

A PRACTICAL STUDY IN THE USE OF AUTOMOTIVE WASTE OIL  
AS A FUEL FOR FIRING CERAMICS

by

ROBERT ALEXANDER FROMME

B. F. A., Bethany College, 1968

---

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

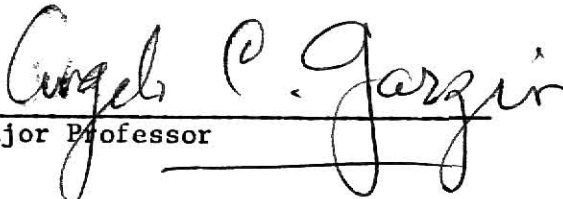
MASTER OF ARTS

Department of Art

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1974

Approved by:

  
Major Professor

LD  
2668  
T4  
1974  
F77  
C.2

Document

## TABLE OF CONTENTS

|  | Page |
|--|------|
| LIST OF FIGURES . . . . .  | vi   |
| LIST OF TABLES . . . . .   | vii  |
| LIST OF PLATES . . . . .   | viii |
| LIST OF PORTFOLIO PLATES . . . . .                                       | ix   |
| PERSONAL ACKNOWLEDGMENTS . . . . .                                       | x    |
| Chapter  |      |
| 1. INTRODUCTION . . . . .  | 1    |
| THE FOUNDATIONAL HYPOTHESES . . . . .                                    | 3    |
| LIMITATIONS OF THE STUDY . . . . .                                       | 4    |
| THE ORGANIZATION OF THE STUDY . . . . .                                  | 4    |
| 2. A REVIEW OF PERTINENT HISTORICAL BACKGROUND IN THE                    |      |
| USE OF OIL AS A FUEL . . . . .   | 6    |
| NATURAL DRAFT WASTE OIL COMBUSTION SYSTEMS . . . . .                     | 7    |
| W. J. Readhead's Waste Oil Burning Kiln . . . . .                        | 9    |
| Olsen's Gravity Drip Plate Burner . . . . .                              | 12   |
| Oil Combustion Principles of the Readhead and<br>Olsen Burners . . . . . | 17   |
| Petroleum antiquity . . . . .  | 18   |
| Natural draft combustion . . . . .                                       | 20   |
| The Astrakan oil stove and the use of water<br>for combustion . . . . .  | 21   |
| Soot prevention . . . . .  | 23   |

| Chapter  | Page |
|--|------|
| Early French natural draft oil burners . . . . .                                     | 24   |
| The Korting 'venturi' oil burner . . . . .   | 28   |
| FORCED AIR WASTE OIL BURNERS . . . . .   | 30   |
| Oil Combustion Principles of the Waste Oil<br>Pipe Burner . . . . .                  | 42   |
| 3. THE FUEL . . . . .  | 45   |
| GENERAL HYDROCARBON COMPOSITION OF THE FUEL . . . . .                                | 46   |
| Paraffin . . . . .   | 47   |
| Naphthene . . . . .  | 49   |
| Aromatic . . . . .   | 52   |
| IMPURITIES IN THE FUEL . . . . .   | 53   |
| Oxidation of the Fuel . . . . .  | 53   |
| Additives . . . . .  | 54   |
| Other Impurities . . . . .   | 55   |
| Potential Characteristics of Waste Oil Kiln Fuel . . . . .                           | 56   |
| 4. FUEL GATHERING, CLEANING AND STORAGE . . . . .                                    | 58   |
| FUEL GATHERING . . . . .   | 58   |
| Individual Contributors . . . . .  | 59   |
| Commercial Oil Service Stations . . . . .  | 61   |
| Industrial Sources for Waste Oil Fuel . . . . .                                      | 65   |
| CLEANING THE FUEL . . . . .  | 66   |
| Screening the Fuel . . . . .   | 66   |
| Fuel Settling . . . . .  | 67   |
| FUEL STORAGE . . . . .   | 67   |
| 5. THE DESIGN, CONSTRUCTION AND OPERATION OF A WASTE<br>OIL BURNING SYSTEM . . . . . | 69   |

## Chapter

## Page

|   |     |
|---|-----|
| THE DESIGN AND CONSTRUCTION OF A FORCED AIR WASTE<br>OIL PIPE BURNER SYSTEM . . . . . | 70  |
| Fuel Storage and Burner Feed . . . . .  | 70  |
| The Oil Burners . . . . .   | 74  |
| The Blowers . . . . .   | 74  |
| The Natural Gas Preheat Burners . . . . .   | 76  |
| The Kilns . . . . .   | 80  |
| The combustion, flue, and stack areas of the<br>reduction stoneware kiln . . . . .    | 86  |
| The combustion area of the salt kiln . . . . .  | 87  |
| The Raku kiln . . . . .   | 89  |
| THE OPERATION OF A FORCED AIR WASTE OIL PIPE<br>BURNER SYSTEM . . . . .               | 89  |
| Operation of the Reduction Stoneware Kiln . . . . .                                   | 90  |
| Preheating the kiln . . . . .   | 90  |
| Water smoking and quartz inversion . . . . .  | 92  |
| Sulfur control in the kiln operation . . . . .  | 92  |
| Later reduction to the maturation temperature . . . . .                               | 94  |
| Operation of the Stoneware Salt Kiln . . . . .  | 97  |
| Operation of the Raku Kiln . . . . .  | 99  |
| 6. SAFETY, POLLUTION AND CERAMIC CHEMISTRY RELATED TO                                 |     |
| THE USE OF WASTE OIL FOR FIRING CERAMICS . . . . .                                    | 102 |
| SAFETY . . . . .  | 102 |
| POLLUTION . . . . .   | 103 |
| Carbon . . . . .  | 103 |
| Sulfur . . . . .  | 104 |
| Hydrochloric Acid Fumes and Chlorine Gas . . . . .                                    | 105 |



| Chapter  | Page |
|--|------|
| Nitrogen and Organic Gases . . . . .                             | 105  |
| CERAMIC CHEMISTRY RELATED TO WASTE OIL FIRING . . . . .          | 106  |
| Sulfur Effects on the Clay and Glazes . . . . .                  | 106  |
| Vapor Glaze Caused by Ceramic Chemicals<br>in the Fuel . . . . . | 108  |
| 7. CONCLUSIONS . . . . .   | 111  |
| A PORTFOLIO OF WASTE OIL FIRED POTTERY . . . . .                 | 114  |
| BIBLIOGRAPHY . . . . .   | 136  |

## LIST OF FIGURES

| Figure   | Page |
|--|------|
| 1. Readhead's Waste Oil Burner . . . . .                   | 10   |
| 2. Olsen's Oil Drip System . . . . .                       | 13   |
| 3. Olsen's Oil Drip Burner . . . . .                       | 15   |
| 4. The Astrakan Oil Stove . . . . .                        | 22   |
| 5. Audouin's Oil Grates . . . . .                          | 26   |
| 6. Audouin and Sainte-Claire Deville's Oil Grate . . . . . | 27   |
| 7. Kortling's Oil Burner . . . . .                         | 29   |
| 8. Variations of the Soldner Pipe Burners . . . . .        | 31   |
| 9. Variations of Soldner's Oil Carburetor . . . . .        | 32   |
| 10. Soldner's Adjustable Orifice Pipe Burner . . . . .     | 37   |
| 11. The Kinkel Burner . . . . .                            | 41   |
| 12. Prior Vaporizing Pot Type Burner . . . . .             | 43   |
| 13. Fuel Storage and Burner Feed for the Study . . . . .   | 73   |
| 14. The 'Alfred' Preheat Burner . . . . .                  | 78   |

## LIST OF TABLES

| Table   | Page |
|---|------|
| 1. Paraffin Hydrocarbons . . . . .                      | 50   |
| 2. Equipment for the Waste Oil Burning System . . . . . | 71   |
| 3. Equipment for the 'Alfred' Preheat Burners . . . . . | 79   |

# LIST OF PLATES

| Plate |  | Page |
|-------|--|------|
| I.    | A Photograph of the Potter Adjusting the Flow of Waste Oil Fuel With a Valve Located Well Away from the Radiant Heat of the Burner Port and Kiln Firebox . . . . . | 75   |
| II.   | An Overhead View of the Forced Air System Showing How the Brick Air Control Gates were Positioned Between the Vacuum Cleaner Hoses and the Burners . . . . .       | 77   |
| III.  | An Exterior View of the Reduction Stoneware Kiln with Its Waste Oil Burner System in Operation . . . . .   | 81   |
| IV.   | An Interior View of the Reduction Stoneware Kiln Showing the Two Fire Channel Openings Through Which Gases of Combustion Rise into the Ware Chamber . . . . .      | 82   |
| V.    | An Exterior View of the Stoneware Salt Kiln . . . . .  | 83   |
| VI.   | A Closer View of the Salt Kiln Showing the Bag Wall Bricks of One 'Hot-Spot' Firebox . . . . .   | 84   |
| VII.  | A Photograph of the Raku Kiln Showing the Opening of the 'Hot-Spot' Firebox Located Under the Floor at the Back of the Kiln . . . . .                              | 85   |

# LIST OF PORTFOLIO PLATES

| Plate   | Page |
|---|------|
| I. Bellarmine Revisited . . . . .                     | 115  |
| II. Bellarmine Revisited # 3 . . . . .                | 116  |
| III. Cosmic Classic # 3 . . . . .                     | 117  |
| IV. The Spirit of Sand Creek . . . . .                | 118  |
| V. The Seeds of Its Own Destruction . . . . .         | 119  |
| VI. A Pilgrim Bottle . . . . .                        | 120  |
| VII. Virility Dance Bottle . . . . .                  | 121  |
| VIII. Seed Pod Vase . . . . .                         | 122  |
| IX. Devilry Wine-Pot . . . . .                        | 123  |
| X. Processional Form of an Etruscan Revival . . . . . | 124  |
| XI. Virility Bottle . . . . .                         | 125  |
| XII. Saint George Whistle . . . . .                   | 126  |
| XIII. Set of Slab Bottles . . . . .                   | 127  |
| XIV. Illiad Bottle . . . . .                          | 128  |
| XV. Odyssey Cups . . . . .                            | 129  |
| XVI. Screeching Venus with a Forked Tongue . . . . .  | 130  |
| XVII. Baroque Nouveau: Cosmic Classic # 2 . . . . .   | 131  |
| XVIII. Slab Bottle with Grid . . . . .                | 132  |
| XIX. Green Dragon Whistle . . . . .                   | 133  |
| XX. Cosmic Sand Dollars . . . . .                     | 134  |
| XXI. Chicken Whistle . . . . .                        | 135  |

## PERSONAL ACKNOWLEDGMENTS

The acknowledgments of the many contributions made to the realization of the thesis must begin with two potters who have had a primary influence in my life and work. Ray Kahmeyer, Bethany College and Angelo Garzio, Kansas State University, were responsible for the first and lasting insights into the world of meaning in clay. Angelo Garzio served the important function of previewing this study and he offered zealous and skilled assistance throughout the duration of my studies at Kansas State. Jerrold Maddox and John Vogt, both of the Department of Art, Kansas State University, served in the capacity of committee members for my graduate work. The time which they devoted to reading the text and their helpful suggestions were greatly appreciated. Other craftsmen who were quite helpful as the study progressed included Paul Soldner, Warren MacKenzie, Glenn Nelson, Karl Martz, Charles Lakofsky, Karen Karnes, Al Kinkel, Tim Ballingham and Harold Moore. Elliott House and Dave Spore of the Interpace Corporation; Willis G. Lawrence, Dean of the College of Ceramics, Alfred University and Ward Jones of the Durby Petroleum Company, retired; all offered experienced judgments concerning their areas of the study subjects.

Nedra Sylvis offered valuable service through typing and helping to correct the final manuscript. Credit also must go to Ronald Sitts for the portfolio photography of waste oil fired work included in the closing pages of the thesis.

## Chapter 1

### INTRODUCTION

Radiocarbon dates assigned to pottery discovered in Japan and Mongolia indicate that the potter's craft has been sustained for nearly nine thousand years.<sup>1</sup> The sustenance of this craft has been dependent upon three cosmic essentials; earth, water and fire. Earth has served the craft as a source of clay and glaze chemicals. Water has contributed the means by which the earthen materials were rendered plastic and useful during the primary forming stages of the potter's work. The ceramic process, however, could not be culminated until the chemical constitution of the potter's ware was altered through an ordeal by fire. Fire, the ultimate tool of the ceramist, has given the ware its final indurated degree of permanence.

The requisite heat energy for the potter's kiln could result from either; (1) the combustion of carbonaceous fuel, or (2) of more recent development, electrical resistance.

Archaeological discoveries of charcoal in caves of Peking men living in the Second or Mindel Glacial of the Pleistocene have inferred that the combustion of carbonaceous fuel had become a tool of men living nearly six hundred thousand years ago.<sup>2</sup> Therefore, the use of

---

<sup>1</sup>William Howells, Back of History: The Story of Our Own Origins (Garden City: Doubleday and Company, Inc., 1963), p. 134.

<sup>2</sup>Ibid., pp. 64-72.

carbonaceous fuel as the first source of heat energy for pottery production was a natural development in the history of the craft. The use of electrical resistance as a source of heat energy for the potter's kiln was a relatively modern invention, by comparison, for the earliest electric kilns date from the 1920's.<sup>3</sup> The popular application of electrical resistance as a source for heat energy in pottery production did not appear until the 1940's.<sup>4</sup>

The use of electrical resistance in pottery kilns has been characterized by cleanliness and ease in kiln operation; however, restrictions concerning the lack of a flexible atmosphere, limited temperature range, and excessive equipment and operation costs have also accompanied the use of this source of heat energy.<sup>5</sup> As a result, most contemporary potters have preferred the flexible atmosphere, high temperature potential, and lower equipment and operation costs which have accompanied the use of carbonaceous fuel.

Carbonaceous fuels which have been used throughout history include wood, grass, animal dung, coal, peat, natural gas, and numerous other petroleum products such as, liquified petroleum gas, kerosene and diesel fuel oil. Certain types of kiln constructions with fire grates and ash pits have been used by potters to achieve high temperatures with the solid fuels of wood, grass, animal dung, coal and peat. Combustion complications have also accompanied the use of the liquid fuels of kerosene, diesel, and other fuel oils. Like solid carbonaceous fuels,

---

<sup>3</sup>Daniel Rhodes, Kilns: Design, Construction, and Operation (Philadelphia: Chilton Book Company, 1968), p. 141.

<sup>4</sup>Ibid.

<sup>5</sup>Ibid., p. 142.



they too have specialized combustion problems requiring devices for the atomization of the liquid prior to combustion. Liquid fuels like solid fuels, must be converted into a gaseous state before combustion begins.<sup>6</sup> As a result, the gaseous forms of carbonaceous fuel such as bottled petroleum and natural gas have been the ideal fuels for present day pottery kilns.<sup>7</sup> These fuels have been relatively safe, easily burned, and reasonably priced.<sup>8</sup> Unlike the combustion devices required for burning solid and liquid fuels, gas burners have been simple in construction, easy to operate, and relatively inexpensive.<sup>9</sup>

Recent developments in the world petroleum industry have forced fuel prices to increase. Through selective marketing and inflated sale prices, the world petroleum suppliers have affected artificial fuel shortages among the world consumer nations. As a result, fuel prices for oil and gas kilns have risen. In addition, contemporary potters have occasionally experienced inconvenience due to low priority ratings and limited fuel supplies at the petroleum retail outlets.

The use of automotive waste oil as a fuel for firing ceramics could be a possible timely solution to the potter's problems of fuel cost and availability.

#### THE FOUNDATIONAL HYPOTHESES

The subsequent study was founded on the hypotheses that automotive waste oil could serve as a practical fuel for firing ceramics.

---

<sup>6</sup>Daniel Rhodes, Kilns: Design, Construction, and Operation (Philadelphia: Chilton Book Company, 1968), p. 60.

<sup>7</sup>Ibid., p. 75.

<sup>8</sup>Ibid., p. 75.

<sup>9</sup>Ibid., p. 75.

## LIMITATIONS OF THE STUDY

Limitations were imposed on the study concerning; (1) material costs, (2) technical knowledge of the craftsman, (3) time, (4) location.

The study was directed toward the contemporary potter who must keep the cost of his equipment and its operation to a minimum in order to experience a profit from his work.

Many complicated problems concerning sophisticated burner design, thermal chemistry and combustion engineering were left outside the scope of this study. An effort was made to keep the study research on a level of technical knowledge which could be easily understood and used by contemporary potters.

The majority of the experimentation for this study took place in the Ceramics Area of West Stadium, Kansas State University. The project was extended over a period of three years.

## THE ORGANIZATION OF THE STUDY

The organization of the study has developed as a progression which was intended to serve as a foundational guide to potters who plan to design and develop waste oil burning systems for firing ceramics. The progression started as a basic survey of oil combustion history. This survey has served as a point of departure for an understanding of contemporary methods for burning liquid fuels and waste oils as sources of heat energy for pottery kilns. During the course of the historical survey of oil burning, a prominent problem became evident involving the relationship of burner designs and their specific fuels. The problem of burner-fuel relationships served to justify the inclusion of a second

part in the study progression which dealt with the characteristics of automotive waste oil, its probable composition, and its dissimilarity to conventional fuel oils. Following the material dealing with waste oil composition, chapters were included concerning fuel gathering, cleaning and storage considerations. These chapters were followed by information concerning the design, construction, and operation of a waste oil burning system for firing ceramics. This body of research material has included a final chapter with considerations on such topics as, safety, pollution and problems of ceramic chemistry which are directly related to the use of automotive waste oil for firing ceramics. The closing chapter of the progression has recorded an objective summary of the use of automotive waste oil for firing pottery.

## Chapter 2

### A REVIEW OF PERTINENT HISTORICAL BACKGROUND IN THE USE OF OIL AS A FUEL

Historical combustion methods have provided a body of knowledge concerning problems and principles which have proven relevant to the burning of heavy fuel oil. A critical review of specific combustion systems will, therefore, yield fundamental insight into the problems of firing ceramics with automotive waste oil.

The preliminary research for this chapter of the study was divided into seven major areas of interest concerning the history of oil burning; (1) The Ancient World, (2) Early Russian Oil Burners, (3) Early Development of American Oil Burners, (4) Early Oil Burning in Western Europe, (5) Oil Burning After 1900, (6) Domestic Oil Burners and (7) Recent Automotive Waste Oil Burning Systems for firing Ceramics. An overwhelming body of information was recorded in the early draft of the chapter, but the bulk of that information appeared to be peripheral and only slightly related to the problems of burning automotive waste oil as a fuel for firing ceramics. As a result, the chapter has been condensed to avoid the confusion and reading fatigue which resulted in the lengthy complete review of the use of oil as a fuel. For those readers who may desire more information about the history of oil burning, the study has suggested the following sources of information; (1) Romp's Oil Burning, (2) Moyer's Oil Fuels and Burners, (3) Steiner's Oil Burners, (4) Rhodes' Kilns: Design, Construction, and Operation and

(5) Olsen's The Kiln Book. The footnotes and bibliographical entries of the study have provided additional information in the form of the location, company and date of publication which should aid the interested reader in an effort to locate the texts.

The present format for this chapter has its foundation in the meager history of waste oil burning kilns. Unlike the bountiful history of fuel oil burning, the history of the use of automotive waste oil has little to offer the contemporary potter who may plan to use this fuel as a source of heat energy for firing ceramics. Information regarding this subject has, with few exceptions, remained unpublished. As a result, the chapter format has included a review of the available publications and additional information concerning waste oil firing which was collected through personal interviews and correspondence. This information has served the study as the opening waste oil history for two distinct chapter sections; (1) Natural Draft Waste Oil Combustion Systems and (2) Forced Air Waste Oil Systems. Each of these sections have been supplemented with selected accounts of earlier historical oil combustion methods in order to point out the combustion principles used in the introductory waste oil burning systems.

#### NATURAL DRAFT WASTE OIL COMBUSTION SYSTEMS

The earliest attempt at firing ceramics with automotive waste oil have gone unrecorded. Conjecture has placed the time of the earliest experimentation with this fuel to be around 1929. October of 1929 marked the crash of the New York Stock Exchange, and the opening of the great economic crises of the 1930's. Prior to this date, the automobile industry had been growing by leaps and bounds throughout the

more industrialized nations of the world. With the automobile, came the use of lubricants for its internal combustion engine. When these seemingly unrelated facts are viewed together, the situation of the late 1920's and early 1930's could have easily given rise to experimentation with the use of automotive waste oil as a possible fuel for potters caught in the economic crisis. The study has assumed that the potential of automotive waste oil as a fuel was in the air in 1929, for one of the books concerning domestic heating with oil published in that year, included a warning as to the potential hazards of using 'crank-case oil' as heating fuel.<sup>10</sup>

The earliest published information concerning the use of waste oil for firing ceramics appeared in the summer of 1959.<sup>11</sup> A short four and one half page article in a British review, Pottery Quarterly, concerned a water injected, Venturi, evaporation plate, natural draft burner which had been developed by W. J. Readhead for firing an eight cubic foot pottery kiln.

In the course of the article, Readhead stated:

There is nothing new in using this very cheap fuel and it can be burned with a negligible amount of smoke and fumes.<sup>12</sup>

Readhead's statement implied that potters were very familiar with the use of automotive waste oil by 1959, but his suggestion concerning the fact that the fuel could be burned with a negligible amount of smoke and

---

<sup>10</sup>P. E. Fansler, House Heating with Oil Fuel (New York: Heating and Ventilating Magazine Company, 1929), p. 27.

<sup>11</sup>W. J. Readhead, "A Waste-Oil Burning Kiln," Pottery Quarterly, Summer, 1959, pp. 52-56.

<sup>12</sup>*Ibid.*, p. 52.

fumes was a bit misleading. The contemporary potter has been conditioned to the ease of operation and exceedingly efficient combustion of natural gas and fuel oil burners of recent years, and therefore, should be prepared to tolerate the smoke and fumes which do result from the combustion of sulfur laden waste oil when it is burned in a natural draught burner of the Readhead variety.

#### W. J. Readhead's Waste Oil Burning Kiln

The Readhead burner, Figure 1, was constructed of one-quarter inch steel plate and five-eighths inch water pipe.<sup>13</sup> The Venturi plate combustion system encouraged the fuel flame to enter the kiln chamber from beneath the floor of the kiln.<sup>14</sup> The natural draught of a twelve to fourteen foot chimney was sufficient to draw the gasses through the kiln.<sup>15</sup> The air supply for combustion was controlled by placing bricks or metal plates over the burner port of the firebox.<sup>16</sup> Readhead indicated that the air control of the system was quite critical and the flow should be regulated to allow just enough air for complete combustion without cooling the combustion chamber and forcing a loss of efficiency in the system.<sup>17</sup>

Readhead used a blow-lamp or kerosene soaked rag to play flame on the Venturi plate before turning on the fuel and water.<sup>18</sup> He indicated that the burner must be well heated before fuel combustion could take place.<sup>19</sup> The burner operated on a fuel-water mixture of

---

<sup>13</sup>W. J. Readhead, "A Waste-Oil Burning Kiln," Pottery Quarterly, Summer, 1959, p. 52.

<sup>14</sup>Ibid., p. 52.

<sup>15</sup>Ibid.

<sup>16</sup>Ibid.

<sup>17</sup>Ibid.

<sup>18</sup>Ibid., p. 53.

<sup>19</sup>Ibid.

**THIS BOOK  
CONTAINS  
NUMEROUS PAGES  
WITH DIAGRAMS  
THAT ARE CROOKED  
COMPARED TO THE  
REST OF THE  
INFORMATION ON  
THE PAGE.**

**THIS IS AS  
RECEIVED FROM  
CUSTOMER.**



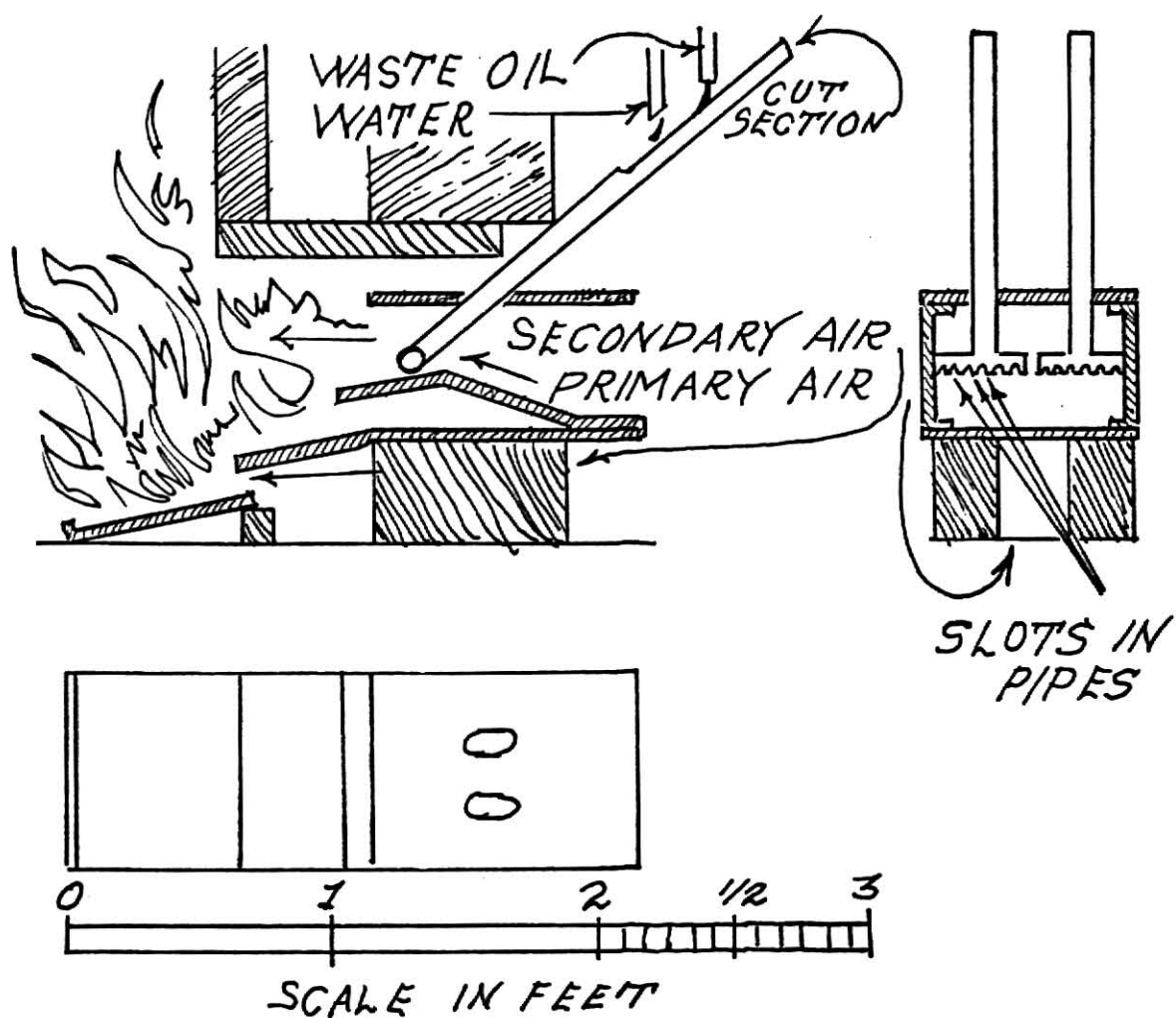


Figure 1

Readhead's Waste Oil Burner<sup>20</sup>

<sup>20</sup>W. J. Readhead, "A Waste-Oil Burning Kiln," Pottery Quarterly, Summer, 1959, p. 54.

three parts fuel to one part water.<sup>21</sup> He suggested that heat transition and the flow of the fuel-water mixture should be progressive; however, the control should always be a bit on the lean side rather than using too much fuel.<sup>22</sup> An excess of fuel had a cooling effect on the Venturi plate and resulted in a loss of combustion efficiency in the system.<sup>23</sup>

The oil for this system was cleaned by passing it through an eighty mesh sieve.<sup>24</sup> Readhead used an upright, forty gallon drum to store the sieved oil where the fuel was allowed to settle before it was pumped into an upper drum for storage and burner feed.<sup>25</sup> The upper drum was mounted horizontally on top of the upright container and a stirrup pump was used to pump the fuel into the upper drum.<sup>26</sup> A one half inch supply pipe was fixed to the upper drum and carried the fuel to the supply taps and flexible metal piping which delivered the fuel to the burner.<sup>27</sup>

The remainder of Readhead's article was concerned with details of construction for his kiln design. The article has served as a short but helpful addition to the meager body of published information concerning the use of automotive waste oil for firing ceramics. Perhaps the most admirable contribution which Readhead made in his study was the use of water with the fuel. He made no mention of his reasons for using water in his system; however, the advantages will be recounted later in this section of the study chapter. The operation of the early Astrakan

---

<sup>21</sup>W. J. Readhead, "A Waste-Oil Burning Kiln," Pottery Quarterly, Summer, 1959, p. 53.

<sup>22</sup>Ibid.      <sup>23</sup>Ibid.      <sup>24</sup>Ibid.      <sup>25</sup>Ibid.

<sup>26</sup>Ibid.      <sup>27</sup>Ibid.

oil stove will point out how the use of water with waste oil served as a pulverizing agent with the fuel in a physical activity and also helped prevent soot and smoke through a chemical relationship in the combustion of the fuel.

Other historical oil burners were related to the Readhead waste oil system. Later in this section of the chapter, pertinent historical background for Venturi Burners and natural draft burners will be recorded to help the reader understand the combustion of the Readhead waste oil system.

#### Olsen's Gravity Drip Plate Burner

The same principles of natural draft combustion which Readhead's burner used were also employed in a drip plate systems constructed by Frederick L. Olsen in Australia and in Denmark.<sup>28</sup> The Olsen burner system design was also used in a three chambered climbing kiln belonging to Les Blakebrough in Australia.<sup>29</sup> Information regarding this drip burner design, Figure 2, was published in The Kiln Book, by Olsen, in 1973. The majority of the information concerning this burner was directed toward the use of fuel oil or kerosene in the kiln. However, concerning this system, Olsen has stated, "When low on money, I have used sump oil. . . ."<sup>30</sup>

The Olsen kilns used three drip plates at each of three fire port flues making a total of nine plates for each of his kilns and the Blakebrough kiln employed three evaporation plates at each of six fire

---

<sup>28</sup>Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), p. 87.

<sup>29</sup>Ibid.

<sup>30</sup>Ibid.

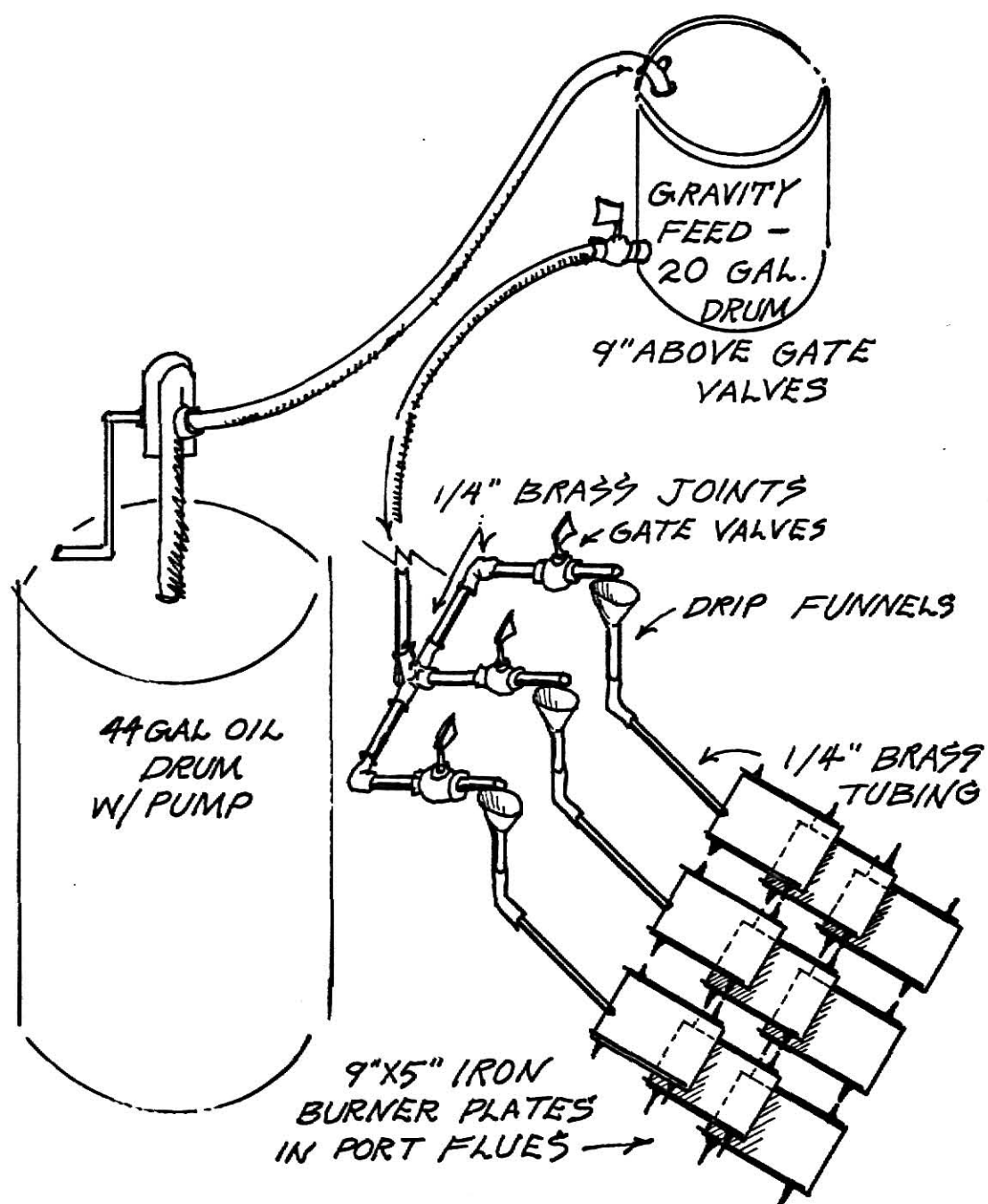


Figure 2

Olsen's Oil Drip System<sup>31</sup>

<sup>31</sup>Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), p. 87.

port flues making a total of eighteen evaporation burner plates in his kiln.<sup>32</sup> Olsen has indicated that three plates per flue channel was the preferable number needed for efficient combustion.<sup>33</sup>

The plates, Figure 3, were nine inches by five inches and had a lip which ran down each side to prevent the fuel from spilling over the sides before it reached the end of its proper flow.<sup>34</sup> Olsen's plates were set parallel with a three inch height difference and a two inch overlap on a slope of two to nine inches for burning diesel oil.<sup>35</sup> The slope of the burner plates were varied according to the viscosity of the fuel used so a ratio of approximately one to nine inches would have been used to burn waste oil.<sup>36</sup>

Olsen's plate system was built into stacks of fire bricks with loose bricks spanning the plate channels.<sup>37</sup> With the loose construction of the plate system, he was able to easily remove the bricks for adjusting and cleaning the carbon clinker build-up which accumulated during burner operation.<sup>38</sup> A stack of damper bricks were used in front of each set of plates to control the air intake of the system.<sup>39</sup> Inside the chamber, a span of fire bricks were placed nine inches from the kiln wall to create a firebox-bagwall, running the length of the kiln chamber wall.<sup>40</sup>

Olsen controlled the rate of fuel flow by three gate valves which were located between the main fuel line and each set of drip

---

<sup>32</sup>Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), p. 87.

<sup>33</sup>Ibid.

<sup>34</sup>Ibid.

<sup>35</sup>Ibid.

<sup>36</sup>Ibid.

<sup>37</sup>Ibid.

<sup>38</sup>Ibid.

<sup>39</sup>Ibid., p. 88.

<sup>40</sup>Ibid., p. 88.

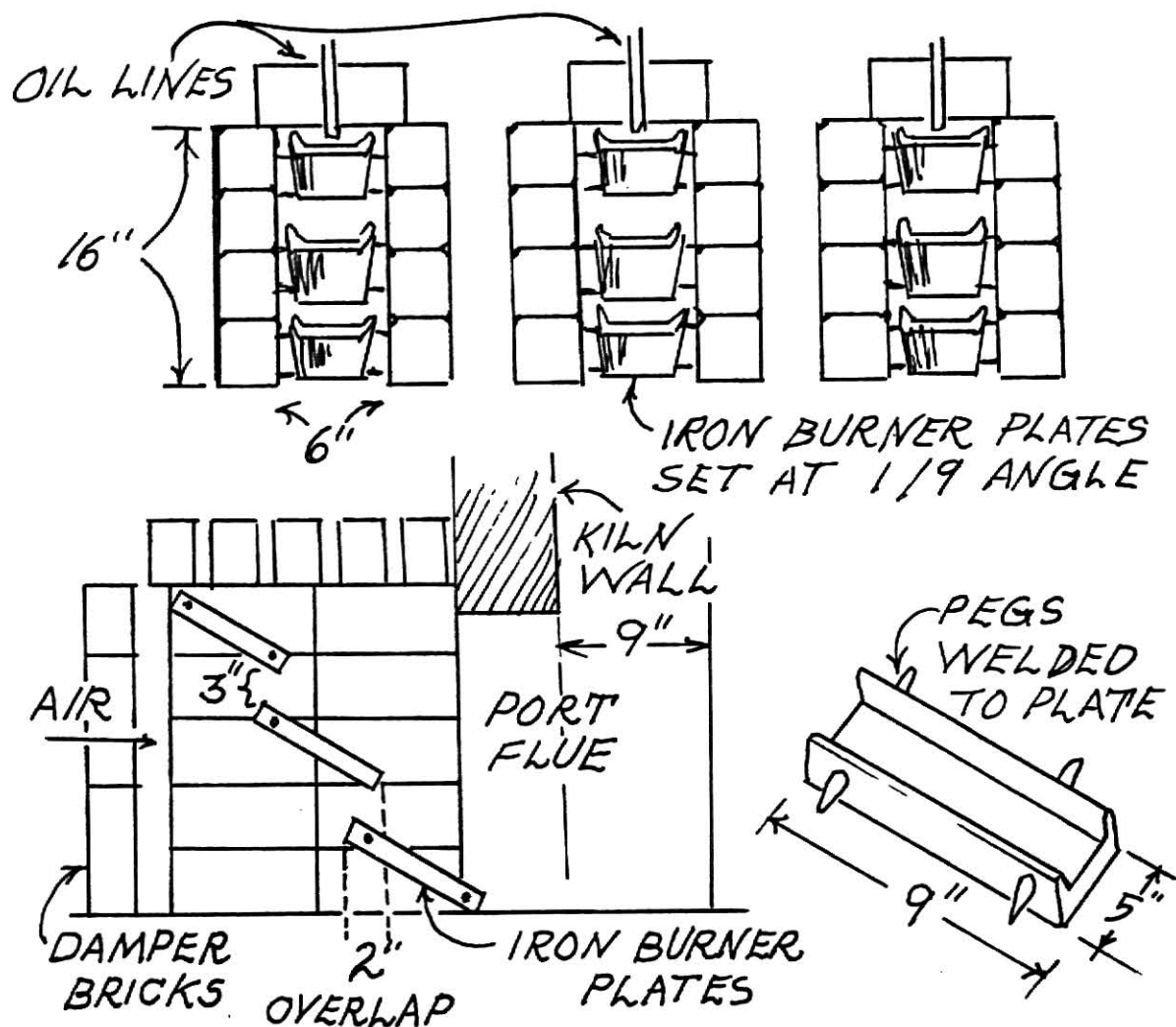


Figure 3

Olsen's Oil Drip Burner<sup>41</sup>

<sup>41</sup>Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), p. 88.

plates.<sup>42</sup> Brass tubing was used to deliver the fuel from the gate valves to each drip plate set and the pressure of the fuel was maintained through a gravity feed system or tank located ten feet above the plates.<sup>43</sup> Like Readhead, Olsen used kerosene-soaked rags placed at the bottom plate of each set to ignite the burner system.<sup>44</sup> The rags were lit, placed in position, and then a small quantity of fuel was adjusted to drip down to the burner plate and on to the burning rags.

The combustion of fuel in the Olsen system was accompanied by problems of carbon clinker build-up in the inlet flues and drip channels.<sup>45</sup> These areas of the system were periodically cleaned with an iron rod or poker.<sup>46</sup>

Another technique which Olsen used to keep the inlet flues and drip channels free of carbon clinker build-up involved pouring a little water down the channels every hour with the fuel.<sup>47</sup> As mentioned previously, the physical and chemical activity of water with combusting fuel has been recorded later in this chapter with reference to the Astrakan Oil Stove.

When Olsen's kiln neared the later stages of the firing, the flow of oil was regulated to insure that burning would take place on all three burner plates.<sup>48</sup>

The kilns used by Olsen ranged in size from 45 to 60 cubic feet and were fired with three channel ports each.<sup>49</sup> The fuel consumption of

---

<sup>42</sup>Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), p. 87.

<sup>43</sup>Ibid., p. 88.

<sup>44</sup>Ibid., pp. 87-89.

<sup>45</sup>Ibid.

<sup>46</sup>Ibid.

<sup>47</sup>Ibid.

<sup>48</sup>Ibid.

<sup>49</sup>Ibid.

both kilns, when fired to 1300° centigrade ranged from 60 to 75 gallons of waste oil.<sup>50</sup>

Olsen failed to give an indication of the total hour duration of his firing cycle. He did mention, however, that the overall firing time was dependent upon the number of burner plate sets used in each kiln.<sup>51</sup> In other words, the greater number of burners would fire the kiln faster. The placement and number of oil drip ports was determined by the length of the front inlet flue walls in Olsen's kilns. His burner ports were placed nine inches apart leaving from four and one half to nine inches between the corners of the kiln and the first and last burners of the fire port wall.<sup>52</sup> Olsen has suggested that the maximum number of ports needed for any given kiln was one oil drip port per nine inches of inlet flue wall.<sup>53</sup> The minimum number of ports was one oil drip port per eighteen inches of inlet flue wall.<sup>54</sup>

#### Oil Combustion Principles of the Readhead and Olsen Burners

The Readhead and Olsen oil burners were developed to operate on natural draft principles. Both systems used water in connection with their operation. These burner systems were designed to function through the evaporation of the heavy liquid fuel into a gaseous state for combustion. Heated evaporation plates were used to accomplish this combustion in both systems. The Readhead burner also made use of the

---

<sup>50</sup>Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), pp. 87-89.

<sup>51</sup>Ibid.

<sup>52</sup>Ibid.

<sup>53</sup>Ibid.

<sup>54</sup>Ibid.



Venturi principle to encourage air to enter the combustion chamber of the kiln and to force a fuel-air mix in that area of the system.

To explain these combustion principles, the author has selected information regarding the history of oil burning.

Petroleum antiquity. History has not recorded when man first learned of the combustion potential of petroleum. In the early days of petroleum use, men found that the material could serve a great variety of needs, one of which was combustion.

Noah's ark is said to have been caulked with bitumen, probably transported from the shores of the Dead Sea.<sup>55</sup> Vessels from the time of Abraham containing bitumen have been found on the ancient site of Ur in Chaldea.<sup>56</sup> The book of Job from the Bible records a rock which poured out streams of oil.<sup>57</sup> Marco Polo recorded in the thirteenth century that his travels in the Baku district of Siberia had brought him into contact with a fountain of oil which could be used for burning.<sup>58</sup>

Over seven thousand years ago the Egyptians made extensive use of bitumen for embalming purposes and the Babylonians used bitumen as a mortar for building walls.<sup>59</sup> The Phoenicians made extensive use of asphalt to waterproof their fleet five thousand years ago.<sup>60</sup>

---

<sup>55</sup>James I. Clower, Lubricants and Lubrication (New York: McGraw-Hill Book Company, Inc., 1939), pp. 2-3.

<sup>56</sup>Ibid.      <sup>57</sup>Job 29:6.

<sup>58</sup>James A. Moyer, Oil Fuels and Burners (New York: McGraw-Hill Book Company, 1937), p. 1.

<sup>59</sup>Clower, loc. cit.      <sup>60</sup>Clower, loc. cit.

The Vestal Virgins, serving the Latin goddess of earth and fire, probably burned petroleum oil in the lamps of the cult<sup>61</sup> and the Roman historian Pliny stated in his history of the world that oil obtained from Sicily was used in the lamps of the temple of Jupiter.<sup>62</sup> With the Greek precedent of pouring 'burning water' on the sea to destroy a Scythian fleet, a Roman general, Belisarius, in A. D. 533 taught the Vandals of North Africa about oil by smearing it on swine, lighting it, and then driving the blazing, squealing pigs against them.<sup>63</sup>

The Crusaders learned about the disastrous combustion potential of oil in the form of flame-throwers when they stormed the walls of Constantinople from A. D. 1096 to 1270.<sup>64</sup>

When the Europeans first came to the New World they found that the Indians were using crude petroleum for toothaches and headaches.<sup>65</sup> They are said to have regarded oil springs with religious awe and reverence<sup>66</sup> and they are believed to have used oil for burning as well as for healing.<sup>67</sup> The Incas were mixing petroleum with sand and gravel and using it as a mortar in the construction of stone houses and roads.<sup>68</sup>

Of these early uses for petroleum, the records of oil combustion have served this study as an introduction to natural draft combustion.

---

<sup>61</sup>James A. Moyer, Oil Fuels and Burners (New York: McGraw-Hill Book Company, 1937), p. 1.

<sup>62</sup>James I. Clower, Lubricants and Lubrication (New York: McGraw-Hill Book Company, Inc., 1939), pp. 2-3.

<sup>63</sup>Ibid.

<sup>64</sup>Ibid., p. 3.

<sup>65</sup>Ibid.

<sup>66</sup>Ibid.

<sup>67</sup>Moyer, loc. cit.

<sup>68</sup>Clower, loc. cit.

Natural draft combustion. Complete combustion has been defined as the oxidation of organic materials, producing  $\text{CO}_2$  and heat.<sup>69</sup> A clear explanation of combustion chemical action has been recorded by F. L. Olsen:

Hydrocarbons have a great affinity for oxygen. . . . Thus with excess oxygen, hydrocarbons can burn to form the carbon dioxide and water, resulting in complete combustion. An example is the complete combustion of a simple hydrocarbon of methane:  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$  plus Heat--or even simply to show combustion-- $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$  plus Heat.<sup>70</sup>

Of course, a general necessity in the start of this chemical action has been the application of a flame, or some method of creating an environment of kindling temperature.<sup>71</sup> After the chemical action of combustion has begun, however, the reaction will remain exothermic, or will continue to liberate heat energy, as long as the basic requirements of hydrocarbons and oxygen are present in the desired quantity. Therefore, petroleum, after kindling temperature was reached, could have been burned by early men as long as there was sufficient oxygen and hydrocarbons for the chemical action. When combustion takes place with only the natural atmospheric draft of its environment, it is called natural draft combustion. Natural draft principles were, no doubt, the earliest methods of combusting petroleum and they were the principles which were in operation in the Readhead and Olsen burner systems for burning waste oil.

---

<sup>69</sup>Daniel Rhodes, Kilns: Design, Construction, and Operation (Philadelphia: Chilton Book Company, 1968), p. 59.

<sup>70</sup>Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), p. 82.

<sup>71</sup>Ibid.

A later section of this chapter will deal with systems for burning waste oil where forced air principles are used for combustion, but forced air systems involved equipment complications which were probably beyond the capability of early man. These equipment complications were also avoided in the natural draft systems of Readhead and Olsen.

The Astrakan oil stove and the use of water for combustion. As stated earlier, both the Readhead and Olsen waste oil burners used water to aid in the combustion of their systems. Readhead used a continuous flow for his system while Olsen used water to clean the carbon clinker build-up in his drip plate system. Information regarding the Astrakan oil stove will aid in an understanding of the use of water in the combustion of heavy waste oil.

In the early years of the nineteenth century, the Russian industry which produced oil for lamps began refining its product from crude mineral oil.<sup>72</sup> The process soon yielded an abundance of heavy, unsaleable mineral residue which became a fuel for home heating in that country. The apparatus employed for the combustion of this waste oil fuel was called the Astrakan oil stove.<sup>73</sup> The Astrakan oil stove, Figure 4, consisted of one or more flat dishes positioned in the bottom of the stove wherein waste oil and water flowed by gravity from separate reservoirs. The fuel and water mixture was heated by radiant heat from refractory bricks located above the oil dishes and in the path of the flames from the fuel.

---

<sup>72</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 4.

<sup>73</sup>Ibid.

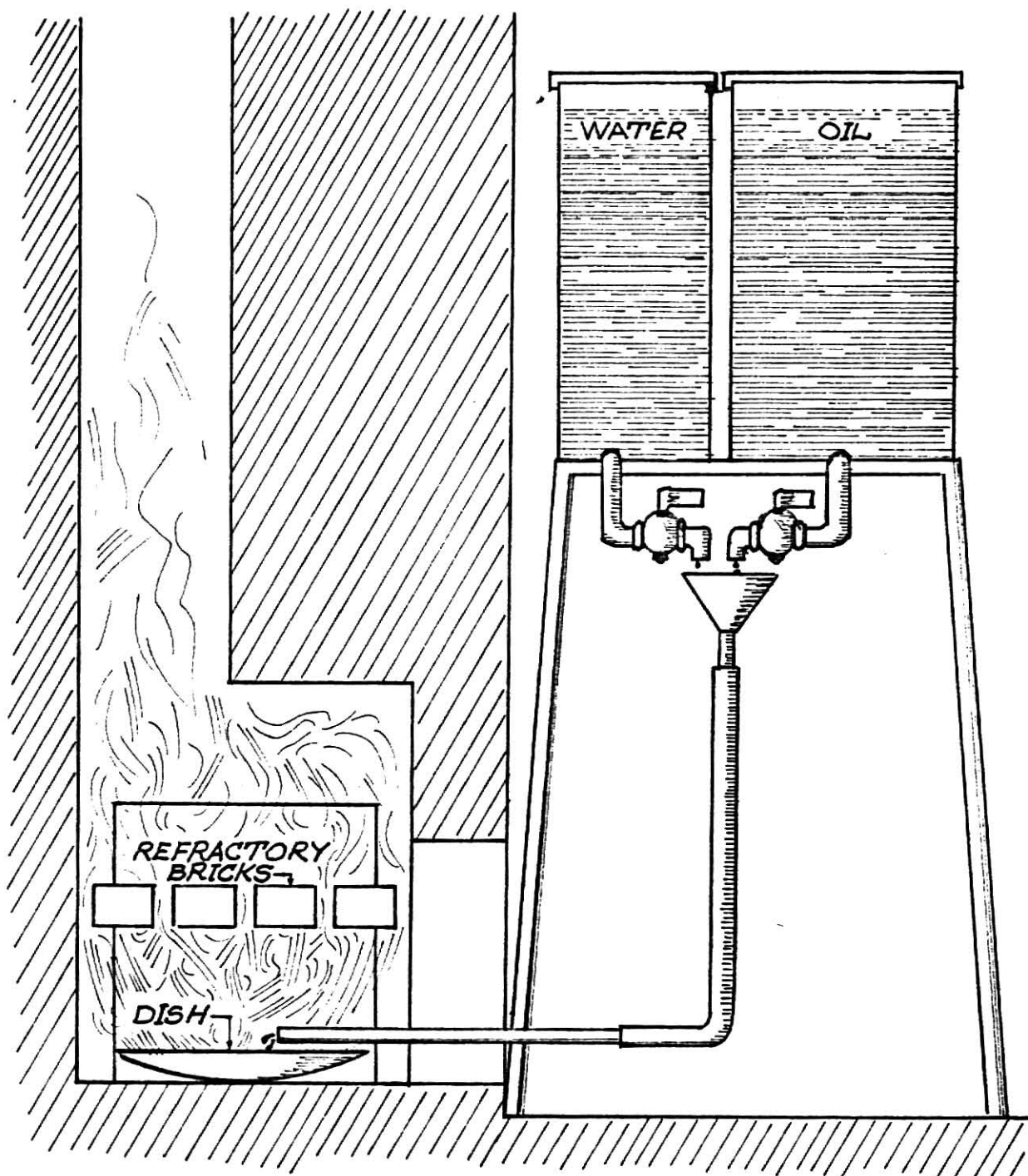


Figure 4

The Astrakan Oil Stove<sup>74</sup>

<sup>74</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 4.

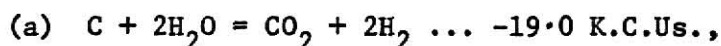
The use of water in the Astrakan oil stove served the combustion of heavy fuel in two ways: (1) pulverization, a physical action, (2) soot prevention, a chemical action.<sup>75</sup>

The principle of pulverization as a physical activity in a heated water and fuel environment has been explained by W. G. Lawrence:

As you know oil and water do not mix. The water will separate from the oil into small spherical droplets. When a mixture of oil and water droplets drops onto a hot plate or any other high temperature environment the water will immediately vaporize with almost an explosive force. This sudden volatilization of the water droplets causes the oil surrounding each water droplet to be blown out into the surrounding atmosphere in tiny droplets. The greater the force of the exploding water droplets the smaller will be the size of the oil droplets formed. As you know the smaller the size of the oil droplet spheres formed by this sudden volatilization of the water the greater the surface generated per unit weight of oil. . . . Since combustion can take place only on the surface of oil, the more surface generated the better the combustion.<sup>76</sup>

Soot prevention. In addition to the physical action of pulverization in the Astrakan oil stove, a chemical action was at work preventing soot and smoke. The interaction of steam with incandescent carbon has been explained by Bone and Townend:

The interaction between steam and carbon are of course endothermic. At low temperatures (500° to 600° C.), the chief products are carbon dioxide and hydrogen, according to the equation:

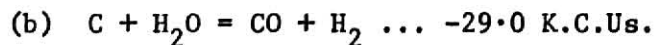


Whereas, at temperatures of 1000° C. and upwards, the main result is the production of equal volumes of carbon monoxide and hydrogen, the so-called 'water-gas' reaction, as follows:

---

<sup>75</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 4.

<sup>76</sup>Based on personal correspondence between Dr. Willis Grant Lawrence, Dean, as well as, Professor of Ceramic Engineering of New York State College of Ceramics, Alfred University, and the writer.



At intermediate temperatures, the products correspond with the simultaneous occurrence of both reactions, the second gradually asserting itself as the temperature rises, until at  $1000^\circ \text{C.}$ , it almost entirely supersedes the first. Hence, in flames it is only the second one that need be considered.<sup>77</sup>

Since CO is actually a fuel and will burn if any oxygen is present,<sup>78</sup> the Astrakan oil stove could have been operated with a minimal amount of soot and smoke with the proper adjustments of fuel, air and water.

The physical and chemical activity of water as used in the Astrakan oil stove was the same activity which was employed by Readhead in his natural draft system and Olsen in the cleaning operation of his waste oil burners. For a greater understanding of natural draft systems which operate through the evaporation of the fuel on a heated surface the study has turned to some early developments in France where the greatest advancements in natural draft combustion were to take place. These developments in France have proven to be the ancestor systems of the Readhead and Olsen natural draft waste oil burners.

Early French natural draft oil burners. The first oil burning systems in France resulted, like the Astrakan oil stove in Russia, from the accumulation of mineral waste oil in the petroleum refining process. The idea in France was to find a use for the residue tar oil which

---

<sup>77</sup>W. A. Bone and Donald T. A. Townend, Combustion in Gases (London: Longmans, Green and Company Ltd., 1927), p. 321.

<sup>78</sup>Willis G. Lawrence, Ceramic Science for the Potter (Philadelphia: Chilton Book Company, 1927), p. 130.

resulted from the early French gas works.<sup>79</sup> The first work in this direction was accomplished by the same gas technologists who devised the gas-lighting in Paris.<sup>80</sup> The Gas Technologist, Audouin, constructed a furnace, Figure 5, in 1867.<sup>81</sup> This waste oil system consisted of a number of verticle fire bars which were covered with a film of oil. This film was, in turn, evaporated and combusted by the radiant heat of the furnace flame.

The first Audouin oil grate furnace was improved by its designer working with Sainte-Claire Deville, another gas technologist. Their new system, Figure 6, employed a set of inclined fire bars and adjustable air registers which gave a higher velocity to the primary air at the point where the oil films on the fire bars were being evaporated.<sup>82</sup> This new system resulted in a thorough mixing of air and oil gas. Therefore, the system achieved a very clean and complete combustion of the tar oil.<sup>83</sup>

The Audouin and Sainte-Claire Deville oil grate furnace was the first industrial application of natural draft as a motive force for oil burning.<sup>84</sup> Audouin pointed out the necessity of reducing all possible resistance to the air and focussing the air velocity on the oil film evaporation area of the furnace.<sup>85</sup> He also remarked on the importance of minimum excess air and its influence on oil combustion.<sup>86</sup> An excess

---

<sup>79</sup> Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 10.

<sup>80</sup> Ibid.

<sup>81</sup> Ibid., p. 9.

<sup>82</sup> Ibid.

<sup>83</sup> Ibid.

<sup>84</sup> Ibid., p. 11.

<sup>85</sup> Ibid., p. 11.

<sup>86</sup> Ibid., p. 11.



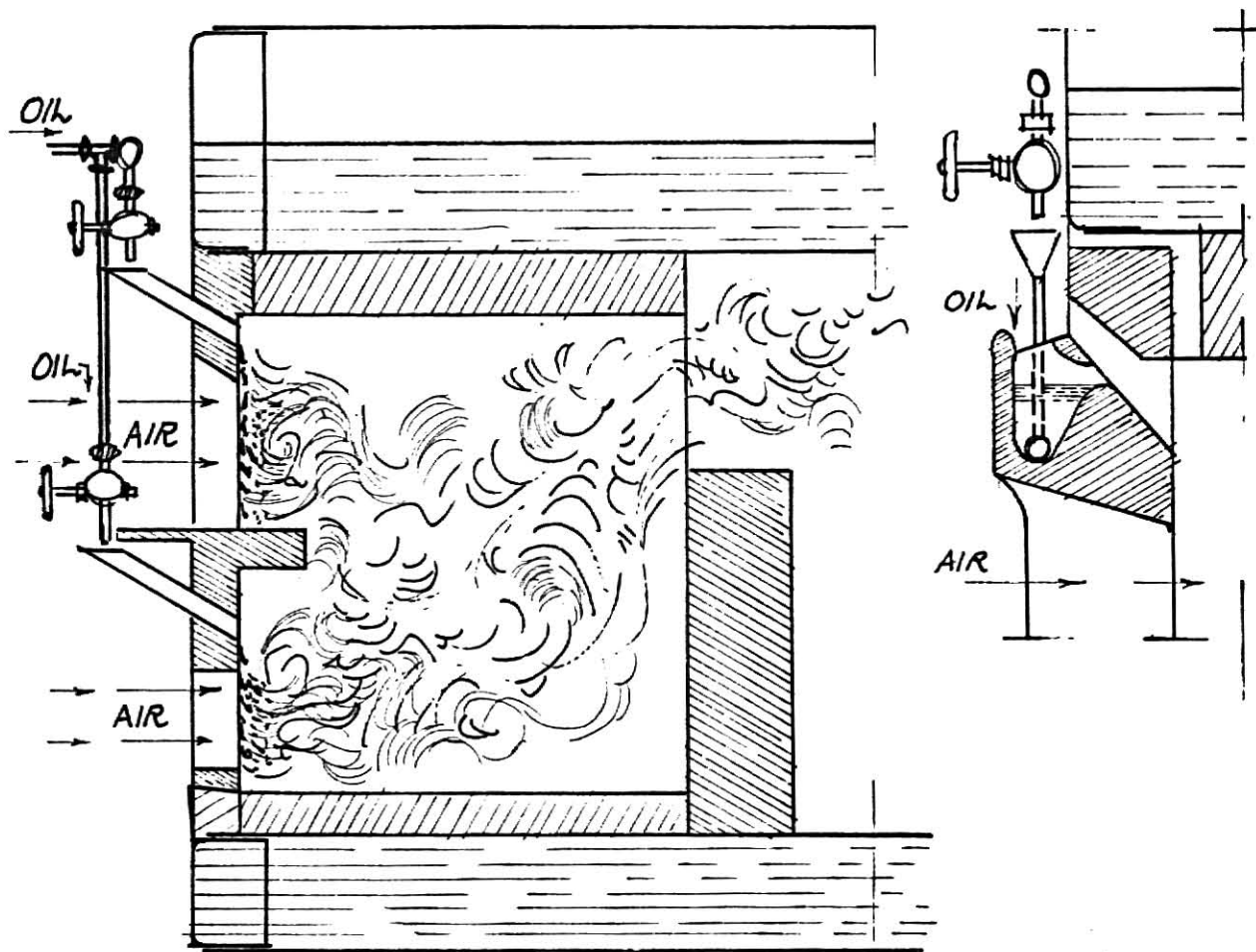


Figure 5

Audouin's Oil Grates<sup>87</sup>

<sup>87</sup> Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 10.

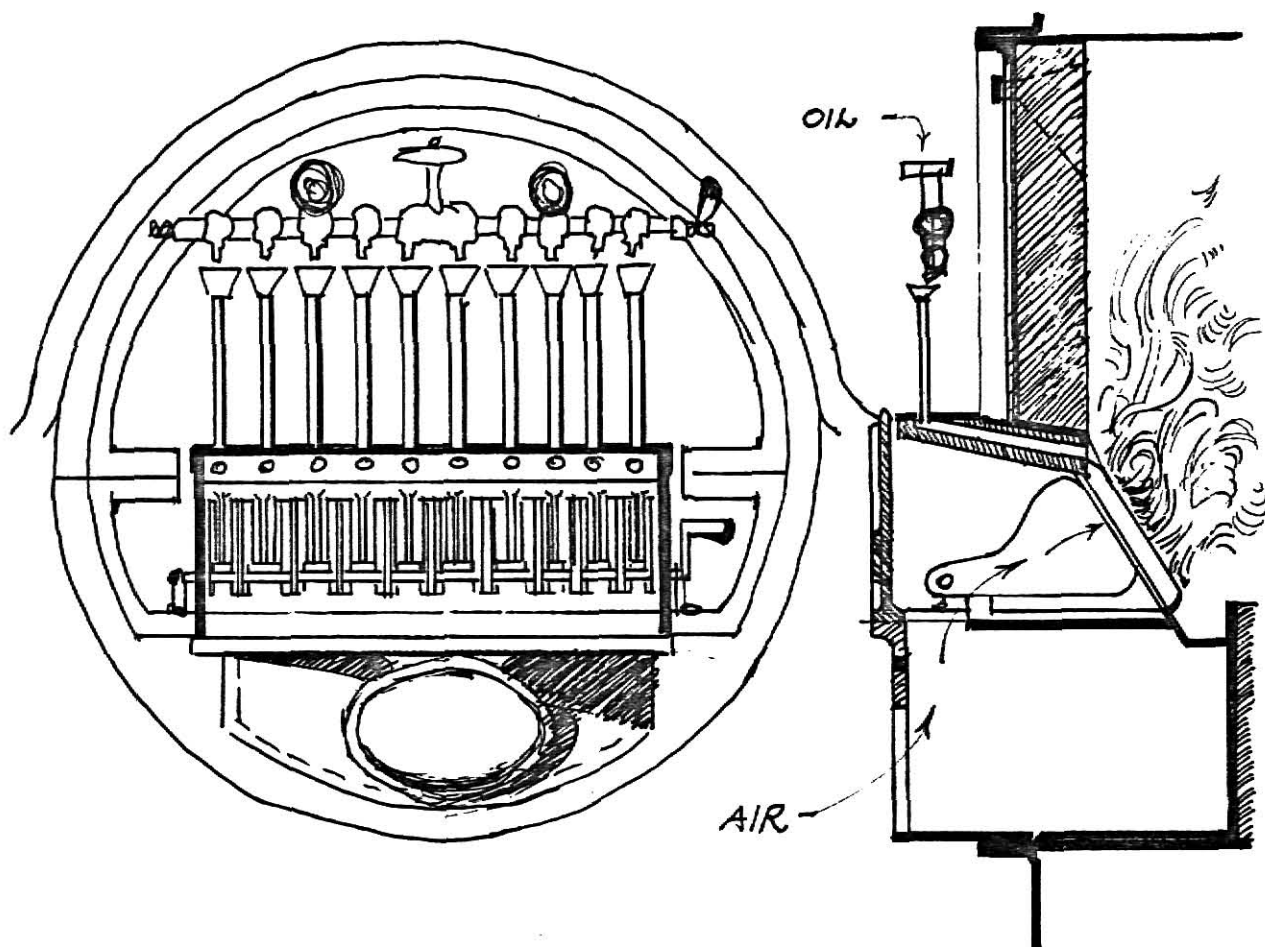


Figure 6

Audouin and Sainte-Claire Deville's Oil Grate<sup>88</sup>

<sup>88</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 10.

of air in the area of combustion caused a lowering of temperature and a subsequent loss of combustion efficiency.<sup>89</sup>

The design of the Audouin and Sainte-Claire Deville oil furnace employed a constriction of the air at the point of combustion and an expansion of the combusting gas in the fire box. This design has also been used by Readhead in his waste oil burner for firing ceramics and it makes use of the Venturi principle.

The Korting 'venturi' oil burner. The references for this study have not indicated that Audouin was aware that his second furnace design made use of the Venturi Principle. The forerunner of 'venturi' oil burners has been generally accepted to be a design by Korting who developed a system which used steam and the 'venturi principle' for the basic velocity and suction concepts for steam, oil and air mixture in his burner.<sup>90</sup> The Korting system, Figure 7, included a double constriction and expansion in the burner tube, and a fine pulverization of fuel with the steam and air at the burner tip.<sup>91</sup>

The 'venturi principle' was first investigated in 1779 by the Italian physicist G. B. Venturi.<sup>92</sup> The principle affords efficient means of converting pressure into velocity by using a suitable combination of constricted and expanded conical tubes.<sup>93</sup> The velocity which

---

<sup>89</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 11.

<sup>90</sup>Ibid., p. 7.      <sup>91</sup>Ibid., p. 7.

<sup>92</sup>Daniel Rhodes, Kilns: Design, Construction, and Operation (Philadelphia: Chilton Book Company, 1968), p. 76.

<sup>93</sup>Romp, op. cit., p. 15.

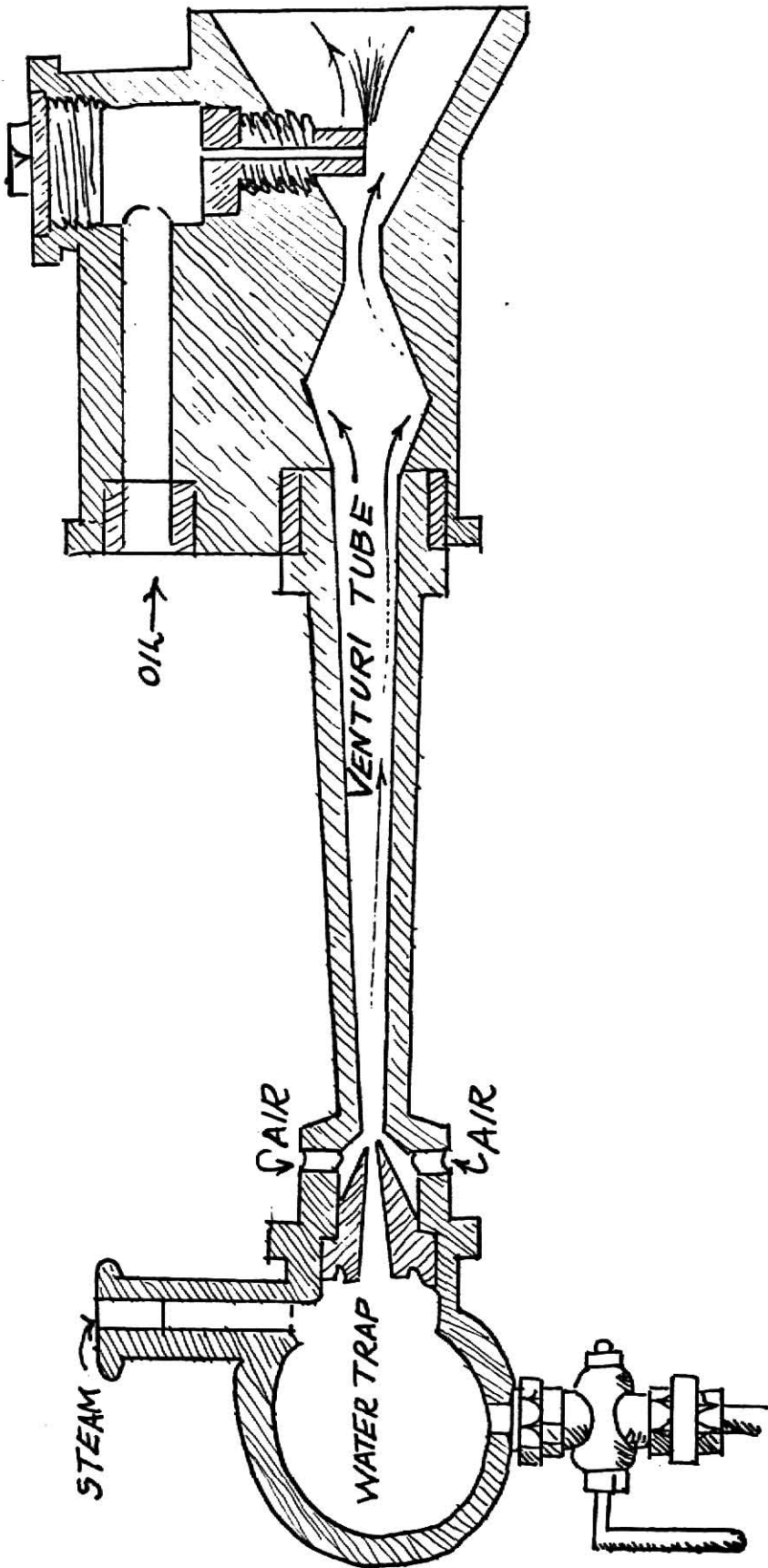


Figure 7  
Korting's Oil Burner<sup>94</sup>

<sup>94</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 7.

was created could be applied to encourage pulverization of fuel as well as to encourage the suction of primary air into the burner system.

The Korting 'venturi' burner was not of the natural draft variety because of its use of steam. However, the constricted and expanded areas in the Korting, Readhead and Audouin burners functioned to improve oil combustion through the physical principles which were discovered by Venturi.

#### FORCED AIR WASTE OIL BURNERS

Like the natural draft burners used by Readhead and Olsen, forced air burners have received only light publication. These forced air burners were fairly recent solutions to the potter's firing system. The pipe burner variations, Figures 8 and 9, gained popularity among potters working in the late 1960's and early 1970's.<sup>95</sup> Paul Soldner has deserved the credit for developing the burner concept. The present use of these systems was due to Soldner's efforts to expose their potential with numerous Raku workshops which he conducted throughout the United States in the 1960's and 1970's. The interest in Soldner's technique of burning oil resulted in a four page article about the design and operation of the burner in the January/February, Craft Horizons in 1968.<sup>96</sup> The next month, Craft Horizons carried a follow up letter from Soldner which requested an excuse for the publication's elimination of two diagrams from his article of the previous month.

---

<sup>95</sup>Statement by Angelo C. Garzio, Personal interview, August 10, 1974.

<sup>96</sup>Paul Soldner, "Workshop with Paul Soldner: firing with oil," Craft Horizons, No. 1, XXVIII (January/February, 1968), 17-19.

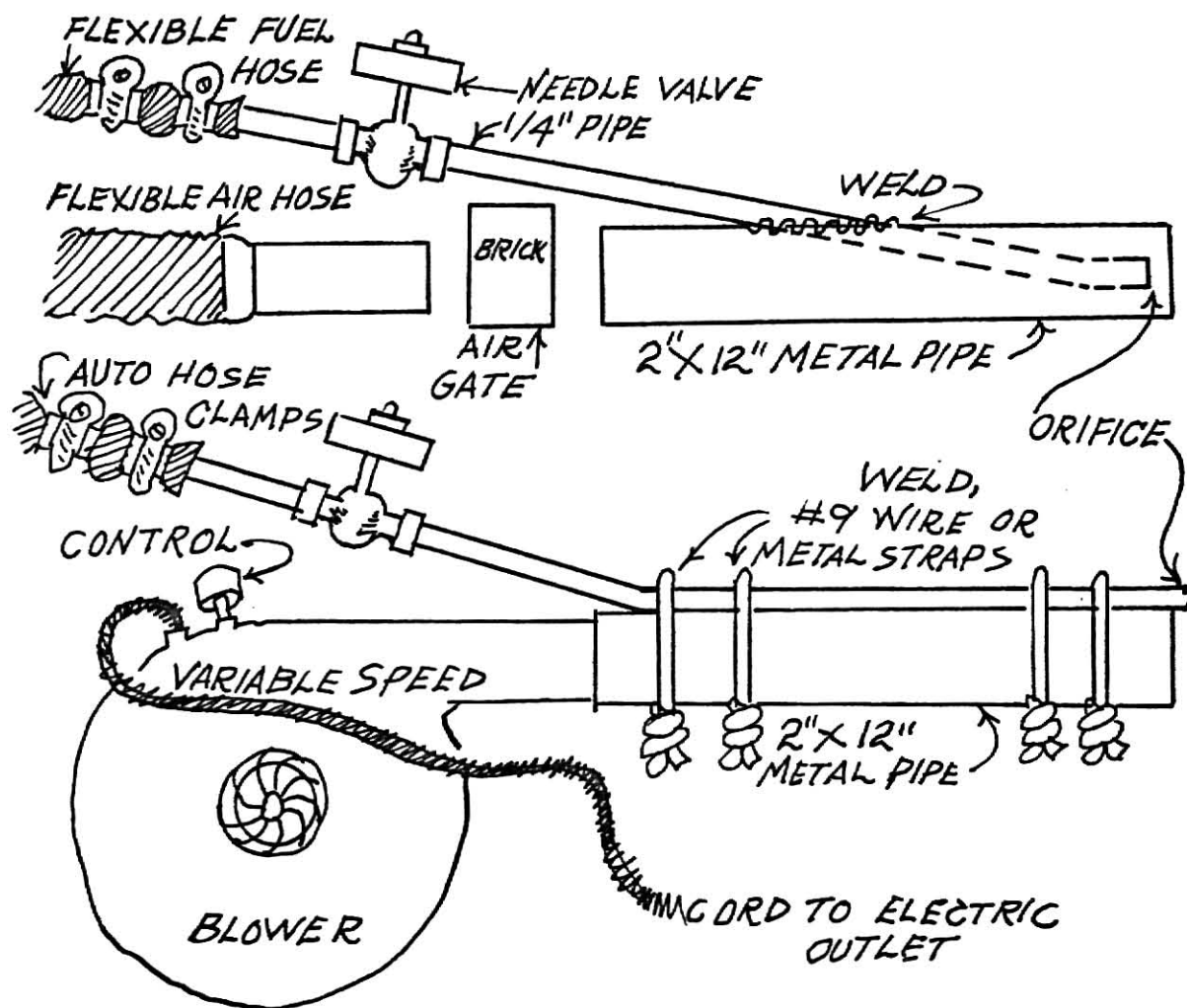


Figure 8

Variations of the Soldner Pipe Burners<sup>97</sup>

<sup>97</sup> Demonstration and lecture by Angelo C. Garzio ("The Soldner Waste Oil Pipe Burner") at Kansas State University, March 17, 1972.

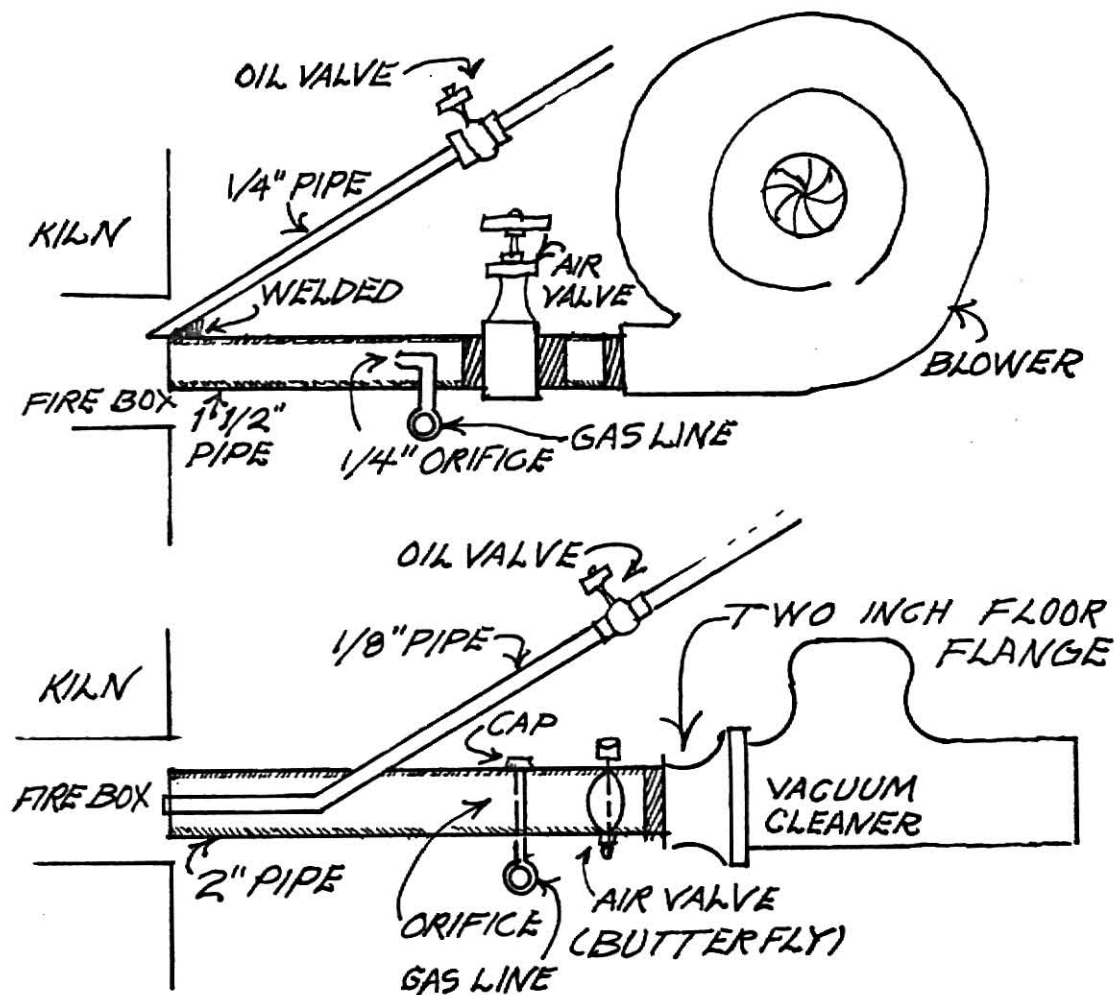


Figure 9

Variations of Soldner's Oil Carburetor<sup>98</sup>

<sup>98</sup>Paul Soldner, "Letter: Firing with Oil Diagrams," Craft Horizons, No. 2, XXVIII (March/April, 1968), 7.

Diagrams of his burners were included with Soldner's letter of the following months.<sup>99</sup> In short, the contemporary potter should be able to consult both issues of the magazine in order to piece together the full idea of Soldner's information regarding this burner.

The waste oil pipe burner was developed to involve a forced air source, such as the blower from a vacuum cleaner, which could deliver a reasonable and consistent quantity of air to the burner pipe of the system.<sup>100</sup> Electricity has served as the usual power source for most fans and blowers, so the operation of the forced air pipe burner has presupposed an easy or close source of power for blower operation.

Concerning the air supply, Soldner has stated:

Although a vacuum cleaner will suffice for the air supply, a high pressure wheel blower, powered by a constant duty motor, is recommended for heavy firing schedules. Air pressure is more important for oil firing than it is for gas firing. Thus a squirrel cage blower will not work with oil although it is commonly used with gas. Oil, being a liquid, needs more air to combine with it for combustion.<sup>101</sup>

Air control devices have varied in this system, ranging from a simple air gate of bricks between the air source and the burner pipe, to more sophisticated but expensive power control devices to regulate the speed of the blower or vacuum cleaner exhaust. Soldner suggested using either a commercial air gate valve the same diameter as the air pipe from the blower, or a butterfly valve built into the burner.<sup>102</sup>

---

<sup>99</sup>Paul Soldner, "Letter: Firing with Oil Diagrams," Craft Horizons, No. 2, XXVIII (March/April, 1968), 7.

<sup>100</sup>Demonstration and lecture by Angelo C. Garzio ("The Soldner Waste Oil Pipe Burner") at Kansas State University, March 17, 1972.

<sup>101</sup>Paul Soldner, "Workshop with Paul Soldner: firing with oil," Craft Horizons, No. 1, XXVIII (January/February, 1968), 16.

<sup>102</sup>*Ibid.*



The first section of this chapter noted that the Readhead and Olsen waste oil systems were developed on the principle of natural draft and did not require the additional complications of blower and electricity in their operation. However, the waste oil pipe burner designed by Soldner has utilized the added force of the primary air to aid in fuel pulverization. The combustion efficiency of the forced air burner has justified the complications of blower operation in the system. Soldner has indicated that the only reason for not using a forced air operation for firing with waste oil would be if electricity was not available at the potter's kiln site.<sup>103</sup> The efficiency of a forced air system was far greater than that of a natural draft system. Soldner suggested that the fuel consumption of the natural draft operation usually involved double the quantity needed to fire the same kiln to the same temperature with a forced air system.<sup>104</sup>

In addition to the blower, the pipe burner required an iron pipe capable of withstanding radiant heat from the kiln fire box.<sup>105</sup> The diameter of the pipe has ranged from one and a quarter inches to four inches in diameter. The pipe extended in length for twelve to eighteen inches.<sup>106</sup> A smaller fuel feeder pipe was also required for the system and this pipe could range from one quarter to one half inch in diameter.<sup>107</sup> The feeder pipe should be at least as long as the larger burner casing.

---

<sup>103</sup>Statement by Paul Soldner, personal interview, August 13, 1973.

<sup>104</sup>Ibid.      <sup>105</sup>Ibid.

<sup>106</sup>Paul Soldner, "Workshop with Paul Soldner: firing with oil," Craft Horizons, No. 1, XXVIII (January/February, 1968), 16.

<sup>107</sup>Ibid.

The fuel pipe may be positioned on the larger blower pipe with a weld, metal clamps or heavy wire. It can also extend into the air pipe and be welded into position.<sup>108</sup> Of course, if the feeder pipe is to extend into the casing, a hole must be made in the larger pipe and the feeder pipe may have to be bent for alignment in the system.

When the oil feeder pipe is positioned with the larger burner pipe, one end of the fuel pipe will become the orifice end of the burner. Therefore, its exact location in relation to the end of the burner pipe should be considered. If the feeder pipe is to be secured on the larger casing, the orifice should be positioned even with or slightly ahead of the larger burner tip. This location will insure that the fuel from the orifice will fall on the stream of air flowing from the blower and through the large casing. If the feeder pipe is to penetrate the casing, the exact location of the orifice in relation to the casing tip must remain a matter of personal preference. When the orifice remains back of the burner tip, inside the casing, a greater pulverization of fuel can be expected as the oil is dispersed with the expanding air leaving the confines of the burner pipe casing.<sup>109</sup> If the orifice of the burner is positioned ahead of the casing tip, the fuel will remain in a concentrated stream for a longer period of time before it is pulverized by the force of the primary air of the system.<sup>110</sup>

---

<sup>108</sup> Demonstration and lecture by Angelo C. Garzio ("The Soldner Waste Oil Pipe Burner") at Kansas State University, March 17, 1972.

<sup>109</sup> Statement by Paul Soldner, personal interview, August 13, 1973.

<sup>110</sup> Ibid.

A realistic solution to the dilemma of orifice position in the system has been offered by Soldner who designed a burner with a flexible or adjustable feeder pipe, Figure 10.<sup>111</sup> Soldner's system has afforded the potter an opportunity to adjust the orifice location of the burner to the conditions of the kiln firing.<sup>112</sup> If his kiln operation required combustion near the burner tip, the feeder pipe was pulled back to locate the orifice well inside the casing. If the firing required combustion farther inside the kiln fire box, the orifice was extended to a point beyond the tip of the burner casing.

The waste oil pipe burner must also include a means of controlling the flow of fuel to the orifice. One end of the fuel feeder pipe should be threaded to receive this control. The controlling device or valve has traditionally been located near the back of the burner or well away from the kiln burner port. A variety of valves have served the purpose of fuel control for the system, but some of these valves were not designed with the viscosity and constitution of liquid fuel in mind. Soldner has suggested that an oil needle valve has worked best for his operation with plenty of control over the exact amount of fuel for the fire.<sup>113</sup> The experimenter has found that a standard needle valve for water will prove acceptable with only a slight loss in fuel control, while most fuel gate valves force the potter to sacrifice a great deal of control over the fuel flowing to the burner orifice.

---

<sup>111</sup>Statement by Paul Soldner, personal interview, August 13, 1973.

<sup>112</sup>Ibid.

<sup>113</sup>Ibid.

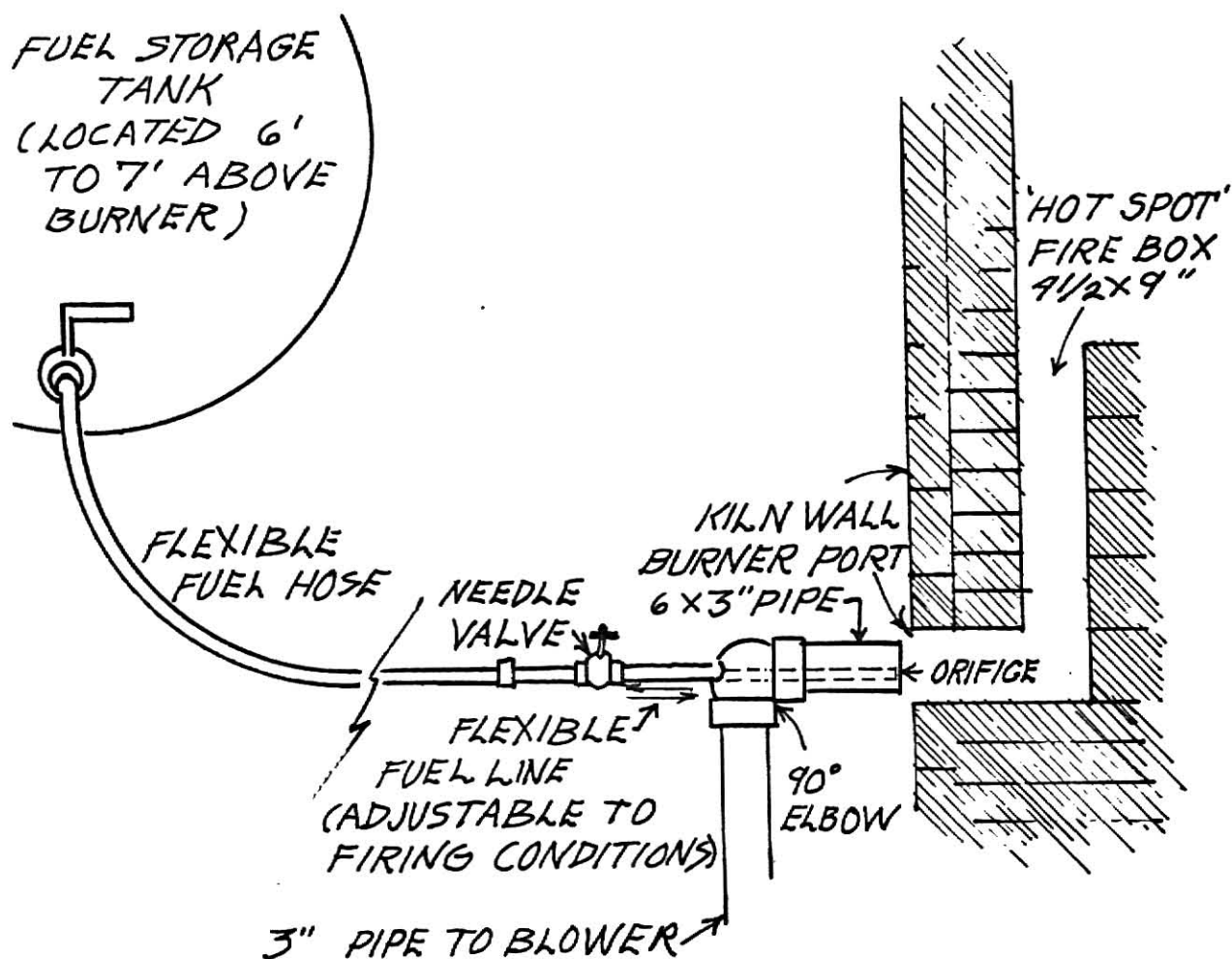


Figure 10

Soldner's Adjustable Orifice Pipe Burner<sup>114</sup>

<sup>114</sup> Demonstration by Paul Soldner, personal interview, August 13, 1973.

Concerning the firebox design of the system, Soldner stated in 1968:

The size and shape of the firebox is not critical. For example, the area behind the bag wall in a downdraft kiln is adequate. So also is the space under the floor of an updraft kiln. I have successfully used a simple target brick placed about six inches inside the kiln. The opening from the outside leading to the firebox should be only large enough for the end of the carburetor pipe. Secondary air is not used with a forced draft system.<sup>115</sup>

The system which Soldner has used in recent years included a preference concerning the size of the fire box. Soldner has preferred a small 'hot spot' firebox in his kilns.<sup>116</sup> His experience from 1968 to 1973 suggested that a small firebox for the burner has avoided the problem of carbon klinker build-up which resulted when the fuel from the burner was pulverized and then allowed to cool as it moved into a larger fire box area in the early stages of the firing.<sup>117</sup> For this reason he has kept the dimensions of his kiln fire boxes around four and one half by nine by thirteen and one half inches, with the longest dimension serving as the height of the area.<sup>118</sup> The small confined area subjects the fuel to an immediate exposure of heat with combustion insured as the fuel moves up into the kiln chamber. The 'hot spot' fire box provided enough heat in a concentrated area to crack the liquid fuel to a gaseous state prior to combustion.

---

<sup>115</sup>Paul Soldner, "Workshop with Paul Soldner: firing with oil," Craft Horizons, No. 1, XXVIII (January/February, 1968), 16.

<sup>116</sup>Statement by Paul Soldner, personal interview, August 13, 1973.

<sup>117</sup>*Ibid.*

<sup>118</sup>*Ibid.*

Another suggestion by Soldner has involved the location of the fuel storage tanks for the waste oil pipe burner system. Of course, safety concerns have required that the storage tank be located several feet from the burner area of the kiln, but Soldner has found that the most consistent gravity feed elevation for fuel storage tanks should involve a height of from three to seven feet above the burners.<sup>119</sup> The elevation of fuel storage at a height greater than seven feet has tended to require frequent and drastic fuel control adjustments at the burner as the fuel level in the storage tank dropped during the firing.<sup>120</sup> An elevation for the tank at less than three feet has often failed to supply a sufficient amount of gravity pressure in the system for trouble free operation of the burner.<sup>121</sup>

With reference to the basic concept of this system, Soldner has stated:

First of all, the kiln is an integral part of the system. In a broad sense, the kiln is the burner. The pipes, blower, and valves that may look like a burner are really only a device to mix oil with air and to deliver this mixture to the kiln. No combustion takes place in this device. It will not support a flame by itself outside of the kiln. For want of a better term to describe the above mechanism, I will refer to this delivery apparatus as a carburetor. I repeat, the carburetor is not a burner. It is a mixing device.<sup>122</sup>

---

<sup>119</sup>Statement by Paul Soldner, personal interview, August 13, 1973; see also Paul Soldner, "Workshop with Paul Soldner: firing with oil," Craft Horizons, No. 1, XXVIII (January/February, 1968), 16.

<sup>120</sup>Statement by Paul Soldner, personal interview, August 13, 1973.

<sup>121</sup>*Ibid.*

<sup>122</sup>Paul Soldner, "Workshop with Paul Soldner: firing with oil," Craft Horizons, No. 1, XXVIII (January/February, 1968), 16.

Concerning fuels for the oil burning system, Soldner has pointed out that the flash point of lighter fuel oils is lower than that of the heavier fuels.<sup>123</sup> As a result, the lighter fuels should be used for preheating the kiln fire box and the early stages of the firing.<sup>124</sup> He used the heavier fuel oils and drain oil for the later stages of his kiln firing.<sup>125</sup> One of the burner designs used by Soldner also included a small gas orifice in the air pipe to make preheating with natural or bottled gas possible.<sup>126</sup>

Although Soldner has concentrated on the use of fuel oils in his pipe burner, the study has drawn heavily from his article in *Craft Horizons* and from personal communication with him because his system has proven quite successful in the use of automotive waste oil as a fuel. His burner has served the study in the later chapters on burner design, construction, and operation. Variations on his system were used to fire all of the test pottery of the thesis.

Another variation of the waste oil pipe burner has been developed by Al Kinkel, Figure 10, which was reported to have an improved efficiency with waste oil.<sup>127</sup> Kinkel has used the basic composition of the pipe burner with the addition of a length of thirty to forty inches of six inch pipe casing which served as an evaporation and combustion

---

<sup>123</sup>Paul Soldner, "Workshop with Paul Soldner: firing with oil," *Craft Horizons*, No. 1, XXVIII (January/February, 1968), 19.

<sup>124</sup>*Ibid.*      <sup>125</sup>*Ibid.*

<sup>126</sup>Paul Soldner, "Letter: Firing with Oil Diagrams," *Craft Horizons*, No. 2, XXVIII (March/April, 1968), 7.

<sup>127</sup>Based on personal correspondence between Al Kinkel, California potter teaching stoneware at Opus 4, Morrison Colorado in July, 1973, and the writer.

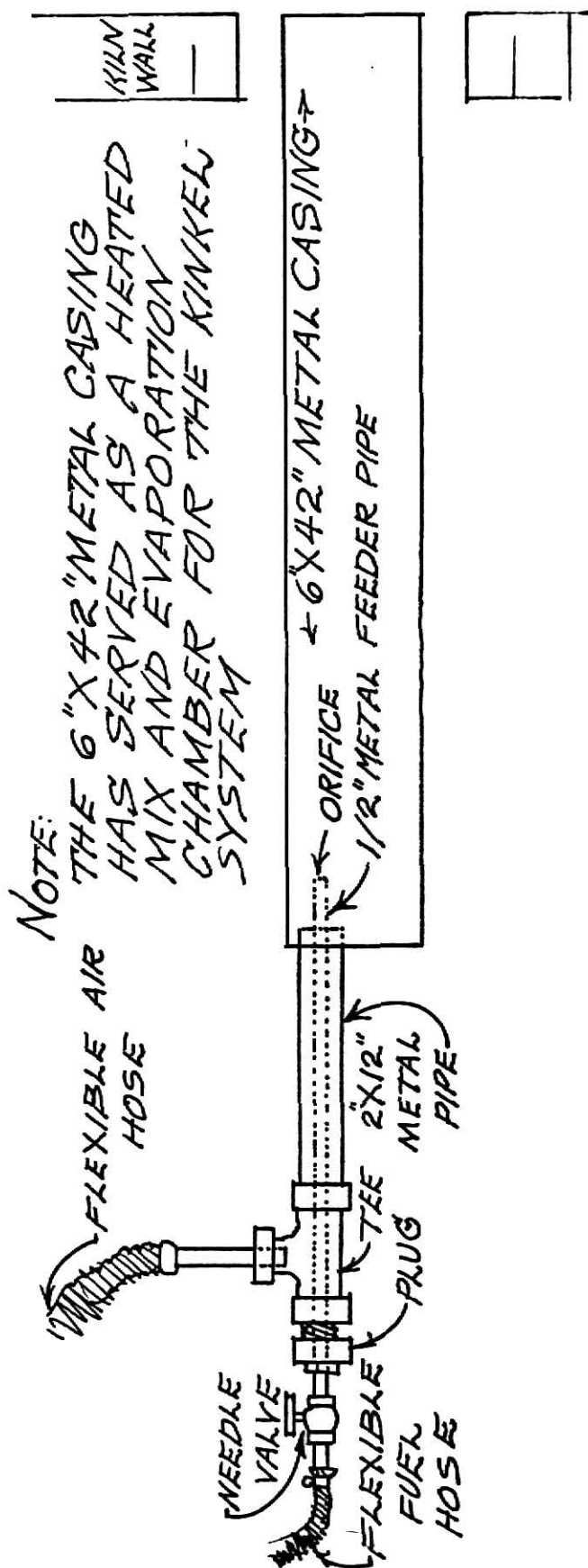


Figure 11  
 The Kinkel Burner<sup>128</sup>

<sup>128</sup> Personal correspondence between Al Kinkel, and the writer.



chamber for the waste oil prior to its introduction into the kiln fire box.<sup>129</sup>

Oil Combustion Principles of the  
Waste Oil Pipe Burner

The majority of early oil burner designers have used steam, compressed air, and natural draft evaporation plates to cause a pulverization of liquid fuel. The use of steam and compressed air required additional equipment to produce and control the media of fuel pulverization. The natural draft evaporation systems also had drawbacks due to the sensitive natures of the systems regarding the flexuation of atmospheric pressure and wind in the burners.<sup>130</sup> In the early 1920's most of the natural draft burner manufacturers were faced with a general sales slump and many of the companies turned to the production of what was called the 'mechanically assisted' evaporation burners of the vaporizing pot type.<sup>131</sup> These domestic oil systems consisted of a fire pot in which fuel was admitted without previous atomization. The fuel in the system was evaporated, cracked and burned by blowing into the system, a strong current of turbulent air.<sup>132</sup> These burners required a fan or blower system and used a larger quantity of air at a lower pressure compared to the compressed air oil systems which came before. The Prior vaporizing pot type oil burner, Figure 11, has served the study as an example of these mechanically assisted burners which avoided many of

---

<sup>129</sup>Based on personal correspondence between Al Kinkel, California potter teaching stoneware at Opus 4, Morrison, Colorado in July, 1973, and the writer.

<sup>130</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), pp. 4-33.

<sup>131</sup>*Ibid.*, p. 32.

<sup>132</sup>*Ibid.*, p. 32.

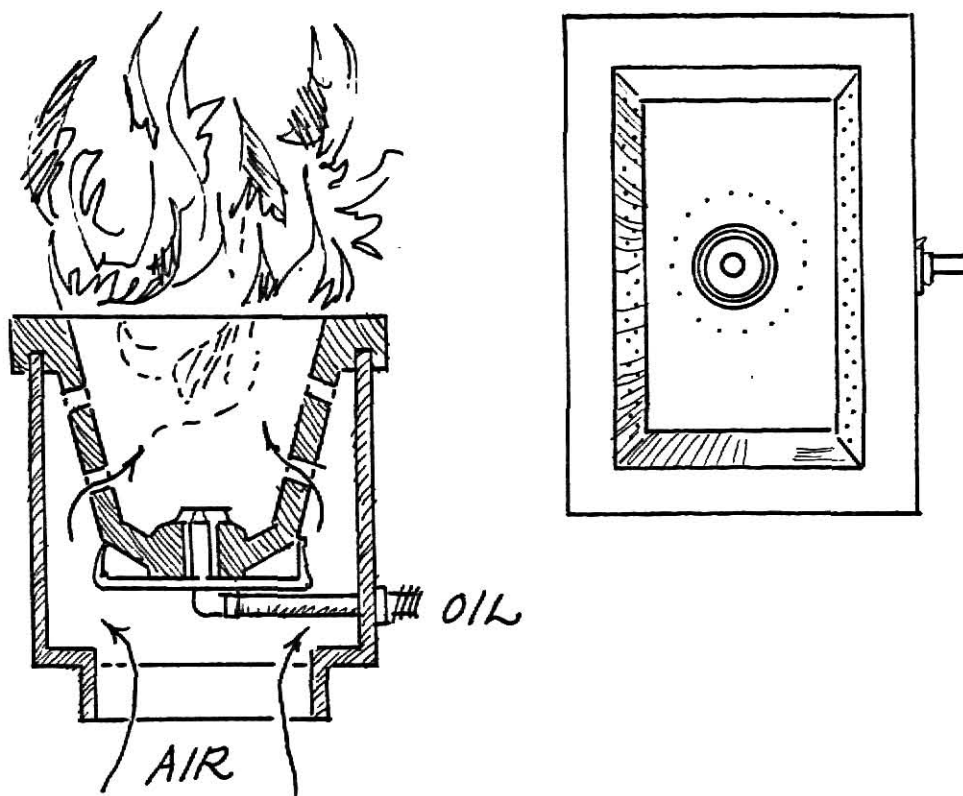


Figure 12

Prior Vaporizing Pot Type Burner<sup>133</sup>

---

<sup>133</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 32.

the combustion problems common to the natural draft burners.<sup>134</sup> These forced air oil burners of the 1920's have represented the ancestral design for the waste oil pipe burner.

The potter has, no doubt, been quick to notice that the forced air combustion principles used in the waste oil pipe burner and the earlier vaporizing pot type burners were nearly the same principles common to most of the familiar forced air gas kiln systems of today. Of course, the liquid state of oil fuel and the greater viscosity of waste oil has placed a greater burden of evaporation, pulverization, and fuel-air mixture on the kiln fire box in the waste oil pipe system.

The additional evaporation and combustion chamber used by Al Kinkel has served to match the evaporation combustion of the vaporizing pot type burners where a heated metal surface was provided to receive the fuel and air for combustion before entering the firebox of the furnace or kiln.

---

<sup>134</sup>Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 32.

## Chapter 3

### THE FUEL

Any attempt to record a correct chemical evaluation of automotive waste oil would be an impossible task for a number of reasons. Crude petroleum has been proven to vary a great deal in chemical composition according to the geographic locations where it is found.<sup>135</sup> Once the crude has been pumped from the ground, a sizeable number of manufacturers employ differing techniques to refine it, isolate its heavy distillates and arrive at basic lubrication oil stocks of varying chemical compositions.<sup>136</sup> By the time the oils have reached their commercial outlets, the basic stocks have been altered through a variety of additives used to improve the engine service of the lubrication products.<sup>137</sup> During the period of time that the oils are in service as lubricants, their constitution continues to change through the activity of heat, engine wear, fuel seepage, and grime from the atmosphere, entering the lubrication oil.<sup>138</sup> Lastly, the very act of gathering waste oil from a variety of engines and storing it to be used as fuel for firing

---

<sup>135</sup>Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), p. 157.

<sup>136</sup>James I. Clower, Lubricants and Lubrication (New York: McGraw-Hill Book Company, 1939), pp. 21-41.

<sup>137</sup>Brinley Pugh, Practical Lubrication, An Introductory Text (London: Butterworth and Company Ltd., 1970), pp. 192-200.

<sup>138</sup>*Ibid.*; see also Zuidema, *op. cit.*, pp. 40-76; see also Clower, *op. cit.*, pp. 248-279.

ceramics contributes to the chemical change of the liquid. As the many used oils, their additives, and their impurities are mixed in the storage tank, they continue to interact and change in composition.<sup>139</sup>

In spite of the impossible task of recording a correct chemical evaluation of waste oil, a study of the use of waste oil as a fuel for firing ceramics has indicated that certain chemical inclusions of the material have effected problems in the combustion of the fuel, while other impurities in its composition have proven to effect the ceramic materials of the potter's ware and kiln. Therefore, the study of waste oil as a fuel for firing ceramics has required that consideration be given to certain general characteristics of the hydrocarbon composition of this fuel, as well as the many impurities which it contains and liberates into the kiln atmosphere as combustion takes place.

#### GENERAL HYDROCARBON COMPOSITION OF THE FUEL

The foregoing chapters of this study have pointed out the numerous problems of fuel oil combustion and the basic need to force a compositional change upon liquid fuels, reduce the size of the liquid droplets, and force the fuel from a liquid to a gaseous state before combustion could take place. The reduction of droplet size of liquid fuels through the physical activity of pulverization or atomization has been accomplished through a variety of means in the history of oil burning. Chapter two of this study noted that steam, compressed air,

---

<sup>139</sup> Brinley Pugh, Practical Lubrication, An Introductory Text (London: Butterworth and Company Ltd., 1970), p. 31; see also James I. Clower, Lubricants and Lubrication (New York: McGraw-Hill Book Company, 1939), p. 249.

fuel pressure, and evaporation have all been used to accomplish the pulverization of the fuel. That chapter also noted that liquid fuel combustion required a fuel decomposition to arrive at a gaseous state with the capacity to burn. With the addition of sufficient heat, the chemical bonds of the complicated compounds in lubrication oil can be broken down to form gaseous configurations of combustible carbon.<sup>140</sup>

In order to understand this thermal decomposition, this study has required a general review of hydrocarbon chemistry relative to lubrication oil. Lubricating oils are composed of such a complex mixture of complicated hydrocarbons that it has been extremely difficult to identify specific compounds and the exact percentage of their occurrence in the liquid.<sup>141</sup> However, as lubricating oils fall into three main hydrocarbon groups, paraffin, naphthene and aromatic,<sup>142</sup> a review of the simplest structures of these groups should serve the study as a foundation to understanding the process of thermal decomposition or cracking.

### Paraffin

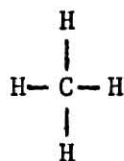
Carbon has a valency or chemical bonding power of four and the valency of hydrogen is unity, so the simplest hydrocarbon, methane, can be represented diagrammatically by

---

<sup>140</sup>James I. Clower, Lubricants and Lubrication (New York: McGraw-Hill Book Company, 1939), p. 31; see also Ir. H. A. Romp, Oil Burning (The Hague: Martinus Nijhoff, 1937), p. 8.

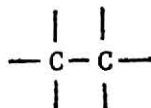
<sup>141</sup>Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), p. 41.

<sup>142</sup>Ibid.

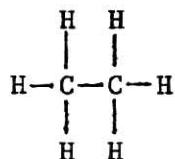


and its chemical formula is  $\text{CH}_4$ .

Carbon atoms have the property of being able to link together in this manner:

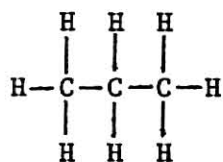


and each carbon atom can join with further hydrogen atoms, such as is the case with ethane. Ethane can be diagrammatically represented as

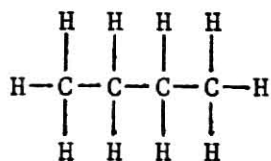


with a chemical formula of  $\text{C}_2\text{H}_6$ .

The simple process of linking can continue indefinitely, resulting in a series of straight chain hydrocarbons. For examples, propane can be represented as



with a chemical formula of  $\text{C}_3\text{H}_8$ , and butane can be represented as

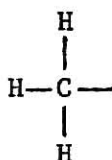


with a chemical formula of  $\text{C}_4\text{H}_{10}$ .

Methane, ethane, propane and butane make up the normal gaseous paraffins and all have boiling points of under one degree centigrade.

When the process of linking continues beyond these four gases, the physical states of the straight chain paraffins change to liquids and then to solids, as the number of carbon and hydrogen atoms increase.

In these normal paraffins the chain is symmetrical, each end consisting of the atomic grouping



and this atomic group is known as a 'methyl' group. Together, the paraffins form a series in which such physical characteristics as boiling point and specific gravity increase as the value or number of atoms increase. Table 1 lists the first 21 members of the series. In general, an assumption can be made concerning the combustibility of the simpler hydrocarbons and the retardation of that combustibility as the number of atoms multiply in the formulas.

### Naphthene

In addition to the normal or straight chain paraffins, it is possible to have different arrangements of the atoms in hydrocarbon fuels with the same number of carbon and hydrogen atoms present. The naphthenes or cycloparaffins which make up about half of certain lubrication oil stocks<sup>143</sup> represent the potential arrangement differences among hydrocarbons.

A simple example of a naphthene is cyclo-hexane which has the structure

---

<sup>143</sup>Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), p. 158.



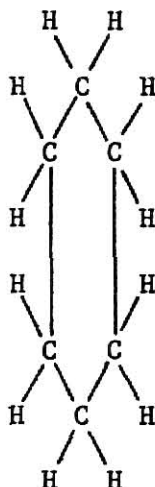
Table 1  
Paraffin Hydrocarbons

| Name        | Formula                         | Physical state | Boiling point, °F. | Specific gravity |
|-------------|---------------------------------|----------------|--------------------|------------------|
| Methane     | CH <sub>4</sub>                 | Gas            | -263.0             | 0.415*           |
| Ethane      | C <sub>2</sub> H <sub>6</sub>   | Gas            | -135.4             | 0.446**          |
| Propane     | C <sub>3</sub> H <sub>8</sub>   | Gas            | -34.6              | 0.536**          |
| Butane      | C <sub>4</sub> H <sub>10</sub>  | Gas            | 33.1               | 0.601**          |
| Pentane     | C <sub>5</sub> H <sub>12</sub>  | Liquid         | 97.3               | 0.631            |
| Hexane      | C <sub>6</sub> H <sub>14</sub>  | Liquid         | 156.2              | 0.660            |
| Heptane     | C <sub>7</sub> H <sub>16</sub>  | Liquid         | 209.1              | 0.684            |
| Octane      | C <sub>8</sub> H <sub>18</sub>  | Liquid         | 256.3              | 0.707            |
| Nonane      | C <sub>9</sub> H <sub>20</sub>  | Liquid         | 303.4              | 0.718            |
| Decane      | C <sub>10</sub> H <sub>22</sub> | Liquid         | 345.2              | 0.747            |
| Undecane    | C <sub>11</sub> H <sub>24</sub> | Liquid         | 386.6              | 0.741            |
| Dodecane    | C <sub>12</sub> H <sub>26</sub> | Liquid         | 420.8              | 0.768            |
| Tridecane   | C <sub>13</sub> H <sub>28</sub> | Liquid         | 453.2              | 0.757            |
| Tetradecane | C <sub>14</sub> H <sub>30</sub> | Liquid         | 486.5              | 0.765            |
| Pentadecane | C <sub>15</sub> H <sub>32</sub> | Liquid         | 518.9              | 0.772            |
| Hexadecane  | C <sub>16</sub> H <sub>34</sub> | Solid          | 549.5              | 0.775            |
| Heptadecane | C <sub>17</sub> H <sub>36</sub> | Solid          | 577.4              | 0.778***         |
| Octadecane  | C <sub>18</sub> H <sub>38</sub> | Solid          | 602.6              | 0.777***         |
| Nondecane   | C <sub>19</sub> H <sub>40</sub> | Solid          | 626.0              | 0.777***         |
| Eicosane    | C <sub>20</sub> H <sub>42</sub> | Solid          | 401.0              | 0.778***         |

\*At boiling point.

\*\*At 32°F.

\*\*\*Under 15 mm. pres.



and it is a saturated compound with six carbon atoms and twelve hydrogen atoms, or a chemical formula of  $C_6H_{12}$ .

The cycloparaffins are named after the corresponding straight chain paraffins containing the same number of carbon atoms, but since it takes at least three carbon atoms to form a ring the series starts with cyclo-propane.

In the case of lubricating oil, the naphthenes or cycloparaffins are usually more complicated than the simple example of cyclo-hexane depicted above.<sup>144</sup> Carbon atoms often link together so that side chains are formed on the naphthenes and two or three of these complicated naphthenes or cycloparaffins often unite together to form the very complicated structures of lubrication oils.<sup>145</sup> Other complicated structures have been isolated from lubrication stock where one naphthenic ring has combined with three condensed aromatic rings with paraffinic side chains.<sup>146</sup>

---

<sup>144</sup>Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), pp. 158-159.

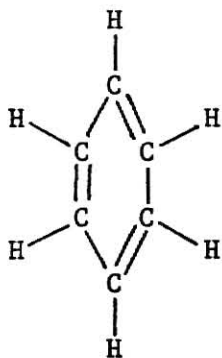
<sup>145</sup>Ibid.

<sup>146</sup>Ibid., p. 159.

### Aromatic

The aromatics form a separate, distinct and peculiar group of hydrocarbon compounds. In the absence of a better representation, these aromatics can be represented containing a basic ring structure with three double bonds per molecule. The representative diagram will not adequately express the chemical behavior of the compound, for the double bonds in this diagram do not represent points of reactivity, and the ring systems of the aromatics are exceptionally stable.

The parent member of the aromatics is benzene with a representative structure of



and the other aromatics can be derived from this basic structure by replacing one or more of the hydrogen atoms with a  $\text{CH}_3$  or more complex groups of atoms.

A detailed study of the chemistry of hydrocarbons is not essential to an understanding of the use of automotive waste oil as a fuel for firing ceramics. However, the preceding efforts should supply the potter with a minimum conception of a few of the complicated compounds which are common in hydrocarbon fuels and especially in lubricating oil stock.

This body of complicated compounds will work against the potter who tries to combust the liquid fuels. He will discover that the chemical bonds of the compounds must be broken with heat before the

hydrocarbons are reduced to a gaseous state. In other words, the potter's burner system and kiln firebox must be able to accommodate the cracking process of liquid fuels if combustion is to be complete.

#### IMPURITIES IN THE FUEL

While lubricating oils for various applications must meet widely different specifications, they have all had one requirement in common. This requirement has been that they should undergo a minimum of change while they are in engine service.<sup>147</sup> The changes which take place with lubrication oil in the engine are due partly to extraneous contamination, but largely to chemical changes in the oil molecules themselves.<sup>148</sup> These chemical changes in the oil molecules are principally involved with oxidation.<sup>149</sup>

#### Oxidation of the Fuel

In the heated and turbulent environment of the lubrication system of an engine, hydrocarbon structures are broken and oxygen attaches to many of the molecules of the oil.<sup>150</sup> This oxidation of a lubricating oil leads to such difficulties as bearing corrosion, ring sticking, lacquer and sludge formation, and excessive viscosity in the engine.<sup>151</sup> This study will avoid the complicated chemistry of hydrocarbon oxidation, but

---

<sup>147</sup>Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), p. 40.

<sup>148</sup>*Ibid.*      <sup>149</sup>*Ibid.*

<sup>150</sup>*Ibid.*; see also Brinley Pugh, Practical Lubrication, An Introductory Text (London: Butterworth and Company, Ltd., 1970), p. 193.

<sup>151</sup>Zuidema, *op. cit.*, p. 40; see also Pugh, *op. cit.*, p. 193.

the fact that this chemical activity has been known to take place in lubrication oils will help the potter to understand why the oil manufacturers have used additives in the basic lubrication oil stock as an effort to avoid or at least, retard the oxidation of their lubrication products.

### Additives

An additive is a substance added to oil in an effort to improve some particular property of the oil.<sup>152</sup> These substances must be soluble in the oil and they are classified according to the property they are intended to accentuate.<sup>153</sup> Manufacturers of lubrication oils have used a great variety of additives in lubrication oils.<sup>154</sup>

The original draft of this study covered each of these additives in an effort to gain an understanding of the types and quantities of chemicals which could be found in automotive waste oil. To avoid additional confusion and reading fatigue, that quantity of information was not included in this draft, but the potter would be interested to find that quantities of sulfur, chlorine, tin, chrome, selenium, tellurium, calcium, barium, magnesium, lead, zinc and sodium have all been used as additives for many lubrication oils.<sup>155</sup> These chemicals have offered a

---

<sup>152</sup>Brinley Pugh, Practical Lubrication, An Introductory Text (London: Butterworth and Company, Ltd., 1970), p. 193.

<sup>153</sup>Ibid.

<sup>154</sup>A few of these additives have been oxidation inhibitors, detergent additives, oiliness additives, compounded oils, film strength additives, extreme pressure additives, anti-wear additives, anti-rust additives, anti-corrosion additives, anti-foam additives, pour point depressants, as well as, many other types.

<sup>155</sup>Pugh, op. cit., pp. 192-200.

variety of characteristics to the use of automotive waste oil as a fuel for firing ceramics. Many of the chemicals have effected the melting temperatures of ceramic glazes fired in kilns using waste oil. Other problems of pollution and glaze flaws can also be attributed to these chemicals in the waste oil fuel. Chapter 6 of the study will cover information regarding these chemicals and their effects when firing ceramics with waste oil.

#### Other Impurities

In addition to the chemicals which were placed in lubrication oil stock by the manufacturers, another class of impurities have resulted through the normal operation of engine lubrication. Perhaps the most common of these impurities are the sludge and varnish deposits which have formed in the oil during low temperature operation of gasoline fueled engines.<sup>156</sup> These deposits result largely from products of incomplete combustion of the fuel which has leaked past the engine pistons and are absorbed in the crankcase oil. In the oil these products have polymerized to resins which are the basis of the varnish and sludge deposits in waste oil.<sup>157</sup>

Other foreign matter in waste oil have been dust and dirt from the atmosphere, iron oxide as a result of corrosion of oil pipes, reservoirs and sumps, water from leaky cooling systems or condensed out of the atmosphere and various other chemicals and liquers which were used in the oil manufacturing process but were not removed completely from the

---

<sup>156</sup>Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), pp. 40-41.

<sup>157</sup>Ibid.

oil stock prior to its use in the engine.<sup>158</sup> In addition, crude petroleum has contained minor amounts of nitrogen, oxygen and sulfur which may continue to remain in the lubrication stock and later in the waste oil fuel for the potter's kiln.<sup>159</sup>

#### Potential Characteristics of Waste Oil Kiln Fuel

With the preceding review of the hydrocarbon chemistry, additives and impurities of waste oil in mind, the potter should be equipped to tolerate a variety of distinctive characteristics which accompany the use of waste oil as a fuel for firing ceramics. He should be prepared to face combustion problems which result from the need to crack the complicated hydrocarbon chemistry of his fuel. He should be prepared to experience a number of color and surface variations in his ceramic ware attributable to the many ceramic chemicals which have found their way into the fuel as additives or other impurities. These elements are released from the fuel during the combustion cycle to contaminate the atmosphere of the kiln. Chapter Six of the study will examine the matter of these ceramic elements in the kiln atmosphere.

To close this chapter of the study, brief mention should be made concerning the potential heat energy of waste oil. Of course, any effort in this direction must be an approximation because the potter's fuel will be composed of many types of used lubrication oils. Using tables by

---

<sup>158</sup>James I. Clower, Lubricants and Lubrication (New York: McGraw-Hill Book Company, 1939), pp. 35-40; see also Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), pp. 248-249.

<sup>159</sup>Zuidema, op. cit., p. 157.

Clower,<sup>160</sup> the experimenter has estimated that waste oil fuel should yield between 143,670 and 147,330 B.T.U./Gallon. In other words, the heat value of waste oil appeared to be slightly higher than that of kerosene and the other common fuel oils.

---

<sup>160</sup>James I. Clower, Lubricants and Lubrication (New York: McGraw-Hill Book Company, 1939), p. 430; see also Hilbert H. Zuidema, The Performance of Lubricating Oils (New York: Reinhold Publishing Company, 1952), Appendix, Table I.



## Chapter 4

### FUEL GATHERING, CLEANING AND STORAGE

Prior to the use of automotive waste oil as a fuel for firing ceramics, the potter must concern himself with the preliminary problems of fuel gathering, cleaning, and storage. These first stages of the use of waste oil have proven to be quite simple operations, yet they require a degree of physical labor on the part of the potter. Waste oil can be an exhausting, messy, and dangerous material if it is gathered, cleaned, and stored without sufficient forethought regarding the equipment, space, time, and safety requirements of the operation. The following section of the study has been directed toward the preliminary concerns of fuel gathering, cleaning, and storage, in an effort to suggest an acceptable and convenient point of departure for the potter who plans to undertake these early stages of the waste oil firing process.

#### FUEL GATHERING

Potential sources of waste oil for the potter's kiln can be divided into three general categories, (1) individual, (2) commercial oil stations and (3) industrial. The gathering equipment needed by the potter will depend upon the nature of his fuel source, the quantity of fuel required for his operation and his financial situation.

### Individual Contributors

Waste oil from the oil changes of vehicles belonging to friends and helpful acquaintances has served as one source of fuel for the potter's kiln. In an effort to avoid the cost of having the oil in these vehicles changed by commercial stations, many people continue to service their own vehicles. When the undertaking is completed, these individuals are faced with the problem of what to do with the used oil. The oil may end up tossed onto the shoulder of a country road, or perhaps the problem has resulted in an added trip to a local filling station where waste oil tanks have been provided for the operation of the station. With a minimum amount of effort, the potter should be able to redirect this waste oil to his kiln location to be used as fuel for his kiln.

When dealing with individual contributors, four five-gallon oil cans have proven to be necessities in the waste oil operation. The five-gallon oil cans cost from \$3.00 to \$5.00 a piece at present, depending upon the design of the can and the outlet where they are sold. Farm supply outlets have proven to serve as useful sources for these oil cans, however, with a bit of good fortune, the potter may be able to locate cheap or free cans through farm auctions, or through contacts with individuals working in an industry.

The most preferable oil can design has included two sizable openings at the top which allows for a very quick displacement of the fuel with air as the can is used for pouring the fuel. A can of this type will pour smoothly without the erratic flow which often results when only one opening and a small air hole are used in the can design. Caps should be provided for both of the top openings of the can to insure that the fuel will not spill while being transported. These caps also prevent

dirt and foreign matter from getting into the fuel while it is in the oil can. The design of the can should also include a handle which is strong enough to carry a full can of fluid without distorting and pulling out of its connections on the can. A final consideration involves the length of the pouring spout on the can. Most cans have a spout which is elevated about two inches from the top of the container; however, the potter will soon discover that a spout of from four to six inches will contribute a greater degree of control over the fluid, especially when pouring from the can into the bung of a horizontal storage tank or barrel.

The five-gallon oil can will contain a quantity of waste oil which can be easily carried and poured, in the process of gathering the fuel. Some potters may choose to accumulate more than four of these cans, if their operations depend upon individual waste oil contributors for the majority of their fuel. These extra cans can be distributed, or at least made available to friends and acquaintances to insure that their oil is redirected to the kiln site. These additional cans, however, may develop into eyesores and storage problems if the potter's kiln site is restricted in its space and location.

In addition to four five-gallon oil cans, the potter who depends upon individual contributors for his fuel will find that a standard galvanized metal funnel will be of service in the gathering operation. The funnel should have a diameter of at least six inches at the top and its smaller end should measure at least one inch across to insure an easy and quick flow of the oil through the device. Some farm supply outlets and hardware stores feature a funnel which includes a screen or strainer in the design. This variety will perform an early cleaning operation on

the fuel while it is used in the gathering stage of the potter's waste oil plan.

Experience with waste oil gathering procedures has also indicated that a good supply of cleaning rags should be kept on hand when gathering the fuel. Accidents have been quite frequent when gathering the oil and a supply of rags will help to avoid the depressing experience of transporting part of the mess of spilled or splattered oil into the fuel gathering vehicle and back to the potter's studio and kiln area. Needless to say, the potter will also do well to have an old pair of coveralls or a heavy smock to protect his clothing during the gathering stage of his waste oil operation.

#### Commercial Oil Service Stations

Service stations which change oil for their customers have provided the majority of the waste oil used in this study. Most stations are equipped with a storage tank for the waste oil. These tanks range from fifty-five gallon drums located above the ground to very large underground tanks with capacities of five hundred to one thousand gallons. The equipment needed for the potter's gathering operation will depend upon the waste oil storage facilities of the stations located in the vicinity of the kiln site. In other words, the potter may find that a station which uses a small fifty-five gallon drum for its storage will require only a minimum investment in equipment to gather the oil from the drum, but another station in the area may have a very large underground tank for the waste oil and the fuel gathering operation will require a more expensive pump to extract fuel from the large tank.

If filling stations are to provide a sizable percentage of the waste oil kiln fuel, the potter should first contact the station

managers in his area and attempt to get permission to gather fuel from their establishments. At that point, the potter will also have a chance to inspect the individual storage facilities of the stations and he will be able to gain an idea of the equipment which will be needed to extract the fuel from their tanks.

Stations which use the smaller storage drums located above the ground will prove to be the most attractive fuel source to the potter who is concerned about the cost of his equipment. If these smaller drums are open at the top, the potter will be able to gather the waste oil by dipping the fuel from the container with a gallon can and pour the fluid into a funnel placed in a five gallon oil can. This method of fuel gathering is the cheapest process, but it is also the most time consuming process recorded in the study. This simple method has also proved to be very messy and will require provisions for cleaning the gathering equipment, before the fuel and equipment can be transported back to the kiln site.

The potter will discover that stations which use the fifty-five gallon drums for storage prefer to maintain a securely covered top on the container, so the potter's task of removing waste oil from the drums is usually more complicated than simply dipping and pouring the fuel. The covered drums contain two small bungs or openings at the top which make gathering the fuel possible, but restrict the potter to the use of a small manual pump or to tipping the drum in an effort to pour the waste oil from the containers. Any effort at trying to pour from the drum has proven to be physically taxing and very dangerous due to the weight of the drum with a quantity of fuel in it. The study does not suggest trying to pour from these drums, but rather to invest in a simple and

reasonably priced pump which should make fuel gathering from covered drums much easier.

The 'Serv-Al' pump model P-100 has been advertised to handle all lubricants, gasoline, kerosene, and alcohol. It will fit the openings or bungs of any closed fifteen, thirty, or fifty-five gallon drum and it has an overall length of forty-two inches. This pump will cost the potter between seven and eight dollars and is available through most local farm supply outlets. The device operates through the upward manual stroke of its handle and its original spout can be replaced by the female coupling of a short length of common garden hose. When the potter has replaced the spout with six to eight feet of hose, he will be able to pump waste oil from a covered drum and into his five gallon oil cans resting on the ground near the drum. This arrangement will free the potter to use both hands to operate the pump. The bottom of the 'Serv-Al' pump tube will also receive a small screen or strainer affixed with wire to keep large foreign matter out of the pump, hose, and fuel.

The aforementioned 'Serv-Al' pump will not help the potter when large tanks are involved. The overall length of the 'Serv-Al' allowed the user to penetrate the storage container only three feet. The surface of waste oil in the large underground tanks will often remain well below this depth.

A number of more expensive pumps are available for the potter who must gather his fuel from these large tanks, providing he can afford to pay at least fifty dollars for the device. The 'Wane Double-Diaphragm' pump has proven to be of service when gathering waste oil from the larger

tanks.<sup>161</sup> This pump will cost around \$50.00 and can be adjusted to the potter's need by replacing the original pump shaft with a variety of one inch pipe extensions to reach the waste oil levels in the large tanks.<sup>162</sup> This pump has been available through most farm supply outlets but the cost of the device may force the potter to avoid its luxury.

In addition to a pump, fuel gathering will require a transportation vehicle, cleaning rags, old cloths, and gathering containers such as the five gallon oil cans mentioned earlier in the study. If the potter has planned on handling quantities of fuel larger than twenty gallons in each trip from the fuel source to the kiln site, he may choose to replace the five gallon oil cans with larger containers, such as fifteen or thirty gallon oil drums. These larger containers will require adjustments in the fuel gathering process, for they are too large and heavy to be manipulated safely by one person. Therefore, they will force the potter to seek help in the process of gathering the waste oil. Larger containers will also force the potter to rely upon a small truck for his fuel gathering vehicle.

At this point in the discussion of fuel gathering, the study must mention that a variety of laws have governed the storage of petroleum liquids such as waste oil. The potter should seek information concerning the laws which govern his area or location. He will find that most commercial filling stations have been forced to store waste oil in large

---

<sup>161</sup>Statement by Harold Moore, a pottery student at Kansas State University, who has had experience with the use of an adjusted 'Wane Double-Diaphragm' pump for gathering waste oil, personal interview, September 7, 1974.

<sup>162</sup>Ibid.

tanks located underground because of the federal, state and municipal laws in that area. Of course, the laws do not restrict the potter from removing the liquid from the tanks for his own use as a fuel, but problems of extracting the fuel from these tanks require an additional expenditure for improved gathering equipment.

#### Industrial Sources for Waste Oil Fuel

The final source for waste oil in this study involved industrial wastes and used engine cleaning fluids. The experimenter has had little experience with fuel sources of this type. However, at least one California potter, Al Kinkel, has been using Diesel engine scrap cleaner from an industrial source for his fuel.<sup>163</sup> The potter may be located in an industrial area where suitable chemicals or petroleum products are available as waste fuel for his kiln.

A word of caution should be inserted at this point. Many cleaning fluids have very low flash points and will prove quite hazardous if used as kiln fuels. The potter should check his fuel source and inquire as to the flash point of the waste material before using it to fire a kiln. Even when filling stations and individual waste oil contributors have served as the fuel source the potter should proceed with caution, for the oil from these sources may be contaminated or diluted with gasoline which was used to clean engine parts. The diluted oil will have a dangerously low flash point and should be avoided as a kiln fuel, keeping safety in mind.

---

<sup>163</sup>Based on personal correspondence between Al Kinkel, California potter teaching stoneware at Opus 4, Morrison, Colorado in July, 1973, and the writer.



## CLEANING THE FUEL

With the use of waste oil as a fuel source for firing ceramics, the potter will discover that a few very simple cleaning methods employed between the gathering process and storage will aid his firing system by removing any large foreign matter which may clog the feeder pipes, control valves and the orifice of his burner system. Cleaning methods will also remove part of the oil sludge caused by the oxidation of the oil while in engine service. This product of oil oxidation will usually be of an acid nature and if it is permitted to collect and remain for any appreciable period in the storage tank it will cause corrosion. The simple fuel cleaning methods suggested in the study have involved (1) screening or straining the fuel and (2) settling of the heavier sludge and water out of the fuel mixture.

### Screening the Fuel

The study has already noted the possibilities of performing an early cleaning activity on waste oil as it is being gathered through the use of screened funnels and by attaching a screen to the bottom of the potter's gathering pump tube. A secondary screening of the fuel will prove very useful when the potter has poured the fuel from his gathering containers into his settling container. The second screening will insure that all of the larger materials such as leaves, twigs, pieces of engine gaskets and so forth common in waste oil will remain out of the kiln burner system. Regular fifteen mesh window screen has served quite well as a device for straining the fuel. On other occasions a kitchen strainer has performed the cleaning service on the fuel used in the study. A variety of fabric materials, such as cheese cloth, have also

proven useful to aid in fuel cleaning. The study has noted that when materials of a very fine weave, such as undershirt material, were used they soon collected a coat of oil sludge and slowed the straining process. These fine weaved fabrics should be avoided to insure a quick and smooth straining process for fuel cleaning.

### Fuel Settling

An upright fifty-five gallon drum has served as a settling container for cleaning the waste oil of this study. The top of the drum was removed and a metal cover was fabricated to fit over the drum and prevent contamination of the fuel after it was strained. A period of ten days of quiet undisturbed settling has proven to be sufficient time for the fuel to rise above any water and sludge in the waste oil. At the end of this allocated time, the oil was siphoned, dipped or pumped off of the water and sludge deposits in the bottom of the settling tank. This fuel often remained in the settling tank for more than 10 days with no detrimental effect noticed.

### FUEL STORAGE

The fuel storage arrangement for the study involved a second fifty-five gallon drum placed upright near the fuel settling container. The fuel was not moved up into an elevated tank for burner feed until the firing cycle was to start. This arrangement allowed for a second settling stage and kept any additional settling of water and sludge out of the bottom of the elevated burner feed tank where it could clog the kiln burner system. Of course, one settling drum would have served the study with the fuel remaining in that drum until firing was to begin. A second

settling drum was available, however, and the experimenter was able to exercise a greater degree of control in the cleaning of the fuel.

Fuel storage during the kiln firing cycle was accomplished in the study using a fifty-five gallon drum elevated at least five feet above the burner system of the kiln. The drum was placed horizontally on a stand with the larger bung for fuel input at the greatest height. The smaller bung was adjusted below to receive the burner feed and control devices of the burner system. This storage-feeder tank was kept at least six feet away from the kiln burners for safety reasons.

The study has suggested that the potter check the local fire regulations for his area before he decides upon the placement of his fuel storage and feeder tanks.

## Chapter 5

### THE DESIGN, CONSTRUCTION AND OPERATION OF A WASTE OIL BURNING SYSTEM

Three years of experience using waste oil as a kiln fuel have provided the information in this chapter of the study.

In the early stages of the project, the remarks of Paul Soldner were primary considerations regarding the overall improved combustion efficiency of a forced air system. On page 34, Chapter Two, this study recorded that Soldner suggested that the fuel consumption of a natural draft operation usually involved double the quantity needed to fire the same kiln to the same temperature with a forced air system.<sup>164</sup> With these remarks in mind, the experimenter chose to concentrate on the use of forced air burner systems of the Soldner variety. With a time limitation on the study, practical experimentation in the use of water injected natural draft burners was left out of the study, in spite of the apparent potential of these simple systems.

The following information has been divided into two sections:  
(1) the design and construction of a waste oil pipe burner and (2) the operation of that waste oil system.

---

<sup>164</sup>Statement by Paul Soldner, personal interview, August 13, 1973.

## THE DESIGN AND CONSTRUCTION OF A FORCED AIR WASTE OIL PIPE BURNER SYSTEM

In keeping with the restricted financial situation of the project, the experimenter discovered that the design and construction of the pipe system could be accomplished with a minimum of cost. Table 2 has listed the price ranges and sources of the materials used to construct the waste oil system of this study.

### Fuel Storage and Burner Feed

Chapter Four noted that a fifty-five gallon drum was placed on a five foot stand in a horizontal position with the large input bung at the top and the small bung at the bottom, Figure 13. The smaller bung received the male coupling of a common water gate valve which served to regulate the flow of the fuel from the tank to the burner feed hoses.

The stand for the storage tank was constructed of scrap two-by-fours. However, experience has suggested that a welded metal stand with locking rollers would aid in the problem of moving the tank and fuel around the potter's kiln area.

A four-inch section of one-quarter inch copper tubing was inserted and secured into the outward end of the water gate valve in the fuel tank. A copper 'T' was attached to this piece of tubing. Two lengths of four-inch copper tubing of the same diameter were secured into the 'T'. Two eight-foot lengths of garden hose were clamped onto the two copper extensions in the 'T' with automobile hose clamps. For reasons of safety, each of these lengths of hose reached to the kiln burners without requiring the location of the tank to be within six feet of the kiln during operation. Near the burner, two six inch

Table 2

## Equipment for the Waste Oil Burning System

| Quantity, item and source                        | Cost    |
|--|---------|
| Gathering, cleaning and fuel storage             |         |
| One funnel: hardware store                       | \$1.00  |
| Four, five gallon oil cans: farmer's cooperative | \$10.00 |
| Two, fifty-five gallon oil drums                 | no cost |
| Sixty feet of used two-by-fours for tank stand   | no cost |
| Two square feet of common window screen          | no cost |
| Oil rags   | no cost |
| One fuel handling smock                          | no cost |
| One 'serv-al' pump: farmer's cooperative         | \$6.95  |
| Burner feed                                      |         |
| Eight automotive hose clamps: auto supply store  | \$2.65  |
| Sixteen feet of used garden hose                 | no cost |
| One water gate valve                             | no cost |
| Twelve inches of 1/4" copper tubing              | no cost |
| One copper 'T' of 1/4" diameter: plumber         | no cost |
| One copper tubing adapter: plumber               | \$ .20  |
| Plumber's service charge                         | \$2.00  |

Table 2 (continued)

| Quantity, item and source  | Cost    |
|--|---------|
| Two Waste Oil Burners  |         |
| Two water gate valves  | no cost |
| Two threaded 1/4" by 6" black pipes  | no cost |
| Two threaded 1/4" by 16" black pipes   | no cost |
| Two, 2" by 12" black pipes   | no cost |
| Welding service for the burners  | no cost |
| Two Blowers  |         |
| Two used 'Compact' vacuum cleaners with hoses:<br>Kirby vacuum cleaner store | \$14.10 |
| Total cost   | \$37.10 |

Quantity, item and source: These entries were taken from the specific study experience of the potter. The quantity and item will vary according to the waste oil burner design and the number of burners needed by the potter. The sources of these items will depend upon the individual potter's location and his own resourcefulness.

Cost: The cost of the equipment has been subject to inflation. As a result, the entries in this table reflect the prices which were paid for the items between January, 1972 and December, 1974. Many of the items which were purchased for the study could be obtained without an outlay of funds. Other items of equipment which cost the potter nothing may not be so cheaply available to other potters.

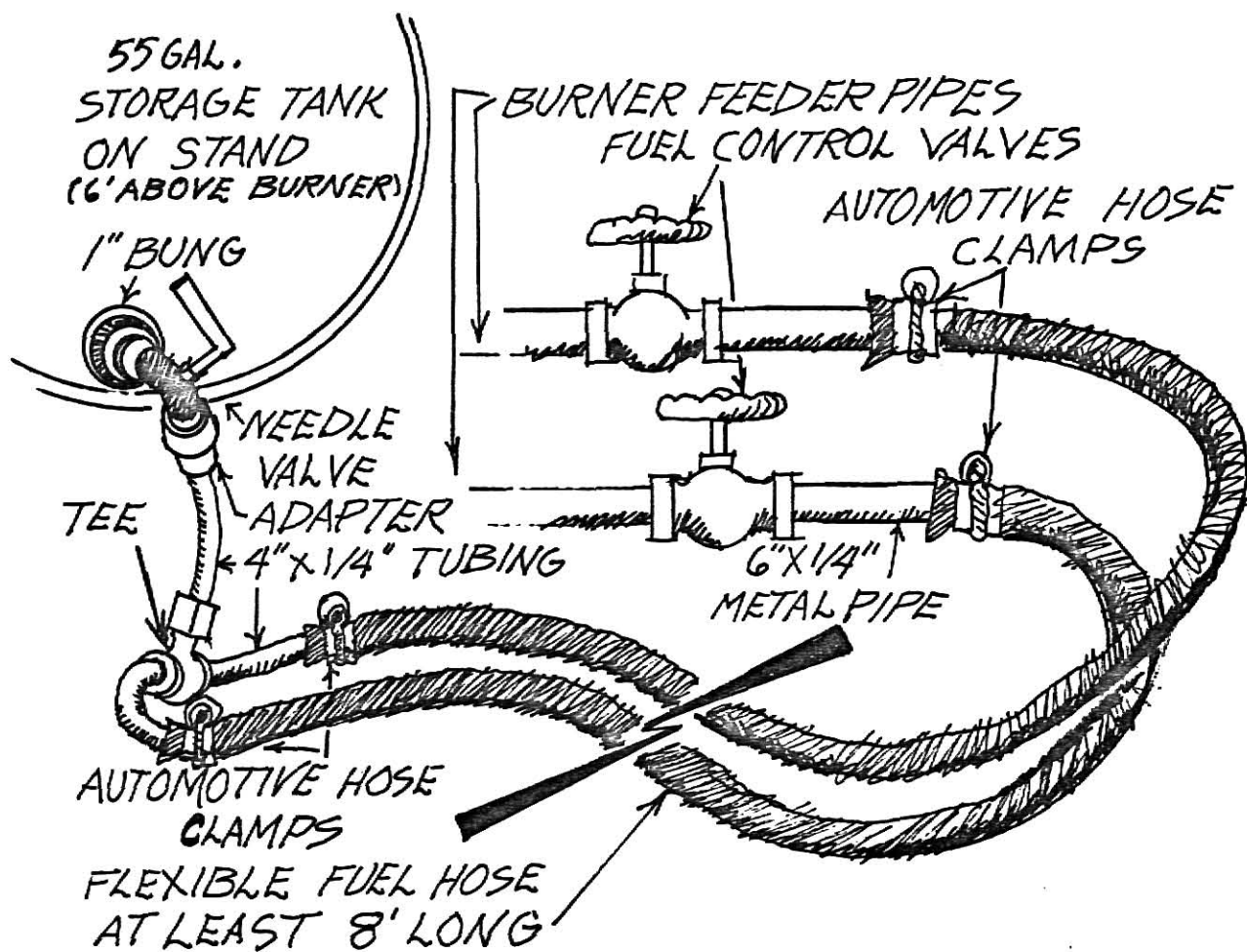


Figure 13

Fuel Storage and Burner Feed for the Study



lengths of one-quarter inch pipe were inserted two inches into the hose and clamped in place using automobile hose clamps. The extensions of pipe were then secured to the threads of fuel control valves at the burners.

#### The Oil Burners

The form of the burner construction resembled the design illustrated at the top of page 31, Figure 8. The two burners of the project were constructed of twelve-by-two inch pipes. These pipes were penetrated by two sixteen-by-one-quarter inch pipes welded into position to serve as fuel feeder pipes for the burners. One end of each feeder pipe served as an orifice for each burner. These ends were positioned inside and almost even with the ends of the larger burner casings. The other ends of the feeder pipes were threaded to fit common water gate valves for fuel control in the system. Plate I has represented the potter in the act of adjusting one of these fuel control valves during kiln operation.

#### The Blowers

The blowers for the forced air burners were old 'Compact,' air-cooled vacuum cleaners. Two of these blowers were used to provide the forced air for the two burners of the kiln system. The flexible hoses of these vacuum cleaners were removed from the front or suction end of the devices and placed into the exhaust ends of the equipment. The dust sacks of the cleaners were removed and the covers over these dust collection areas were kept open during operation. This allowed free passage of air into the self-cooling machines. When full air capacity was needed in the burner system, the other ends of the blower hoses

**THIS BOOK  
CONTAINS SEVERAL  
DOCUMENTS THAT  
ARE OF POOR  
QUALITY DUE TO  
BEING A  
PHOTOCOPY OF A  
PHOTO.**

**THIS IS AS RECEIVED  
FROM CUSTOMER.**

PLATE I



A PHOTOGRAPH OF THE POTTER ADJUSTING THE FLOW OF WASTE OIL FUEL WITH A VALVE  
LOCATED WELL AWAY FROM THE RADIANT HEAT OF THE BURNER  
PORT AND KILN FIREBOX

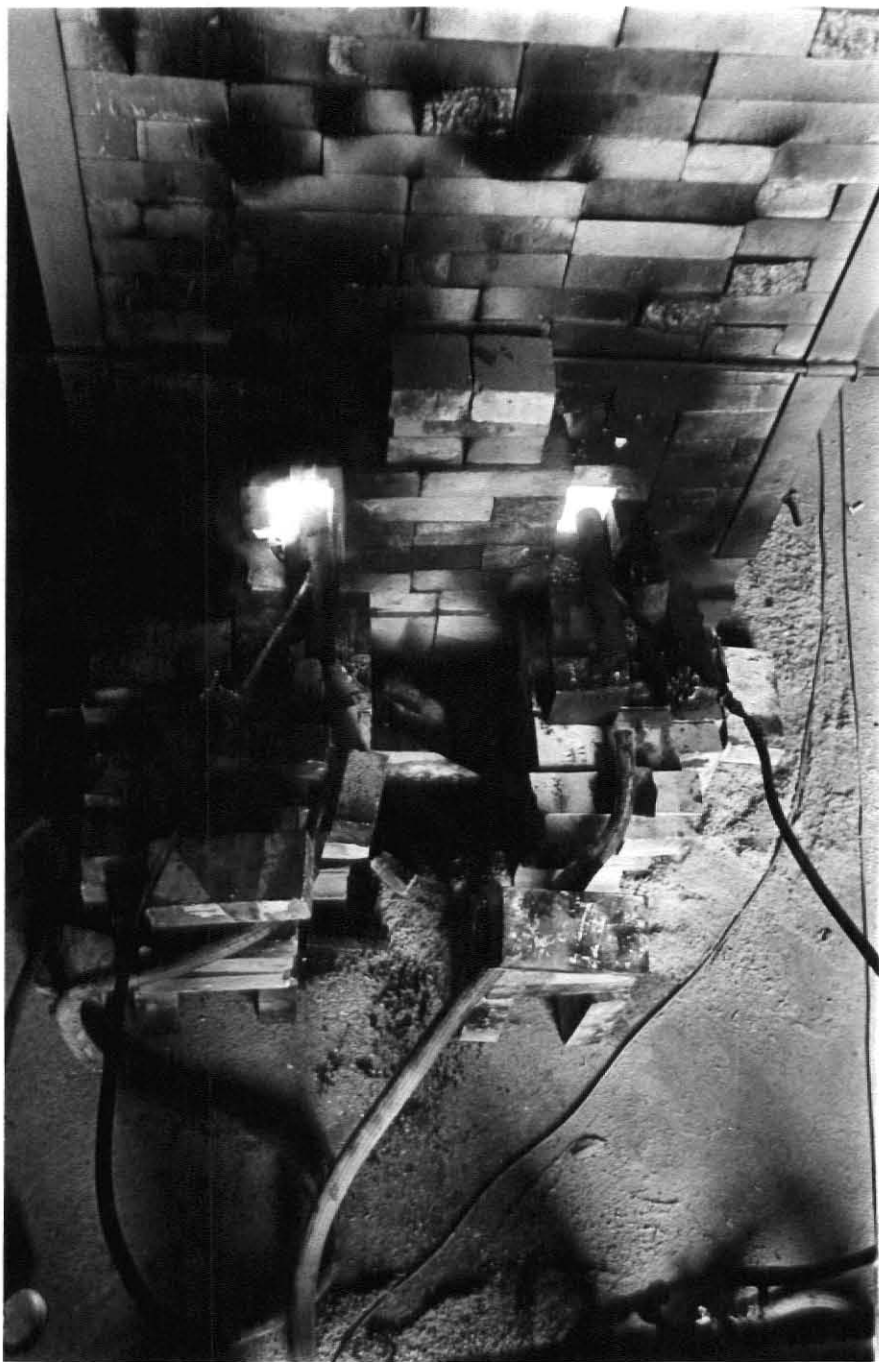
were placed into the two inch pipe casings of the burners. However, when a restricted air force was desired, the air hoses were backed off and secured six inches in line with the rear of the burner casings. Plate II has represented this system. Adjustable bricks were placed between the air hoses and burners to serve as air gates to regulate the air flow from the blowers. The air hoses were held in position with bricks to avoid any slipping which might develop to vary the quantity of air going to the kiln through the burner casings.

A loss of air for the system could have resulted, as well, from the accidental disconnection of the electrical power cords for the blowers. As a result, the power cords were kept away from any well trafficked areas around the kiln. When possible the cords were secured at the outlet to avoid accidental disconnection. Any connections between two different cords were looped and taped together to avoid a loss of air or blower power.

#### The Natural Gas Preheat Burners

Although the earliest experiments were undertaken using waste oil as a preheat fuel in the kilns, the potter turned to natural gas as the fuel for preheating the later experimental firings. Natural gas preheat burners were constructed for this time and effort saving addition to the firing system. These burners were of the 'Alfred' variety, Figure 14. They were constructed to operate on six ounces of natural gas pressure in the fuel lines. At the time of their making, each burner cost \$7.82 to construct of common materials. Table 3 has listed the materials needed for these burners, as well as, the cost of each item in the devices.

## PLATE II



AN OVERHEAD VIEW OF THE FORCED AIR SYSTEM SHOWING HOW THE  
BRICK AIR CONTROL GATES WERE POSITIONED BETWEEN THE  
VACUUM CLEANER HOSES AND THE BURNERS

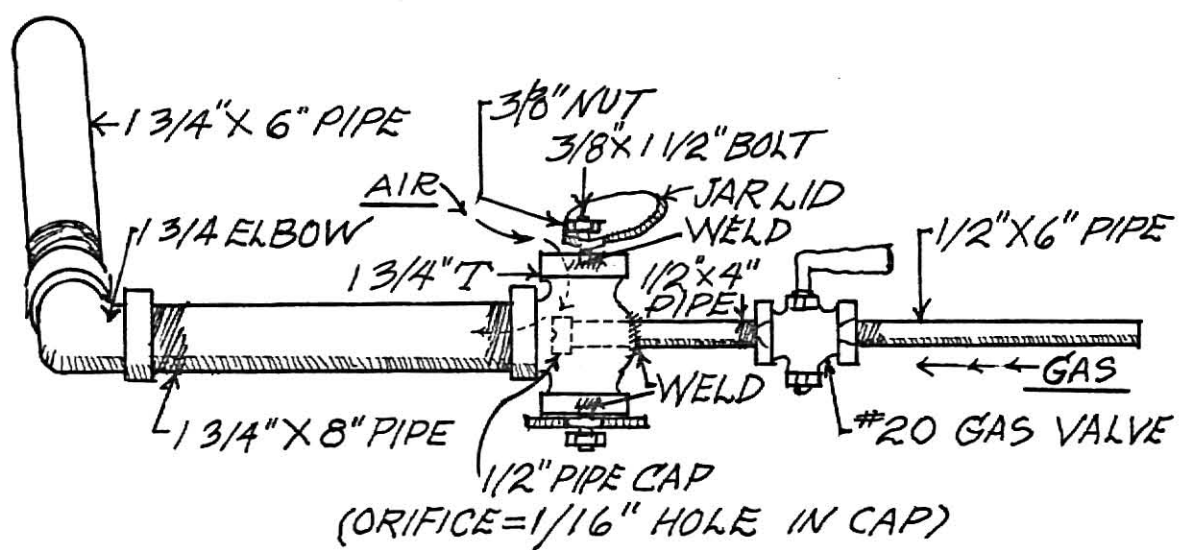


Figure 14

The 'Alfred' Preheat Burner

Table 3  
Equipment for the 'Alfred' Preheat Burners

| Quantity and item          | Cost    |         |
|----------------------------|---------|---------|
|                            | Each    | Total   |
| Two, #20 gas valves        | \$2.59  | \$5.18  |
| Two, 1 3/4" by 8" pipes    | \$ .95  | \$1.90  |
| Two, 1 3/4" by 6" pipes    | \$ .65  | \$1.30  |
| Two, 1 3/4" elbows         | \$ .95  | \$1.90  |
| Two, 1 3/4" (T's)          | \$1.35  | \$2.70  |
| Two, 1/2" by 4" pipes      | \$ .30  | \$ .60  |
| Two, 1/2" by 6" pipes      | \$ .65  | \$1.30  |
| Two, 1/2" pipe caps        | \$ .16  | \$ .32  |
| Four, 3/8" nuts            | \$ .04  | \$ .16  |
| Four, 3/8" by 1 1/2" bolts | \$ .07  | \$ .28  |
| Four, common 3" jar lids   | no cost | no cost |
| Total cost                 | \$7.82  | \$15.64 |

A great variety of cheap and easily-constructed designs for gas burners have been published in recent years. The potter may choose to survey these designs to arrive at a preheat system for his particular waste oil kiln.<sup>165</sup>

### The Kilns

The forced air waste oil pipe burners were used to fire three different kilns. The greatest amount of experience was gained through the operation of a twenty-four cubic foot downdraft reduction stoneware kiln which was constructed for the study. Views of this kiln have been presented in Plates III and IV. A second stoneware salt kiln became available for experimentation after a year of working with the reduction stoneware kiln. The second kiln, a seventeen-cubic-foot downdraft salt kiln, had to be converted from a natural gas system to make it function with waste oil as its fuel. This kiln has been pictured in Plates V and VI. A third kiln, one for Raku firing, was also used to familiarize the writer with the special problems of the waste oil Raku process. The Raku kiln has been represented in Plate VII.

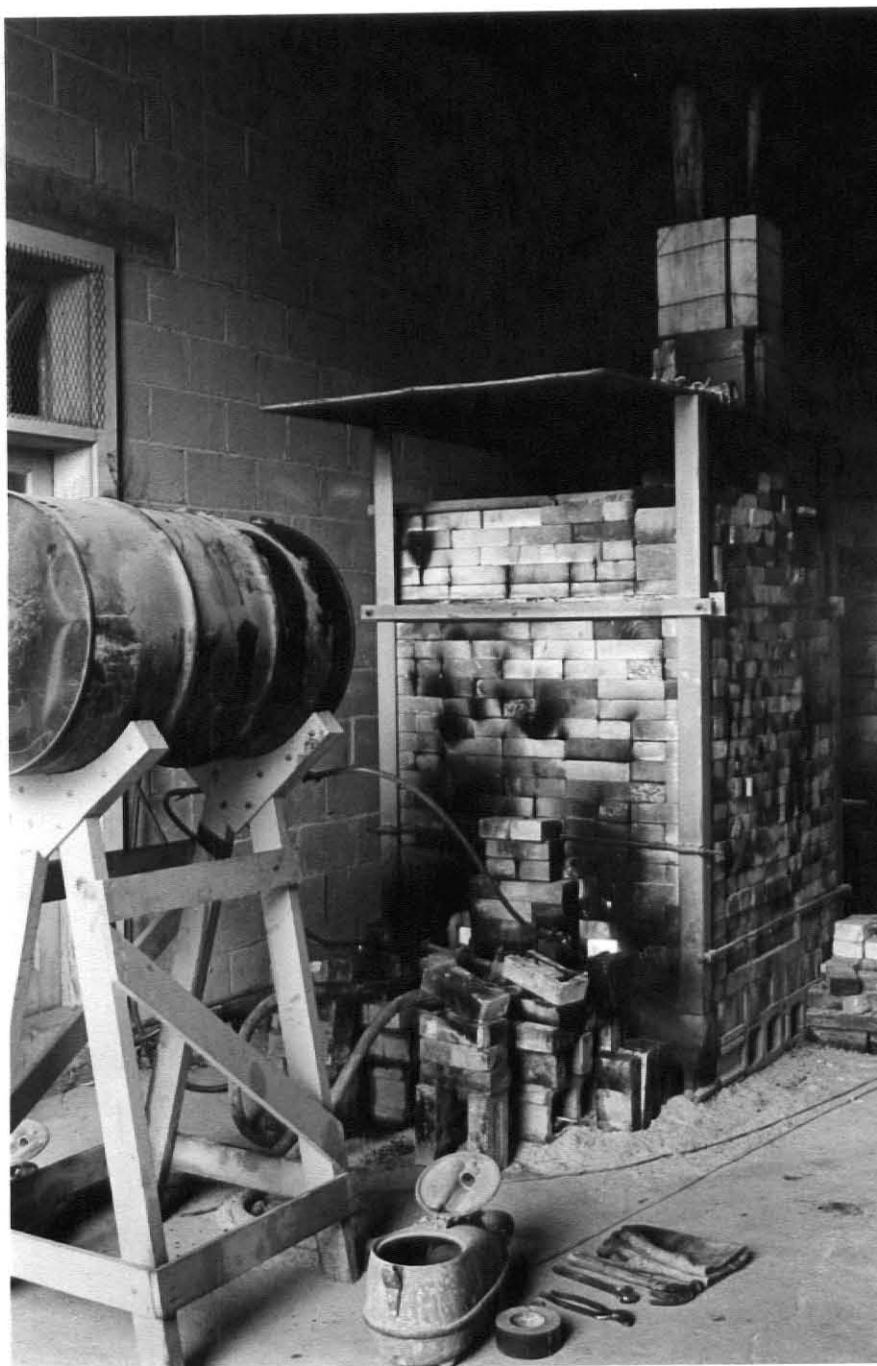
The following remarks will avoid a detailed account of the entire kiln construction and all of the adjustments which were made in the course of the waste oil experimentation. The reader will remember that the forced air pipe burner was only a mixing device for the fuel and air. Without a hot kiln fire box and chamber the device would be

---

<sup>165</sup> Daniel Rhodes, Kilns: Design, Construction and Operation (Philadelphia: Chilton Book Company, 1968), p. 76; see also Frederick L. Olsen, The Kiln Book (Bassett: Keramos Books, 1973), p. 94; see also Robert Piepenburg, Raku Pottery (New York: The Macmillan Company, 1972), pp. 107-111; see also Paul Soldner, "Letter: Firing with Oil Diagrams," Craft Horizons, No. 2, XXVIII (March/April, 1968), 7.

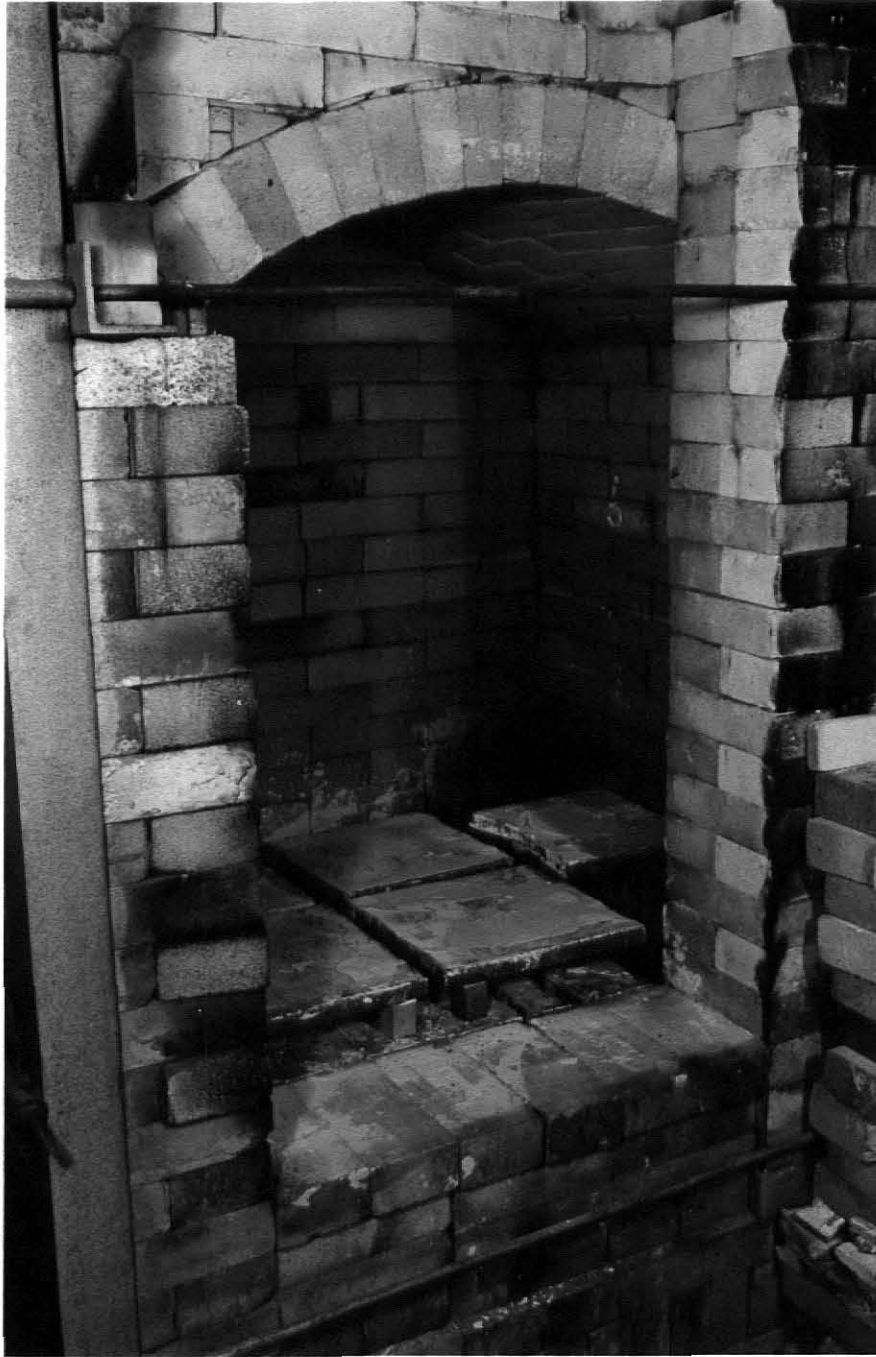


## PLATE III



AN EXTERIOR VIEW OF THE REDUCTION STONEWARE KILN WITH ITS  
WASTE OIL BURNER SYSTEM IN OPERATION

## PLATE IV



AN INTERIOR VIEW OF THE REDUCTION STONEWARE KILN SHOWING THE  
TWO FIRE CHANNEL OPENINGS THROUGH WHICH GASES OF  
COMBUSTION RISE INTO THE WARE CHAMBER

## PLATE V



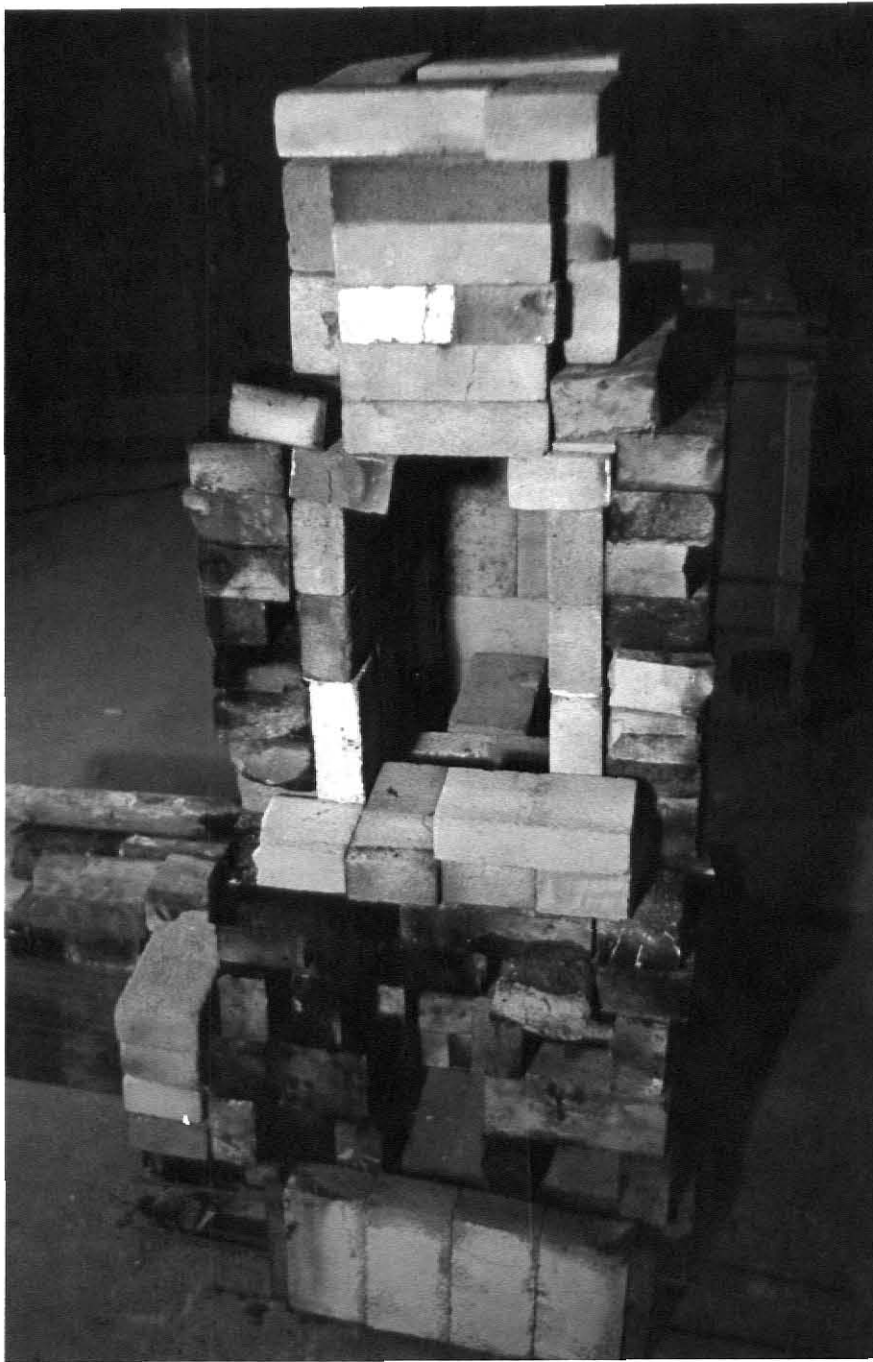
AN EXTERIOR VIEW OF THE STONEWARE SALT KILN

## PLATE VI



A CLOSER VIEW OF THE SALT KILN SHOWING THE BAG WALL  
BRICKS OF ONE 'HOT-SPOT' FIREBOX

## PLATE VII



A PHOTOGRAPH OF THE RAKU KILN SHOWING THE OPENING OF THE  
'HOT-SPOT' FIREBOX LOCATED UNDER THE FLOOR  
AT THE BACK OF THE KILN

valueless; it could not support a flame. Therefore, the study must include a few remarks concerning the most critical combustion areas of each of the three kilns fired with this burner system.

The combustion, flue, and stack areas of the reduction stoneware kiln. The firebox and bagwall in the reduction stoneware kiln were designed and developed with plans which made later adjustments in the combustion areas of the kiln possible. Many arrangements were attempted with the flexible burner ports and floor design. However, the most successful arrangement for this kiln was a construction with two burner ports located nine inches from each corner of the inlet flue wall of the kiln. The kiln used nine inches of wall brick, so these ports were located eighteen inches from the outside corners of the kiln. The ports were placed five inches below the floor level of the kiln. They injected the fuel and air from the burners into fire channels which measured seven inches wide and five inches deep. The channels extended the inside length of the kiln in order to release the combusting gases from the burner up into the kiln chamber on the side opposite the burner ports. Openings were positioned in the kiln floor for this purpose, forming a firebox space across the kiln chamber which measured nine inches out from the kiln wall. No bagwall was needed in this arrangement; the flames simply passed under the kiln floor and up into the chamber on the side opposite the burner ports.

One of the discoveries of the study involved the use of a six by thirty-six inch pipe casing which was cut into two half-tube strips. Each of the two strips were placed in the bottom of the two fire channels under the floor of this kiln. These half-tubes functioned to

insure that the cooler air and fuel from the burner ports would be quickly exposed to heat radiated from the metal casing floors of the fire channels. This arrangement improved the combustion in the kiln.

The use of the half-casings also helped to avoid another problem which soon developed in the stoneware kiln. The primary air and fuel often kept the fire channels quite cool near the burner ports. Fuel would seep into the bricks of the kiln in this area. With the progression of the firing cycle, the oil would eventually reach the outside wall of the kiln case creating a fire hazard on the ground near the burners. The pipe halves in the floor fire channels helped to avoid this problem by keeping more of the fuel evaporating and combusting for kiln energy. Heat collected in the metal on one end of the pipe halves would transfer back to the burner port area where the fuel and air were much cooler.

A central channel was formed between the two outside fire channels under the kiln floor. This central channel opened into the kiln chamber on the burner port side of the kiln. It served to draw the exhaust gases from the kiln chamber and carry them back under the floor to the flue and stack. A damper was positioned on this flue channel near the stack to regulate the exhaust flow and control the atmospheric conditions of the kiln.

The stoneware kiln shared a common thirteen foot stack with the experimental salt kiln of the study. The inside dimensions of this common stack measured nine inches by nine inches.

The combustion area of the salt kiln. As stated earlier, the experimenter was forced to work with the existing construction of this

salt kiln in converting the burner system from one using natural gas to one using waste oil. The 'hot spot' firebox design, mentioned earlier in the study, seemed to offer the best solution to the problems of converting the salt kiln to waste oil. The design of the kiln necessitated locating the fireboxes near the kiln door. These fireboxes measured four-and-one-half by nine by thirteen inches. They were placed just inside the kiln chamber at the outside corners of the kiln wall of door bricks. The burner ports were located four-and-one-half inches below the floor level of the ware chamber, and they delivered the air and fuel from the burners directly into the fire boxes. The 'hot spot' firebox design was very successful. It avoided fuel seepage around the burner ports and it quickly changed the liquid fuel to a combustible gaseous state.

The location of the fireboxes near the kiln door, however, posed another problem in the study. The natural activity of the sodium vapor of the salt kiln at elevated temperatures has been known to cause minor problems in the firing process by glazing the door bricks of the kiln together. The salt kiln of the study forced excessive heat near the door with the result that the door bricks fused together. After the kiln had been fired and cooled, the act of opening the chamber proved quite difficult. The study suggests that the 'hot spot' fireboxes be located well away from the door of salt kilns fired with waste oil.

One of the big advantages of the 'hot spot' firebox was its restricted size. The small firebox insured that the majority of the kiln chamber space could be used for the potter's ware. Because ware placed too close to the hot spot above the fireboxes received a greater



amount of heat and overfired, care should be taken when stacking the chamber.

The Raku kiln. A very simple kiln was constructed for the Raku firings in the study. It was composed of walls seven inches thick and a corbel arch. The ware chamber measured roughly three cubic feet. A nine by eighteen by eighteen-inch 'hot spot' firebox was located below the chamber floor.

Experience with this simple kiln for Raku has indicated that a cast floor and wall for the firebox would help to avoid much of the seepage which resulted at the lower portions of the kiln in the early stages of the firing. The single burner port delivered the fuel and air from one burner into the firebox with such force that the kiln fire resulted in a great deal of fuel, smoke, and flame seepage while the area was being heated. After the firebox gained enough temperature to insure a rapid evaporation and combustion of the fuel the problem of seepage was reduced.

#### THE OPERATION OF A FORCED AIR WASTE OIL PIPE BURNER SYSTEM

The firing techniques of reduction stoneware, salt-glazed stoneware and Raku will be covered in this section. Considerable space has been devoted to the firing process which was developed for the reduction stoneware kiln. This space was required to explain the need of a particular method of kiln operation which would overcome some of the characteristic disadvantages of waste oil combustion.

### Operation of the Reduction Stoneware Kiln

With at least forty gallons of clean fuel in the feeder drum, the burner system ready for operation, and pottery in the kiln stacked ready for an ordeal by fire, the reduction stoneware kiln could be placed into operation.

In addition to the above preparations, a final safety concern involved an accessible location for a fire extinguisher, wrench, pliers, and other tools which were often needed in short order. When care was not taken to keep an order and place for these tools, the experimenter was usually forced to close down the firing system while he looked for his equipment to correct a problem in the kiln operation. The equipment shut-down was avoided when the tools were positioned within arms reach of the potter working near the burner ports of the kiln.

Preheating the kiln. As mentioned, the earliest firings with the reduction stoneware kiln were started using waste oil as the fuel for preheating. The process involved positioning oil saturated newspapers or rags directly inside the burner ports of the kiln. These combustibles were ignited. The valves of the oil burners were positioned so that the burners would drop a very slight amount of fuel into the fires in the burner ports. With tedious attention, a balance of fuel and atmospheric air was obtained to sustain the fire. After an hour of atmospheric combustion, accompanied by smoke, seeping fuel, and the danger of the fire being extinguished by a gust of wind, the forced air of the system was placed into operation.

Bricks were placed between the blower hoses and the burners to restrict the flow of air into the burner ports. After the blowers were

started, the brick air gates were moved back just far enough to allow a slight amount of the forced air to pass into the burners. One-sixteenth inch was often too great a gap in the blower system air gates. Even a slight amount of air could cause the flames in the burner ports to be extinguished. However, with patient attention, the systems were adjusted to allow more fuel flowing into the fires and more air from the blowers moving into the combustion.

When preheating the reduction stoneware kiln with waste oil, the operation always resulted with fuel seepage and excessive smoke in the first hours of operation. The method of preheating also required a great deal of time and attention, but the earliest firing experiments indicated that the fuel could be used with limited success as an agent for preheating the kiln.

As mentioned, later experimentation concerned a system of preheating the kiln fireboxes and chamber with natural gas. This gas preheat process involved the slow but effortless operation of lighting the preheat burners on the evening before the major portion of the firing was to take place. These burners were allowed to heat the kiln to a black-red cast, indicative of 885°F. The burners avoided the problems of smoke and fuel seepage which accompanied the use of waste oil for the preheating job. To change the kiln fire from natural gas preheat to waste oil, the oil burners were inserted into the fire ports along the side of the gas preheat burners. The preheat burners were allowed to burn with the first stages of the waste oil combustion process. When the oil appeared to burn with consistency, the preheat burners were turned off and removed from the burner ports.

Water smoking and quartz inversion. After a period of from four to six hours when preheating with waste oil, or a night of slow preheating with natural gas, the kiln chamber began to show indications of sufficient temperature for the critical periods of water smoking and quartz inversion. The aforementioned black-red cast, indicative of around 885°F. served as a warning of the changes which would soon be taking place in the pottery. The burners and blowers were left at a constant setting for a period of at least one hour to insure that the heat rise would not be too fast and therefore cause flaws in the clay body of the ware.<sup>166</sup> The temperature in the preheated kiln chamber rose quickly using waste oil as the fuel.

Sulfur control in the kiln operation. Every effort was made to keep an oxidation atmosphere in the kiln chamber during the early stages of the first experimental firings of the study. The early stages of later firings were intentionally controlled to force the kiln atmosphere to move back and forth between oxidation and mild reduction. The reason for this change in the original operation plan concerned problems with sulfur in the kiln atmosphere.

---

<sup>166</sup>The following sources have been provided for the potter who may be unfamiliar with the physics and chemistry of water smoking, quartz inversions and the many other changes which take place over the duration of a stoneware firing cycle:

<sup>a</sup>Glenn C. Nelson, Ceramics, A Potters Handbook (New York: Holt, Rinehart and Winston, Inc., 1971), pp. 278-280 and 309.

<sup>b</sup>Daniel Rhodes, Clay and Glazes for the Potter (New York: Greenberg: Publisher, 1957), pp. 12-16, 148-159 and 171-181.

<sup>c</sup>W. G. Lawrence, Ceramic Science for the Potter (Philadelphia: Chilton Book Company, 1972), pp. 111-168.

<sup>d</sup>Alfred B. Searle, The Chemistry and Physics of Clays and Other Ceramic Materials (New York: Van Nostrand Company, 1926), pp. 544-584.

As the temperature rose from dull black-red, water smoking range, to the yellow-orange temperatures of from 1650°F. to 2000°F., sulfur from the waste oil fuel was found in the kiln atmosphere. This presence of sulfur was evident in the form of a variety of glaze flaws. More information regarding these flaws will be mentioned in the next chapter.

Investigating causes for sulfur flaws, the potter found that most of the recent publications dealing with kiln firings and glaze flaws made little mention of the effects of sulfur in the kiln atmosphere. It seemed that the vast majority of potters working in recent years have depended upon natural gas and other low sulfur fuels. As a result, the potter turned to publications dating from 1900 to 1950 hoping to find information regarding the effects of sulfur in the kiln. In those years, fuel oil and coal were common sources of kiln energy, and sulfur was a problem for potters and ceramic manufacturers of that time. Those publications contained information regarding the use of high sulfur fuels.

The results of the investigation indicated that sulfur from the waste oil was reacting with the unfused and partly-fused glazes in the kiln during the early stages of the firing.<sup>167</sup> The sulfuring took place most readily around the water smoking period of the fire. When the kiln was firing under oxidation conditions and over that temperature range, the sulfur took the form of  $\text{SO}_3$  when combined with the glaze chemicals.

---

<sup>167</sup>Cullen W. Parmelee, Ceramic Glazes (2d ed.; Chicago: Industrial Publications, Inc., 1951), pp. 301-302 and 307-313; see also Alfred B. Searle, The Chemistry and Physics of Clays and Other Ceramic Materials (New York: Van Nostrand Company, 1926), pp. 369, 491, 492 and 545.

This sulfate form of the material could be rendered harmless in the glazes through a careful reduction of the sulfates to the sulfide state,  $\text{SO}_2$ . The sulfides were readily decomposed at the lower temperatures and could be freed and dissipated from the glazes. When the waste oil kiln was continuously oxidizing in the early fire, the sulfur changed to a sulfate state in the glaze chemistry which caused major glaze flaws when the kiln temperature reached the maturation point. By controlling the atmosphere so that the kiln would continuously alternate between reduction and oxidation, the sulfur was kept in an unstable state in the glaze. With each reduction cycle, the sulfur moved out of the glaze and was exhausted into the outside atmosphere. Too much early reduction, however caused bloating of the clay body. The technique required a very sensitive fluctuation to avoid both sulfur flaws and carbon bloating.

Later reduction to the maturation temperature. When the kiln chamber took on a yellow-orange cast, the controls were adjusted to insure a mild continuous reduction atmosphere. The waste oil contained so much potential heat energy that the best means of gaining a reduction involved simply cutting back on the primary air from the blowers and partially closing the damper to retard the escaping exhaust gases.

The first seven experimental firings of the kiln were quite unsuccessful in this phase of operation. The kiln was adjusted to give every outward appearance of a reducing atmosphere. To achieve these appearances, the air was cut back slightly, and the damper was closed to restrict some of the exhaust flow. The stack then began to smoke and flames began to lick out around the spy hole plugs and door bricks.

Yet, when these firings were matured and cooled, the ware showed little sign of reduction. Experimentation involving varying the length of the reduction process from six to eight hours was undertaken, yet little improvement in the reduction effects on the ware could be noted. Other experimentation was directed toward the degree of reduction occurring in the kiln. The firings ranged from what seemed to be a medium reduction to firings in which the kiln and stack coughed great quantities of smoke. Carbon feathers would often drift out of the kiln under the heaviest reduction conditions.

The experimental ware which came from these early reduction investigations suggested a pattern which eventually helped to correct the reduction firing technique with the kiln. The best results were gained when the pottery was reduced over a period of six hours with a medium to heavy smoke resulting around the kiln. To extend the fire to that duration without over-firing the pottery, the quantity of primary air had to be reduced. The amount of smoke which resulted from this reduction seemed excessive in these firings.

Fortunately, the potter was able to receive help with reduction effects from several professionals who had had experience with the use of liquid fuels, such as waste oil. Angelo Garzio, Paul Soldner, Warren MacKenzie, Glenn Nelson and Karl Martz were all consulted regarding the reduction problems of the study. With their help, the potter was able to understand that the early reduction firings were undertaken with too great a degree of turbulence in the firing process. The blower systems were operating with such force that a high degree of pressure was evident in the kiln chamber. Primary air was forced beyond the fireboxes and up into the kiln chamber while the fuel was changing to a

variety of carbon states; carbon monoxide, carbon dioxide and free carbon. The carbon monoxide burned with the primary air to form more carbon dioxide. The free carbon also continued to burn in the kiln chamber, but the pressure in the kiln forced much of the carbon out of the chamber by way of the spy holes, loose brick joints, and the flue. This pressured carbon moving out of the kiln gave the outward signs of a reduction fire while, in fact, the ware was being oxidized in the chamber. The simple solution to the problem was to undertake the reduction duration of the fire under very low primary air pressure to allow a better combustion of the fuel and air mixture in the kiln fire box. This insured an accurate indication of the presence of carbon monoxide in the kiln chamber. Later experimental firings with the kiln indicated that a successful reduction could be obtained with low air pressure over a period of four hours.

The problem of smoke remained throughout the kiln experimentation and the study has concluded that this smoke must remain a major disadvantage in the use of waste oil as a kiln fuel. In the course of each experimental firing, a blue haze started to collect in the upper space of the restricted firing area above the kiln. This blue haze was composed of sulfur trioxide and was not the result of incomplete combustion.<sup>168</sup> The matter of the sulfur haze will be recorded in greater detail in the following chapter.

The study has noted that when the waste oil pipe burners were placed too close to the radiant heat of the kiln firebox in the later

---

<sup>168</sup>W. G. Lawrence, Ceramic Science for the Potter (Philadelphia: Chilton Book Company, 1972), p. 133.



stages of the firing, the tip and orifice of the system became very hot. If the burners were allowed to remain too close to the fire ports, waste oil began burning off the tip of the orifice. The fuel began to evaporate inside the fuel feeder pipes of the system. This evaporation involved an expansion in the volume of the fuel. As a result, pressure backed up the fuel in the feeder pipe, and the flow of the fuel into the kiln was retarded by this pressure. The operation of the burners became sporadic. This problem was resolved by keeping the burners out of the burner ports at a distance of one to two inches. At that location, the burner metal could remain cool enough to allow the burner operation to take place as expected.

Pyrometric cones were used to measure the temperature rise in the experimental kiln. The maturation temperatures of the clay bodies and glazes formulated for experimentation were in the cone nine and ten temperature range, 2,336°F. to 2,381°F. When the pyrometric cones in the chamber indicated that this temperature range had been achieved with the waste oil, the firing system was turned off, the damper was closed, the burner ports were covered, and the kiln was allowed to cool.

#### Operation of the Stoneware Salt Kiln

The first two experiments with the stoneware salt kiln involved the use of waste oil in the early preheat stages of the fire. Later experimentation indicated that natural gas preheat burners added ease to the operation of the salt kiln. The firing cycle of the kiln proceeded much the same as did that of the first kiln of the study. After the potter became aware of the sulfur chemistry in the kiln atmospheres,

periodic reduction and oxidation were undertaken in the early stages of the fire.

When a yellow-orange cast was evident in the salt chamber the kiln was allowed to operate in an oxidation atmosphere for the majority of the firings. The fire rose quickly under oxidation conditions and a total duration of the fire included twelve hours of low gas preheat and eight to ten hours of waste oil fire. The oxidation fire gave the salt ware a bright clear character with strong contrast between the salted clay surface and areas which had been coated with a glaze prior to the firing.

Two firings with the salt kiln were undertaken where reduction atmospheric conditions were allowed to impart a much warmer and darker character to the salt ware. In these two firings the reduction cycle was started soon after the chamber indicated that a temperature of 1,650°F. to 2,000°F. had been achieved with a yellow-orange color in the kiln.

The first salting of the kiln usually took place five hours after the oil burners were placed in operation. The chamber temperature at the first salting was around 2,300°F. Between three and six saltings were used in the firings and the amount of salt varied from fifteen to thirty-five pounds. The salt was introduced into the kiln chamber through six salt ports. Two of these ports were located twenty inches above the fireboxes. Two salt ports were located on the sides of the kiln at the same level. Two more ports were located at the rear of the kiln at that level. A two-by-two-by-twenty inch angle iron was used to transport the salt into the kiln chamber. With each salting, the oil burners and blowers were turned down while salting took place and then regulated to full capacity after the salting was finished.

At the close of the fire the kiln was given a final salt. The dampers and ports were closed to keep a concentrated sodium vapor in the chamber as the kiln cooled. The maturation temperature of the kiln at that point was usually between 2,380°F. and 2,390°F.

The last two experiments using the salt kiln with waste oil involved the substitution of sodium bicarbonate, or baking soda, to form a vapor glaze on the ware. This method of firing proved quite successful. There was an increase in the cost of the soda, but a much more tolerable environment around the kiln while it was in operation. The baking soda served to accomplish the glazed surfaces on the ware without the products of hydrochloric acid fumes which were common when salt was used. Additional information regarding alternatives to the use of salt to obtain a vapor glaze can be found in a variety of recent publications.<sup>169</sup>

#### Operation of the Raku Kiln

The oxidation Raku system was started using a gas preheat burner and laying the waste oil pipe burner along side the natural gas system. The air was kept at a minimum in the early minutes of the fire with a very slight amount of oil moving into the flame of the gas burner. After one half hour of oil and gas fire, the preheat burner was removed and the kiln was able to function with only the waste oil system in operation. With an hour of waste oil fire the three cubic feet ware

---

<sup>169</sup> Richard Behrens, "An Alternative to Salt Glazing," Ceramics Monthly, XXII, 8 (October, 1974), p. 44; see also W. G. Lawrence, Ceramic Science for the Potter (Philadelphia: Chilton Book Company, 1972), pp. 165-168; see also H. G. Schurecht and K. T. Wood, "The Use of Borax and Boric Acid Together with Salt in Salt Glazing," Ceramic Experiment Station Bulletin Number II (Alfred: New York State College of Ceramics, 1942).

chamber was red-orange and the glazes inside were showing signs of melt. After an hour and fifteen minutes of waste oil firing, the first load of ware was ready to be removed from the kiln.

To remove the ware, the burner and air systems were turned down to a very low level of operation and the stack of door bricks were removed. Caution was exercised when regulating the burner system: if the adjustments of primary air and fuel at the lower level were not correct, an excess of air going through the burner cooled the firebox. When this happened, the preheat burner was needed to insure a continuous combustion of oil when the system was placed back into operation for the second load of Raku ware. When the adjustments of air and fuel were correct, the firebox remained hot and the second load of ware required only simple adjustments to raise the temperature back up to the point of glaze maturation. Of course, the first load of ware required the greatest length of time to reach maturation temperature; the later loads required less time.

Regarding the use of waste oil for firing Raku pottery, the study also found that the oil could serve as a reducing element after the ware had been removed from the oxidation fire. Sawdust, leaves and newspaper have traditionally served this function with Raku, however, a metal container with a series of small drip holes in its bottom served the reduction process when it was placed over the hot, freshly fired forms. Waste oil was poured onto the bottom of the inverted container and allowed to drip onto the forms inside.

Other experiments using waste oil to reduce the hot Raku ware included localized reduction by placing a rag which had been dipped in

waste oil over the specific areas of the pottery where reduction was desired.

Organic matter, such as sawdust, could be saturated with the fuel producing a more carbon-charged combustible to place over the hot forms. The waste oil made the other organic materials last longer and it produced a better carbon concentration in the atmosphere around the cooling Raku ware.

## Chapter 6

### SAFETY, POLLUTION AND CERAMIC CHEMISTRY RELATED TO THE USE OF WASTE OIL FOR FIRING CERAMICS

This chapter was included to serve the potter's understanding of the specific problems of safety, pollution and glaze flaws which have accompanied the use of automotive waste oil fuel. These three concerns may seem unrelated at first glance, however, each of the matters relate to the chemical composition of the waste fuel.

#### SAFETY

This kiln fuel was a relatively safe fuel for firing ceramics. The fuel required a flash point ranging from 390°F. to 500°F. before combustion could take place. This high temperature, in spite of its effects of slow fuel combustion in the kiln operation, served to avoid combustion problems with the fuel while it was being gathered, cleaned, and stored prior to firing. The slow combustibility of the fuel gave waste oil handling many advantages not common to the use of natural gas, kerosene, and the other fuel oils which ignited at lower temperatures.

Waste oil use carried with it the hazard of never knowing the exact chemical constitution of the fuel. The danger of getting oil which had been diluted with gasoline was ever present. For this reason, safety equipment in the form of a petroleum flame fire extinguisher and buckets of earth were kept near the kiln location. Water was never used in an effort to stop the combustion of the fuel for reasons which were

recorded in Chapter 2 of the study. The potter will remember that water served the combustion of the Astrakan oil stove, the Readhead and the Olsen waste oil systems through fuel pulverization and soot prevention. Therefore, its use to control or to stop an accidental flame in the area of the kiln would result in an effect opposite the original safety intent of the potter.

In the course of the study other safety problems became apparent. These safety problems revolved around the composition of the exhaust gases which were released during the operation of the waste oil kiln.

### POLLUTION

Recent concerns regarding air pollution suggest that the potter using waste oil should be aware of the pollutionary contribution which he makes in the operation of his kiln. The chemical constitution of waste oil has forced a greater degree of air pollution in the area of the kiln than was common to the use of gas and fuel oil fired kilns.

#### Carbon

Complete combustion of clean hydrocarbon fuel in air has resulted in the formation of carbon dioxide and water vapor. These gases were not harmful and should not be considered as pollutants. When combustion was incomplete, however, carbon monoxide was formed. In other cases, incomplete combustion resulted in the formation of soot or carbon smoke. These carbon products of incomplete combustion were pollutionary. The potter must be cautioned to make every effort to minimize their formation in the operation of his kiln. The operation of the reduction stoneware kiln produced carbon monoxide needed for the reduction of the

ware in the chamber. This form of the carbon exhaust was allowed to burn to carbon dioxide in the heated stack of the kiln. Pollution was kept to a minimum. The major problems of pollution regarding the reduction process were produced when the burners were poorly adjusted during the early stages of the fire. The fuel burned imperfectly and large particles of free carbon and smoke were the result of the adjustment.

### Sulfur

As stated earlier, automotive waste oil contained a great quantity of sulfur due to the natural crude oil from which it came, the chemicals used in its refining process, and the additives which were placed in the oil by the lubrication manufacturer. When waste oil was burned, air contaminants of sulfur dioxide and sulfur trioxide resulted. Sulfur dioxide was a colorless and invisible product, while sulfur trioxide produced a blue haze around the kiln.

These gaseous oxides of sulfur were very toxic. Both of these oxides have been proven to produce lung injury at concentrations of five to ten parts per million.<sup>170</sup> When the sulfur oxides combined with water vapor, acid aerosols were formed.<sup>171</sup> These aerosols have had the potential of damaging vegetation, metals and fabrics.<sup>172</sup> The smoke and sulfur haze around the waste oil kilns of the study were often concentrated to a degree which caused irritation to the eyes and respiratory system of the potter. This local problem could have been avoided if the kilns were located in an open area where the sulfur oxides and acid

---

<sup>170</sup>W. G. Lawrence, Ceramic Science for the Potter (Philadelphia: Chilton Book Company, 1972), p. 133.

<sup>171</sup>Ibid.

<sup>172</sup>Ibid.



aerosols were allowed to drift away from the potter's work area. In spite of this possibility, the waste oil kilns would have continued to pollute the atmosphere with the sulfur from the fuel. Sulfur pollution has remained one of the most apparent draw backs concerning the use of automotive waste oil as a fuel for firing ceramics.

#### Hydrochloric Acid Fumes and Chlorine Gas

Another form of air pollution common to the use of waste oil has involved hydrochloric acid fumes which result in the combustion of the fuel. The potter will remember that chlorine was one of the chemicals listed in Chapter 3 of the study concerning the additives which lubrication oil manufacturers put in their products. With the combustion of waste oil, this chlorine reacted with the water vapor present in the kiln atmosphere to form hydrochloric acid. This acid remained in a gaseous state and was drawn out of the kiln chamber through the flue and stack. Both hydrochloric acid vapor and chlorine gas are extremely toxic to animal and plant life.<sup>173</sup>

#### Nitrogen and Organic Gases

Nitric oxide and nitrogen dioxide have also resulted in the combustion process of the waste oil kilns.<sup>174</sup> These products were not directly formed from the chemistry of the fuel, but were the natural products of the high temperature combustion process where atmospheric nitrogen and oxygen were combined to form the oxides of nitrogen.<sup>175</sup> The oxides of nitrogen have combined with the hydrocarbon derivatives,

---

<sup>173</sup>W. G. Lawrence, Ceramic Science for the Potter (Philadelphia: Chilton Book Company, 1972), p. 140.

<sup>174</sup>Ibid., p. 134.

<sup>175</sup>Ibid., p. 134.

or oxygenates, of the waste oil combustion to produce another form of pollution with the fuel.<sup>176</sup> The oxygenates included aldehydes, ketones, alcohols and organic acids.<sup>177</sup> These derivatives reacted with nitrogen dioxide to produce plant damage and eye irritation. Nitrogen and organic gas pollution is the natural result of the firing processes of all ceramic kilns. As a result, the potter should not consider this type of pollution as a major draw back concerning the use of waste oil as a fuel.

#### CERAMIC CHEMISTRY RELATED TO WASTE OIL FIRING

The discussion of additives and other impurities which appeared in Chapter 3 of the study has served as a point of departure for the following information regarding the ceramic chemistry of waste oil firing. The statements in that chapter indicated that sulfur, tin, chrome, selenium, tellurium, calcium, barium, magnesium, lead, zinc, sodium and iron could be expected in the chemical constitution of waste oil. Of this group, sulfur resulted in a variety of glaze flaws on the pottery which was fired in the course of the study. The other chemicals have resulted in minor color, surface and melting temperature changes within the glazes and clay fired in the kilns.

##### Sulfur Effects on the Clay and Glazes

References were frequently made in the earlier sections of the study concerning the kiln operation and pollution problems attributed to

---

<sup>176</sup>W. G. Lawrence, Ceramic Science for the Potter (Philadelphia: Chilton Book Company, 1972), p. 136.

<sup>177</sup>Ibid.

the oxides of sulfur. Information recorded in the air pollution section, Chapter 6, indicated that pollution from the sulfur in the oil had remained one of the major weaknesses of waste oil as a potter's fuel. Concerning kiln operation, Chapter 5 suggested that certain steps were taken to control the harmful effects of sulfur in the clay and glazes of the kiln chamber. The study mentioned that sulfur gases lagged in their flow through the kiln. The unfused and partly fused glazes and clay dissolved or reacted with the sulfur gases. In the firing, the sulfates which were formed by the action of sulfur with the bases in the glazed ware remained until higher temperatures were reached. At the higher temperatures, the sulfates in the kilns decomposed and yielded gas bubbles, blisters, dry and dull matt surfaces, and in very bad cases, shriveled glaze surfaces.<sup>178</sup> Common names for the glaze flaws caused by sulfur are: feathering, blistering, wrinkling, mattness, dullness, starving, cutlery or knife marks, discoloration, polka dot, airing, sweatmarks, and struck effects.<sup>179</sup>

Experience with waste oil suggested that this sulfuring took place in the very early stages of the fire when the ware was water smoking. The potter was able to resolve some of the sulfuring at this

---

<sup>178</sup>The following references have been suggested for the potter who would like to learn more about the effects of sulfur on clay and glazes: Cullen W. Parmelee, Ceramic Glazes (2d ed.; Chicago: Industrial Publications, Inc., 1951), pp. 301-302 and 307-311; see also Alfred B. Searle, The Chemistry and Physics of Clays and Other Ceramic Materials (New York: Van Nostrand Company, 1926), pp. 68, 122 and 241; see also John H. Koenig and W. H. Earhart, Literature Abstracts of Ceramic Glazes (Ellenton: College Offset Press, 1951), pp. 65, 101, 123, 211 and 295.

<sup>179</sup>Cullen W. Parmelee, Ceramic Glazes (2d ed.; Chicago: Industrial Publications, Inc., 1951), p. 308.

period by forcing an atmospheric change from oxidation to reduction and back again to oxidation while the ware was being fired through the lower temperatures. That process rendered the sulfates harmless, forcing a chemical change to the sulfide state. The sulfur was readily decomposed at the lower firing temperatures and the sulfides were freed from the ware. The sulfur gases were dissipated back into the kiln atmosphere and removed through the kiln flue and stack.

The oxides of sulfur effected nearly all of the ware fired in the study, however, only one fourth of the pieces which were tested showed signs of sulfuring as a major problem. In many cases the subtle color and surface changes of the sulfured glaze added a pleasant variety and depth to the character of the pottery. After the firing operation was adjusted to eliminate part of the sulfuring problems some of the sulfur flaws remained in the later experiments. The study, therefore, indicated that the potter must, at present, accept this sulfur problem as one of the inherent characteristics of the waste oil process.

#### Vapor Glaze Caused by Ceramic Chemicals in the Fuel

Shortly after the study was undertaken, a very thin surface of glaze material began to show up on the test pottery. This thin vapor glaze was first evident on pottery which had undergone a bisque fire and had been located in the chamber near the kiln firebox. Later experiments at higher temperatures proved the potter's suspicions to be justified. In these tests, all of the pottery with raw clay exposed to the kiln atmosphere took on this same thin film of glaze. As the study progressed, many of the kiln posts, shelves and the interior chamber

walls began to show slightly abnormal effects of glaze forming vapor from the firings.

The evidence of a slight vapor glaze in the waste oil chamber was attributed to the presence of the many ceramic glaze chemicals placed in the oil to serve as additives for the motor lubrication process. These fluxes were lead, sodium, calcium, zinc, barium and magnesium. Lead, sodium, and calcium served as fairly active glaze chemicals. They began to melt at very low temperatures of red heat in the kiln. Zinc, barium, and magnesium served the glaze chemist as more refractory bases, and they did not start to melt until a yellow-orange color in the kiln indicated a temperature of near 1750°F. The study should stress that each of these glaze ingredients exerted specific characteristics in glazes. Those characteristics varied greatly in terms of the individual color response, degree of hardness and general activity in the melt of the glaze.<sup>180</sup>

In addition to the common bases which resulted from the combustion of waste oil, other chemicals were liberated from the fuel. These chemicals caused other changes in the glazes and clays of the experimental ware. Selenium and tellurium, for example, were common colorants for the glass industry and they no doubt effected slight changes in the pottery when they were liberated from the waste oil.

---

<sup>180</sup>The following references have been suggested for the potter who would like to learn more about the effects of ceramic chemicals found in waste oil when they are exposed to the potter's ware: Glenn C. Nelson, Ceramics, A Potter's Handbook (New York: Holt, Rinehart and Winston, Inc., 1971), pp. 228-242; see also Cullen W. Parmelee, Ceramic Glazes (2d ed.; Chicago: Industrial Publications, Inc., 1951), pp. 11-37; see also Daniel Rhodes, Clay and Glazes for the Potter (Philadelphia: Chilton Books, 1957), pp. 61-77.

The oxides of iron and chrome were also present in the fuel. Both chrome and iron served as common glaze colorants and they exerted a degree of fluxing ability when placed in a ceramic glaze.

Oxides of tin were also present in the fuel. Tin has been a common glaze chemical used to effect mattness or at least opacity to ceramic glazes. It is of a refractory character and may have entered into the formation of a vapor glaze in the kiln atmosphere. However, it would not have functioned as an active flux in the chamber.

The study noted that the nature of the fuel prohibited any scientific research into the specific ceramic chemicals in the fuel and the effect of each of these chemicals on the test ware. The chemicals were introduced into the kiln atmosphere as a variable group without the potter's having specific knowledge of their percentage in that group. As a result, the formulation of glazes and clay bodies adapted to the characteristics of waste oil firing must remain an intuitive project for each potter using the fuel.

## Chapter 7

### CONCLUSIONS

Concerning the foundational hypotheses of this study, the findings indicate that automotive waste oil could serve as a practical fuel for the ceramic kiln. A problem has remained, however, concerning the degree of practicality of the fuel for the contemporary potter.

References made to the limited amount of published information on waste oil fuel served to suggest that experimentation with the fuel would provide a much deeper knowledge of the nature of the material: the degree of physical labor required in its use, the cost of the construction of a combustion system, and many other relevant subjects such as pollution, glaze flaws and the general aesthetic character of ware fired with the fuel. Previous published information has overlooked most of these important concerns. As a result, this study should serve the contemporary potter with a much more objective and learned understanding of the practicality of the fuel.

A variety of weaknesses or disadvantages to using the fuel have been noted. The time and taxing physical labor which were required to develop the oil system and to gather, clean and store the fuel were great. The use of the fuel proved practical for only the more energetic potters who could afford to devote the required time and labor needed in the operation. The potter should note that the time spent with the fuel and its system would, no doubt, cut into the time needed in the creative or more productive activities of the craft.

Sulfur in the fuel posed some disadvantages because it required a sensitive operation of the kiln in specific stages of the firing. Many young or inexperienced potters will be unable to handle the sensitive fire of the sulfur laden fuel. Their efforts will result with ware which has many flaws from the harmful chemical activity of sulfur in the kiln atmosphere.

The problem of air pollution from sulfur and chlorine was also viewed as a drawback in kiln operation with waste oil.

The harmful effect of the slight vapor glaze from the ceramic bases, colorants, and opacifiers were other disadvantages. Those effects shortened the life of the potter's kiln and furniture.

Most of the aforementioned disadvantages can be countered with advantages to the use of this fuel. When using the fuel, the potter helped to avoid the traditional waste of the material. In other words, the use of waste oil was ecologically feasible. A majority of the lubrication recycle establishments which were once located throughout the United States were unable to make their function profitable enough to stay in business. As a result, vast quantities of waste oil have been dumped into our environment. This fuel caused damage to vegetation and eventually found its way into water deposits, streams and rivers where it continued to cause injury to the environment. When the fuel was not thrown out as a total waste, it was collected by industrial concerns such as asphalt plants and junk yards which used it as a fuel in their work. In other words, if the potter does not use the fuel, some other interest will burn this fuel without regard for the air pollution which its combustion causes. Hopefully, with a continued interest in the use of this material as a kiln fuel, contemporary potters will be able to

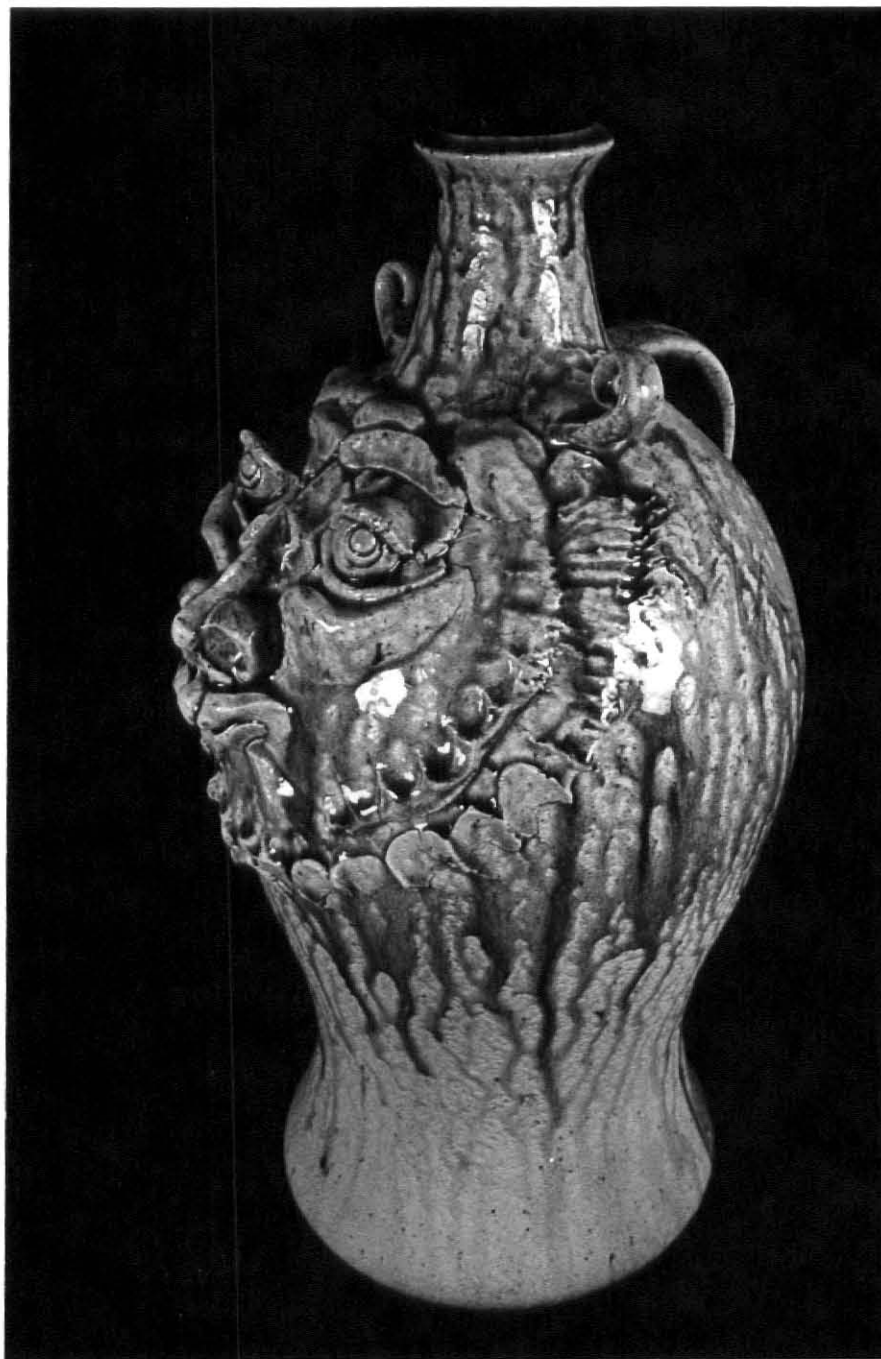


discover cheap means of removing sulfur and chlorine from the fuel before it is burned. If and when these discoveries take place the fuel will present even greater advantages for the potter.

The relatively cheap materials which can be used to construct a waste oil system help to make the fuel advantageous. The cost of equipment and fuel will continue to be very important concerns for the potter. Using waste oil, he can often justify his time and labor through savings in fuel and equipment costs. A continued interest and experimentation with waste oil fuel and equipment will, no doubt, result in much improved equipment and kiln firing techniques. This continued interest and experimentation will improve the present value of automotive waste oil for firing pottery.

A PORTFOLIO OF WASTE OIL FIRED  
POTTERY

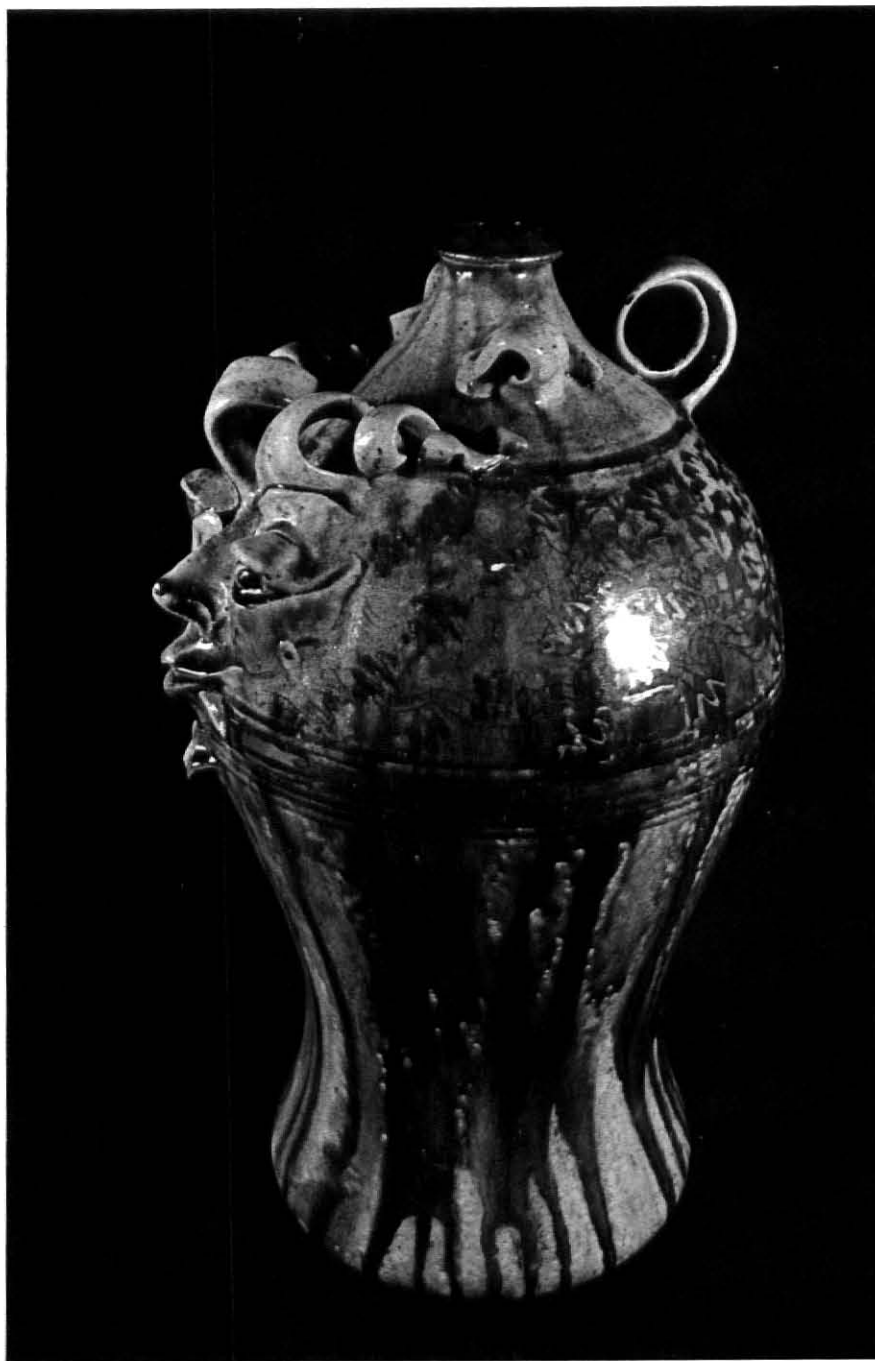
## PORTFOLIO PLATE I

BELLARMINE REVISITED<sup>181</sup>

---

<sup>181</sup>The anthropomorphic character of this wheel thrown jug was achieved by sprigging. The vapor-glazed form was fired to stoneware maturation with waste oil. It measured 18 1/2 inches tall.

## PORTFOLIO PLATE II

BELLARMINE REVISITED # 3<sup>182</sup>

---

<sup>182</sup> Like the preceding jug of the series, the anthropomorphic character of this thrown form was achieved by sprigging. This vapor-glazed, stoneware form was also fired with waste oil. This pot measured 18 inches tall.

## PORTFOLIO PLATE III

COSMIC CLASSIC # 3<sup>183</sup>

---

<sup>183</sup>This vapor-glazed stoneware form was fired with waste oil in an oxidation atmosphere. Porcelain and stoneware clay coils were sprigged and paddled onto the surface of the thrown form. This bottle measured 36 inches tall.

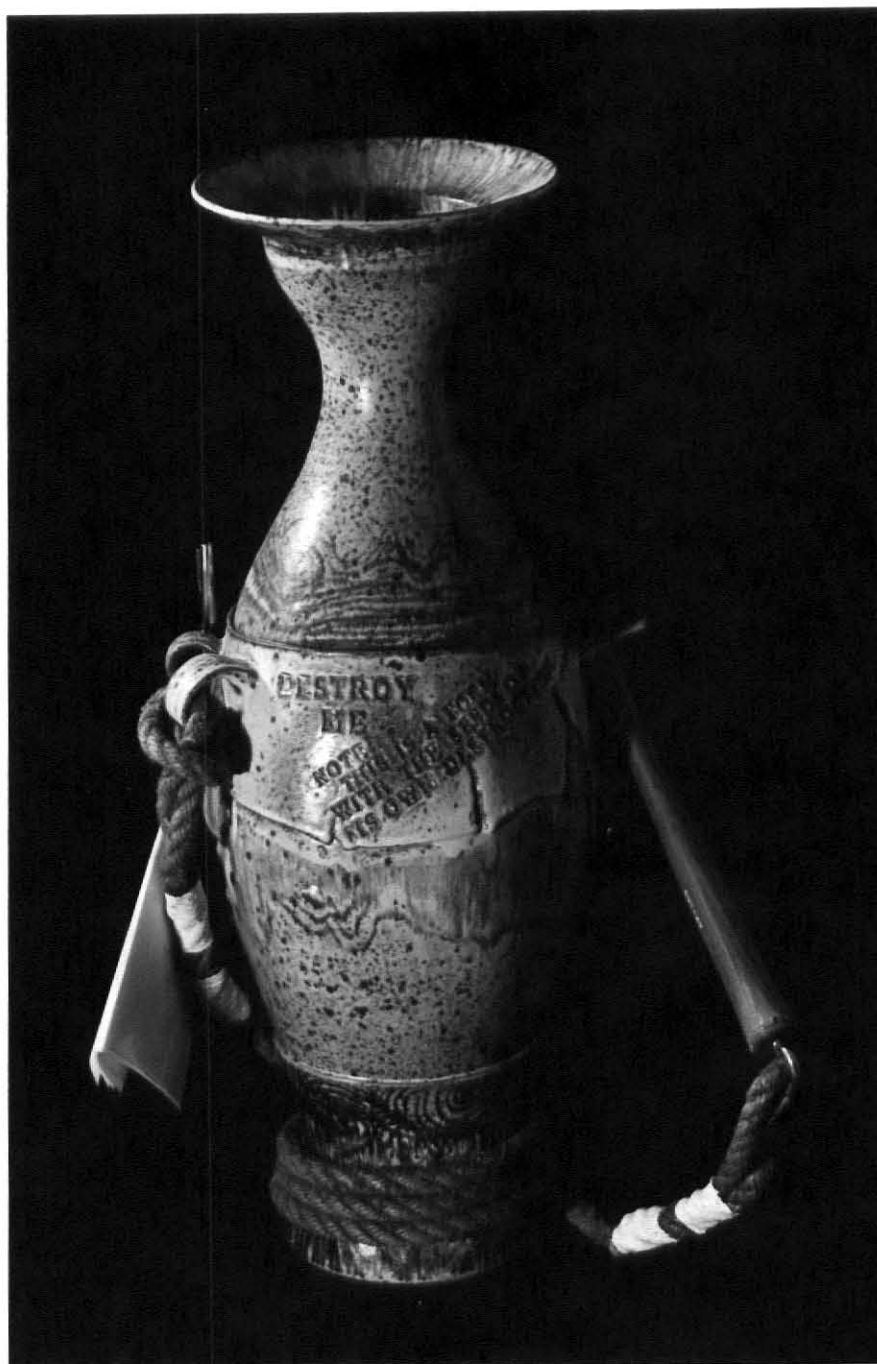
## PORTFOLIO PLATE IV

THE SPIRIT OF SAND CREEK<sup>184</sup>

---

<sup>184</sup>This waste oil fired whistle was constructed of altered thrown forms and sprigged clay. Feathers were later added to create the wings of the spirit. The stoneware form produced three tones and measured 18 1/4 inches tall.

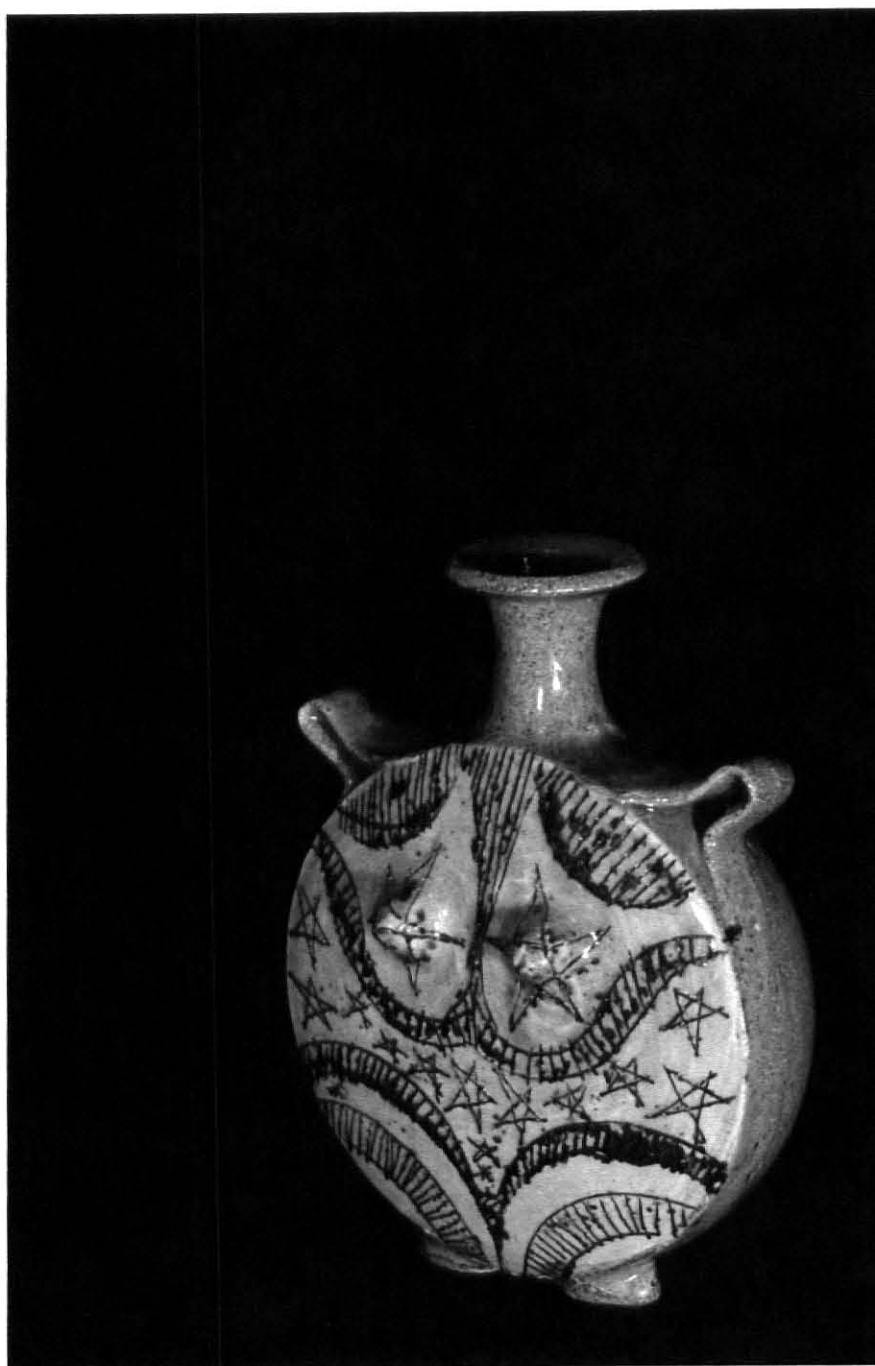
## PORTFOLIO PLATE V

THE SEEDS OF ITS OWN DESTRUCTION<sup>185</sup>

---

<sup>185</sup>This unfinished stoneware form was thrown on the potter's wheel. The rope, hammer, ball-point pen and documentation sheet were included to offer an air of indeterminacy to the pot. The waste oil fired bottle will be completed at the moment of its destruction. It measured approximately 34 inches tall.

## PORTFOLIO PLATE VI

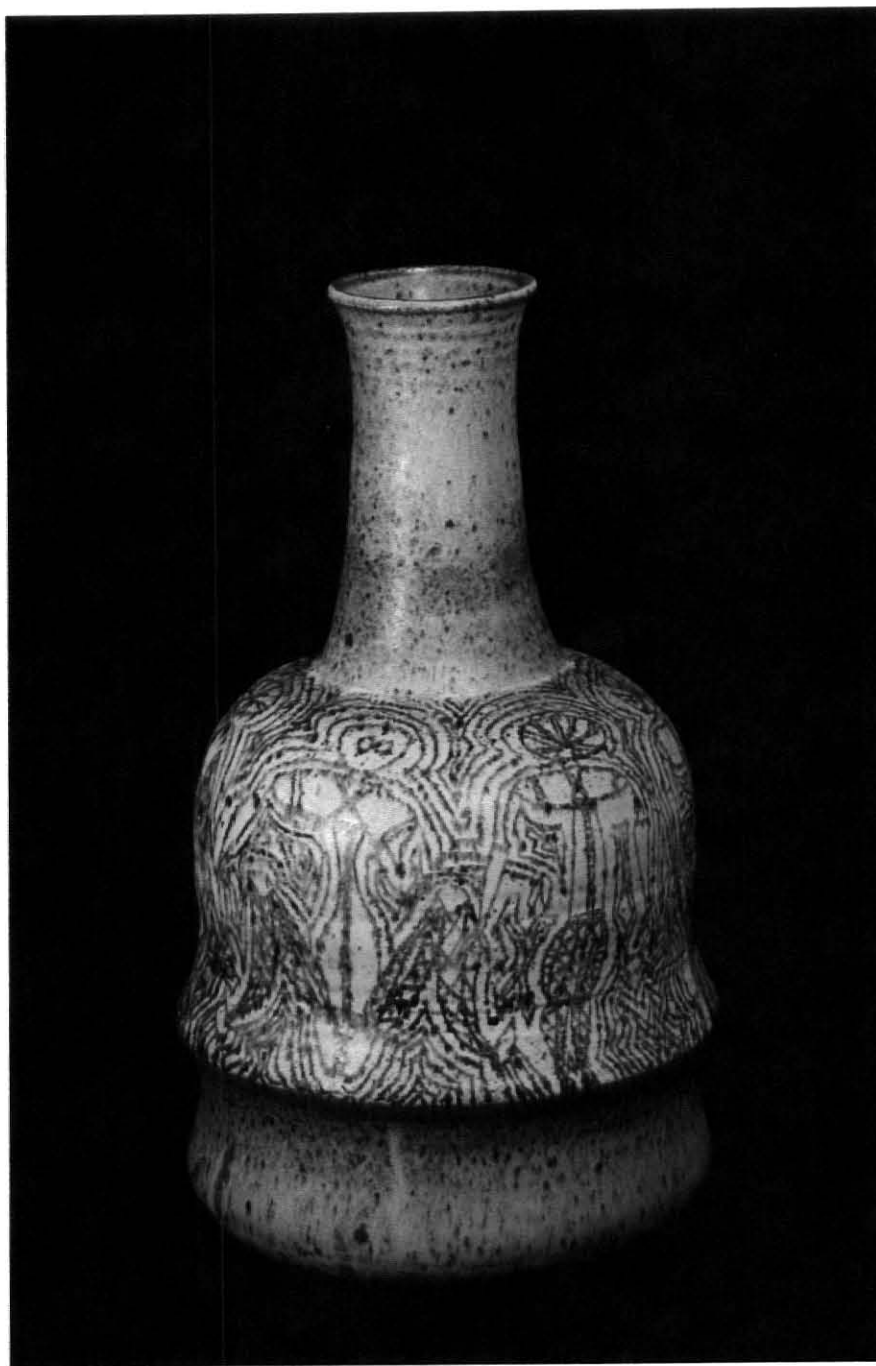
A PILGRIM BOTTLE<sup>186</sup>

---

<sup>186</sup>Automotive waste oil served as the fuel to fire this pot to stoneware maturation. The embellishment of this thrown form was achieved by scratching through a coat of wax and into white slip on the form in a leather-hard state. Oxides of iron and cobalt were later brushed onto the wax and deposited in the lines made by the pointed tool. The form measured 7 inches tall.



## PORTFOLIO PLATE VII

VIRILITY DANCE BOTTLE<sup>187</sup>

---

<sup>187</sup>The linear embellishment of this form was also accomplished using a pointed tool to scratch through a coat of wax at the leather-hard stage. This stoneware form was fired with the waste fuel and it measured 17 inches tall.

## PORTFOLIO PLATE VIII

SEED POD VASE<sup>188</sup>

---

<sup>188</sup> A stoneware vapor-glaze was deposited on this waste oil fired form from the potter's wheel. The vase measured 41 inches tall.

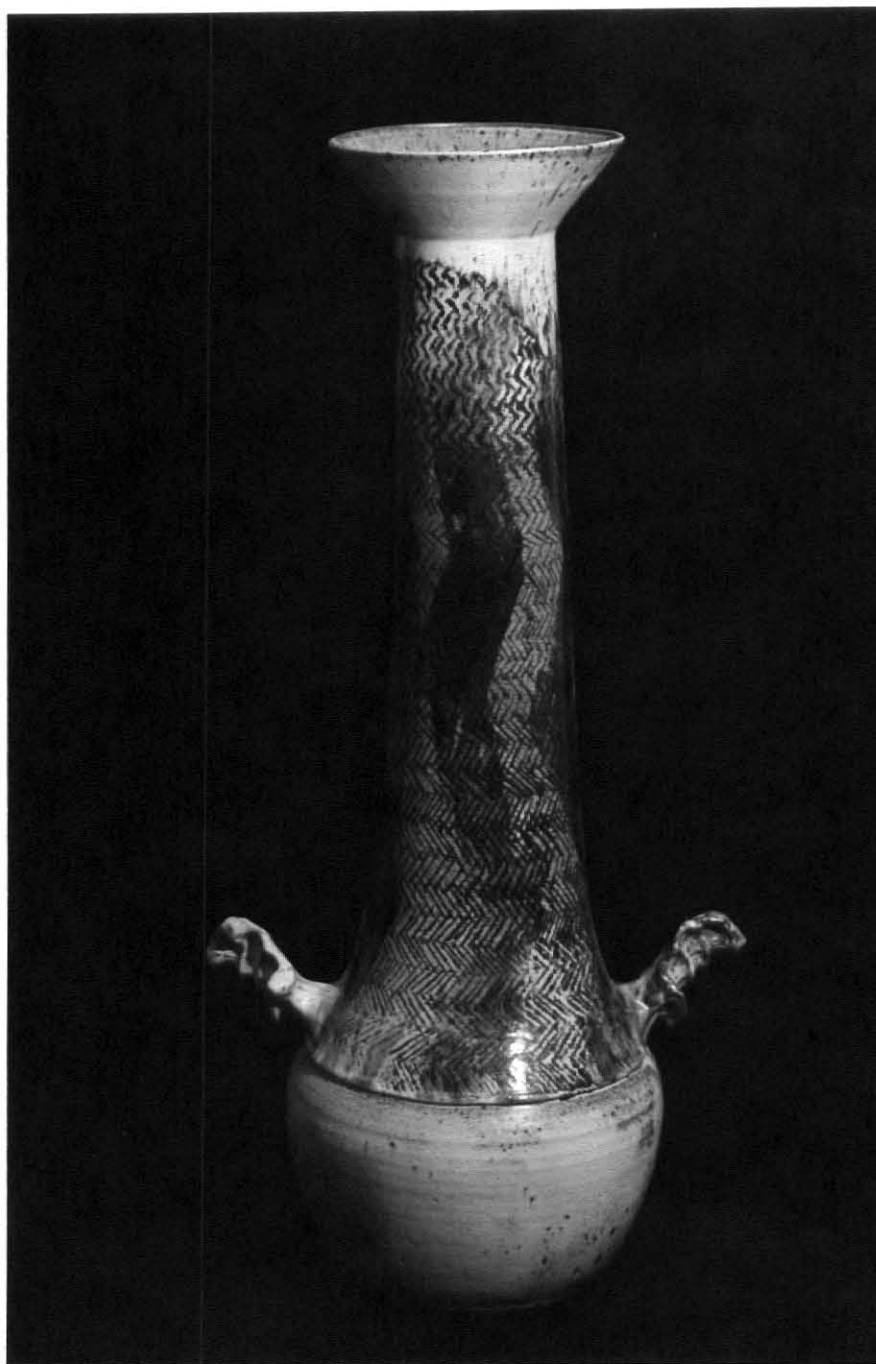
## PORTFOLIO PLATE IX

DEVILRY WINE-POT<sup>189</sup>

---

<sup>189</sup>This vapor-glazed, waste oil fired piece measured 7 inches tall. It was constructed of thrown forms with the face of the devil modeled by sprigging.

## PORTFOLIO PLATE X



PROCESSIONAL FORM OF AN ETRUSCAN REVIVAL<sup>190</sup>

---

<sup>190</sup>Iron oxide inlay through wax resulted in the linear pattern on the central surface of this waste oil fired work. The stoneware form measured 42 inches tall and was thrown on the wheel.

## PORTFOLIO PLATE XI

VIRILITY BOTTLE<sup>191</sup>

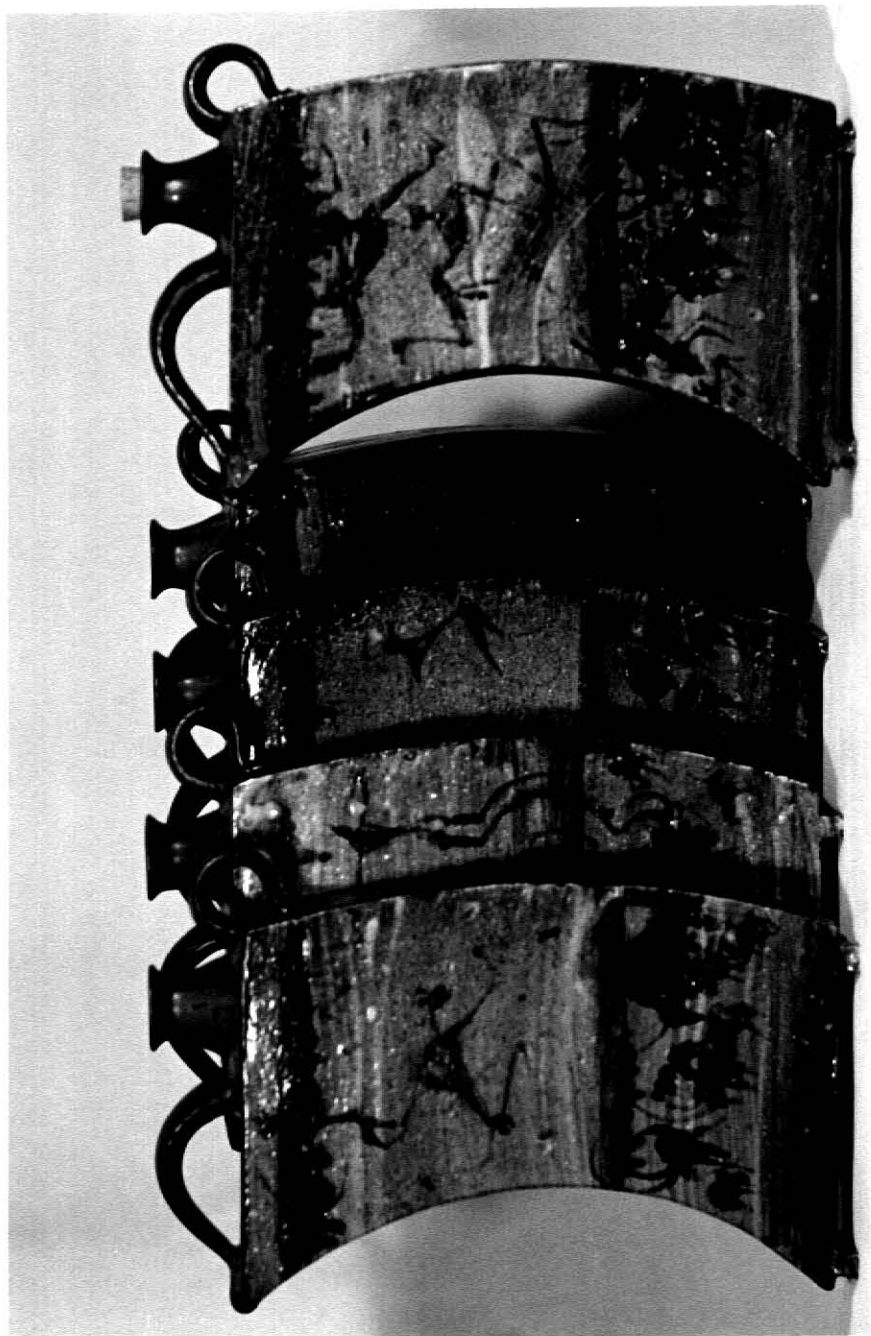
---

<sup>191</sup>The aforementioned wax-oxide technique was used to create the glaze pattern of this waste oil stoneware pot. The form was constructed of thrown parts with the bull and bird forms later added by sprigging. This bottle measured 11 inches tall.

## PORTFOLIO PLATE XII

SAINT GEORGE WHISTLE<sup>192</sup>

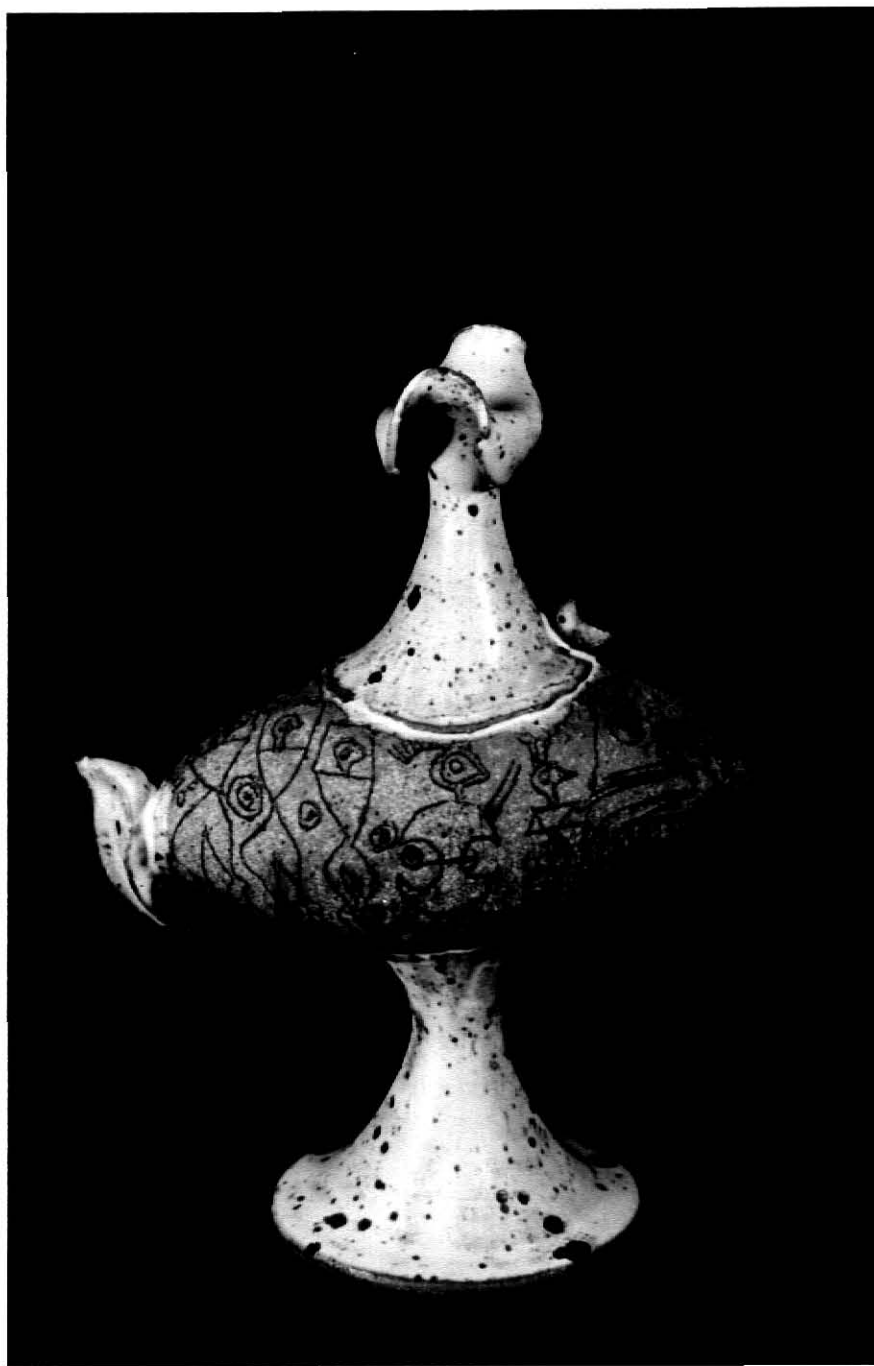
<sup>192</sup>This stoneware whistle was constructed of pinched and thrown parts. The linear surface treatment was achieved using cobalt oxide stain under the white glaze. The form measured 12 inches tall.



SET OF SLAB BOTTLES<sup>193</sup>

<sup>193</sup> This set of stoneware bottles involved the slab method of construction and the use of engobe and stain under a thin celadon glaze. The forms were fired with waste oil and they measured 12 inches tall.

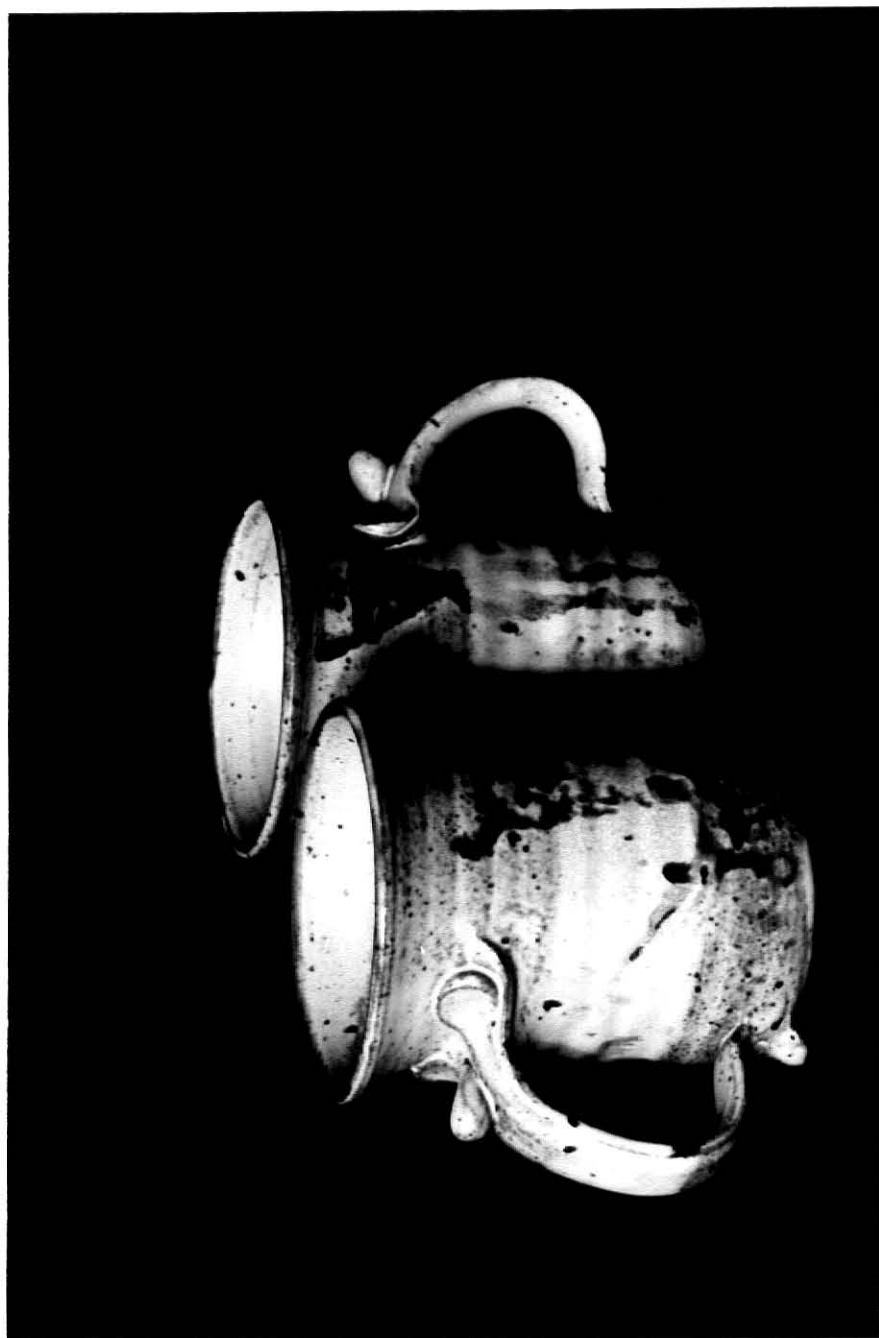
## PORTFOLIO PLATE XIV

ILIAD BOTTLE<sup>194</sup>

---

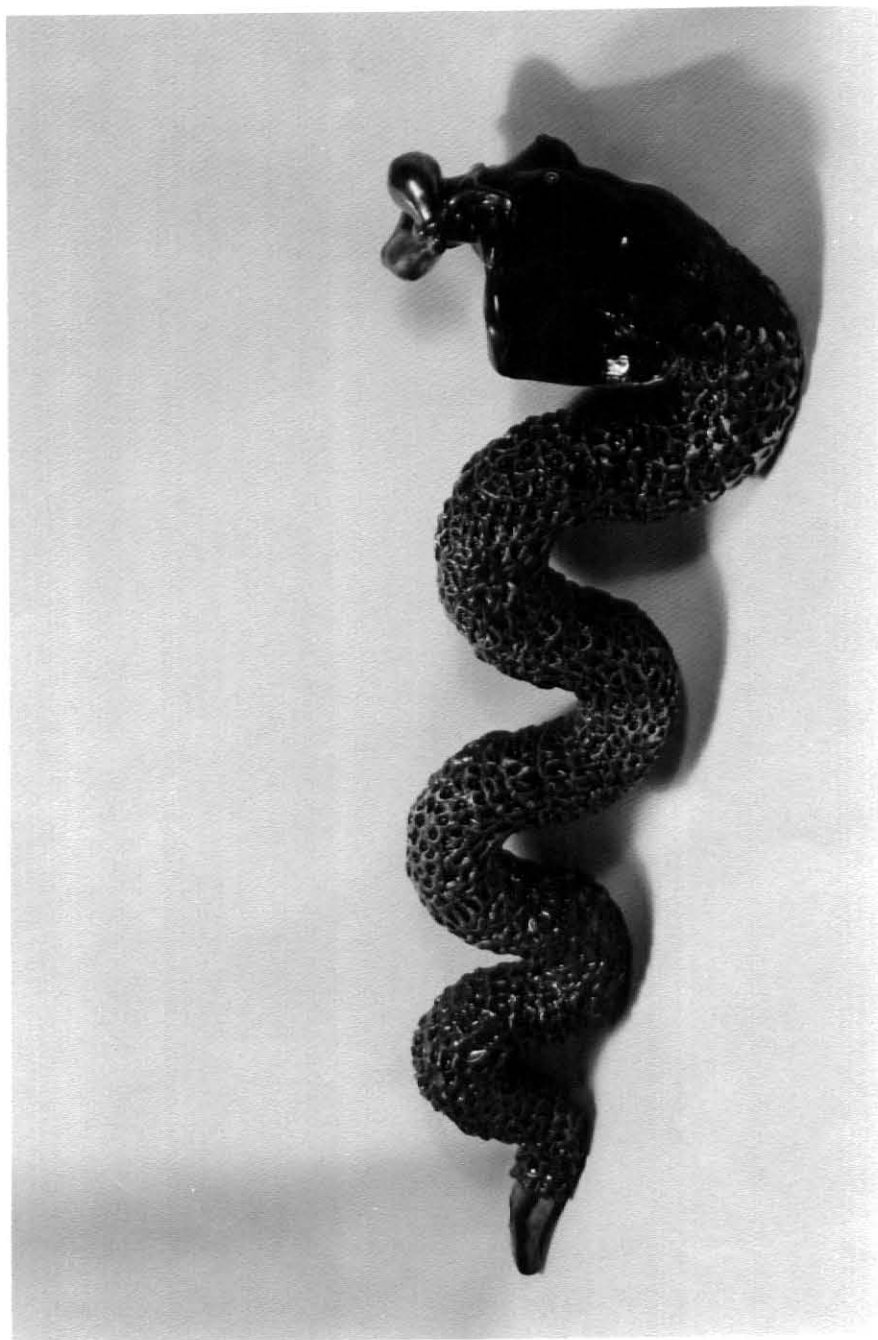
<sup>194</sup>The construction of this stoneware form involved an assembly of thrown shapes. The linear archaic symbols on the central space were achieved using wax and a pointed tool at the leather-hard state. The finished form measured 7 inches tall.





ODYSSEY CUPS 195

195, These functional forms were fired to stoneware maturation with automotive waste oil. The archaic symbols were executed using iron oxide stain under a white glaze. The cups measured six inches tall.

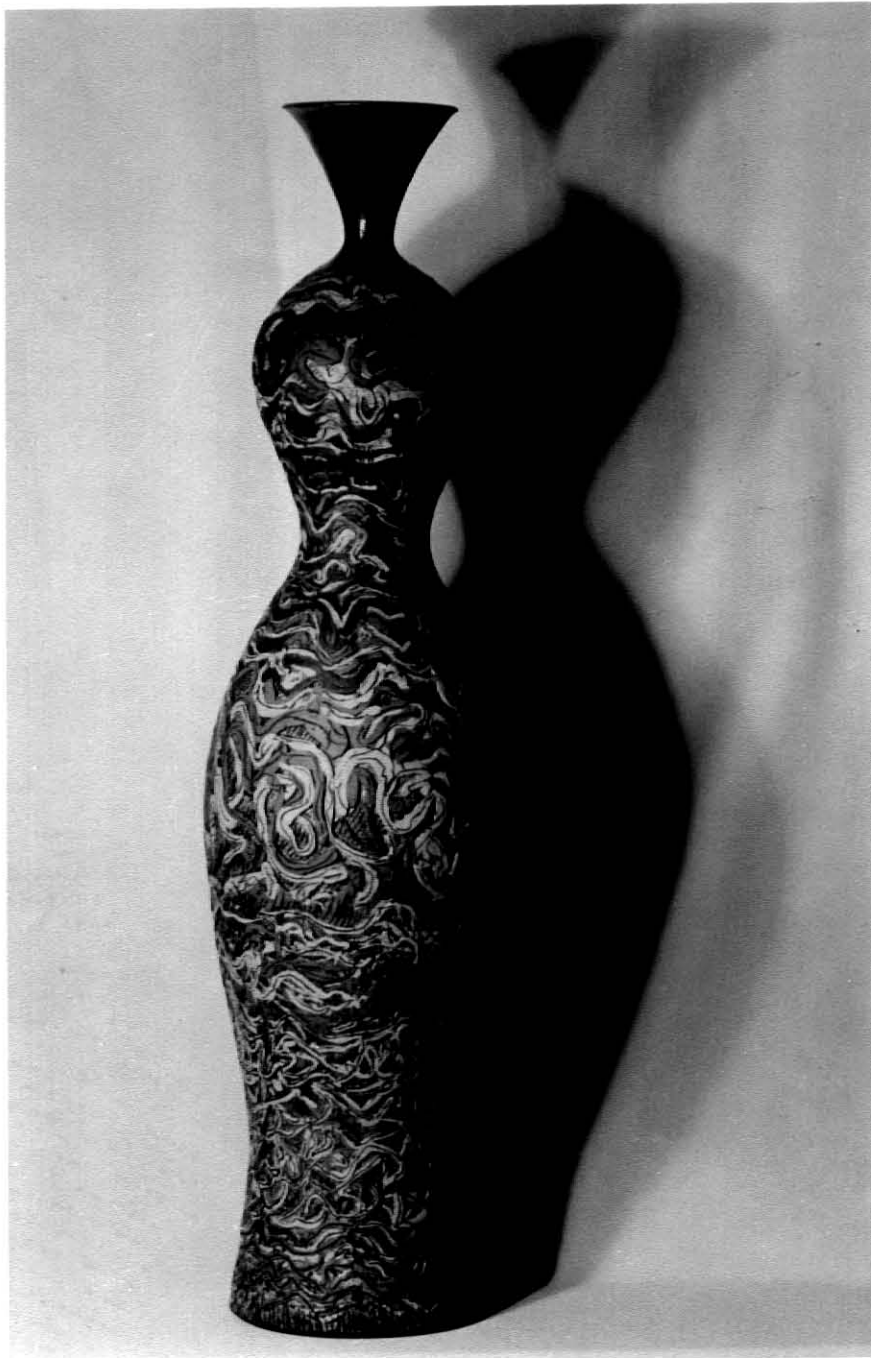


SCREECHING VENUS WITH A FORKED TONGUE<sup>196</sup>

---

<sup>196</sup>This stoneware whistle was constructed of thrown shapes, sprigged and modeled. The form measured 5 inches tall and 18 inches long.

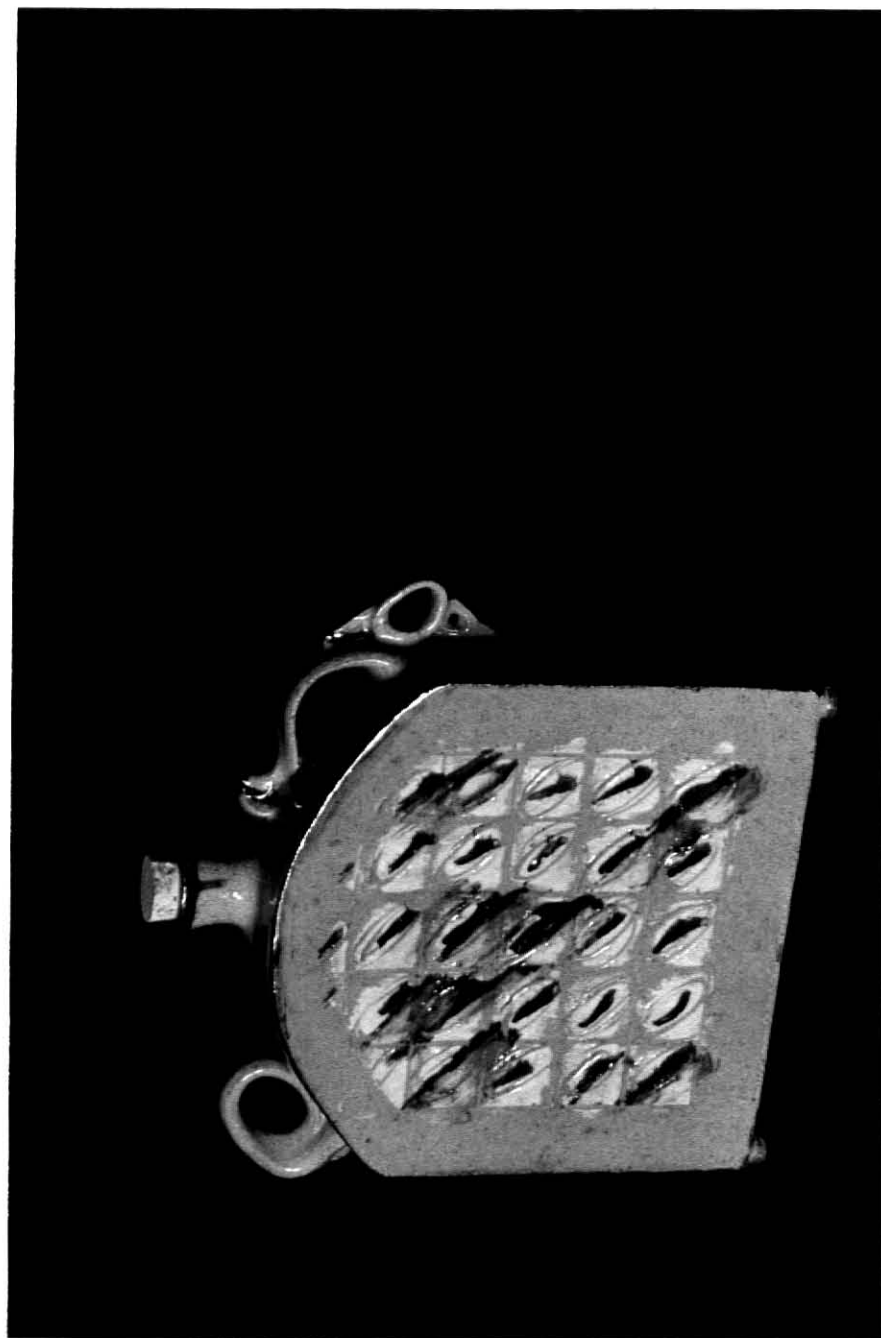
## PORTFOLIO PLATE XVII



BAROQUE NOUVEAU: COSMIC CLASSIC #2<sup>197</sup>

---

<sup>197</sup> Sprigged and paddled coils of porcelain and stoneware clays were used on the surface of this thrown form. It was fired to maturation with waste oil and it measured 42 inches tall.



SLAB BOTTLE WITH GRID<sup>198</sup>

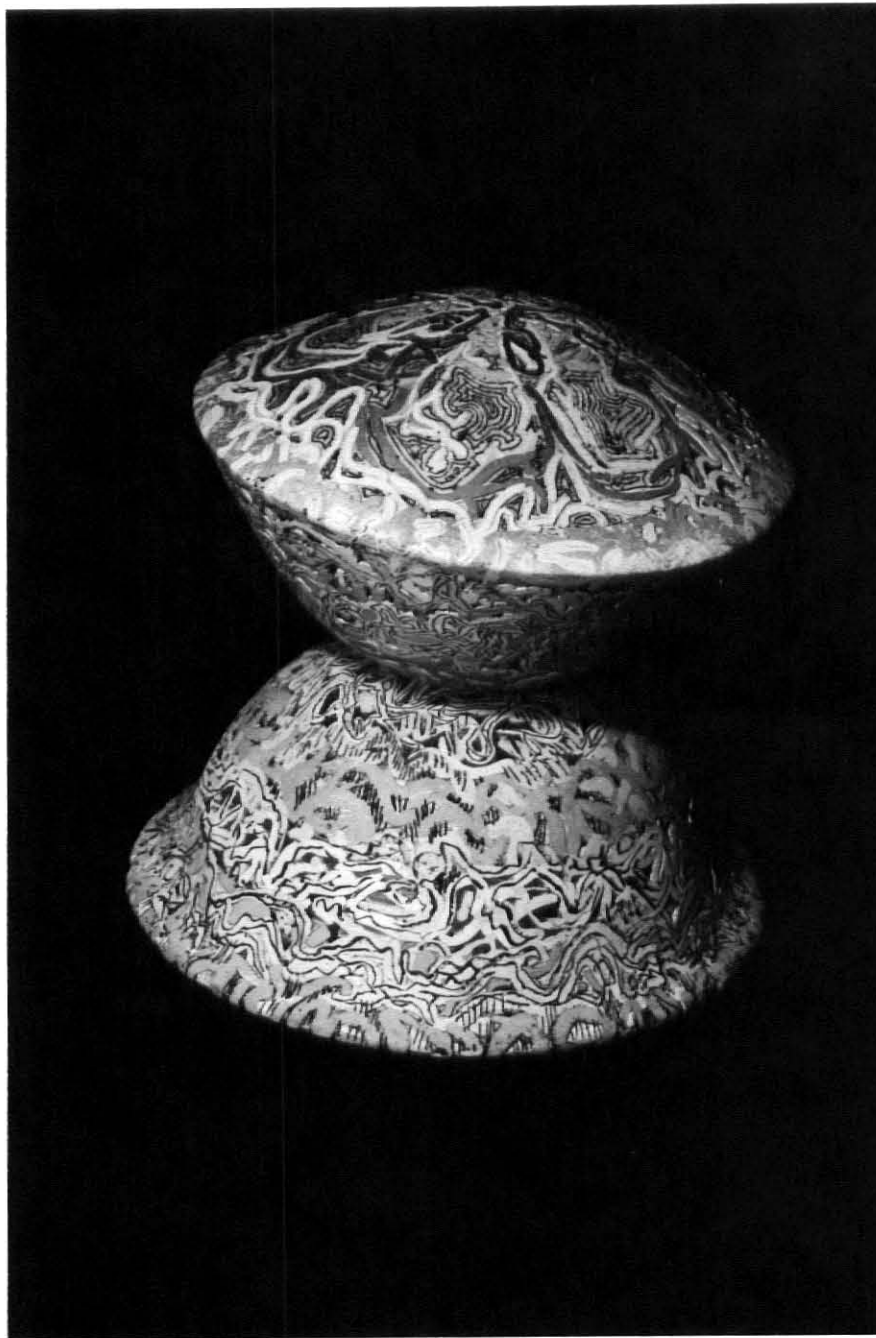
<sup>198</sup> Sgraffito through white slip was used to establish the grid on this slab form. After the waste oil stoneware firing, accents of gold luster were added over the celadon glaze. The bottle measured 10 inches tall.



GREEN DRAGON WHISTLE<sup>199</sup>

<sup>199</sup>This seven toned whistle resulted from a mixture of thrown shapes and modeled sprigging. The stoneware form was fired in a reduction atmosphere with waste oil. The whistle measured 10 inches tall.

## PORTFOLIO PLATE XX

COSMIC SAND DOLLARS<sup>200</sup>

<sup>200</sup>This stoneware form was constructed of thrown shapes. Porcelain and multicolored clay coils were sprigged and paddled onto the surface. The form was waste oil fired and it measured 13 inches tall.



CHICKEN WHISTLE<sup>201</sup>

<sup>201</sup>This salted whistle was constructed using thrown forms and modeled sprigging.  
The whistle measured 5 inches tall.

## BIBLIOGRAPHY

### A. BOOKS

- Bone, W. A., and Donald T. A. Townend. Combustion in Gases. London: Longmans, Green and Company Ltd., 1927.
- Campbell, William Giles. Form and Style in Thesis Writing. 3d ed. Boston: Houghton Mifflin Company, 1969.
- Clower, James I. Lubricants and Lubrication. New York: McGraw-Hill Book Company, Inc., 1939.
- Fansler, P. E. House Heating with Oil Fuel. New York: Heating and Ventilating Magazine Company, 1929.
- Howells, William. Back of History: The Story of Our Own Origins. Garden City: Doubleday and Company, Inc., 1963.
- Koenig, John H., and W. H. Earhart. Literature Abstracts of Ceramic Glazes. Ellenton: College Offset Press, 1951.
- Lawrence, Willis G. Ceramic Science for the Potter. Philadelphia: Chilton Book Company, 1927.
- Moyer, James A. Oil Fuels and Burners. New York: McGraw-Hill Book Company, 1937.
- Nelson, Glenn C. Ceramics, A Potter's Handbook. New York: Holt, Rinehart and Winston, Inc., 1971.
- Olsen, Frederick L. The Kiln Book. Bassett: Keramos Books, 1973.
- Parmelee, Cullen W. Ceramic Glazes. 2d ed. Chicago: Industrial Publications, Inc., 1951.
- Piepenburg, Robert. Raku Pottery. New York: The Macmillan Company, 1972.
- Pugh, Brinely. Practical Lubrication, An Introductory Text. London: Butterworth and Company, Ltd., 1970.
- Rhodes, Daniel. Clay and Glazes for the Potter. Philadelphia: Chilton Books, 1957.
- \_\_\_\_\_. Kilns: Design, Construction and Operation. Philadelphia: Chilton Book Company, 1968.



Romp, Ir. H. A. Oil Burning. The Hague: Martinus Nijhoff, 1937.

Searle, Alfred B. The Chemistry and Physics of Clays and Other Ceramic Materials. New York: Van Nostrand Company, 1926.

Zuidema, Hilbert H. The Performance of Lubricating Oils. New York: Reinhold Publishing Company, 1952.

#### B. PERIODICALS

Behrens, Richard. "An Alternative to Salt Glazing," Ceramics Monthly, XXII, 8 (October, 1974), 44.

Readhead, W. J. "A Waste-Oil Burning Kiln," Pottery Quarterly, Summer, 1959, 52-56.

Soldner, Paul. "Letter: Firing with Oil Diagrams," Craft Horizons, No. 2, XXVIII (March/April, 1968), 7.

\_\_\_\_\_. "Workshop with Paul Soldner: Firing with Oil," Craft Horizons, No. 1, XXVIII (January/February, 1968), 17-19.

#### C. PAMPHLETS

Schurecht, H. G., and K. T. Wood. "The Use of Borax and Boric Acid Together with Salt in Salt Glazing," Ceramic Experiment Station Bulletin, No. 2. Alfred: New York State College of Ceramics, 1942.

#### D. OTHER SOURCES

Alfred University, College of Ceramics. Personal correspondence between Willis G. Lawrence, Dean, as well as, Professor of Ceramic Engineering, and the writer. September 14, 1973.

Bowling Green State University. Personal correspondence between Charles Lakofsky, Department of Art, and the writer. July 8, 1973.

Indiana University. Personal correspondence between Karl Martz, Department of Art, and the writer. June 14, 1973.

Interpace Corporation. Personal correspondence between Elliot House, Director of Marketing, and the writer. July 23, 1973.

\_\_\_\_\_. Personal correspondence between Dave Spore, Director of Ceramics, Consumer Products Division, and the writer. August 7, 1973.

Jones, Ward. Derby Refining Company Retired. Personal interview.  
December 15, 1972.

Kansas State University. "The Soldner Waste Oil Pipe Burner,"  
Demonstration and lecture by Angelo C. Garzio. Department of Art.  
March 17, 1972.

Moore, Harold. Personal interview. September 7, 1974.

Opus 4. Personal correspondence between Al Kinkel, Workshop Instructor,  
and the writer. July 8, 1973.

Soldner, Paul. Personal interview. August 13, 1973.

\_\_\_\_\_. Personal correspondence between Paul Soldner, Aspen,  
Colorado, and the writer, July 8, 1973.

Stoney Point Pottery. Personal correspondence between Karen Karnes  
and the writer. August 7, 1973.

University of Minnesota, Minneapolis. Personal correspondence  
between Warren MacKenzie, Department of Art, and the writer.  
August 6, 1973.

\_\_\_\_\_, Duluth. Personal correspondence between Glenn C. Nelson,  
Department of Art, and the writer. July 8, 1973.

A PRACTICAL STUDY IN THE USE OF AUTOMOTIVE WASTE OIL  
AS A FUEL FOR FIRING CERAMICS

by

ROBERT ALEXANDER FROMME

B. F. A., Bethany College, 1968

---

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Department of Art

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1974

Recent developments in world petroleum industry have forced kiln fuel prices to increase. The study was founded on the hypotheses that waste oil could serve as a practical fuel for the potter.

The study progression involved an attempt to gather all of the available published information concerning the use of this fuel to fire the potter's ware. The information which was accumulated proved to be very scanty. The study required further research into the history of oil burning in order to present a more complete record of knowledge concerning the principles of combustion used in burning waste oil in the potter's kiln. Details concerning both natural draft systems and forced air combustion were written down and supported with oil burning history.

In the course of the study, a need for information regarding the chemical constitution of waste oil fuel became very apparent. Research in this direction was undertaken. Matters of general hydrocarbon composition, as well as, the impurities in the fuel were recorded.

The major portion of the study progression was involved with the development and operation of a practical waste oil burning system. Matters of fuel gathering, cleaning and storage were stated. Experiences in the design, construction and operation of a waste oil pipe burner system were included.

A variety of problems with the fuel became evident in the course of the study. The presence of sulfur from the fuel proved to be a major problem in the kiln atmosphere. The sulfur caused glaze flaws and specific methods of kiln operation were developed to avoid the sulfur flaws. These new methods of kiln operation were applied to reduction

stoneware firing, stoneware salt glazing techniques and Raku firing at lower earthenware temperatures.

Important characteristics of waste oil fuel were covered in a later section which involved concerns of safety, air pollution, and ceramic chemistry. The study has pointed out that the many ceramic chemicals in the fuel have formed a vapor glaze in the kiln which exhibited alterations in glaze surface, color and character of the test pottery.

Conclusions of the study state the disadvantages of the use of waste oil in light of our present knowledge of the material and its potential for the potter. These disadvantages were countered by advantages to the use of the fuel. Automotive waste oil proved to be a practical kiln fuel. The degree of this practicality, however, must remain open to future experimentation and research with the material. The study will provide a respectable, authoritative point of departure for the contemporary potter who may plan to develop and experiment with waste oil burning systems for firing ceramics.