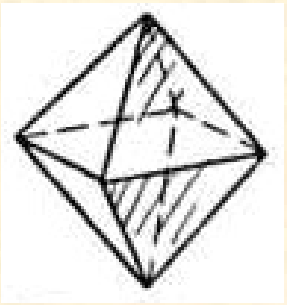

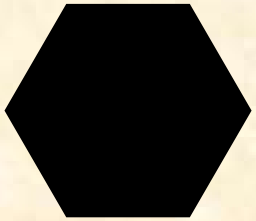

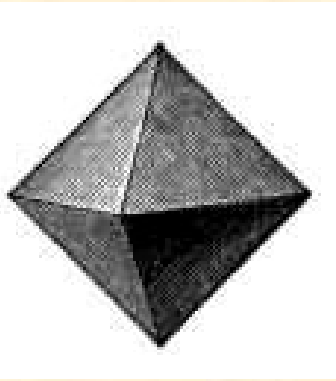

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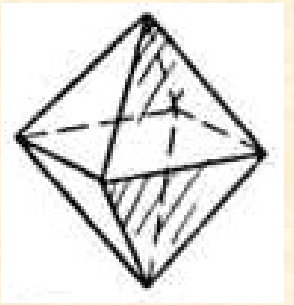

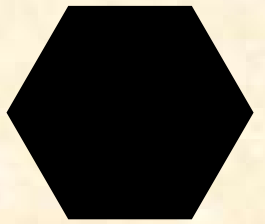

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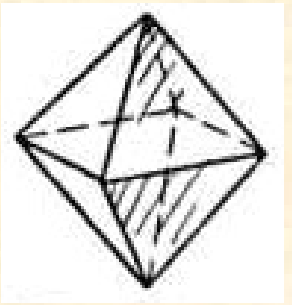

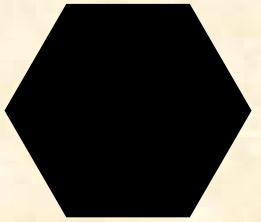

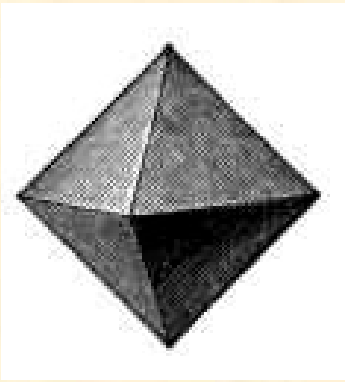

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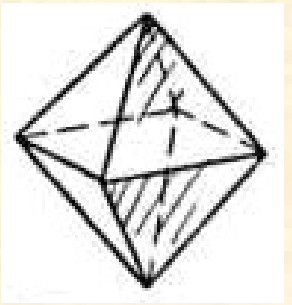

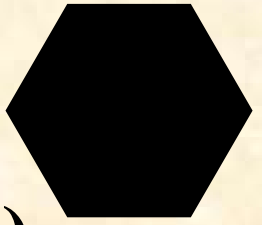

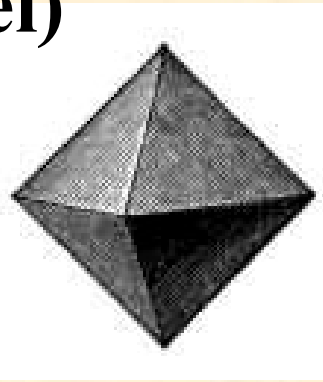

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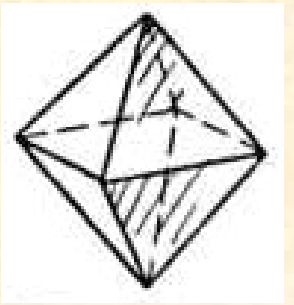
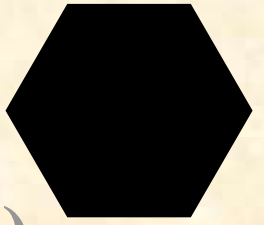
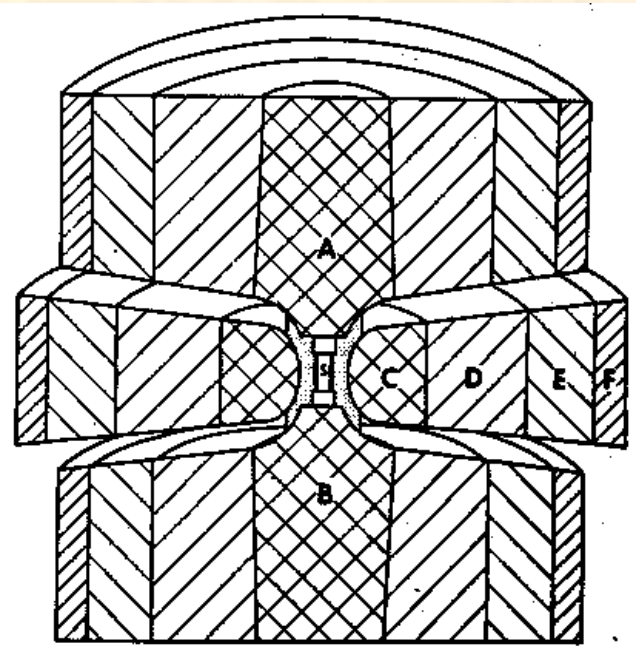




High-Pressure Research

The main problems stem from the need for materials that will continue to function at those extreme T-P conditions.



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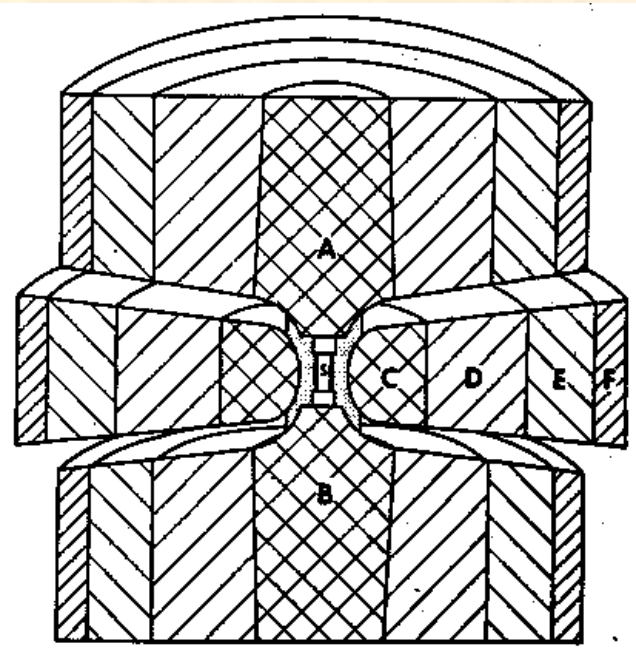

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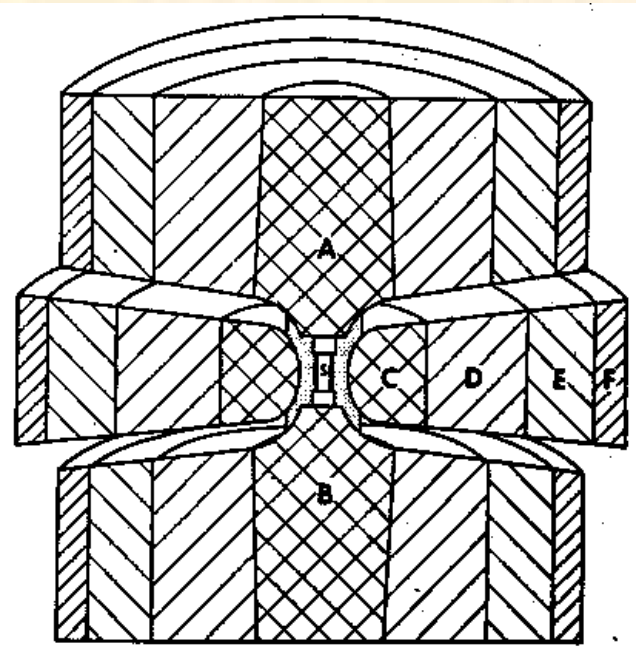
- **GE effort**
  - **Tapered pistons**
  - **Belt seal (Tracy Hall)**



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- **Independent run by outsider on Dec. 31 confirmed technique**

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- **Very similar process**

Synthetic Diamond Industry

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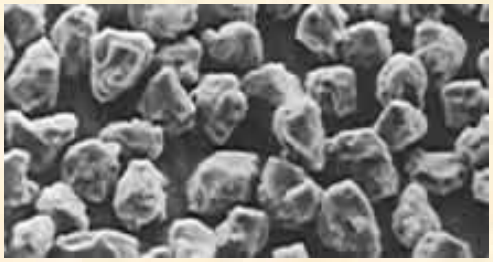
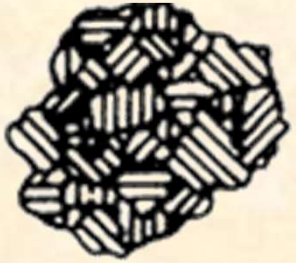
DuPont Diamonds

- Synthesis by explosives (or implosives) - a shock-compaction technique





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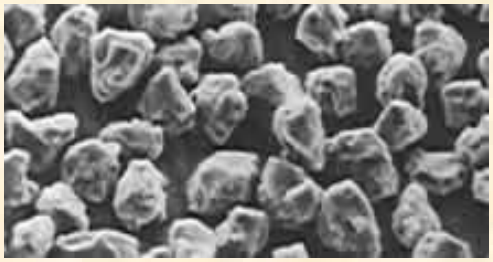

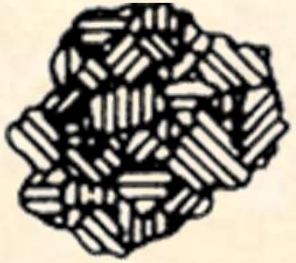

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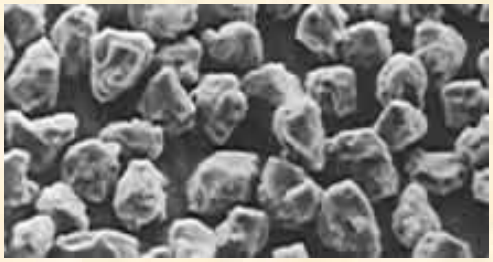

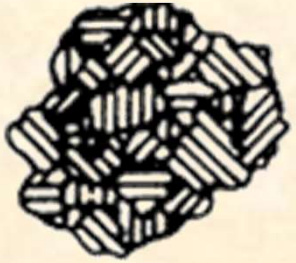

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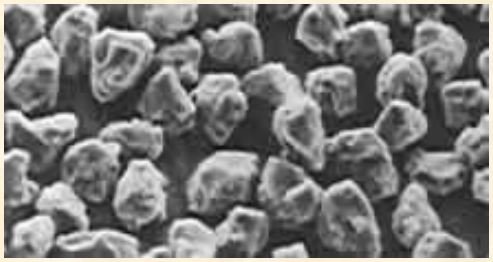

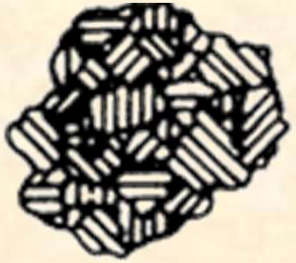

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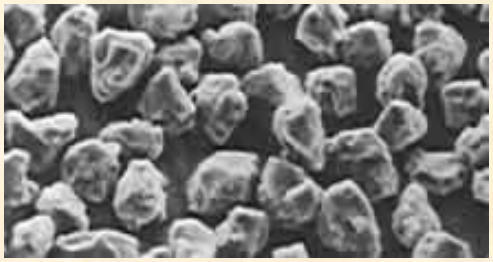

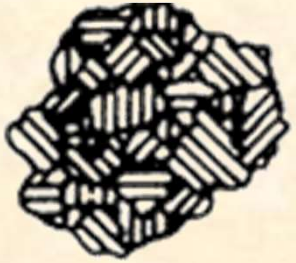

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- Synthesis by explosives (or implosives) - a shock-compaction technique
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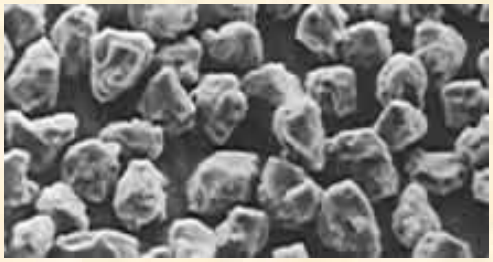

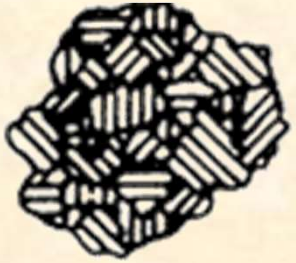

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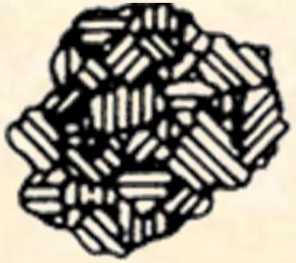

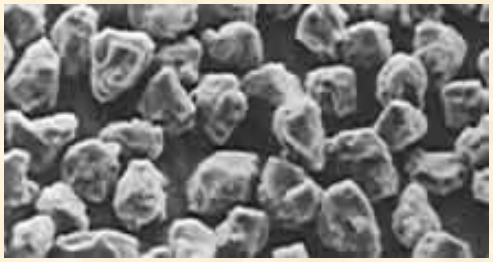

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- **Used to Cost more than naturals but now….**

Recent Developments - Gemesis

Recent article (Wired) about Gemesis in Sarasota, FL

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Main source is the Accendo Collection

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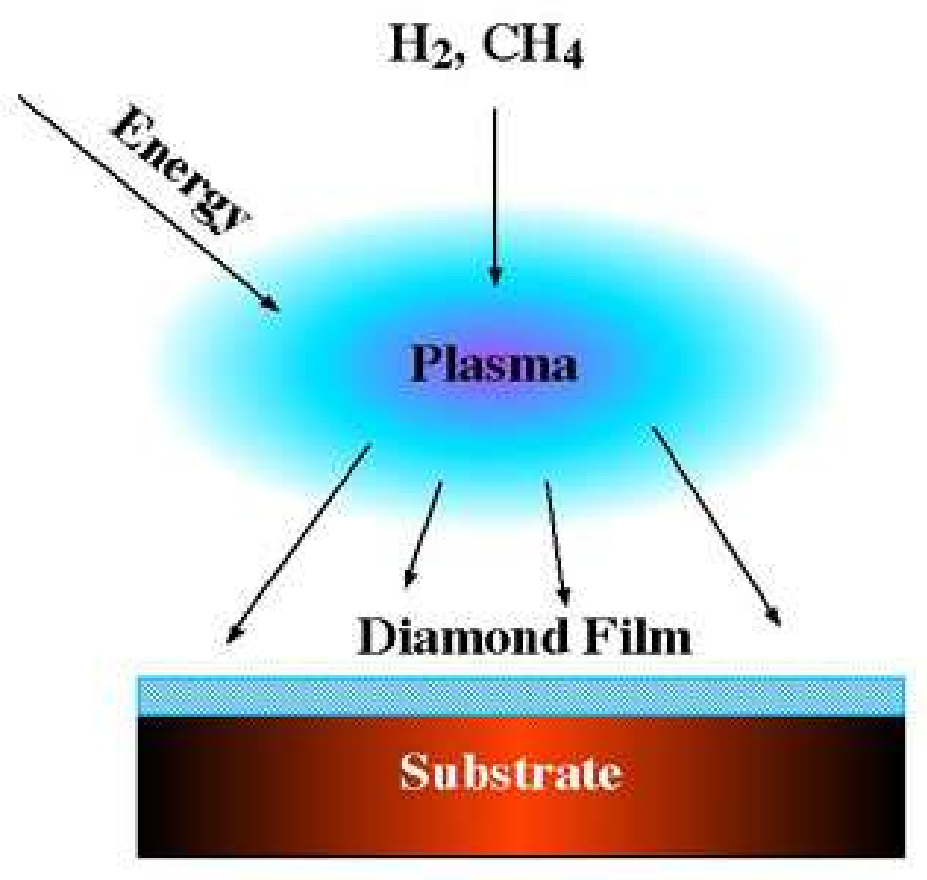
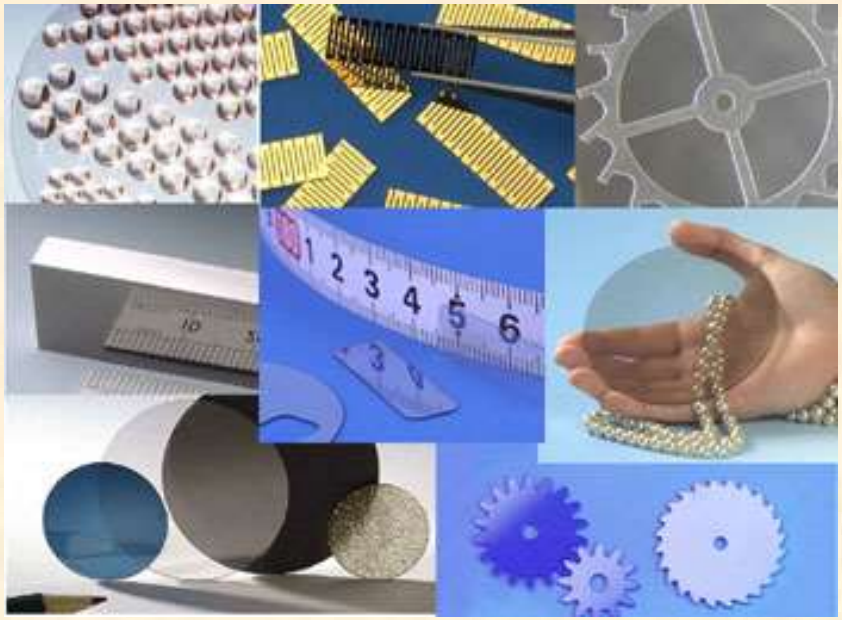
CVD Process





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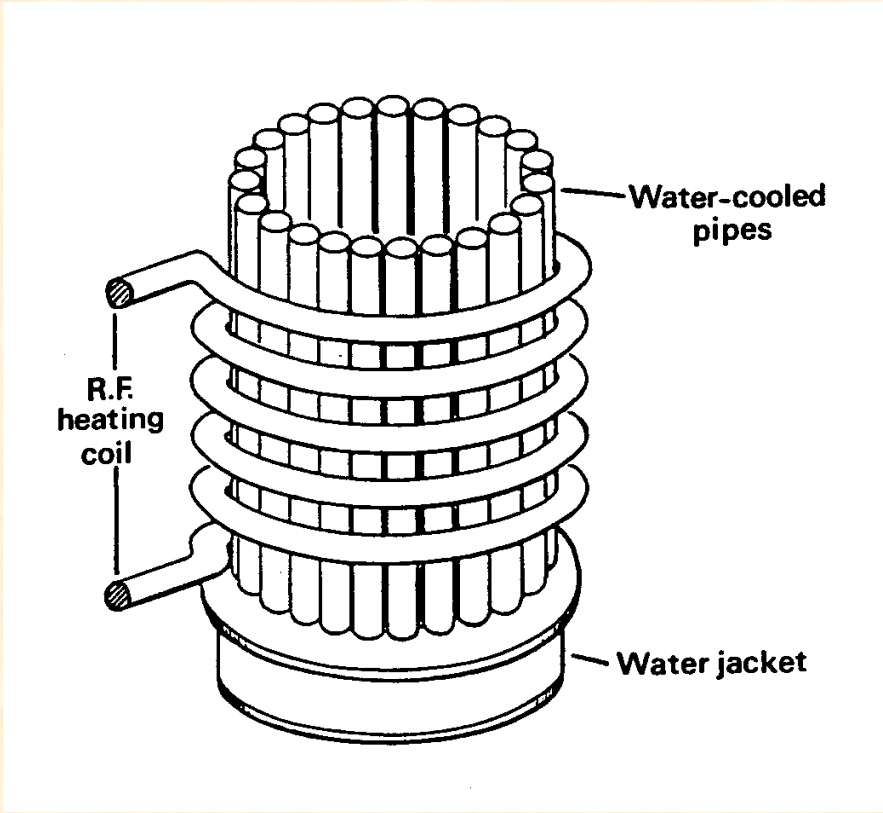

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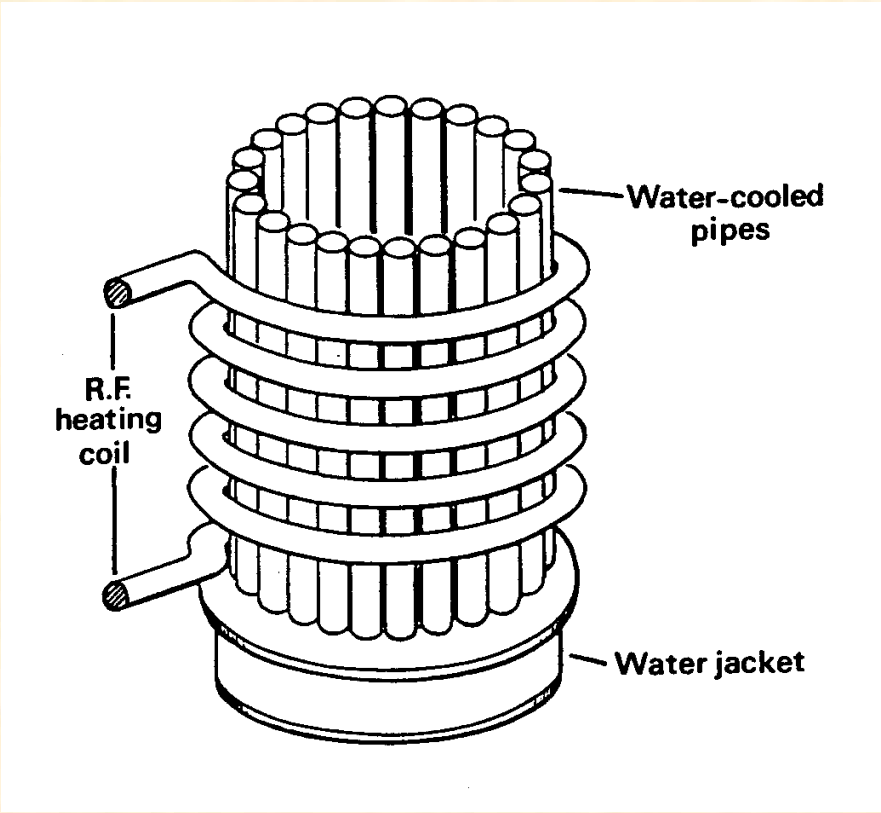

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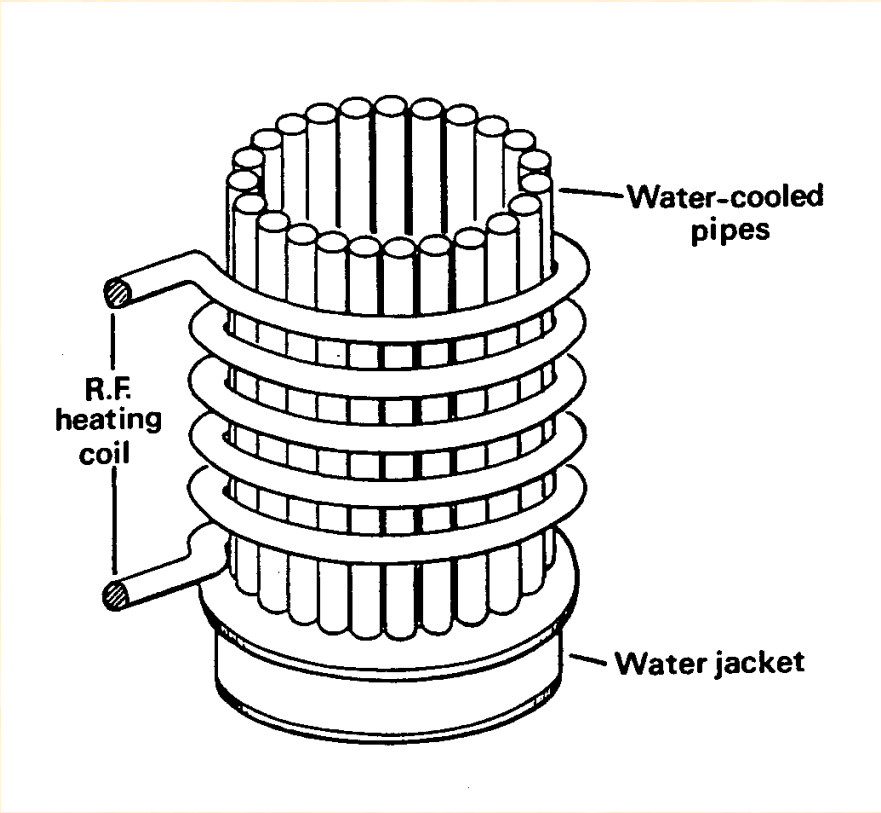

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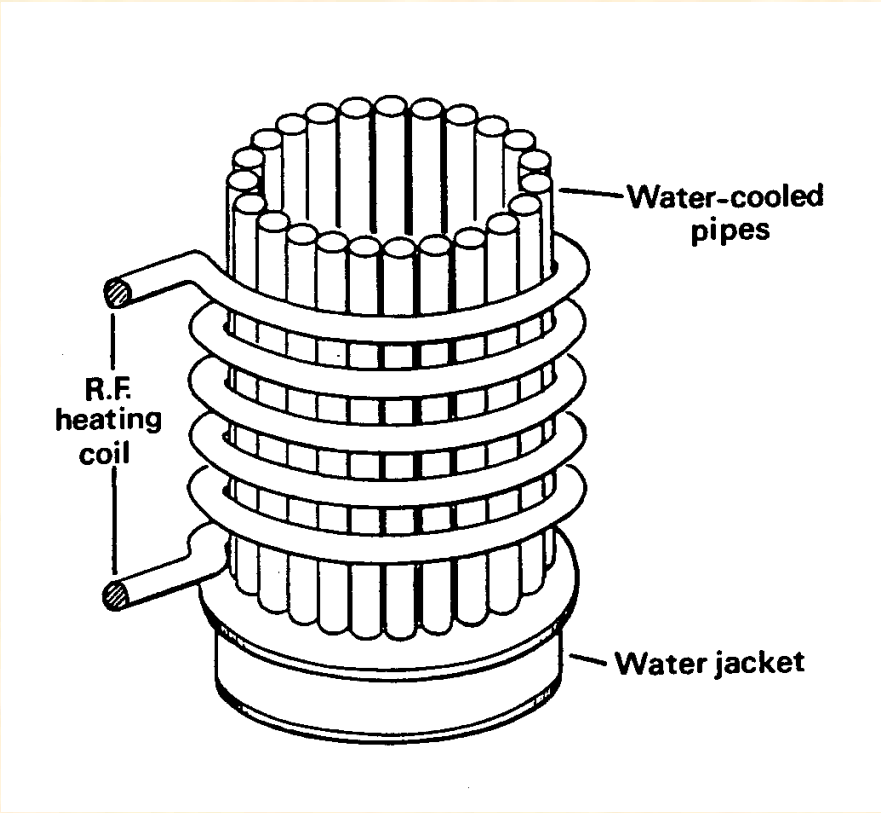

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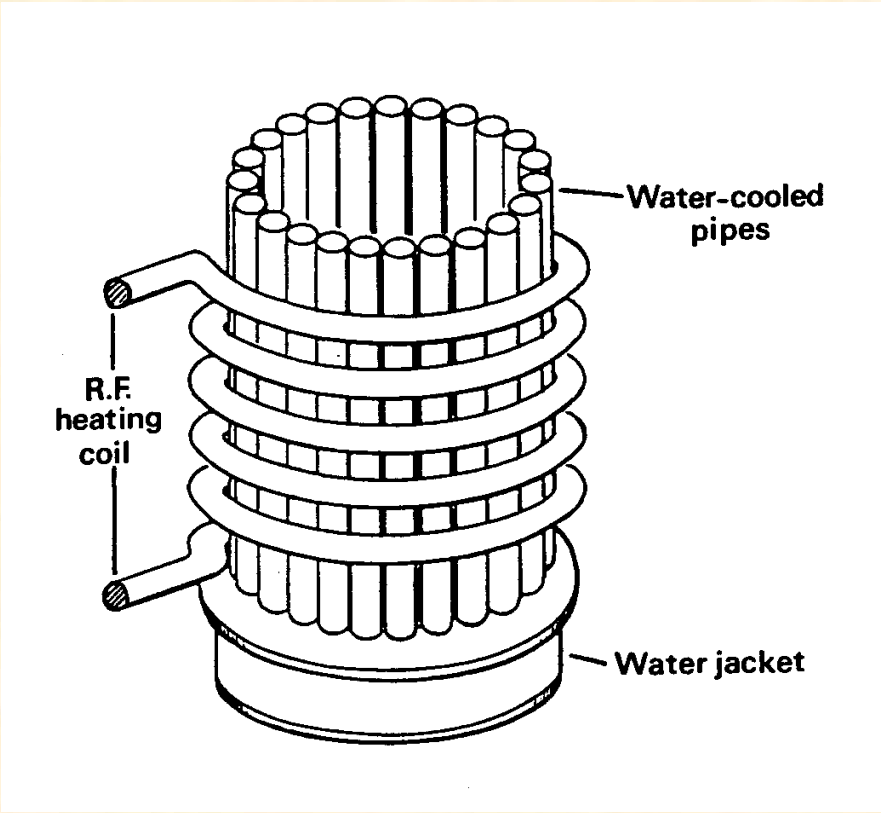

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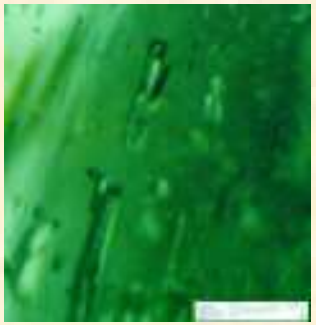

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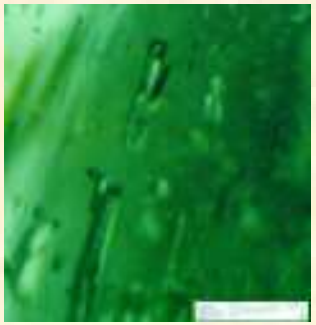

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That's All Folks!

You may now applaud!

I'll be happy to answer questions now.