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# Glass Furnace Project: October 1981-March 1982

**Katherine M. Armstrong and Larry M. Klingler**

May 14, 1982

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DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA

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Miamisburg, Ohio 45342

operated by
**MONSANTO RESEARCH CORPORATION**
a subsidiary of Monsanto Company

for the
**U. S. DEPARTMENT OF ENERGY**
Contract No. DE-AC04-76-DP00053

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# Foreword

Under the sponsorship of the DOE Division of Waste Management, Production and Reprocessing, and the direction of the Idaho Operations Office which is responsible for the management of Low Level Waste Programs, Mound is responsible for evaluation of the joule-heated glass melter concept for in situ burning and immobilization of Low Level Nuclear Waste.

Previous reports on this project are:

| | |
|---|---|
| October 1980 - March 1981 | MLM 2825 |
| April - September 1981 | MLM 2876 |

# Contents

Page

# Abstract

The purpose of the Glass Furnace Project is to evaluate the use of a joule-heated glass furnace, fitted with a Mound-developed offgas system, to reduce the volume of contaminated waste typical of that from nuclear power plants. As part of the project, several different waste types, including dry solid waste, ion exchange resin, and sludge, will be burned in the glass furnace unit. Combustion characteristics and radionuclide behavior in the glass furnace and associated offgas system will be monitored to determine optimum operating conditions. The project will provide an evaluation of the glass furnace as a volume reduction technique for the nuclear power industry as well as design criteria that can be used in constructing such a system by the end of FY-1984.

The first half of FY-1982 was devoted to completion of the installation, checkout, and startup of the furnace unit and control systems. Compatibility studies to determine the effects of refractory and simulated waste on the soda-lime glass matrix were also performed in conjunction with the Mound Glass Ceramics group. These studies include chemical durability testing to discern the optimum waste loading of the glass.

Finally, an experimental procedure was designed to determine the combustion efficiency of the incinerator. The combustion offgas will be monitored during experimentation to determine such related parameters as optimum feedrate and total oxygen requirements.

# Introduction

The purpose of the Glass Furnace Project is to evaluate the use of a joule-heated glass furnace, fitted with a Mound-developed offgas system, to reduce the volume of contaminated waste typical of that from nuclear power plants. Disposal of highly contaminated organic ion exchange resin is a particularly pressing problem in the nuclear power industry since conventional incineration produces an ash residue that is highly radioactive and contains radionuclides that migrate from immobilization matrices such as cement.

Glass furnace treatment destroys the organic content of waste and evaporates any water present, while avoiding the problems of handling and inadequate immobilization of radionuclides. Ash does not remain in glass, per se; the components of ash are dissolved in the glass.

The glass is drained from the furnace and then cooled until it hardens into a solid, leach-resistant mass that immobilizes all radioisotopes present. Most types of solid and liquid radwastes produced by a light water reactor (LWR) facility can be treated and immobilized in the glass furnace (Penberthy unit) in the same way.

As part of the project, several different waste types, including dry solid waste, ion exchange resin, and sludge, will be burned in the glass furnace unit. Combustion characteristics and radionuclide behavior in the glass furnace and associated offgas system will be monitored to determine optimum operating conditions. The project will provide an evaluation of the glass furnace as a volume reduction technique for the nuclear power industry and design criteria that can be used in constructing such a system.

A milestone schedule is shown in Figure 1.

# Milestone 2 pre-experimental stage

## Construction completion and checkout

Installation of the Penberthy furnace unit was completed on November 19, 1981. On November 20, Larry Penberthy, President, Penberthy Electromelt International Inc., arrived at Mound to inspect the unit and instruct personnel on startup and maintenance procedures.

Startup of the furnace unit was completed on January 7, 1982. Following Mr. Penberthy's advice, the furnace was initially maintained at 250°F for several days, by means of the propane pilot burner, to cure the refractory and prevent cracking during startup. The temperature in the chamber was then raised ∿40°F/hr., using the burner, until the glass was capable of conducting electricity, at which point the electrodes could take over the temperature control of the melt. The temperature of the electrodes at this time was ∿1000°F which, due to electrode cooling, is several hundred degrees lower than the actual glass temperature. The temperature of the melt is currently being maintained at an idle level of 1800°F.

On February 12, the drain system was tested to ensure operability and to determine the ease of obtaining glass

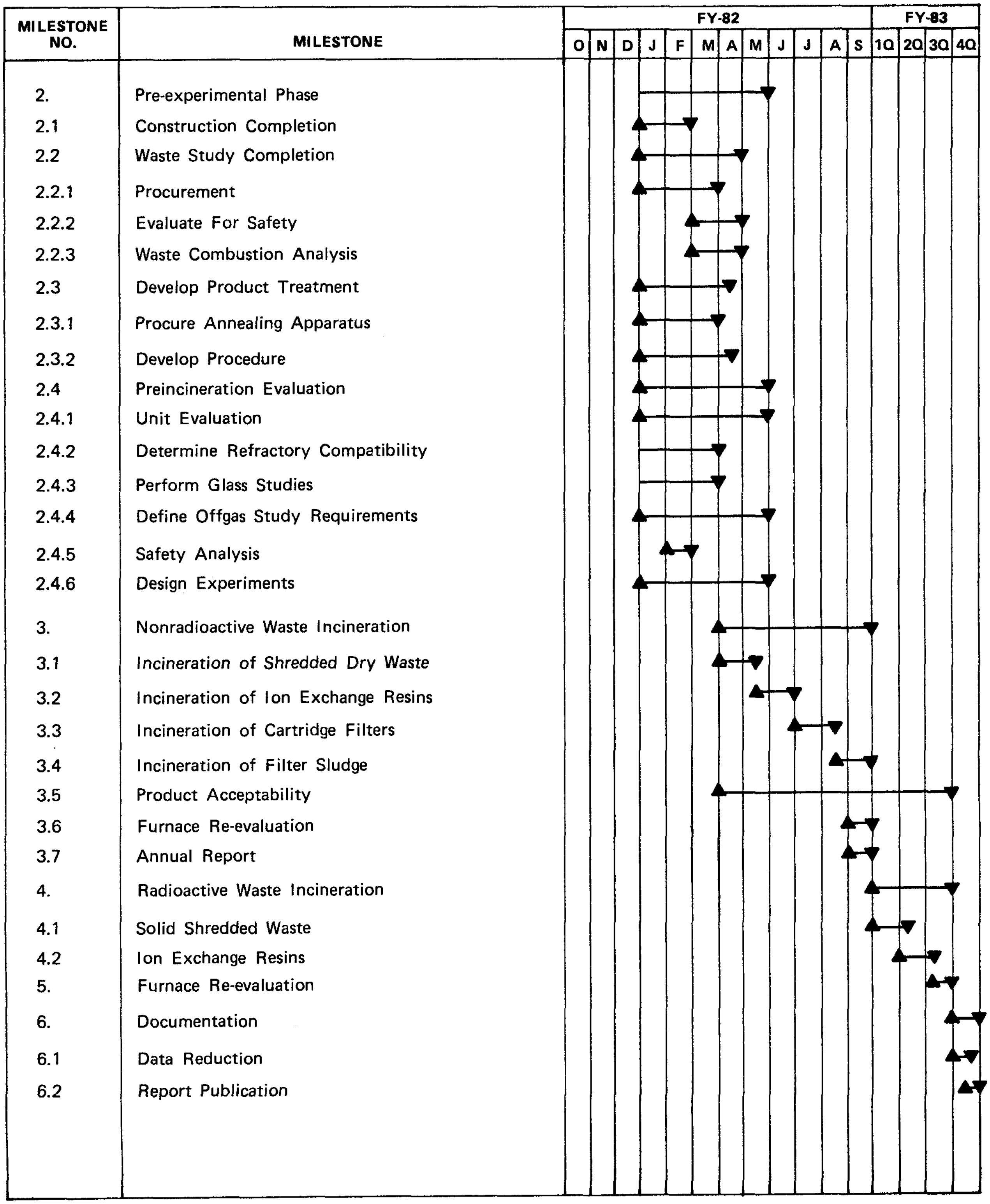


FIGURE 1 - Milestone schedule for glass furnace evaluation.

samples. The furnace was heated to 2000°F, prior to initiation of the test, to lower the overall viscosity of the glass. The resistance heater in the drain was then activated, and temperature and power readings were taken every 3 min. As the drain approached 1300°F, long thin strings of glass began to appear. At 1850°F, the glass was draining in approximately 2 in. x 3/4 in. drops. However, 45 min into the test, drain power was suddenly lost, and the drain cooling system failed immediately thereafter.

An investigation into the reason for the drain malfunction points to a combination of circumstances responsible for this event. It is now recognized that the temperature of the melt should have been brought up to at least 2400°F. At this temperature, convection and conduction from the molten glass would have caused the drain to heat faster, thus preventing the current overload accrued by relying too heavily on the resistance heater to raise the drain temperature. A current-limiting device located in the drain control mechanism would also have averted a drain failure.

Figures 2 through 5 show the drain after removal for repair. Figure 6 details the drain coupling in the furnace unit.

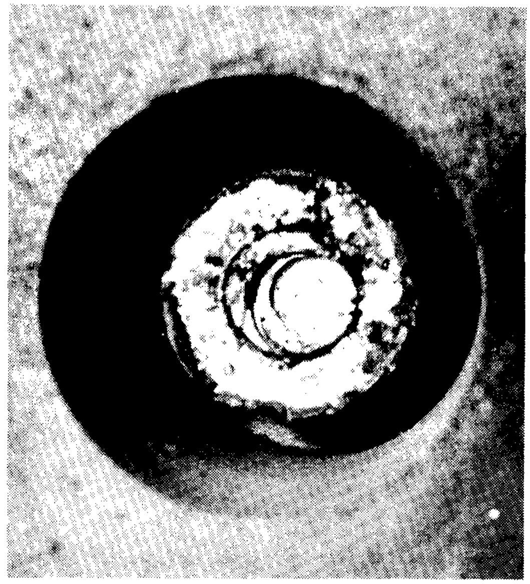

FIGURE 3 - Detail of point of failure in outer sleeve.

The proximity of the cooling water routing system to the drain and its subsequent damage by drain-generated heat was responsible for the failure of the drain cooling system.

## Glass studies

Properties of the basic glass matrix to be employed in the glass furnace evaluation studies were established in studies performed December through February. A bulk component analysis, by means of atomic absorption, of the Honeygold soda-lime silica cullet to be used as the immobilization matrix for this project, is shown in Table 1. A Differential Thermal Analysis (DTA) was performed, revealing the actual melting

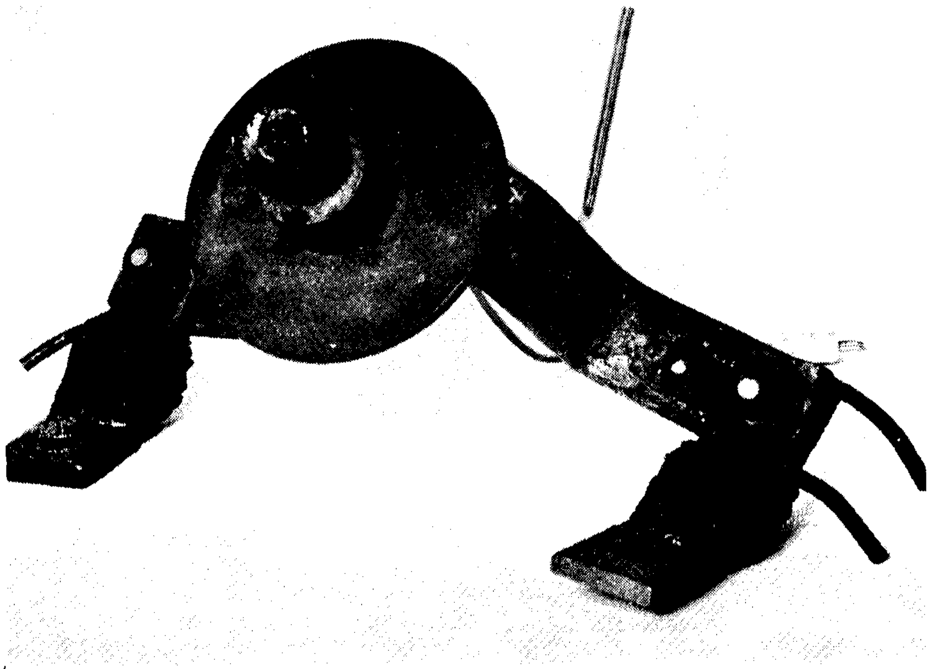

FIGURE 4 - Inner structure of drain/heater with bus bars.

FIGURE 5 - Detail of point of failure on inner structure.

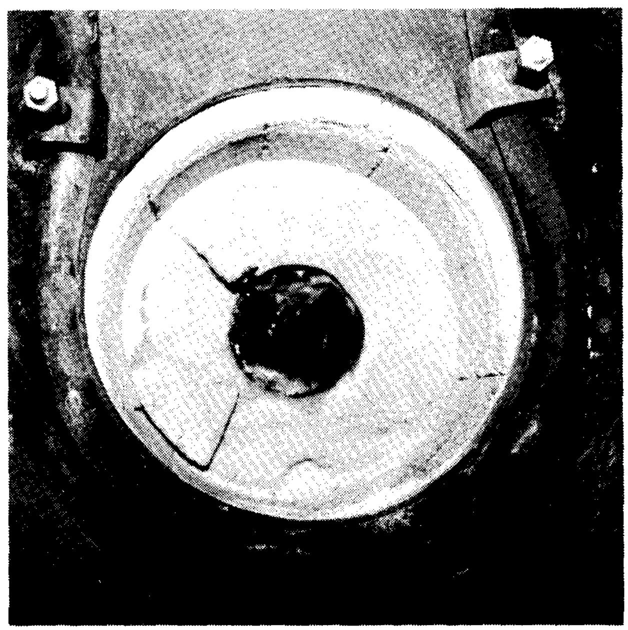

FIGURE 6 - Drain coupling in furnace unit

Table 1 - COMPOSITION OF HONEY-GOLD SODA-LIME SILICA CULLET[a]

| Component | Composition (wt %) |
|---|---|
| $SiO_2$ | 74.80 |
| CaO | 6.15 |
| MgO | 3.80 |
| $Na_2O$ | 14.39 |

[a]Product of Anchor Hocking Corp., Lancaster, Ohio

Samples taken from the furnace, during the experimental phase, for chemical and physical analysis, will be brought slowly through the annealing range by an annealing furnace currently being purchased.

Glass compatibility studies were performed in February, in conjunction with the Mound Glass Ceramics Laboratory, to determine the effects of refractory and waste on the soda-lime glass matrix being used in the waste incineration experimentation. For these studies, batches of simulated waste, consisting of a "worst case" 50% ash-50% sludge mixture, were made. The data used to prepare the simulated waste (see Table 2) were obtained from elemental analyses of calcined ash and sludge produced by the Mound Cyclone Incinerator. Four waste loadings were investigated: 0, 10, 20, and 30% by weight. For each case, the waste was added to 450 g of glass cullet and electrically heated to the molten stage. Fingers of refractory samples, of the same type lining as the glass furnace,

Table 2 - COMPOSITION OF SIMULATED WASTE

| Element | Sludge (wt %) | Ash (wt %) |
|---|---|---|
| Na | 14.8 | 0.35 |
| Al | 15.9 | 17.8 |
| Si | 15.5 | 17.8 |
| Ti | 2.0 | 3.0 |
| Zn | 2.0 | 3.0 |
| Fe | 1.0 | 2.5 |
| Pb | 0.8 | 0.04 |
| Ca | 0.9 | 2.0 |
| Mg | 0.3 | 3.0 |
| P | | 0.05 |
| Mn | | 0.06 |
| Cr | | 0.30 |
| Sn | | 0.05 |
| Ni | | 0.08 |
| Cu | | 0.05 |
| Ag | | 0.05 |
| B | | 0.05 |

It was found that, although at a temperature of 2640°F the melt is most easily poured, the glass/waste mixture at that temperature is extremely corrosive to the refractory (See Figure 7). This corrosion was greatly alleviated by reducing the temperature to 2400°F (See Figures 8 and 9). Therefore, when waste is actually being burned in the full-scale furnace unit, the temperature will be controlled at 2400°F until sampling from the drain is required, at which time the temperature will be briefly raised to lower the viscosity and facilitate pouring.

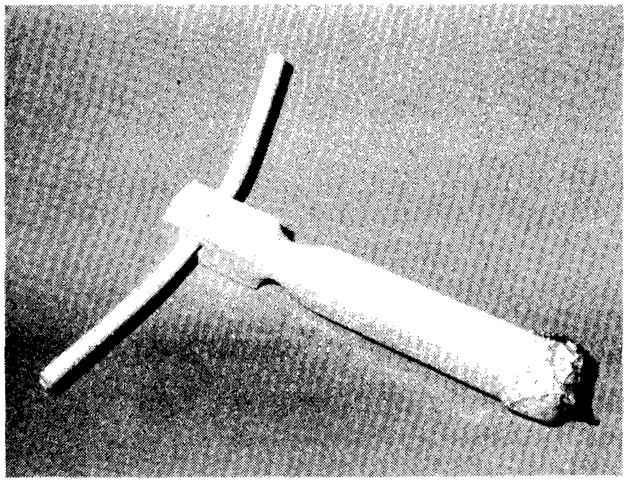

FIGURE 7 - Refractory corrosion caused by 2640°F glass melt. Refractory sample was 4 in. x 1/2 in. x 1/2 in.

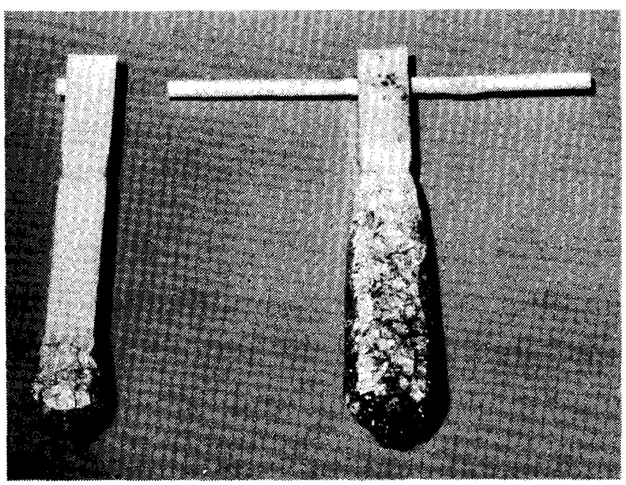

FIGURE 8 - Corrosion caused by 0% and 10% waste loading of 2400°F glass melt. Refractory sample was 4 in. x 1/2 in. x 1/2 in.

Chemical durability tests, in the form of the MCC-1 Static Leach Test*, are currently under way for samples obtained from the compatibility studies. Samples of the glass/waste mixture from each waste loading batch are being subjected to 3, 7,

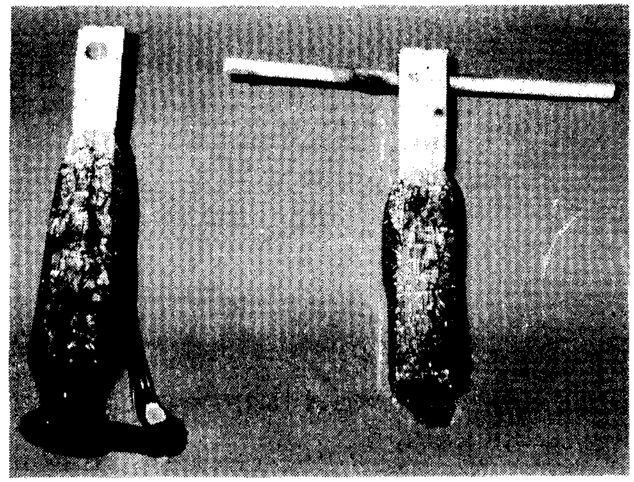

FIGURE 9 - Corrosion caused by 20% and 30% waste loading of 2400°F glass melt. Refractory sample was 4 in. x 1/2 in. x 1/2 in.

## Experimental design

The experimental procedures required to fulfill the scope of the project were delineated as a result of interfaces with the Mound Experimental Design Group. Using this group as a resource resulted in a less repetitive, more efficient experimental plan, due to their expertise in statistical applications. It has been recognized that the most important parameter to be investigated in the full-scale experimental phase is combustion efficiency. Other parameters, such as operating cost, optimum feed rate, and excess oxygen requirements, can all be determined by first focusing on the combustion efficiency, then relating this to each of the other parameters.

The experimental procedure finally agreed upon will measure combustion efficiency by determining: 1) the percent oxygen in the offgas, 2) particulates present

Twelve runs will then be performed for each of the four waste types being investigated (dry trash, ion exchange resin, filter sludge, and cartridge filters) according to the experimental matrix shown in Table 3. As shown, two experiments will be performed per day followed by two to four days of furnace idle time.

Each experiment will consist of adjusting the waste feed rate and oxygen level to the recommended experimental conditions. The system will be brought to equilibrium (30 to 60 min), then operated for 1 hr during which time pertinent offgas data will be collected from oxygen sensors, the combustibles monitor, and particulate filters.

According to the Experimental Design Group, adherence to this procedure will allow for the determination of morning or afternoon effects on results (not expected), testing for equal variance at each set of conditions, and a chance to examine operating feasibility at extremes. It will also be determined if it is practicable to model combustion efficiency as a linear function of feed rate and total oxygen in the combustion air.

Data already obtained from the Compatibilities Studies, with regard to the waste loading capacity of the glass, will be verified with periodic sampling of the glass/waste mixture during experimentation. These samples will then be exposed to chemical and physical durability testing for comparison with the previous results.

Table 3 - EXPERIMENTAL MATRIX

| | Morning Conditions | | Afternoon Conditions | |
|---|---|---|---|---|
| Set | Feedrate | Total $O_2$ | Feedrate | Total $O_2$ |
| 1 | low | low | intermediate | intermediate |
| 2 | high | low | high | high |
| 3 | intermediate | intermediate | low | high |
| 4 | high | high | intermediate | intermediate |
| 5 | low | high | low | low |
| 6 | intermediate | intermediate | high | low |

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