THE DEVELOPMENT OF CONE TEN ASH GLAZES USING LOCALLY AVAILABLE VEGETABLE ASHES

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by

Bessie Irene Glover

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BESSIE IRENE GLOVER. The Development of Cone Ten Ash Glazes Using Locally Available Vegetable Ashes. (Under the direction of Paul R. Minnis, Professor, School of Art, East Carolina College.)

The study, The Development of Cone Ten Ash Glazes Using Locally Available Vegetable Ashes, is a technical Thesis presented to the Faculty of the School of Art, East Carolina College, in partial fulfillment of the requirements for the degree, Master of Arts.

The study deals with a history of ash in which traditional usage of the glaze material is discussed. The study further explores the problems of ash procurement and processing, and establishes approaches to the solution of problems relating thereto.

The formulation of high percentage vegetable ash glazes maturing at cone ten is the main problem of the thesis. This is resolved with the formulation of five workable vegetable ash glaze formulas.

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CHAPTER I

THE PROBLEM DEFINED AND DELIMITED

Introduction

The present thesis is largely motivated by a thesis written at East Carolina College in 1962 by Kenneth Clayton Nuber entitled, The Utilization of Locally Available Vegetable Matter Ash as Fluxing Agents in Glazes Maturing at 1180° Centigrade. Nuber's thesis was motivated by a conviction that commercially processed glaze chemicals rule out naturally occuring earth-bound human qualities found through use of less sophisticated materials such as wood or vegetable ash.

It is this root feeling about a phase of ceramic art which led the investigator to continue Nuber's line of study. This investigator, being from a rural environment, was able to see the potential use of many materials which would not occur to the city dweller. Nuber's thesis was then expanded along lines which were not available to him. Facilities for firing at cone ten were not available at East Carolina College in 1962. Nuber's work, therefore, dealt with the development of a fusibility rating scale for ash to be used in glazes designed to mature at cone five.

The investigator, having a cone ten, open flame kiln at her disposal chose to work at that temperature; and, being a native of the area, was more familiar with material readily available in a rural environment. Both of the above factors

coupled with the initial motivation of the Nuber study led the investigator to pursue the present thesis.

Statement of the Problem

The problem, therefore, is to expand the Nuber thesis by discovering reliable new local sources of ash, to use such ash in the development of workable glaze formulas designed to mature at cone ten, and to develop five or more formulas containing at least forty per cent or more of ash. A further purpose of the study is to collect under one cover the scattered information dealing with the whole field of ash glazing.

Purpose of the Study

The purpose of the study is, further, to explore Nuber's thesis by:

1. Surveying the history of ash glazing.
2. Finding new sources of reliable raw materials for ash glazes.
3. Having found such sources, to develop new glazes using them.
4. Testing a variety of coloring possibilities.
5. Establishing clear guide lines for the development of ash glazes.

Significance of the Study

The study is important because:

1. A workable approach to the development of ash glazes from locally available sources is developed.

2. The study solves problems that would be insurmountable obstacles to the beginner regarding the gathering, burning, processing, and use of the ash in the glaze formula.

3. It produces reliable new sources of ash.

4. It produces a guide to ash glaze formulation.

5. It produces improved methods of ash procurement, burning, and washing.

6. It produces new glaze formulas, colors, and textures.

Delimitations of the Study

The study will be limited as follows:

1. It will deal with tests fired at cone ten.

2. The source of ash will be locally available.

3. The final formulas will contain at least forty per cent or more of ash.

4. All testing will be conducted on an empirical basis.

5. The ashes used in the study will be soy bean stalk ash, peanut hay ash, tobacco ash, pecan leaf ash, maple wood ash, hickory wood ash, and dogwood ash.

6. Testing will involve both unwashed and washed ash.

7. The ash will not be chemically analyzed.

8. The use of the glaze will be limited to pottery.

Definition of Important Terms

Ash glaze

The glaze coating or a glaze composition containing wood or vegetable ash.

Aklali

A strong flux. Present in solutions of water and ash, partially removed by washing or ash. (See Chemical Analysis pp. 16-17)

Batch limits

Recommended proportions of raw materials based on their interaction in a glaze formula. (See Testing Approaches p. 21)

Bisque

The first firing of ceramic ware or unglazed fired ware.[1]

"Breaking"

The visual appearance of color or value change in a glaze resulting from a varying underlying surface. Glaze tends to drain from high points and collect on straight or depressed surfaces.

Colorant

A metallic oxide or earth pigment used as a coloring agent in glazes.[2]

Cone

A heat indicator. A commercially produced pressed stick, glaze-like in composition, designed to melt at a specific temperature.[3]

Crawling

A glaze fault. Glaze collects in beads on the surface of the ware leaving exposed areas of bare clay.

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[1] John B. Kenny, Ceramic Design (1963), p. 316.

[2] Daniel Rhodes, Clay and Glazes for the Potter (1957), p. 127.

[3] Kenny, op. cit., p. 316.

Crazing

A glaze fault. A network of small cracks in a glaze.

Crystallization

When crystals grow in the surface of a glaze. Such glazes usually contain rutile, zinc, or other crystal-forming oxides.[4]

Earthenware

A general classification or porous, low temperature ceramic ware.[5]

Fluid

A glaze fault occuring when a glaze flows excessively, running off vertical surfaces and collecting in thick pools.

Flux

A melting agent basic to glaze formulation.[6]

Fuming

A very thin glazed surface extending beyond the perimeter of actual glaze coating.

Gloss

A shiny, smooth surface.

Immature

A glaze fault. Glaze has a rough surface and usually is not properly fused.

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[4] Ibid., p. 316.

[5] Bernard Leach, A Potter's Book (1956), p. 266.

[6] Ibid., p. 269.

Kiln

A refractory lined chamber in which ceramic ware is fired.

Mat

A glaze surface having a dull finish.

Oxidation

Firing a kiln so that complete combustion takes place. If an open flame kiln is used a supply of air adequate to achieve complete combustion is allowed to enter the kiln. The atmosphere is free of carbon and smoke. When firing an electric kiln one expects oxidation.[7]

Pinholing

A glaze fault. The surface of the glaze contains many tiny holes.

Reduction

This type of firing can best be accomplished in an open flame kiln. Here the amount of air entering the kiln is controlled. By reducing the amount of air entering the kiln a smoky, carbon filled atmosphere can be produced. When the kiln is being fired in this manner combustion is complete. In actual firing, periods of reduction are alternated with periods of oxidation.[8]

Reliable source of ash

A source that can be depended upon to produce an ash that will give consistent results in a given formula year after year.

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[7] Ibid., pp. 275. 276

[8] Ibid., p. 278.

Shard

A fragment of a pot.

Stoneware

A general classification of dense, high-fired ceramic ware. Also refers to clays used in the production of this ware.[9]

Viscosity

Refers to the resistance to fluidity of the glaze in its molten state. A glaze lacking in viscosity would be excessively fluid.[10]

Waxy mat

A mat glaze surface with a soft luster or semi-sheen.

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[9] Ibid., p. 281.

[10] Kenny, op. cit. p. 318.

CHAPTER II

A HISTORY OF ASH GLAZING

Historical Usage of Ash Glazing

Early Near Eastern Contributions. -- There is an early history of pottery throughout the Near East. The first glazing techniques, attributed to the Egyptians, date back to 5000 B. C. As early as 3300 B. C. a complicated polychrome technique of glazing was used by the Egyptians.[1] In Persia, pre-historic pottery was produced during the Chalcolithic period (ca. 3500 B. C. - 1500 B. C.). During the Bronze Age (2500 B. C. - 1500 B. C.) pottery was made on a hand-turned tournette and fired in a closed kiln with drafts.[2] Glazing in India dates back to 3000 B.C. The clay bodies and glazes were similar to those used by the Egyptians.[3]

This early pottery was earthenware, that is, porous nonvitrified ware.[4] Near Eastern potters were unable to make stoneware pottery (ware fired at a temperature in the range 1230° C. - 1320° C., or cone 7 - cone 11) because refractory clays were not found in the area, thus making it impossible to build kilns capable of temperatures in excess of 1100° C. (cone 1).[5]

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[1] Cullen W. Parmelee, Ceramic Glazes (1948), p. 2.

[2] Arthur Upham Pope, Masterpieces of Persian Art (1945), p. 4.

[3] Parmelee, op. cit., p. 2.

[4] Daniel Rhodes, Stoneware and Porcelain (1959), p. 4.

[5] Ibid., pp. 3-4.

The Egyptians had knowledge of the potter's wheel as early as 3000 B. C. It is generally believed to have been carried indirectly to China through the civilizations of Asia Minor and Central Asia.[6]

Chou Dynasty Contributions.-- In China refractory clays were abundant. Through use of these clays the Chinese began to make stoneware about 500 B. C.[7] There is evidence that a type of white stoneware-like pottery was being made at Anyang, China, as early as 1400 B. C. - 1100 B. C. This ware was decorated by carving into the surface of the vessel, but was unglazed.[8]

By late in the Chou dynasty (1122 B. C. - 249 B. C.), pottery was decorated with glass paste and applied reliefs. Such pots are dated 400 - 300 B. C.[9] Late Chou potters learned to build kilns from refractory clays and to fire them to high temperatures, using wood for fuel. As the firing took place, ash from the fire-mouths drifted through the kiln, settled on the inside walls and on the pots, and formed a glaze-like coating.[10] Using this information, Chou potters developed techniques for making glazed stoneware prior to the Han dynasty (206 B. C. - A. D. 220).

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[6]Ibid., p. 4.

[7]Ibid., p. 3.

[8]Basil Gray, Early Chinese Pottery and Porcelain (n.d.), pp. 1-2.

[9]Ibid., p. 2.

[10]Rhodes, op. cit., p. 7.

The earliest use of wood ash in glazing occured about 300 B. C. and was probably accidental in nature as described above. The glaze on this pre-Han pottery usually appears on one side of the shoulder of the piece as the result of ash from the fire settling on the ware during the firing process.[11] The glaze on this pottery is usually gray-green or brown, rather cloudy, and has a tendency to run and accentuate the surface variations of the pot.

Han Dynasty Contributions. -- Later potters collected ash from the fire-mouths of kilns and deliberately applied it to the surface of their pots. In Han ware this simple ash glaze was invariably used in the natural state. There was no addition of coloring agents to the formula because potters of that age were unaware of their existence.[12] These glazes were brown-green in color, the result of iron inherent in the glaze materials fired in a reducing atmosphere. The amounts of iron vary from one and a half per cent in the lighter glazes to twenty per cent in the darker glazes.[13]

According to Bernard Leach, the earliest stoneware glazes were transparent olive. Leach reproduced this type of glaze using a mixture of siliceous clay and

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[11] Ibid.

[12] Ibid., p. 8.

[13] Bernard Leach, A Potter's Book (1956), p. 137.

forty per cent of oak ash.[14] Hamada Shoji says the earliest stoneware glazes were brown and composed of either a single natural stone, clay, or a mixture of one of these with wood ash.[15]

T'Ang Dynasty Contributions. -- During the T'ang dynasty (A.D. 618 - 906), three types of vitreous ware were produced. Of these three types, stoneware represents a continuation of the earlier Han tradition in ash glazing. Here the glaze was applied over a gray clay body. The glaze, based on the brown glaze found on late Han ware, was developed into two types during the T'ang dynasty. The first was a light glaze made of whitish clay or ground stone mixed with wood ash. The second was a dark glaze composed of clays and stones containing iron, to which the darker color was attributed.[16]

Korean Influence. -- Korea's geographic position is such that it forms a land bridge between continental Asia and Japan. As such it received a variety of cultural contacts among which China was a major influence. The Chinese of the Han Dynasty were able to establish their most successful colony, Lo-lang (108 B.C. - A.D. 313), in northeastern Korea. Through this colony they were able to instill, by force and example, a bias for Chinese models which can be seen in subsequent Korean art.[17]

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[14] Ibid., p. 8.

[15] Ibid., p. 136.

[16] Ibid., p. 137.

[17] Charles Ryder Dibble, The John R. Fox Collection at Syracuse University (1964), p. 11.

The Three Kingdoms period of Korean art existed from 57 B.C. until A.D. 668. Silla was the third and last of the Three Kingdoms. Korean ceramics from this period vary in color from tan to dark gray and were fired to a comparatively high temperature. The results resembled stoneware in hardness. The pots were unglazed, but often show a kiln gloss or traces of natural ash glaze.[18] The Korean potters of the Silla period, under the direct influence of the Han Chinese potters, began to employ the Chinese stoneware glazing techniques using wood ash in much the same manner as their predecessor.

Early Japanese Contributions. -- From Korea, stoneware production and related techniques spread to Japan. The first historical age in Japan is the Yayoi period (ca. 200 B.C. - A.D. 200). The Yayoi were Mongolians whose exact origin is unknown. However, these people resided in Korea before migrating to Japan. Landing first in Kyushu, they gradually moved over the Japanese islands. Yayoi pottery is found all over Japan.[19]

A new type of pottery came into existence in Japan during the Yayoi period. The ware originated among the Suebe people who emigrated to Japan from Kudura, Korea during the fifth century. The ware was called Sue ware after its originators. The pottery, used only for festivals, was also called Iwaibe, meaning

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[18]Ibid., p. 14.

[19]Hugo Munsterberg, The Ceramic Art of Japan (1964), p. 61.

sacred ware.[20] Sue ware may be distinguished from earlier Japanese pots by three characteristics: (1) the ware was fired to approximately 1200° C., (2) the body was hard and gray, and (3) sometimes the ware was decorated with a greenish natural ash glaze.[21] At village sites in Nagano and Aichi prefectures, large amounts of ash glazed Sue ware have been excavated. Almost every stoneware pottery shard recovered from the sites at Harade in Nagano prefecture has a wood ash glaze on the outer surface.[22] It has been discovered that the kilns at Gifu and Aichi Prefectures produced Sue ware intentionally glazed with wood ash.[23] The early glazes have an uncalculated effect. This distinguishes them from ash glazes deliberately produced following the tenth century, when advanced techniques came into common use.[24]

Late Japanese Contributions. -- Japanese potters were under the influence of T'ang dynasty China during the Asuka age (A.D. 552 - 646), and the Nara period (A.D. 646 - 794). Using colored glazes introduced by the Chinese, Japanese potters produced glazes showing more control than was possible with

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[20] Ibid., p. 64.

[21] Ibid.

[22] Fujio Koyama (ed.), Japanese Ceramics from Ancient to Modern Times (1960), p. 20.

[23] Ibid.

[24] Ibid., p. 18.

the natural wood ash gloss which formed during the kiln firing.[25] Potters of the early Heian period (A.D. 794 - 1185) still reflect the T'ang Chinese influence. The production of Sue ware continued during this period. "The development of natural wood ash glazes during (the) early Heian (period) resulted in some splended pieces."[26] In the Kamakura period (A.D. 1185 - 1333) Tokoname ware was glazed with natural wood ash glazes that dripped over the outer surface of the pots in a spontaneous manner.[27] The folk potters of the Tokugawa regime (A.D. 1615 - 1868), also employed ash glazing in their pottery making.[28]

In Japanese traditional country potteries today, the most usual stoneware glazes are a mixture of natural stones or clay with wood ash. At the town of Mashiko, the local building stone is ground to achieve a rust glaze known as Kaki. By adding ten per cent of medium wood ash to the stone it becomes the black glaze known as tenmoku.[29]

Contemporary Japanese Contributions. -- Contemporary Japanese potters continue to use traditional ash glazing techniques. Hamada Shoji, the Japanese potter probably best known to the western world, uses ash glazing extensively.[30]

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[25]Munsterberg, op. cit., p. 86.

[26]Ibid., pp. 87-88.

[27]Ibid., p. 92.

[28]Ibid., p. 224.

[29]Leach, op. cit., p. 137.

[30]Munsterberg, op. cit., p. 247.

In forty years of potting, Hamada says he has required nothing more for glazing than wood ash, and straw or reed ash, mixed with either feldspar or lime.[31] Hamada's glaze for stoneware is a combination of ratios between 80 to 20, and 70 to 30 per cent of feldspar and wood ash fired to about 1260° C. to 1300° C., or cone 8 to cone 10.[32] To achieve a translucent stoneware glaze, he mixes equal parts of feldspar, wood ash, and straw or reed ash. By adding five per cent of copper oxide to the translucent glaze, he obtains a green glaze. He also produces a strong green by adding copper oxide to white slip used under the ash glaze.[33] For a transparent glaze he increases the wood ash in the glaze from sixty to eighty per cent of the glaze.[34]

Contemporary American Usage. -- A number of contemporary American potters employ ash glazing in their work. Among them are Denis Chasek and Jane Parshall. Using maple leaf ash as forty per cent of their glaze formula, they produce a soft mat glaze which picks up the black sand in their clay body when fired in a reducing atmosphere.[35] Irene Hamel, who studied under Bernard Leach, fires her pottery to cone 9-10 in a reducing atmosphere. She

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[31]Susan Peterson, "Simple work at Shoji Hamada's farm," Creative Crafts, Vol. 4, (May - June, 1963), 26.

[32]James E. Noah, "A Workshop with Hamada," Ceramics Monthly, Vol. II (October, 1963), 20.

[33]Ibid., p. 19.

[34]Ibid., p. 20.

[35]"Biographical Sketches," Design Quarterly, 42-43 (1958) 55.

She uses naturally occuring materials such as lava, stone, and different kinds of wood ash.[36] Another potter, Frances Sensha, uses slip clays such as "Bear Canyon" and fluxes the clay with wood ash to achieve a glaze.[37] Marie Woo also uses ash glazes extensively. Employing iron as her colorant, she achieves a wide range of colors including deep reds, blues, greens, yellows, and browns.[38]

Ash Glaze Technology

Chemical Analysis.-- The English potter, Bernard Leach, studied for a number of years under the Japanese master, Kenzen. Since much of glazing done by the Japanese involved the use of wood ash in the glaze formula, Leach worked extensively with this type of glaze.

Based upon analysis by Darting Hall Laboratories (1938 - 1939) of the different vegetable ashes used in Japanese glazes, Leach classified the ashes into three categories; hard, medium, and soft.[39] The ashes involved in the classification were sieved to rid them of foreign matter, such as sand, and washed to remove soluable alkalies. The remaining proportions of alumina and silica to alkalies was the basis upon which Leach divided the ashes into the three

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[36]Ibid., p. 57.

[37]Ibid., p. 62.

[38]Ibid., p. 64.

[39]Leach, op. cit., p. 159.

categories.[40] It was the proportion of alumina and silica to alkalies in the ash which determined the main effect of the ash in the glaze. However, the proportion of ingredients other than alumina, silica, and alkalies varied from ash to ash. This variation in the ash accounted for the special effects produced by a stoneware ash glaze.[41]

Chemical analysis of wood and vegetable ashes reveals that the following chemicals usually occur within the stated limits: (1) alumina, 10-15 per cent, (2) silica, 30-70 per cent, (3) potash, up to 15 per cent, and (4) lime, up to 30 per cent. Also present in small amounts are iron oxide, phosphorous, and magnesia together with other elements.[42] Because wood ash contains, in addition to silica and alumina, considerable amounts of alkalies such as potash and soda which act as fluxes, they have a relatively low fusion point.[43] Most types of ash will melt at approximately cone 10 (1300°C.) to a fluid glass.[44]

Washing alters the composition of an ash. Sulphates, chlorides, and soluable potash are eliminated by the first washing.[45] Excessive washing will

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[40] Ibid.

[41] Ibid.

[42] Daniel Rhodes, Clay and Glazes for the Potter (1957), p. 188.

[43] Ibid., p. 58.

[44] Ibid., p. 188.

[45] Leach, op. cit., p. 161.

remove too much potash thereby reducing the effectiveness of the ash as a flux.[46]

Heat further alters the composition of ash. Carbonates are found in ash in combination with other ingredients until they are released as carbon monoxide gas at approximately 900°C., (cone .010).[47] Among the ingredients in ash is magnesia which will combine with silica in definite proportions at the first opportunity in a rising temperature. This combination is called a eutectic. After this first combination has taken place, the residue will either harden or soften the glaze.[48] Magnesia which forms a viscous flux with silica over a long range of vitrification has a strong effect in the glaze as does alumina which does not readily lend itself to combinations with other chemicals.[49] Silica of vegetable origin differs from quartz and flint which are of chemical origin, and in combination with fluxes melts more readily than silica from chemical sources. However, in a highly siliceous ash vegetable silica remains suspended as a crystaline opacifier.[50]

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[46]Rhodes, op. cit., p. 188.

[47]Leach, op. cit., p. 161.

[48]Ibid., p. 159.

[49]Ibid.

[50]Ibid., pp. 159-160.

Ash Burning Techniques. -- The Japanese traditionally burn matter to an ash in open bonfires on a clean surface such as gravel or brick. Burning is done on calm days to avoid a large glaze which would carry off light ash and reduce the remaining quantity by burning the ash white.[51]

In 1962, Kenneth Clayton Nuber's study at East Carolina College dealt with ash glazing. In conjunction with the study he constructed a stove for burning materials to produce ash. The stove was made of two five-gallon metal cans, the first of which was to be used as a burner can after having had the bottom cut away. A draft door was cut in the side of the second can and a one-fourth inch mesh, galvanized screen was placed on top of the can. This became the draft and collection can when placed beneath the first can. As the raw material burned in the top can, the ash was allowed to pass through the screen and fall into the collection can below. This device served as a satisfactory means of producing an ash which was free from impurities such as sand.[52]

Ash Washing Techniques.-- The traditional Japanese method of washing ash is to first mix the ash with water, then remove the scum and charcoal which rises to the surface with a sieve. This partially burned matter is dried and burned further at the next burning. The mixture is immediately decanted, leaving sand and grit in the bottom of the container. The ash and water mixture is then run

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[51]Ibid., p. 160.

[52]Kenneth Clayton Nuber, The Utilization of Locally Available Vegetable Matter Ash as Fluxing Agents in Glazes Maturing at 1180° Centigrade (unpublished master's thesis, East Carolina College, 1962), p. 3.

through a 10 to 100 mesh screen. The residue from the screening is added to the first charcoal for drying and further burning. Next the ash and water mixture is run through a 100 to 200 mesh screen according to the requirements of the glaze for which the ash is intended. The ash is then allowed to settle and the greater part of the water containing soluable alkalies is decanted. Fresh water is added and the decanting repeated until the water is clear and tasteless. The ash is then dried and stored.[53]

Another process for washing ash is to mix the ash with a quantity of water then pass the slurry through an eighty mesh screen. Material that does not pass through the screen is discarded. The ash and water solution is then placed in a container, and the ash is allowed to settle. The water containing soluable alkalies is decanted.[54] Next the ash is allowed to dry, after which it must be sieved again before it can be used. Sometimes it is desirable to use a large mesh screen to retain coarser grains of ash in order to obtain variations of color in the final glaze.[55]

Ash Procurement. -- It is difficult to procure a consistently reliable source of ash. Ash from one species of trees, for example, may vary in compostion according to the soil in which the trees grew.[56] The silica content of straw, grass, and reeds may vary as much as fifteen per cent between spring and late fall cutting.

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[53] Leach, op. cit.

[54] Rhodes, op. cit., p. 188.

[55] Leach, op. cit., p. 142.

[56] Rhodes, op. cit., p. 188.

The maturity of a given plant determines the amount of silica found in the ash. The proportion of silica to other ingredients found in an ash is largest if the plant is mature, smaller if the plant is immature.

Testing Approaches. -- Between 1930 and 1940 Katherine Pleydell-Bouviere worked on glazes using a variety of wood ashes in Coleshill, England. She employed the same formula throughout her tests, and all ashes were sieved through a 120 mesh screen. She worked with the formula: one part ash, one part feldspar, one-half part pikes clay. After testing various kinds of ash in the basic formula, she recorded the results as to color, surface, and glaze faults. She points out that the type of kiln used and the fuel with which it is fired will greatly influence the final results.[57]

Daniel Rhodes suggests the same formula used by Pleydell-Bouviere as a starting point for testing ash glazes, together with the formula: one part wood ash, one part feldspar, and one part clay. He recommends a firing range between cone 8 and cone 11 (1260°C. - 1320°C.).[58]

The following are offered by Rhodes as probable batch limits of materials usual to ash glazes: (1) ash, 20-70 per cent, (2) feldspar, 20-70 per cent, (3) whiting, 5-20 per cent, (4) flint, 15-25 per cent, and (5) clay, 5-20 per cent.[59]

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[57]Leach, op. cit., p. 163.

[58]Rhodes, op. cit., p. 188.

[59]Ibid.

In Nuber's study, dealing with vegetable ash glazes containing at least 30 per cent or more of ash and maturing at cone 5 (1180°C.), no ash was washed or chemically analyzed. The ashes tested were peanut shell ash, Spanish moss ash, mixed hardwood ash, water oak ash, mixed oak and cotton husk ash.[60] Nuber devised an ash fusibility rating scale by which any potter can, through tests of his own, determine the fluxing potential of a given ash. Nuber concluded that ashes receiving a rating in the 1 to 5 area of his scale can successfully be substituted in almost any high ash percentage glaze formula as a flux.[61]

Ash glazing techniques are probably more or less familiar to most contemporary potters. The difficulty of ash procurement and the unpredictable nature of the glazes are factors many potters may consider when deciding whether to use this type of glaze.

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[60] Nuber, op. cit., pp. 18-19.

[61] Ibid., pp. 13-14.

CHAPTER III

THE PROBLEM

Collection and Burning Procedure

Seven items were chosen to be burned to produce ashes for this study - soy bean stalks, peanut hay, tobacco, pecan leaves and three hardwoods: maple, hickory and dogwood. Of the seven items selected all except peanut hay were collected on the farm of E. E. Glover in Beaufort County, North Carolina. The peanut hay was acquired from two sources, the farms of Owen Jones and Ralph Taylor, in Martin County, North Carolina. The first materials were burned during November, 1964, except tobacco which was burned during September, 1965. Materials were burned thereafter when it became necessary to replenish the supply or when raw materials were available.

Four methods were used to burn the materials involved in the study. The first system of burning was suggested in the Nuber thesis (see p. 19). Here two five-gallon steel cans were converted into a burning stove. Nuber's plan was altered in that the bottom of the burner can was not removed and replaced with wire. Instead, a number of holes were drilled in the bottom to allow (1) the draft to be effective, and (2) the ash to sift through into the collection can. The Nuber stove was otherwise unaltered. The burning equipment worked well, but the size of the stove so limited the amount of material which could be burned at one time

that it was impractical. Therefore, it became necessary to find a means by which large amounts of material could be burned in a short time.

The second method of burning employed a fifty-gallon steel drum which was converted into a stove. This was accomplished by removing the top of the drum and cutting a draft in the side at the bottom. The top of the drum which had been previously removed was converted into a lid. Four holes were drilled in the metal to allow two metal strips to be attached to the top. These strips supported the lid as it lay on top of the can and also served as handles. The lid was useful when material was burned on windy days. It reduced the draft and decreased the danger of setting the surrounding area on fire. However, this method was unsatisfactory. An inadequate air supply allowed some material to smoulder rather than burn freely. Extra air was pumped into the can to achieve more complete combustion. An air pump was used for the purpose. This method was not always convenient because it was not always possible to burn materials near the air tank.

In an attempt to improve the draft a third method of burning was devised. A piece of one-half inch galvanized wire was placed on top of the fifty-gallon drum. The material to be burned was placed on the wire and ignited. It burned rapidly but combustion was incomplete. Some partially burned material fell through the wire together with the ash into the collection area at the bottom of the drum.

In an effort to obtain more complete combustion the one-half inch mesh galvanized wire was placed inside the drum just above the draft. It was supported

by bricks standing on end around the inside perimeter of the drum. This allowed the burning to take place entirely within the stove. Smouldering was reduced to a minimum. Using this method the most complete combustion was achieved. (See Figure 1, p. 26).

Because it was difficult to get green hardwoods to burn, an acetylene torch was used to start the fire in an effort to keep the resultant ash free from impurities. In the case of light, dry materials such as peanut hay, a match provided sufficient ignition.

Ash often fell out of the stove through the draft. In order to save this ash and keep it free from impurities a piece of tin was placed under the drum at the draft port. As the ash fell out, it was removed from the tin and placed in a container.

After a material was burned and the ash had cooled, it was sifted through a kitchen flour sieve in order to remove bits of matter that had not burned completely. The ash was then stored in labled containers for later use.

Washing Procedure

All ash selected for this study was tested as described later in the thesis. Disappointing results prompted further processing of the ash. Washing the ash free of some of its soluable alkali and carbon content produced much improved results.

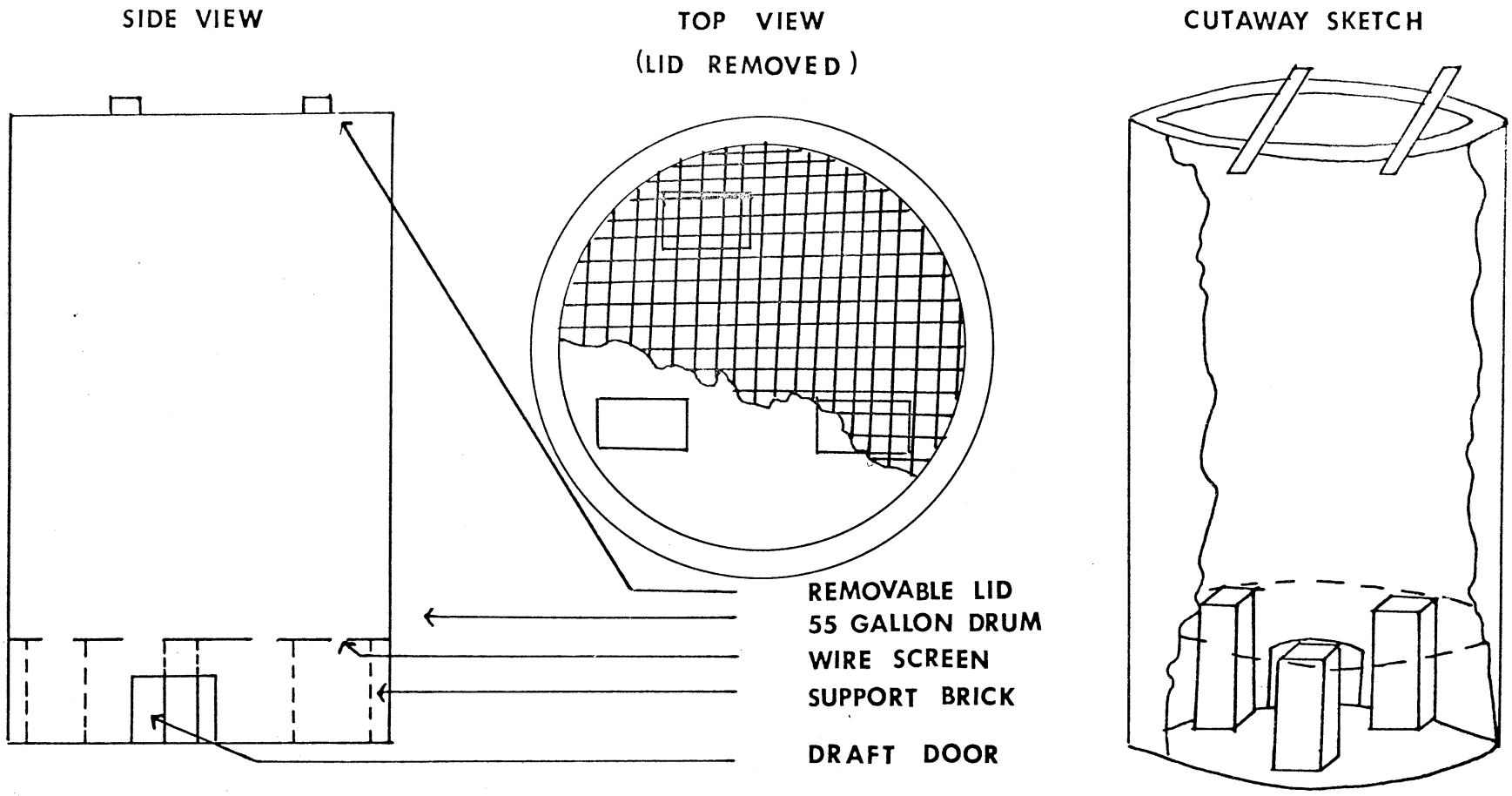


FIGURE 1
ASH BURNING STOVE

Following the decision that washing the ashes would be advantageous, each lot of screened ash was placed in a large container and flooded with water. The ash was mixed thoroughly with the water and then allowed to settle to the bottom of the container. Carbon and bits of unburned material floated to the top. They were siphoned off together with the excess water. The damp ashes were set in the sun in shallow containers or were placed on top of a firing kiln and allowed to dry. After the ash was dry, it was sieved through a fifty mesh screen and placed in containers for storage. Each ash was washed once.

Introduction to Testing Program

The glaze testing program was divided into three major parts, (1) preliminary tests, (2) ash glaze formulation tests and ash substitution tests, and (3) coloration tests.

The preliminary tests are presented in Tables I through IV. The purpose of these tests were to determine: (1) the degree of fusibility of each ash, (2) the best proportions of basic raw materials necessary to ash glazes, (3) the most effective auxiliary fluxes to use in formulation of high ash content glazes, and (4) to test some initial glaze formulas based on information gleaned from the first three tests.

The second major area of testing is presented in Tables V through XII as glazes A through H, and in Tables XIII through XVII, the ash substitution tests.

In each of the tests of glazes A through H, all attempts to produce a workable glaze are presented. In many instances several tests were produced by varying the amounts of a single ingredient. When results proved a given direction in formulation to be a desirable one, a test series was based upon this new direction, therefore, a given test may have a number of different facets. Due to time limitations in some cases it became necessary to abandon a whole test series, even though it seemed promising. Eventually the testing was limited to the five most promising glazes; (1) Glaze B-8, (2) Glaze C-7, (3) Glaze 2C-3, (4) Glaze F-5, and (5) Glaze 2G-6. These formulas were used in the ash substitution tests which were designed to test the effect of each ash in a given formula.

The third area of testing is presented in Tables XVIII through XXII as the coloration tests. The five formulas used in the ash substitution tests were used in the coloration tests. These tests were attempts to find the most effective colorants for use in the chosen formulas.

CHAPTER IV

THE TESTS AND THEIR ANALYSIS

Preliminary Tests

Ash Fusibility Test. -- Ashes for the ash fusibility test were sieved and unwashed. The chosen ash was weighed and placed on a damp bat. It was mixed on the bat with a palette knife so that the ash would absorb a slight amount of moisture from the bat. The ash was then dry-pressed into a pellet shape, using a mold devised from a half-inch pipe into which the ash was packed and then extruded. The buttons were placed on bisque tiles to be fired to 1260° C. A mixture of gum arabic, alcohol and water was dropped on the resultant button. The syrup-like gum solution caused the button to retain its shape through subsequent handling prior to firing.

Those ashes which fused and spread over the surface of the tiles were considered the strongest fluxes. Those which did not fuse were considered weaker fluxes. The fusibility of each ash was tested separately and in one to one combinations with each other. Peanut hay and soy bean stalk ash appeared to be most fusible of the six ashes. In combination the fusibility of the other ashes improved. It may be noted that equal parts of peanut hay and soy bean stalk ash melted to a transparent gloss. The results of this test are shown in Table I.

TABLE I

ASH FUSIBILITY TEST

Peanut Hay	Soybean Stalk	Pecan Leaf	Dogwood	Maple	Hickory
1	2	3	4	5	6
Button fused to fluid opaque mat	Button fused to low mound light yellow	Button attached but powdery	Button not attached powdery	Button not attached powdery	Button not attached powdery
	1+2	1+3	1+4	1+5	1+6
	Button fused and covered surface clear blue gloss	Button fused but not totally melted	Button retained shape, powdery	Button retained shape, powdery	Button retained shape, powdery
		2+3	2+4	2+5	2+6
		Button fused to low mound white mat	Button fused to mound, fuming at edge, off yellow	Button fused to mound, fuming at edges, yellow	Button fused to mound, fuming at edge, yellow
			3+4	3+5	3+6
			Button attached but powdery	Button attached but powdery	Button attached but powdery
				4+5	4+6
				Button not attached powdery	Button not attached powdery
					5+6
					Button not attached powdery

Tri-axial Blending.-- Tri-axial blending was chosen as a means of testing the fusibility of peanut hay ash as a flux in combinations with clay and flint, two basic glaze ingredients. Large amounts of ash were used because it was desirable to incorporate as much ash as possible in the final glaze formulas. Clay and flint were used in amounts generally within suggested batch limits for these materials.

The ash used in the test was sieved and unwashed. The test was fired to cone 10, (1260°C.) in a reducing atmosphere. Fusion buttons were made for this test in the manner described on page 29. The following batches proved the best combinations of the three ingredients tested:

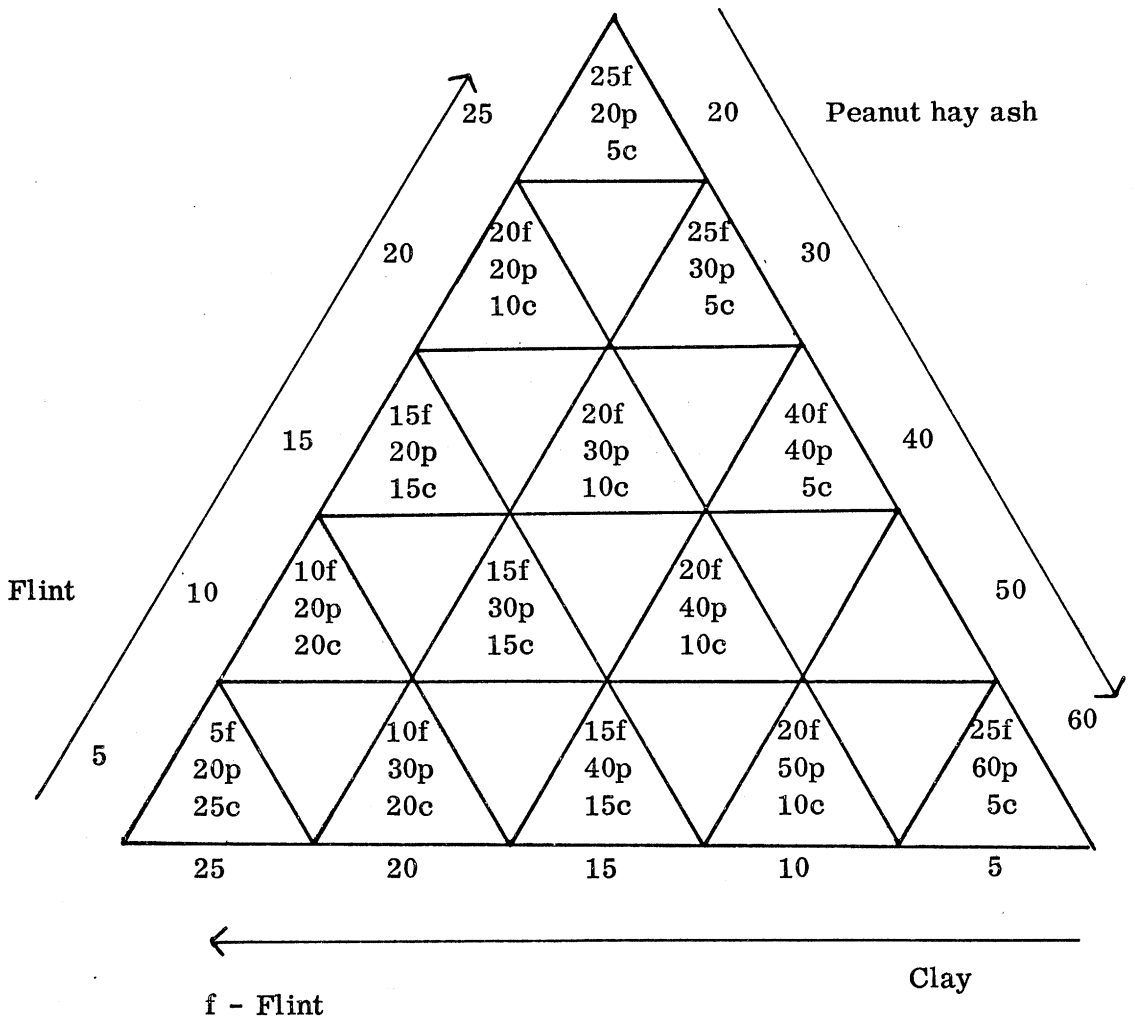
Peanut hay ash	40-60 parts
Flint	20-25 parts
Clay	5-10 parts

The formulas and their fired results are shown in Tables II and II-A.

TABLE II

TRI-AXIAL BLEND

PEANUT HAY ASH, CLAY, FLINT

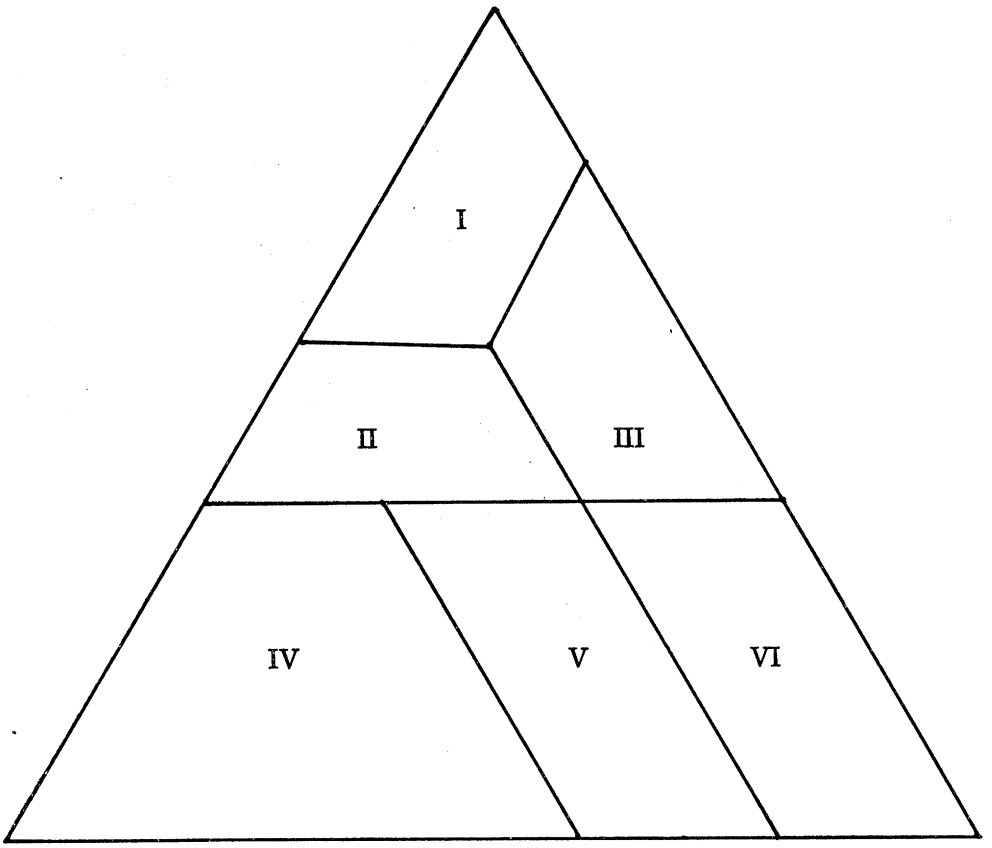


f - Flint
p - Peanut hay ash
c - Edgar plastic kaolin

TABLE II-A

TRI-AXIAL BLEND

PEANUT HAY ASH, CLAY, FLINT



I Button retained shape, fused, glass-like, off white

II Button retained shape, dense, attached to tile

III Button fused to low mound, dark gray

IV Button powdery, unattached

V Button fused to low mound, whitish

VI Button melted to form a gray pinholed glaze

Auxiliary Flux Test. -- Two ashes were chosen to be tested with auxiliary fluxes. The ashes chosen were peanut hay ash, a strong flux, and hickory wood ash, a weak flux. The ashes were sieved and unwashed. The tests were fired to cone 10 in a reducing atmosphere and were fusibility tests. The auxiliary fluxes were plastic vitrox, dolomite, lepidolite, spodumene, frit W-15, and frit 3191.

The results show that dolomite was not effective as an addition to the ash. Lepidolite and spodumene were medium fluxes and plastic vitrox and frits W-15 and 3191 were strong fluxes.

These tests and their results are shown in Table III.

TABLE III

AUXILIARY FLUX TESTS

TEST 1: Peanut hay ash and plastic vitrox			
1-a	Ash	55%	Fluid, covering most of tile, heavily crazed, gray to pink
	Plastic vitrox	45%	
1-b	Ash	50%	Less fluid, crazed, gray to pink
	Plastic vitrox	50%	
1-c	Ash	45%	Much less fluid, crazed, gray to pink
	Plastic vitrox	55%	

TEST 2: Hickory wood ash and dolomite			
2-a	Ash	80%	Button remained unfused and powdery throughout this test
	Dolomite	20%	
2-b	Ash	67%	
	Dolomite	33%	
2-c	Ash	57%	
	Dolomite	43%	
2-d	Ash	50%	
	Dolomite	50%	

TEST 3: Hickory wood ash and lepidolite			
3-a	Ash	80%	Button fused and retained shape, cinder-like
	Ledidolite	20%	
3-b	Ash	67%	Button fused to low mound, brown to green, mat to gloss
	Lepidolite	33%	
3-c	Ash	57%	Button more fluid than 3-b, brown to green, mat to gloss
	Lepidolite	43%	
3-d	Ash	50%	Button most fluid in test, mat brown to gloss green
	Lepidolite	50%	

TABLE III (continued)

TEST 4: Hickory wood ash and frit W-15			
4-a	Ash	80%	Fluid, overrunning entire top of tile. Moss green mat surface
	Frit W-15	20%	
4-b	Ash	67%	More fluid than 4-a, same color
	Frit W-15	33%	
4-c	Ash	57%	Fluidity same as 4-b, mat to gloss, moss green surface
	Frit W-15	43%	
4-d	Ash	50%	Extremely fluid covering top and bottom of tile, gray-green mat surface
	Frit W-15	50%	

TEST 5: Hickory wood ash and spodumene			
5-a	Ash	80%	Button fused to low mound, dark green to brown
	Spodumene	20%	
5-b	Ash	67%	More fluid, crazed, glossy green to brown with impurities on the glaze surface
	Spodumene	33%	
5-c	Ash	57%	Results same as 5-b
	Spodumene	43%	
5-d	Ash	50%	Fluid, dark green gloss to mat brown, crazed
	Spodumene	50%	

TEST 6: Hickory wood ash and frit 3191			
6-a	Ash	80%	Extremely fluid, pinholed, mat to gloss green
	Frit 3191	20%	
6-b	Ash	67%	Extremely fluid, crawls in mat crazed, pinholed gloss, green
	Frit 3191	33%	
6-c	Ash	57%	Extremely fluid, gloss to some mat on outer edges, finely crazed, pinholed, crawls, green
	Frit 3191	43%	
6-d	Ash	50%	Extremely fluid, smooth glossy surface, large crazes, dark green
	Frit 3191	50%	

Initial Glaze Formulation Tests. -- Six trial formulas were devised using information gained from the three preceding tests: (1) the ash fusibility test, (2) the tri-axial blend test, and (3) the auxiliary flux test. Two ashes were used, peanut hay ash, a strong flux, and hickory wood ash, a weak flux. The ashes were used in combinations with clay, flint, and fluxes chosen from those tested in the auxiliary flux test. The ashes were unwashed and sieved. The tests were fusibility tests, fired to cone 10 in an oxidizing atmosphere. Spodumene, lepidolite, and frits W-15 and 3191 appeared to be the most effective auxiliary fluxes. The tests and their results are shown in Table IV.

TABLE IV

INITIAL GLAZE FORMULATION TESTS

Test	Ingredients	Amt.	Description
1	Flint Peanut hay ash Kaolin Spodumene	29.3 58.8 5.8 5.8	Fluid, covering most of tile, crazed, blistered, gloss, gray to pink
2	Peanut hay ash Flint Kaolin Plastic vitrox	58.8 29.3 5.8 5.8	Same result as test 1, except less fluid
3	Peanut hay ash Flint Kaolin Plastic vitrox	40.0 10.0 10.0 40.0	Button fused to high mound, pinholed, glossy,white
4	Hickory ash Spodumene Kaolin Flint	58.8 29.3 5.8 5.8	Very fluid, finely crazed, glossy smooth surface, dark amber
5	Hickory ash Lepidolite Frit W-15 Kaolin	40.0 40.0 10.0 10.0	Very fluid, finely crazed, mat to gloss smooth surface,yellowish
6	Hickory ash Frit 3191 Kaolin	45.0 45.0 10.0	Very fluid, finely crazed, glossy smooth surface, yellow-green

Ash Glaze Formulation and Ash Substitution Tests

Development Data for Eight Ash Glazes.-- Empirically arriving at eight formulas, the investigator began the second phase of the study. Ashes used in these formulas were peanut hay ash, soy bean ash, hickory wood ash, maple wood ash, and after procurement later in the study, tobacco ash. The early tests in this series were fusibility tests using sieved unwashed ash. All tests were fired to cone 10 in a reducing atmosphere. After fusibility was determined, the ingredients were mixed and applied wet to upright tiles or to small pots.

Each ash was washed at some point in this phase of testing. The washing procedure is described on page 25. Tobacco ash was acquired after the other ashes involved in the study had been washed. Part of this ash was washed and part was left unwashed. Two batches of a given formula containing tobacco ash were mixed. Washed ash was used in one formula and unwashed ash in the other. This served as a check on the effects of washing the ash when used in a given glaze formula. This is illustrated in Table X, tests F-4 and F-5. The ash worked better washed than unwashed.

In the cases of the other glazes the effect of washing the ash on the glaze was checked by substituting washed ash for unwashed ash in the last formula in which the ash was used prior to washing. In all cases there was marked improvement of the glaze involved. The developmental data for glazes A through H is presented in Tables V through XII.

TABLE V

DEVELOPMENTAL DATA FOR ASH GLAZE A

INGREDIENTS	SOY BEAN ASH	LEPIDOLITE	FRIT W-15	FLINT	RED CLAY	BENTONITE	HICKORY ASH
Test A	40	30	10	10	10	3	
Type	Fusion						
Surface	Gloss						
Fault	Crazed, too fluid						
Color	Gray-green with black specks						
Test A-1*		30	10	10	10	3	40
Type	Wet						
Surface	Waxy mat to gloss						
Fault	Too fluid, crawling						
Color	Green						
Test A-2		15	15	10	10		50
Type	Wet						
Surface	Dry mat						
Fault	Too fluid						
Color	Green to brown						
Test A-3		18		12	12		59
Type	Wet						
Surface	Mat to gloss						
Fault	Too fluid, craze in gloss						
Color	Green cast						
Test A-4		18		12	12		59
Type	Wet						
Surface	Crusty						
Fault	Immature						
Color	Dead Green-brown						
Test A-5		7		13	13		67
Type	Wet						
Surface	Dry, lifeless						
Fault	Too fluid						
Color	Brown-green						
Test A-6		13		13	13		63
Type	Wet (ash washed)						
Surface	Mat to gloss						
Fault	Too fluid, crazed						
Color	Dark to light opaque green						

*** Each ash was substituted in the original formula. Hickory was the most effective ash, therefore, it was substituted for soy bean ash in the original formula.**

TABLE V (continued)

INGREDIENTS	FLINT	RED CLAY	HICKORY ASH	PETALITE	SPODUMENE	KAOLIN	LEPIDOLITE	PEARL ASH						
Test A-7	13	13	63	13										
Type	Wet													
Surface	Mat to gloss													
Fault	Too fluid, crazing increased, crawling													
Color	Dark to light opaque green													
Test A-8	13	13	63		13									
Type	Wet													
Surface	Mat to gloss													
Fault	Too fluid													
Color	Opaque green with brown spots													
Test A-9	22		56		11	11								
Type	Wet													
Surface	Gloss													
Fault	Crazed, fluidity corrected													
Color	Light green													
*Test 2A-1	25	25	38				13							
Type	Wet													
Surface	Gloss													
Fault	Fluid													
Color	Dark green													
Test 2A-2	25		38			25		13						
Type	Wet													
Surface	Gloss													
Fault	Shivering, fluidity reduced													
Color	Blue-gray, dark blue, over black slip													
Test 2A-3	29		44			12		15						
Type	Wet													
Surface	Gloss													
Fault	Crazed, too fluid													
Color	Gray-green, dark green over black slip													

*All tests beyond this point use washed ash in the formula in 2A series.

TABLE V (continued)

INGREDIENTS	LEPIDOLITE	FLINT	RED CLAY	HICKORY ASH	SPODUMENE	CLAY	CALCINED CLAY	PEARL ASH						
Test 2A-4		25		53		10		13						
Type	Wet													
Surface	Gloss													
Fault	Crazed, fluidity corrected													
Color	Gray-green, dark green over black slip													
Test 2A-5		24		44		18		15						
Type	Wet													
Surface	Gloss													
Fault	Crazed, too fluid													
Color	Gray-green, dark green over black slip													
Test 3A-1	7	14	14	67										
Type	Wet													
Surface	Mat to gloss													
Fault	Fluid, crawling													
Color	Opaque light green to glossy dark green													
Test 3A-2		14	14	67	7									
Type	Wet													
Surface	Mat to gloss													
Fault	Too fluid, crawling													
Color	Light to dark green													
Test 3A-3		14		67	7	14								
Type	Wet													
Surface	Mat to gloss													
Fault	Too fluid, crawling													
Color	Light to dark green, dark gloss green on thick													
Test 3A-4		15		64	6	6	6							
Type	Wet													
Surface	Mat to gloss													
Fault	Too fluid, crawling reduced, crazing in gloss													
Color	Light to dark green													

TABLE VI

DEVELOPMENTAL DATA FOR ASH GLAZE B

INGREDIENTS	MAPLE ASH	FLINT	TALC	SPODUMENE	KAOLIN	BENTONITE
Test B	40	20	10	20	10	
Type	Fusion					
Surface	Gloss					
Fault	Crazed					
Color	Opalescent to gray-green					
Test B-1	40	20	10	20	10	2
Type	Fusion					
Surface	Gloss					
Fault	Crazed					
Color	Opalescent to gray-green					
Test B-2	40	20	10	20	12	
Type	Fusion					
Surface	Gloss					
Fault	Crazed, fluid					
Color	Opalescent					
Test B-3	42	21	21		16	
Type	Fusion					
Surface	Gloss					
Fault	Crazed, less fluid					
Color	Opalescent					
Test B-4	42	21	11	11	16	
Type	Fusion					
Surface	Gloss					
Fault	Crazing increased, fluid					
Color	Opalescent					
Test B-5	44	22	11	11	11	
Type	Fusion					
Surface	Waxy mat to gloss					
Fault	Crazed					
Color	Mossy green					
Test B-6*	42	26	11	11	11	
Type	Wet					
Surface	Waxy					
Fault	Crazed					
Color	White with brown spots, good over slips					

*Ash washed at this point in B series

TABLE VI (continued)

INGREDIENTS	MAPLE ASH	FLINT	TALC	SPODUMENE	KAOLIN	BENTONITE	TOBACCO ASH
Test B-7	42	26	11	11	11		
Type	Wet						
Surface	Mat to gloss						
Fault	Fluidity corrected						
Color	White to brown, good over black slip						
Test B-8		26	10	5	15	2	41
Type	Wet						
Surface	Waxy						
Fault	None						
Color	White on thin, grayed with brown spots on thick						

TABLE VII

DEVELOPMENTAL DATA FOR ASH GLAZE C

INGREDIENTS	PEANUT HAY ASH	FRIT 3191	KAOLIN	NEPHELINE SYENITE	FLINT	DOLOMITE	SPODUMENE							
Test C	45	20	10	15	10									
Type	Fusion													
Surface	Gloss													
Fault	Heavily crazed, very fluid													
Color	Opalescent to white													
Test C-1	45	20	10		10	15								
Type	Wet													
Surface	Gloss													
Fault	Crazed, fluid													
Color	Beige with black flecks and opalescence													
Test C-2	45	20	10		10		15							
Type	Wet													
Surface	Gloss													
Fault	Crazed, fluid													
Color	White to brown with black flecks													
Test C-3	50	20	10		10		10							
Type	Wet													
Surface	Gloss													
Fault	Crazed, too fluid													
Color	Brownish green with opalescence													
Test C-4	53		13		13		13							
Type	Wet													
Surface	Gloss													
Fault	Moss green													
Color	Crazed, too fluid													
Test C-5	56	11	11		11		11							
Type	Wet													
Surface	Satiny													
Fault	Slightly fluid, pinholing													
Color	Creamy white													
Test C-6*	56	11	11		11		11							
Type	**Wet**													
Surface	**Satiny gloss**													
Fault	**Fluid**													
Color	**Grayed white**													

***Ash washed at this point in C series**

TABLE VII (continued)

INGREDIENTS	PEANUT HAY ASH	FRIT 3191	KAOLIN	FLINT	DOLOMITE	SPODUMENE	BENTONITE	ZINC OXIDE						
Test C-7	59	6	12	12		9	2							
Type	Wet													
Surface	Gloss													
Fault	Fluidity corrected													
Color	Grayed white thick, dark gray thin													
Test 2C	45	15	10	10	15			5						
Type	Wet													
Surface	Gloss													
Fault	Crazed, pinholing, too fluid													
Color	Mossy green													
Test 2C-1	45	15	10	20	10		2							
Type	Wet													
Surface	Mat to gloss													
Fault	Crazing and pinholed													
Color	Green to white													
Test 2C-2	45	10	10	25	10		2							
Type	Wet													
Surface	Mat													
Fault	Pinholing													
Color	Grayed White													
Test 2C-3*	45	10	10	25	10		2							
Type	Wet													
Surface	Mat													
Fault	Corrected													
Color	White with yellow and brown flecks													

*Ash washed at this point in 2C series

TABLE VII (continued)

INGREDIENTS	PEANUT HAY ASH	FRIT 3191	KAOLIN	FLINT	DOLOMITE	BENTONITE	CALCINED KAOLIN	RUTILE	SODA FELDSPAR					
Test 2C-4	38	8	8	21	8	2	8	5						
Type	Wet													
Surface	Gloss													
Fault	None													
Color	Creamy white breaking to rutile blues													
Test 2C-5	40	9	9	22	9	2	9							
Type	Wet													
Surface	Gloss													
Fault	Crazed													
Color	Tan with opalescence													
Test 2C-6		10	10	25	10	2			45					
Type	Wet													
Surface	Gloss													
Fault	None													
Color	Gray-blue with black flecks													

TABLE VIII

DEVELOPMENTAL DATA FOR ASH GLAZE D

INGREDIENTS	MAPLE ASH	FRIT 3191	TALC	RED CLAY	BENTONITE	FLINT
Test D	45	30	10	15		
Type	Fusion					
Surface	Gloss					
Fault	Pinholing, fluid, crazed					
Color	Brownish green					
Test D-1	45	30	10	15	3	
Type	Fusion					
Surface	Gloss					
Fault	Crazed, pinholing, fluid					
Color	Brownish green					
Test D-2	45	30	5	15		5
Type	Fusion					
Surface	Gloss					
Fault	Too fluid, crazed					
Color	Green with opalescence					
Test D-3	43	29	5	14		10
Type	Wet					
Surface	Gloss					
Fault	Crazed, crawling, too fluid					
Color	Mossy green					
Test D-4*	43	29	5	14		10
Type	Wet					
Surface	Gloss					
Fault	Extremely fluid, crazed					
Color	Mossy green with opalescence					
Test D-5	60		7	20		13
Type	Wet					
Surface	Mat to gloss					
Fault	Crawling					
Color	Mossy green to brownish					

*Ash washed at this point in D series

TABLE IX

DEVELOPMENTAL DATA FOR ASH GLAZE E

INGREDIENTS	SOY BEAN ASH	RED CLAY	FRIT 3191	HICKORY ASH										
Test E	70	30												
Type	Fusion													
Surface	Gloss													
Fault	Pinholed													
Color	Beige with brown flecks													
Test E-1	67	29	5											
Type	Fusion													
Surface	Gloss													
Fault	Pinholed, more fluid													
Color	Beige with brown flecks													
Test E-2	64	27	9											
Type	Wet													
Surface	Gloss to mat													
Fault	Fluid													
Color	Tan with opalescence													
Test E-3		27	9	64										
Type	Wet													
Surface	Mat													
Fault	Too fluid, crawls													
Color	Greenish brown													
Test E-4*		27	9	64										
Type	Wet													
Surface	Mat													
Fault	Too fluid													
Color	Greenish brown													
Test E-5		30		70										
Type	Wet													
Surface	Mat													
Fault	Crawls, slightly fluid													
Color	Brownish green with yellows													
Test E-6		30	5	65										
Type	Wet													
Surface	Broken mat													
Fault	Too fluid, crawls													
Color	Greenish													

*Ash washed at this point in E series

TABLE IX (continued

INGREDIENTS	HICKORY ASH	KAOLIN
Test E-7	70	30
Type	Wet	
Surface	Crusty	
Fault	Bad surface	
Color	Lifeless brown	

TABLE X

DEVELOPMENTAL DATA FOR ASH GLAZE F

INGREDIENTS	SOY BEAN ASH	ALBANY SLIP	SPODUMENE	BENTONITE	FLINT	TOBACCO ASH
Test F	50	30	20			
Type	Fusion					
Surface	Gloss					
Fault	Heavily pinholed, fluid					
Color	Beige with brown flecks					
Test F-1	50	30	20	3		
Type	Fusion					
Surface	Gloss					
Fault	Heavily pinholed					
Color	Beige to blue and brown on edges					
Test F-2	48	29	19		5	
Type	Wet					
Surface	Gloss					
Fault	None					
Color	Medium green					
Test F-3*	48	29	19		5	
Type	Wet					
Surface	Gloss improved					
Fault	None					
Color	Green breaking to black and red					
Test F-4		29	19		5	48
Type	Wet					
Surface	Gloss					
Fault	Tendency to crawl					
Color	Whitish green					
Test F-5*		29	19	2	5	48
Type	Wet					
Surface	Gloss					
Fault	Crawling corrected by washing					
Color	Green breaking to brown and iron red					

*Ash washed at this point in F series

TABLE XI

DEVELOPMENTAL DATA FOR ASH GLAZE G

INGREDIENTS	MAPLE ASH	FLINT	SPODUMENE	CORNWALL STONE	CLAY
Test G	50	20	15	15	
Type	Fusion				
Surface	Mat, crystaline				
Fault	Too fluid, pinholed				
Color	Mottled light to dark beige with violet				
Test G-1	48	24	14	14	
Type	Fusion				
Surface	Mat, crystaline				
Fault	More fluid				
Color	Mottled light to dark beige with violet				
Test G-2	48	19	14	14	5
Type	Wet				
Surface	Gloss				
Fault	Crazing				
Color	Opalescent				
Test G-3	45	23	14	14	5
Type	Wet				
Surface	Gloss				
Fault	Crazing				
Color	Opalescent				
Test G-4	48	19	10	14	10
Type	Wet				
Surface	Gloss				
Fault	Crazed, too fluid				
Color	Opalescent whitish green				
Test G-5	48	24	10	10	10
Type	Wet				
Surface	Gloss				
Fault	Crazed, too fluid				
Color	More opalescent				
Test G-6*	60	15	5	10	10
Type	Wet				
Surface	Mat to gloss				
Fault	Crazed, too fluid				
Color	Opaque light to dark green				

*Ash washed at this point in G series

TABLE XI (continued)

INGREDIENTS	MAPLE ASH	FLINT	SPODUMENE	CORNWALL STONE	CLAY	TOBACCO ASH	PLASTIC VITROX	ZINC OXIDE
Test G-7		15	5	10	10	60		
Type	Wet							
Surface	Gloss, rough							
Fault	Crawling							
Color	Mottled white							
Test G-8	63	17		11	11			
Type	Wet							
Surface	Mat to gloss							
Fault	Too fluid, crawling, craze in gloss							
Color	Opaque light to dark green							
Test G-9	63	17			11		11	
Type	Wet							
Surface	Mat to gloss							
Fault	Too fluid, crawling, craze in gloss							
Color	Opaque light to dark green							
Test G-10	60	15	5		10			3
Type	Wet							
Surface	Mat to gloss							
Fault	Crawling, crazing							
Color	Light to darker green							
Test 2G	48	24	10	10	10			
Type	Wet							
Surface	Gloss							
Fault	Too fluid, crazed							
Color	Opalescent whitish green							
Test 2G-1	60	20	5	10	5			
Type	Wet							
Surface	Mat to gloss							
Fault	Too fluid, crazed							
Color	Greenish, opalescent							

TABLE XI (continued)

INGREDIENTS	MAPLE ASH	FLINT	SPODUMENE	CORNWALL STONE	BENTONITE	CLAY	RUTILE	RED CLAY	DOGWOOD ASH				
Test 2G-2*													
Type	Wet												
Surface	Mat to gloss												
Fault	Crazed where glaze pools to form gloss												
Color	Beige mat to dark brown gloss with opalescence												
Test 2G-3													
Type	Wet												
Surface	Mat to gloss												
Fault	Too fluid, surface not as nice as 2G-2												
Color	Oak wood breaking to dark gloss brown												
Test 2G-4													
Type	Wet												
Surface	Mat to gloss												
Fault	Too fluid												
Color	Light oak wood to amber gloss												
Test 2G-5													
Type	Wet												
Surface	Mat to gloss												
Fault	Too fluid												
Color	Oak wood breaking to dark gloss brown												
Type	Wet												
Surface	Mat to gloss												
Fault	Too fluid												
Color	Oak wood breaking to dark gloss brown												

*Ash washed at this point in 2G series

TABLE XII

DEVELOPMENTAL DATA FOR ASH GLAZE H

INGREDIENTS	PEANUT HAY ASH	DOLOMITE	NEPHELINE SYENITE	RED CLAY	ALBANY SLIP	TALC	FLINT	FRIT W-15
Test H	50	25	15	10				
Type	Fusion							
Surface	Mat to gloss							
Fault	Fluid, crazing							
Color	Opaque green							
Test H-1	50	25	15		10			
Type	Wet							
Surface	Mat to gloss							
Fault	Fluid, crazed							
Color	On thick, white, on thin, green							
Test H-2	50	25	10		10	5		
Type	Wet							
Surface	Dry mat, crusty							
Fault	Too fluid, unpleasant surface							
Color	Greenish							
Test H-3	45	23	10		10	5	10	
Type	Wet							
Surface	Dry mat							
Fault	Immature, crusty							
Color	Opaque light green							
Test H-4*	50	20	10		10		10	
Type	Wet							
Surface	Mat							
Fault	Immature and crusty							
Color	Opaque light green							
Test H-5	50		10		10		10	20
Type	Wet							
Surface	Gloss							
Fault	Crazing, too fluid							
Color	Green, opalescence on horizontal surface							
Test H-6	50	10	10		10		10	10
Type	Wet							
Surface	Gloss							
Fault	Extremely fluid, crazed							
Color	Green with opalescence							

***Ash washed at this point in H series**

Ash Substitution Tests. -- Each ash was tested in five formulas in order to determine the effect of each ash in a given formula. All ash used in these tests was washed one time. The formulas tested in this manner were Glaze B-8, Glaze C-7, Glaze 2C-3, Glaze F-6, and Glaze 2G-6. The results of these tests are presented in Tables XIII through XVI.

TABLE XIII

ASH SUBSTITUTION TESTS FOR GLAZE B-8

INGREDIENTS	TOBACCO ASH	FLINT	TALC	SPODUMENE	CLAY	BENTONITE	SOY BEAN ASH	PEANUT HAY ASH	PECAN LEAF ASH	DOGWOOD ASH	HICKORY ASH	MAPLE ASH
Glaze B-8	41	26	10	5	15	2						
Surface	Semi-gloss											
Fault	None											
Color	Off white tending toward gray with brown specks											
Glaze B-8		26	10	5	15	2	41					
Surface	Rough mat											
Fault	Immature											
Color	Off white											
Glaze B-8		26	10	5	15	2		41				
Surface	Gloss											
Fault	None											
Color	Gray to white											
Glaze B-8		26	10	5	15	2			41			
Surface	Gloss											
Fault	Crazed											
Color	Gray-green with green specks											
Glaze B-8		26	10	5	15	2				41		
Surface	Gloss											
Fault	None											
Color	Watery green-beige with some white											
Glaze B-8		26	10	5	15	2					41	
Surface	Gloss											
Fault	Crazed											
Color	Watery gray											
Glaze B-8		26	10	5	15	2						41
Surface	**Gloss**											
Fault	**None**											
Color	**Off white tending to blue gray**											

TABLE XIV

ASH SUBSTITUTION TESTS FOR GLAZE C-7

INGREDIENTS	PEANUT HAY ASH	FRIT 3191	KAOLIN	FLINT	SPODUMENE	BENTONITE	SOY BEAN ASH	TOBACCO ASH	PECAN LEAF ASH	DOGWOOD ASH	MAPLE ASH	HICKORY ASH
Glaze C-7	59	6	12	12	8	2						
Surface	Gloss											
Fault	None											
Color	Grayed white on thick to dark gray on thin											
Glaze C-7		6	12	12	8	2	59					
Surface	Glossy, rough											
Fault	Pinholing											
Color	White to dark brown											
Glaze C-7		6	12	12	8	2		59				
Surface	Gloss											
Fault	Pinholing											
Color	Off white with dark brown spots											
Glaze C-7		6	12	12	8	2			59			
Surface	Gloss											
Fault	Too fluid											
Color	Green											
Glaze C-7		6	12	12	8	2				59		
Surface	Mat to gloss											
Fault	Too fluid											
Color	Greenish white mat to dark green gloss											
Glaze C-7		6	12	12	8	2					59	
Surface	Mat											
Fault	Too fluid											
Color	Light green with brown spots											
Glaze C-7		6	12	12	8	2						59
Surface	Mat											
Fault	Too fluid											
Color	Opaque light green											

TABLE XV

ASH SUBSTITUTION TESTS FOR GLAZE 2C-3

INGREDIENTS	PEANUT HAY ASH	FRIT 3191	KAOLIN	FLINT	DOLOMITE	BENTONITE	SOY BEAN HAY	TOBACCO ASH	PECAN LEAF ASH	DOGWOOD ASH	MAPLE ASH	HICKORY ASH
Glaze 2C-3	45	10	10	25	10	2						
Surface	Mat											
Fault	Bubbles if applied thickly											
Color	White with brown spots											
Glaze 2C-3		10	10	25	10	2	45					
Surface	Dry mat											
Fault	Pinholed											
Color	White with brown spots											
Glaze 2C-3		10	10	25	10	2		45				
Surface	Soft gloss											
Fault	Tendency to pinhole											
Color	Off white with brown spots											
Glaze 2C-3		10	10	25	10	2			45			
Surface	Gloss											
Fault	None											
Color	Green with opalescence											
Glaze 2C-3		10	10	25	10	2				45		
Surface	Gloss											
Fault	Crazed, too fluid											
Color	Green with some opalescence											
Glaze 2C-3		10	10	25	10	2					45	
Surface	Gloss											
Fault	Crazed, too fluid											
Color	Dark green to light green											
Glaze 2C-3		10	10	25	10	2						45
Surface	**Gloss**											
Fault	**Crazed, too fluid**											
Color	**Dark green to light green with brown spots**											

TABLE XVI

ASH SUBSTITUTION TESTS FOR GLAZE F-5

INGREDIENTS	TOBACCO ASH	ALBANY SLIP	SPODUMENE	FLINT	BENTONITE	SOY BEAN ASH	PEANUT ASH	PECAN LEAF ASH	DOGWOOD ASH	MAPLE ASH	HICKORY ASH
Glaze F-5	48	29	19	5	2						
Surface	Gloss										
Fault	None										
Color	Light mossy green breaking to browns and some iron red flecks										
Glaze F-5		29	19	5	2	48					
Surface	Gloss										
Fault	None										
Color	Light mossy green with black and iron red flecks										
Glaze F-5		29	19	5	2		48				
Surface	Gloss										
Fault	A bit fluid										
Color	Light ochre with black and brown flecks										
Glaze F-5		29	19	5	2			48			
Surface	Mat to gloss										
Fault	Too fluid, craze in gloss										
Color	Light green mat to dark green gloss										
Glaze F-5		29	19	5	2				48		
Surface	Mat to gloss										
Fault	Too fluid										
Color	Yellow-green mat to dark green gloss										
Glaze F-5		29	19	5	2					48	
Surface	Mat to gloss										
Fault	Too fluid										
Color	Light brown-green mat to dark green gloss										
Glaze F-5		29	19	5	2						48
Surface	**Mat to gloss**										
Fault	**A bit fluid**										
Color	**Dark to light brown mat, to dark green-brown gloss**										

TABLE XVII

ASH SUBSTITUTION TESTS FOR GLAZE 2G-6

INGREDIENTS	DOGWOOD ASH	FLINT	RUTILE	CORNWALL STONE	KAOLIN	BENTONITE	MAPLE ASH	SOY BEAN ASH	PEANUT HAY ASH	PECAN LEAF ASH	HICKORY ASH
Glaze 2G-6	62	10	5	10	10	2					
Surface	Mat to gloss										
Fault	Too fluid										
Color	Light beige woody mat to amber gloss										
Glaze 2G-6		10	5	10	10	2	62				
Surface	Mat to gloss										
Fault	Too fluid										
Color	Light beige, woody mat to amber gloss										
Glaze 2G-6		10	5	10	10	2		62			
Surface	Rough gloss										
Fault	None										
Color	Pink and yellow gloss										
Glaze 2G-6		10	5	10	10	2			62		
Surface	Gloss										
Fault	None										
Color	Soft green to white with brown flecks										
Glaze 2G-6		10	5	10	10	2				62	
Surface	Mat to gloss										
Fault	Fluid										
Color	Soft green to beige with pink cast, woody appearance										
Glaze 2G-6		10	5	10	10	2					62
Surface	Mat to gloss										
Fault	Too fluid										
Color	Light to dark beige with woody appearance										

Coloration Tests

For the third phase of testing, the coloration tests, the five glazes used in the ash substitution tests were used. Six colorants, nickel carbonate, cobalt carbonate, manganese dioxide, Albany slip, rutile, and red iron oxide were chosen to be tested in the glaze formulas. The colorants were tested in varying amounts. The amounts considered by the investigator to have produced the best results are presented in Tables XVIII through XXII. All ashes used in these tests were washed one time.

TABLE XVIII

COLORATION DATA FOR ASH GLAZE B-8

INGREDIENTS	AMT.	GLAZE WITHOUT COLORANTS
Tobacco ash Flint Talc Spodumene Kaolin Bentonite	41 26 10 5 15 2	Off white tending toward gray, semi-gloss with brown specks
COLORANT	**AMT.**	**GLAZE WITH COLORANTS**
Nickel Carbonate	2%	Light brown gloss with brown spots
Cobalt Carbonate	2%	Medium cobalt blue gloss with brown spots
Manganese Dioxide	2%	Brown gloss with pink cast, numerous brown specks
Albany	5%	Gray gloss with numerous brown specks
Rutile	2%	Off white gloss with brown spots
Iron	2%	Light greenish brown gloss with brown spots

TABLE XIX

COLORATION DATA FOR ASH GLAZE C-7

INGREDIENT	AMT.	GLAZE WITHOUT COLORANTS
Peanut ash Frit 3191 Kaolin Flint Spodumene Bentonite	59 6 12 12 8 2	Off white to dark gray gloss with brown spots
COLORANT	AMT.	GLAZE WITH COLORANTS
Nickel Carbonate	2%	Dark brown gloss breaking to yellow over variations in surface of the pot
Cobalt Carbonate	2%	Glossy black breaking to dark blue
Manganese Dioxide	3%	Glossy dark sandalwood brown
Albany	5%	Light blue-gray gloss with dark specks
Rutile	3%	Creamy white gloss with brown spots breaking to light blue
Iron	3%	Iron red breaking to black, opalescent in pools

TABLE XX

COLORATION DATA FOR ASH GLAZE 2C-3

INGREDIENTS	AMT.	GLAZE WITHOUT COLORANTS
Peanut ash Frit 3191 Kaolin Flint Dolomite Bentonite	45 10 10 25 10 2	Mat white with brown specks
COLORANT	AMT.	GLAZE WITH COLORANTS
Nickel Carbonate	4%	Light green mat with brown spots
Cobalt Carbonate	1%	Dark blue to black mat
Manganese Dioxide	2%	Light sandalwood brown mat breaking to dark brown
Albany	8%	Off white mat with brown spots
Rutile	3%	Opaque off white mat with brown specks
Iron	5%	Deep yellow ochre gloss breaking to black

TABLE XXI

COLORATION DATA FOR ASH GLAZE F-5

INGREDIENTS	AMT.	GLAZE WITHOUT COLORANTS
Tobacco ash Flint Bentonite Spodumene Albany	48 5 2 19 29	Mossy gray-green breaking to brown and iron reds, gloss
COLORANT	AMT.	GLAZE WITH COLORANTS
Nickel Carbonate	2%	Dark brown gloss with some yellow
Cobalt Carbonate	3%	Dark green or dark blue to black gloss
Manganese Dioxide	3%	Dark beige gloss with brown specks
Albany	5%	Pale gray-green semi-gloss with iron burning through in spots
Rutile	5%	Light green semi-gloss to orange and off white with brown specks
Iron	2%	Brownish gloss with some yellow and black

TABLE XXII

COLORATION DATA FOR ASH GLAZE 2G-6

INGREDIENTS	AMT.	GLAZE WITHOUT COLORANTS
Dogwood ash Rutile Kaolin Bentonite Cornwall stone Flint	62 5 10 2 10 10	Beige mat with woody appearance breaking to crazed amber gloss with some opalescence
COLORANT	AMT.	GLAZE WITH COLORANTS
Nickel Carbonate	2%	Deep ochre brown woody mat breaking to dark brown gloss with crazes
Cobalt Carbonate	1%	Greenish brown to grayed blue mat with woody appearance breaking to dark blue crazed gloss
Manganese Dioxide	2%	Very dark brown mat breaking to brown gloss
Albany	5%	Light beige to orange mat having the appearance of wood grain, breaking to amber and blue gloss
Rutile	5%	Gray-beige to pink woody mat, breaking to blue and amber gloss with rutile crystals
Iron	2%	Light brown ochre woody mat with black flecks breaking to dark brown gloss

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

The problem of this investigation was to expand the Nuber Thesis, to find reliable sources of ash and to use such ash in the development of at least five workable formulas, designed to mature at cone 10, containing forty per cent or more of ash. A further purpose of the study was to write a history of ash glazing.

It was necessary to procure a large quantity of the various ashes to be used in the study. Residence in a rural environment led the investigator to choose a farm source for the raw materials. The materials chosen were those believed to be easiest to gather from year to year. The chosen raw materials were soy bean stalks, peanut hay, pecan leaves, tobacco, hickory wood, and dogwood, all of which were collected from farm sources in eastern North Carolina.

Various methods of burning were tried in an attempt to find the most effective means of burning a large quantity of material with the resultant ash free from impurities. Finding the stove suggested in the Nuber thesis inadequate, a stove made of a fifty gallon steel drum was designed for the purpose. After some alteration to the original plan for the larger stove, an acceptable stove was built. It served as an efficient means of burning large amounts of matter in both open and sheltered areas.

Initially, processing of ash involved sifting it through a fifty mesh screen to free it of large pieces of partially burned matter. At a point in the testing program it became necessary to wash the ashes. One washing proved sufficient for the purposes of the present investigation.

The testing program leading to the development of the glazes was divided into three phases. In phase one, ash fusibility was determined, auxiliary fluxes were tested, proportions of raw materials basic to ash glaze formulation were tested, and initial glazes were formulated. The second area of testing dealt with the attempted development of eight empirical glaze formulas and substitutions of the various ashes used in the testing program in each formula. Phase three involved tests of various colorants in the five best glaze formulas.

Findings of the Study

Procurement. -- The difficulty of ash procurement is minimized in a rural environment. The easiest materials to acquire are farm products already packaged for market such as baled peanut hay. Scrap tobacco is another easy to acquire material and can be obtained directly from the farmer or from a tobacco processing company. Wastes that result from harvesting procedures, such as soy bean stalks must be gathered by hand. It is also necessary to gather these stalks almost immediately after harvesting because they deteriorate rapidly when exposed to weather conditions. Pecan leaves present much the same problems as soy bean stalks. If it is desirable to burn a particular type of leaf

it is helpful to have a grove of the given species of tree such as a pecan tree grove. This helps to improve the reliability of the ash and to keep it free from other varieties of leaves. Hardwoods are difficult to acquire because of the problems involved in cutting and moving trees. If they must be purchased they are expensive. However, it is possible to obtain some glaze effects only with hardwood ash which makes them a desirable inclusion in any extensive ash glazing program.

Sources. -- The investigator's rural environment led to investigation of farm sources as a first possibility for materials to produce ash. Agricultural products and wastes were explored as possible reliable sources. Crops grown under controlled cultivation were used. Hardwoods were also investigated as possible reliable sources.

The farm products chosen for this study were peanut hay, soy bean stalks, and tobacco, all common crops in eastern North Carolina. Because it is usual to grow pecans for market in this area, pecan leaves were chosen as a likely reliable, procurable source. The hardwoods chosen are common to the region making them a procurable source either from a farm or a local lumber yard.

Storage. -- Storage is necessary for two reasons. First, to prevent deterioration of the matter and secondly, to allow time to burn the materials. Some matter, i.e., tobacco, burns quite slowly.

Storage presents a problem to almost anyone attempting to acquire enough material to produce a usable sample of ash. One bushel will yield approximately

one hundred grams of ash.[1] Storage problems are minimized in a rural environment. Packaged farm products offer the easiest storage possibilities to the user living in an urban environment. Hardwoods are also comparatively easy to store. Wood burns fastest when it is dry, therefore, it should be stored under cover. Materials such as leaves and stalks are more difficult to store because it takes an extremely large quantity to produce a usable sample of ash.

Burning. -- A portable stove which can be carried to the field simplifies the burning of agricultural wastes such as soy bean stalks. The material can be gathered and placed in the stove and burned immediately, eliminating transportation and storage of the matter. This material burns rapidly, especially if there is a slight breeze. It is necessary to burn such materials before weather causes deterioration.

Hardwoods can be effectively burned in a fireplace but, if one is not available, they can be as effectively burned in the ash burning stove. If the wood is green it is difficult to start the fire, and the wood burns slowly. Dry woods burn more rapidly.

It should be noted that the tobacco used in the study was flue cured before burning. The peanut hay was dry as were the soy bean stalks and pecan leaves. It is impossible to burn green or wet vegetable matter.

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[1] Kenneth Clayton Nuber, The Utilization of Locally Available Vegetable Matter Ash as Fluxing Agents in Glazes Maturing at 1180° Centigrade (unpublished master's thesis, East Carolina College, 1962), p. 3.

Washing. -- After a material has been reduced to ash in the ash burning stove it is desirable to sieve it through a fifty mesh screen to remove bits of unburned matter. This unburned matter is then set aside for further burning with the next batch.

Traditionally one washes ash by flooding the batch with water and stiring the solution. The carbon and bits of unburned matter are decanted after they rise to the top of the solution. Then this matter is dryed and reburned. This step in processing can be simplified in two ways. First, burning in a well designed stove produces even combustion which eliminates most of the unburned matter and secondly, sifting prior to washing eliminates the redrying process necessary before the partially burned matter can be reused. A good stove will also keep the ash free of dirt and sand.

The Japanese recommend washing ash by repeatedly flooding and decanting the water until the water is clear and tasteless. The investigator has not found it necessary to wash the ash more than once. The ashes when washed for this study were sieved, flooded with water, stired vigorously, then allowed to settle to the bottom. The water containing soluable alkalies was then baled off and the ash allowed to dry.

Drying.-- Drying can best be accomplished by placing the wet ash in a shallow container on top of a firing kiln. It may also be dried rapidly by setting shallow containers of ash in the sun or by permitting air drying. After the ash

is dry it is desirable to sieve it again. A fifty mesh screen is adequate. Sifting at this point enables one to economize storage space and facilitates glaze mixing.

Conclusions

Procurement. -- The difficulty of ash procurement is minimized in a rural environment. The easiest materials to acquire are packaged farm products. Also, an occasional agricultural surplus or by-product of agricultural processing plants can simplify the collection and sometimes the burning process. Hardwoods are more difficult to acquire and can be expensive due to the amount of time and labor required to cut and move trees. Any decision to make extensive use of ash glazing should be based on a careful weighing of the inherent difficulties of procurement.

Sources and Reliability. -- With regard to the problem of ash reliability it is probable that a cultivated farm crop will be a highly reliable source of raw materials from year to year. Peanut hay was acquired from two different sources over a period of two harvesting seasons, and soy bean stalks were procured from the same farm over a two year period. The ash resultant from burning of this matter from different sources and in different years produced the same effect in a given glaze formula, indicating that agricultural sources can be depended upon to give fairly uniform results from year to year.

Here it may be noted that even the most reliable source of ash, such as a farm commodity grown under controlled conditions, will be inconsistent if for

no other reason than that the weather is an uncontrollable factor. Soil analysis and other farm means of crop control help to make agricultural products and by-products a reliable source. Since trees generally grow under less controlled conditions and over a much longer growing period, the hardwoods are a less reliable source of ash. Also, if it became necessary to purchase them, hardwoods could prove to be an expensive source of ash. One medium sized tree will not produce much more than a gallon of ash. The advantages of a yearly grown commodity as a source of ash are, in addition to high reliability, inexpensiveness of material and easy procurement. This is especially true of peanut hay, tobacco, and soy bean stalks.

Storage. -- Because such large quantities of raw materials are required to produce a usable sample of ash if storage is necessary it becomes a problem whether one lives in a rural or urban environment. Facilities for storing large amounts of raw materials should be a prime consideration of anyone planning an extensive ash glazing program, as it is not always possible to burn matter upon acquisition. It may be noted, however, that hardwoods and packaged farm products, such as hay, offer the easiest storage possibilities. Immediate burning of raw materials is desirable from two standpoints. First, the material produces more and better ash if no deterioration takes place, and secondly, ash may be stored in a much smaller area than the raw material required to produce the sample.

Burning. -- More efficient means of burning can be devised, but they are not essential to an extensive ash glazing program. More than one large stove would probably be an adequate solution to the problem of burning large amounts of matter.

In regard to the burning of specific materials, light dry matter, such as peanut hay, soy bean stalks, and leaves burn easily. The stove works best in the open or anywhere it is possible to achieve a strong draft when this type of burning is done. There is some tendency to smoulder if the draft is inadequate. Green hardwoods are difficult to burn. Drying the raw material is helpful in shortening the burning time, but is not essential. It is impossible to burn undried vegetable matter.

Washing. -- In all cases washing the ash improved the glaze. Washing the ash once proved sufficient for the investigator's purposes. It is believed that this step could be eliminated from ash processing entirely by designing glazes to accept unwashed ash. Chemical analysis of the ash would facilitate such formulation as it would formulation of ash glazes using washed ash.

The hardwood ash glazes show comparatively little change due to ash washing. Washing the vegetable ash seems to be a necessity to reduce glaze fluidity while retaining a high ash content in the formula.

Drying.-- The best drying procedure is to remove as much water as possible from the ash. It may require a week or more for the ash to settle entirely. Then

place the ash in shallow containers and set them on top of a firing kiln or in sunlight. A quick method for drying small quantities of ash is to place the damp ash in shallow bisque pots and place it under a sun lamp. Ash must be dry to be weighed accurately because wet ash is heavier than dry ash.

Color. -- Most ash glazes have an inherent color. They are usually green, brown, or brown-green. Occasionally the base glaze is off white, usually having flecks of brown or brown-green. Colorants may be added to ash glazes in the same manner in which they are added to ordinary glazes. However, it is not uncommon to get unusual variations in color and surface texture when using ash glazes. Some ash glazes tend to have a crystaline surface. The ash glaze often has a tendency to break from mat to gloss and to accentuate surface variations of the fired ware, and to be fluid.

Application. -- To be usable any type of glaze must have certain characteristics. The glaze must be plastic enough to allow easy application to bisque ware and not craze in its dry state prior to firing. The ingredients must remain suspended to allow even application of the glaze and to maintain its usability if storage is necessary. The glaze should not be excessively fluid in its molten state and should also be free of the common glaze faults-crazing, crawling, shivering, pinholing, and immaturity. In relation to ash glazes some of these properties are hard to achieve. Because grains of ash are more coarse and heavy than commercially prepared glaze ingredients they tend to settle to the bottom of the glaze mixture.

It was found that an addition of two per cent of bentonite to the glaze formula helps to keep the grains of ash in suspension both during application of the glaze and storage. Due to a characteristically low clay content ash glazes generally have a tendency to craze after application to the bisque ware. The glaze surface may be burnished with the finger tips to prevent crawling of the molten glaze.

Formulation Guide.-- As a guide to ash glaze formulation some important considerations have been brought together by this research. When setting out to formulate a new ash glaze it is helpful to have some basic information about the nature of the ash with which you plan to work. Information as to the degree of fusibility of a given ash is helpful. A simple method of determining the fusibility of an ash or a number of ashes is to make a fusibility test such as the one described on pp. 29-30.

It is also valuable to the glaze formulator to have some knowledge of auxiliary fluxes. The investigator found that lepidolite, spodumene, cornwall stone, nepheline syenite, dolomite, and frits W-15 and 3191 were the most effective auxiliary fluxes. Pearl ash produced interesting results, and needs further investigation. Petalite and plastic vitrox produced unfavorable results each time they were used.

Like other types of glazes, ash glazes need a clay content. Additions of clay in amounts from ten to twenty-five per cent of the glaze are usually sufficient. An addition of two per cent of bentonite to the glaze formula acts to keep the

heavier grains of ash in suspension in the liquid glaze, permitting even application of the glaze to bisque ware.

At times it is necessary to add silica to the glaze formula to supplement the silica inherent in the ash. On the basis of this research the investigator recommends an addition of between five to twenty-five per cent of silica to the ash glaze.

Recommendations

The following are offered as recommendations to the investigator pursuing a study of ash glazing:

1. Further development of the existing formulas presented in this study could allow future investigators time to fully develop these glazes with all of their coloring potential.

2. The glazes should be developed for firing in oxidation.

3. Laboratory analysis of the ash could be made to determine its principle flux and ratio to alumina and silica. This would rule out the trial and error approach which is necessary without such analysis.

4. Ashes from vegetable origin other than hardwoods, because of apparent high flux contents as compared with hardwood ash, could be developed into lower temperature glazes, maturing at earthenware temperatures.

5. Exploration of alkali water resultant from ash washing as a basis for development of new decoration techniques.

6. Exploration of what has been considered glaze faults in this study, for example crawling tendencies, which might be capitalized upon to produce unusual and controlled use of faults to produce special effects glazes.

7. Drifting wood ash is known to produce accidental glaze effects by collecting on the surface and shoulders of the ware. Wood burning kilns could be fired by inserting the ash producing weeds or farm crops to be burned in the fire box at optimum points in the firing. Hopefully drifting vegetable ash would be deposited on the surface and shoulders of the ware resulting in accidental vegetable ash glaze effects.

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