2

TECHNICAL REPORT GL-90-26

US Army Corps of Engineers

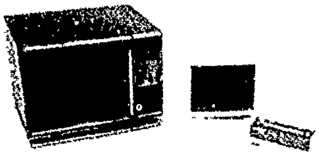
COMPUTER-CONTROLLED MICROWAVE DRYING OF POTENTIALLY DIFFICULT ORGANIC AND INORGANIC SOILS

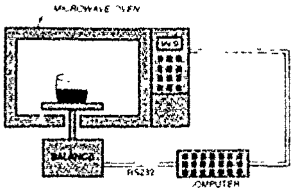
by

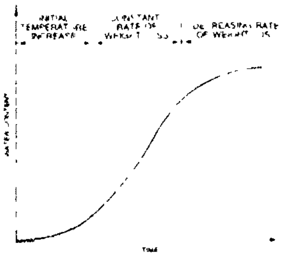
Paul A. Gilbert

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199







December 1990

Final Report

GEOTECHNICAL LABORATORY

Prepared for US Army Engineer Division, Ohio River
Cincinnati, Ohio 45201-1159

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

3. DISTRIBUTION/AVAILABILITY OF REPORT
Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
Technical Report GL-90-26

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
USAEWES
Geotechnical Laboratory

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS *(City, State, and ZIP Code)*
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

7b ADDRESS *(City, State, and ZIP Code)*

8a. NAME OF FUNDING/SPONSORING ORGANIZATION
USAED, Ohio River

8b. OFFICE SYMBOL *(If applicable)*

9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)*
Cincinnati, OH 45201-1159

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

11 TITLE *(Include Security Classification)*
Computer-Controlled Microwave Drying of Potentially Difficult Organic and Inorganic Soils

12. PERSONAL AUTHOR(S)
Gilbert, Paul A.

13a. TYPE OF REPORT
Final report

13b. TIME COVERED
FROM ________ TO ______

14 DATE OF REPORT *(Year, Month, Day)*
December 1990

15 PAGE COUNT
202

16 SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17 COSATI CODES

FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
See reverse

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This report is the second in a series on a microwave drying system for rapid water content developed at the US Army Engineer Waterways Experiment Station. The focus of the first report in the series was on development of equipment and the investigation of its use on inorganic soils. The focus of the present reported investigation is on microwave system drying of potentially difficult soils and earth materials, some of which have a history of requiring special treatment for ordinary conventional oven water content determination. Materials tested in this investigation are gravels, gravelly soils and earth-rock mixtures, dredged materials, fly ash, gypsum rich soils, calcite rich soils, organic clay, peat, and halloysite rich soils.

Because specimen sizes too large to be practical for the microwave system would be required for representative samples in earth-rock mixtures, a procedure is outlined to determine water content based on knowledge of earth-rock composition. Gravels, dredged

(Continued)

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21 ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a NAME OF RESPONSIBLE INDIVIDUAL

22b TELEPHONE *(Include Area Code)*

22c OFFICE SYMBOL

Previous editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

18. SUBJECT TERMS (Continued).

Compaction control equipment
Computer-controlled equipment
Field monitoring equipment
Microwave oven
Rapid water content measurement
User's manual
Water content

19. ABSTRACT (Continued).

materials, organic clay, fly ash, and calcite rich soils are demonstrated to dry satisfactorily in the system using the same procedure as for normal inorganic soils. The system was used to dry materials containing amounts of organic material varying from about 2 percent to about 90 percent, and it was demonstrated that even though special software was required to dry highly organic soil (peat), the equipment dried these materials satisfactorily The system failed to properly dry gypsum rich soils. Special software was required to dry peat and halloysite rich soils, and the development and documentation of this special software are given along with a version of the software for drying inorganic soils written for International Business Machines compatible computers. Additionally, an enhanced version of the original software written for the Commodore 64 computer is given. This version allows for calculations of dry density and allows input and output of many additional pieces of information for site and test identification and documentation.

Data from use of the microwave system on two US Army Corps of Engineers field projects are included along with an evaluation by field personnel who used the equipment. The results of all soil tests are included. It is concluded that the equipment will successfully dry all the potentially problem soils investigated to the conventional oven water content with the exception of gypsum rich soils.

PREFACE

The study reported herein was sponsored by the US Army Engineer Division, Ohio River (ORD), under IAO No. ORD-88-57, dated 24 May 1988. The investigation was conducted by the US Army Engineer Waterways Experiment Station (WES) during FY 1988 and FY 1989.

The study was conducted under the direction of Dr. William F. Marcuson III, Chief, Geotechnical Laboratory (GL), WES, and under the general supervision of Dr. Don C. Banks, Chief, Soil and Rock Mechanics Division (S&RMD), and Mr. Gene P. Hale, Chief, Soils Research Center (SRC), S&RMD, GL. The project engineer for the study was Mr. Paul A. Gilbert, SRC, S&RMD. This report was prepared by Mr. Gilbert. Special thanks are extended to Mr. Terry V. Jobe, SRC, S&RMD, for his invaluable advice and assistance with computer programming. Project monitors for this study were Messrs. David P. Hammer and John W. Emmerich, ORD.

COL Larry B. Fulton, EN, is the Commander and Director of WES. Dr. Robert W. Whalin is the Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres

---

* To obtain Celcius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

COMPUTER-CONTROLLED MICROWAVE DRYING OF POTENTIALLY DIFFICULT ORGANIC AND INORGANIC SOILS

PART I: INTRODUCTION

Background

1. This investigation is the second in a series concerned with developing equipment and experimental techniques for rapid water content determination using microwave radiation. In the first investigation, a computer-controlled microwave oven system was developed along with its controlling software to allow rapid, accurate, and reliable water content determination of inorganic soils. The investigation and its findings (which included a development of the theory of microwave heating, design, and construction of the equipment, and use and calibration of the equipment) were documented in Gilbert (1988).

2. The equipment developed, called the Computer Controlled Microwave Oven System (CCMOS), uses a microcomputer to continuously monitor mass (water) loss of the soil specimen under test. The computer responds to specific software-recognized cues by electronically manipulating the microwave oven function through specially designed interface circuits and terminates the test when certain conditions are satisfied which signal that a water content consistent with that obtained in a conventional oven maintained at 110 ± 5° C has been reached.

3. A patent search was conducted to investigate the uniqueness of the system; as a result of the search, it was determined that the US Army Engineer Waterways Experiment Station (WES) Microwave Drying System is unique, and a patent has been applied for (application number 259661) at the United States Patent Office. Uniqueness of the system stems from the fact that the computer controlled system responds with variable power control to changes in the specimen.

4. The initial investigation focused, primarily, on inorganic soils with no unusual properties. The 1987 WES software-driven microwave drying system worked very effectively on normal soils, but there was no assurance that it would work on more difficult materials. In engineering practice, unusual and sometimes difficult soils must often be utilized for construction; therefore, the water content of these soils must also be determined in a rapid

and accurate manner. Problems have been encountered in very early studies (Gilbert 1974) when utilizing microwave energy to dry highly organic soils and soils containing high percentages of certain ferrous iron compounds.

5. There is, therefore, the need to expand the use of the WES Microwave System to nonroutine soils that must be used in construction and to fine-tune the system, making it more convenient and safe to operate.

Objective and Scope

6. The objective of this study is to extend the use of the WES Microwave Oven System for use with nonroutine materials. This objective will be achieved by acquiring the unusual materials desired for study, testing them in the microwave oven system and the conventional oven, collating the results, and then modifying software and procedures when necessary to achieve the desired correlation between microwave system and conventional oven water contents. The materials to be studied and investigated are gravels and earth-rock mixtures, dredged materials, fly ash, gypsum rich soils, calcite rich soils, peat, and tropical residual soils.

7. Because of the widespread distribution and use of International Business Machines (IBM) (and IBM clone) computer hardware, the software driving the WES Microwave System will be made IBM compatible.

PART II: INTERNATIONAL BUSINESS MACHINES COMPATIBLE SOFTWARE

8. In the early 1980's, IBM published technical specifications for several models of personal computers in the open literature. Consequently, vendors from the private sector responded with IBM clones and compatible personal computers which met the specifications set down by IBM. Personal computers consistent with these specifications became available from many vendors; these were immensely popular and achieved worldwide distribution within 5 years.

9. Because of widespread use and availability of IBM and IBM compatible personal computers and interface peripherals, it was determined necessary to prepare software to allow control of the WES microwave drying system with IBM compatible computers. The IBM system is directly RS232 compatible through a built-in nine pin serial port; communication with the balance of the WES microwave equipment through an RS232C interface is necessary for system operation. A parallel digital input/output (I/O) interface card PIO12 and a specially prepared microwave oven interface circuit board are required for communication with the microprocessor of the microwave oven (Figure 1). The PIO12 interface is a 24 bit parallel digital I/O card manufactured by Metrabyte Corporation of Taunton, MA; this card is inserted into a slot of the computer. The cost of the card was approximately $120 in early 1988. Connection of the I/O card to the microwave oven interface circuit board requires five leads from the PIO12 card, as shown on Figure 1, three leads from port A of the card, a 5-V source, and a ground. The five leads from the PIO12 card connect to an integrated circuit chip, 74LS138, which is a three to eight line decoder; this decoder in turn connects to two semiconductor switches, AD7511D1. These three devices make up the microwave oven interface circuit, described in detail by Gilbert (1988). To control the WES Microwave System with a Commodore 64 computer, a special transistor-transistor logic (TTL) signal booster circuit must be prepared with the same five leads that connect to the microwave oven interface board (Gilbert 1988). However, the difference in cost between the system which allows control with IBM compatible personal computers and the Commodore 64 computer is small (less than $100), and with the Commodore 64 system, the computer can be dedicated exclusively to the microwave system.

10. Different versions of IBM compatible microwave system controlling

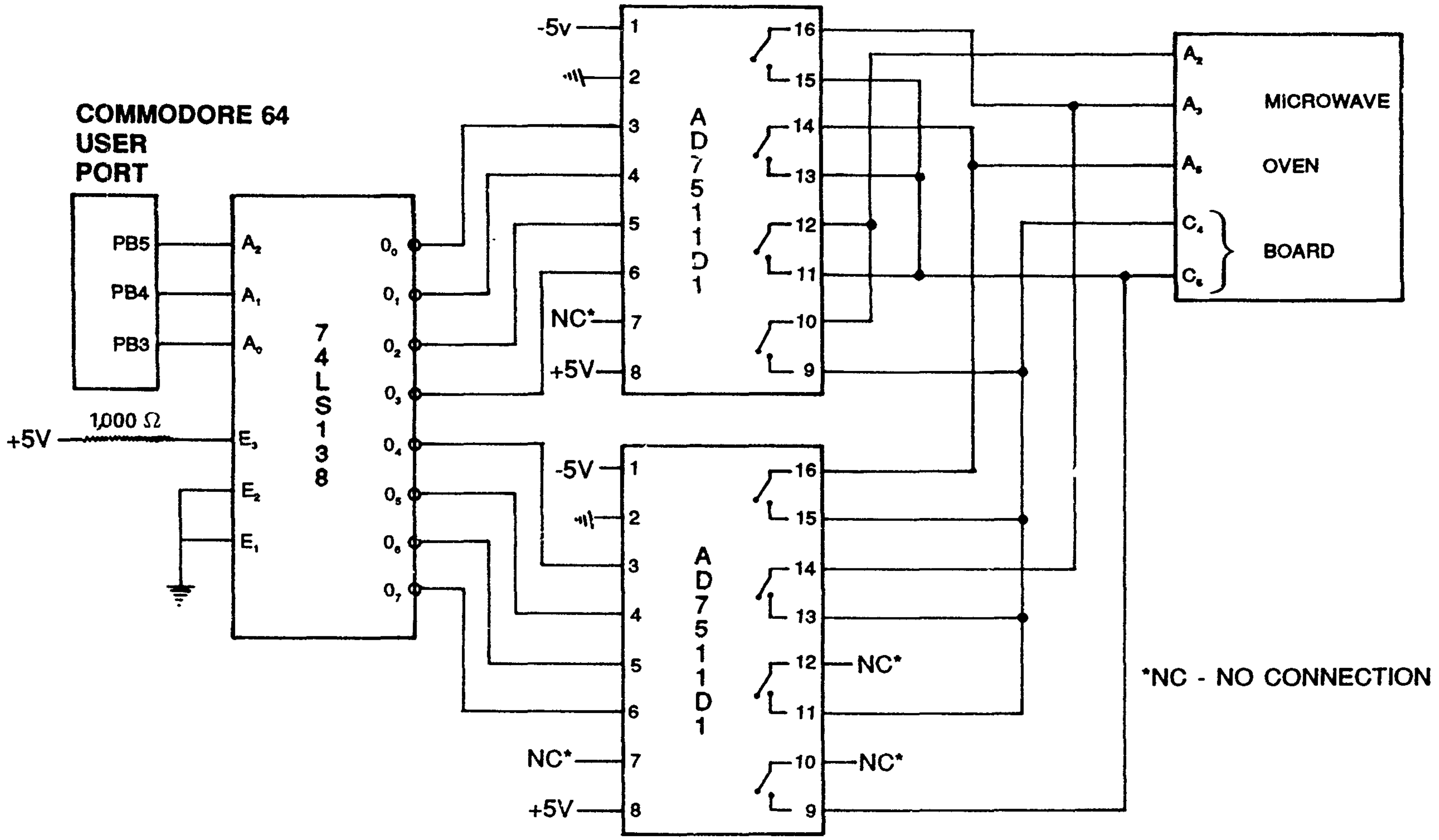


Figure 1. PI012 connection to microwave oven board interface circuit

software to accomplish specific drying tasks are shown as source codes in Appendices D, E, and F, to dry normal inorganic clay and sand, peat and highly organic soil and microwave resistant materials, respectively. Microwave resistant materials are those that require higher power application than normal soils; these materials are in contrast to peat and highly organic soils, which require lower power application than normal soils to reach the conventional oven water content. The software for drying normal inorganic soils is a direct conversion from the Commodore 64 code given in Gilbert (1988). The computer programs for peat and microwave resistant materials (such as halloysite) had to be developed specifically for those materials, and the development will be described later. The IBM versions of the software include a display of total elapsed time since the beginning of the test in addition to total time of microwave exposure. Total elapsed time includes "resting" time as well as time of microwave exposure. All the codes, except that for peat, give the user the option to compute dry density by inputting (during initialization) density specimen volume in cubic feet (determined from a balloon test or sand cone device) and density specimen weight. The software will store these values and when the final water content has been determined will compute and display dry density based on this water content.

11. The Commodore 64 version of the software has been enhanced to allow tabulation of total and microwave exposure times as well as the capability to compute dry density. The operation of the programs will be exactly the same except that the Commodore 64 monitor is only 40 characters wide and the enhanced information cannot fit onto the monitor screen. Therefore, the additional information will appear only on the hard copy from the printer. The enhanced Commodore software is given in Appendix G. Examples of the enhanced output for both the IBM and Commodore driven systems are shown in Figures 2 and 3.

12. For any of the IBM or Commodore 64 software versions, a printer is optional and has to be specified by the user, since provision has to be made for the printer in the timing sequence of the program.

```
                    MICROWAVE OVEN

              WATER CONTENT DETERMINATION

  District: HUNTINGTON   Project: YATESVILLE DAM  Contract: CQGQY383

  Location: YATESVILLE WV   Date: 11/23/90            Time: 1605

Sample No.: 34-C  Classification: CL       Tare Weight (g): 97.69
                                     Wet Weight + Tare (g): 148.10

DENSITY SPECIMEN VOLUME IN CUBIC FEET =  9.294787E-04
DENSITY SPECIMEN WET WEIGHT IN GRAMS  =  50.44

  ELAPSED      DRYING         WEIGHT          WATER
TIME (SEC)   TIME (SEC)        (G)         CONTENT (%)

__________   __________    __________    _____________
     0            0          148.1           0.00
    30           30          147.8           0.06
    60           60          145.9           4.56
    90           90          144.1           8.62
   120          120          142.7          12.00
   150          150          141.7          14.55
   180          180          141.1          16.13
   240          210          140.6          17.48
   300          240          140.4          18.03
   361          270          140.2          18.59
   421          300          140.0          19.15
   481          330          139.9          19.43
   541          361          139.8          19.71
   601          391          139.7          20.00
   661          421          139.7          20.00
   841          421          139.7          20.00
WATER CONTENT = 20.00 %
 FINAL WEIGHT = 139.7 G
TOTAL ELAPSED TIME : 841 Sec
 TOTAL DRYING TIME : 421 Sec
       TECHNICIAN : PAG
  DRY DENSITY = 99.70 PCF
```

Figure 2. IBM printer output

```
                         MICROWAVE OVEN
                   WATER CONTENT DETERMINATION

  DISTRICT: HUNTINGTON    PROJECT: YATESVILLE          CONTRACT: 12345
  LOCATION: WV               DATE: 4/19/89                 TIME: 1530
SAMPLE NO.: 1      CLASSIFICATION: CH            TARE WEIGHT (G): 59.09
                                            WET WEIGHT + TARE (G): 114.4

DENSITY SPECIMEN VOLUME IN CUBIC FEET = 9.294787E-04
DENSITY SPECIMEN WET WEIGHT IN GRAMS  = 49.7

 ELAPSED               DRYING              WEIGHT             WATER
TIME (SEC)           TIME (SEC)             (G)             CONTENT (%)

    0                    0                 114.4               0
   32                   32                 114.4               0
   64                   64                 113.8               1.096
   96                   96                 112.5               3.558
  128                  128                 111.69              5.133
  160                  160                 111.19              6.142
  192                  192                 110.9               6.756
  252                  223                 110.69              7.17
  312                  254                 110.59              7.378
  492                  254                 110.5               7.378

WATER CONTENT = 7.58%

FINAL WEIGHT = 110.5 G

TOTAL ELAPSED TIME = 492 SEC

TOTAL DRYING TIME = 254 SEC

     TECHNICIAN:  TVJ
DRY DENSITY = 109.5 PCF
```

Figure 3. Commodore 64 enhanced output from printer

PART III: HOMOGENIZATION OF WATER CONTENT SPECIMENS

13. The conventional constant temperature oven is the standard for accuracy in water content determination. For this reason, the microwave drying system should occasionally be checked against the conventional oven. For a valid comparison, care should be taken to ensure that specimens placed in both oven systems are as identical as possible. To achieve identical specimens, a single specimen should be placed in a vessel, broken up into small pieces, thoroughly mixed, and then "split" into two water content specimens for the microwave system and conventional oven.

Water Content Variation in Clay Chunks

14. Water content in clays of high plasticity may be highly heterogeneous even after long periods of curing because of the low permeability sometimes characteristic of clays and the fact that small particles of highly plastic clays bind and hold water molecules so tightly that they cannot easily move through the soil mass. Therefore, uniform distribution of water content throughout a large volume of specimen may not occur even after long periods. Consequently, if a large water content specimen is not properly "homogenized" before it is separated into the microwave and conventional oven specimens, two specimens with different water contents may be placed in the microwave and conventional oven systems and comparison of the systems will not be valid.

15. The degree of homogenization in terms of the size of particles into which specimens are broken is significant. For example, in one experiment, large chunks of a medium plastic clay (called pullout clay) (liquid limit (LL) = 53 percent, plasticity index (PI) = 34 percent) were allowed to stand uncovered and dry in the WES soils laboratory under conditions of relative humidity about 60 percent and temperature about 25° C. After drying for 3 days in the open air, the large chunks were randomly separated into two batches and processed: one batch was broken up into smaller chunks of soil about 2 in.* in size; the second batch was shredded with a cabbage shredder into about 0.1-in. granules. The two batches were then cured for 3 days in airtight containers, and 72 conventional oven water contents consisting of

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

about 100 g each of wet soil were taken from each batch. The resulting water contents are shown tabulated in Tables 1 and 2. In 72 water contents, the maximum variation in water content in the batch with the 2-in. chunk was 8.62 percentage points, and the standard deviation of that population was 2.006 percentage points.

Water Content Variation in Homogenized Clay

16. Maximum water content variation in the batch shredded to 0.1-in. granules was 0.33 percentage points with a standard deviation of 0.066 percentage points. Breaking the soil up into very small granules "homogenized" the material to the extent that, for experimental purposes, two random samples taken from the container of granules were identical. However, two samples taken from the container of 2-in. chunks of material were not identical and may have shown substantial difference in water content.

17. This experiment shows quite clearly the importance of properly homogenizing and splitting water content specimens for comparison tests Additionally, the experiment demonstrates that significant spatial differences in water content may be measured in the field for some materials even with careful sampling techniques. The solution may be to test large water content specimens or perform many water content tests in critical areas of construction.

18. The problem of water content heterogeneity decreases with decreasing material plasticity. For example, the movement of interstitial water occurs much more easily in sands and silts than in clays, and water content sampling and equilibrium problems are far less significant in these materials. Therefore, better correlation between microwave system and conventional oven water contents may be obtained for silts and sands than for plastic clays, but this is a function of the ease of material sampling and not necessarily a problem with the microwave system.

Table 1

Water Content Variation in 2-in. Chunks of Pullout Clay

Sample Number	Water Content %	Sample Number	Water Content %
1	22.48	37	22.44
2	22.71	38	23.68
3	17.19	39	24.68
4	23.80	40	24.34
5	21.08	41	23.76
6	19.87	42	25.38
7	21.25	43	22.71
8	21.42	44	23.62
9	18.33	45	25.08
10	18.06	46	21.98
11	21.38	47	23.09
12	24.30	48	20.65
13	25.29	49	24.37
14	25.25	50	22.73
15	19.05	51	21.84
16	23.78	52	23.08
17	23.34	53	23.71
18	25.39	54	23.84
19	22.90	55	23.51
20	25.37	56	22.31
21	25.81	57	23.60
22	22.72	58	24.26
23	24.35	59	23.12
24	20.70	60	18.89
25	24.74	61	21.27
26	22.13	62	23.37
27	25.28	63	21.90
28	25.38	64	20.72
29	20.00	65	20.48
30	24.14	66	22.47
31	20.98	67	23.28
32	25.41	68	22.50
33	25.11	69	25.18
34	18.61	70	23.68
35	21.95	71	23.72
36	20.20	72	22.34

Note: Average Water Content = 22.788 percent.
Standard Deviation = 2.006 percent.
Maximum Variation = 8.62 percent.

Table 2

Water Content Variation in 0.1-in. Granules of Pullout Clay

Sample Number	Water Content %	Sample Number	Water Content %
1	28.90	37	28.77
2	28.92	38	28.91
3	28.92	39	28.90
4	28.89	40	28.90
5	28.79	41	28.95
6	28.87	42	28.98
7	28.93	43	28.78
8	28.84	44	28.83
9	28.76	45	28.88
10	28.90	46	28.94
11	28.88	47	28.86
12	28.86	48	28.92
13	28.86	49	28.82
14	28.98	50	28.88
15	28.91	51	28.97
16	28.83	52	28.92
17	28.87	53	28.90
18	28.87	54	28.86
19	28.86	55	28.76
20	28.82	56	28.77
21	28.89	57	28.75
22	28.84	58	28.91
23	28.82	59	29.02
24	28.86	60	28.79
25	28.82	61	28.95
26	28.85	62	28.78
27	28.83	63	28.84
28	28.86	64	28.78
29	28.88	65	28.70
30	28.88	66	28.69
31	28.86	67	28.84
32	28.88	68	28.84
33	28.88	69	28.84
34	28.86	70	28.80
35	28.83	71	28.73
36	28.83	72	28.73

Note: Average Water Content = 28.855 percent.
Standard Deviation = 0.066 percent.
Maximum Variation = 0.33 percent.

PART IV: DEHYDRATION OF CLAY MINERALS

19. The relationship between propensity of a clay mineral to dehydrate at a temperature between 150° C and 250° C and close correlation between microwave and conventional oven water content was discussed at length by Gilbert (1988). Less weight loss between those temperature ranges will correspond to better microwave/conventional oven correlation. Many exotic and unusual clay minerals exist, some of which are rare and some of which exist only in specific areas of the world. The difficulty and expense of acquiring and assembling a large number of these unusual materials for testing are obvious. However, the appropriateness of drying certain minerals in the microwave oven and the expected correlation with a conventional oven can be deduced by considering dehydration characteristics between 150° C and 250° C. For this purpose, dehydration characteristics of a number of clay minerals have been assembled in Appendix C. The tables shown were taken from Nutting (1943). The "weight ratio" used in the tables is the ratio of the weight at any temperature to the weight at some reference temperature, usually 800° C. However, 800° C is not always the reference temperature; some chlorites and silicates are referenced to 1,000° C, some micas are referenced to 100° C, and some carbonates are referenced to 50° C. From these tables, the relative difference in water content between microwave system and conventional oven may be estimated based on the dehydration characteristics of a given clay mineral.

20. It must be stated that the dehydration tables of Appendix C were determined in a constant temperature oven in which the respective minerals were allowed to come to constant weight at a given temperature. Relatively long periods of time were required for some minerals to reach constant weight. Therefore, even if the tables of Appendix C show a significant relative weight change between 150° C and 250° C for a specific mineral, it does not mean that mineral cannot be successfully dried in the microwave system. A calibration test should be performed and compared with a test from the conventional oven because, although temperatures may rise to 250° C in specimens in the microwave oven, the time of high temperature exposure is short and the zone of high temperature development is often localized, especially since microwave energy application in the WES Microwave System is intermittent in the last stage of drying.

PART V: EARTH-ROCK MIXTURES

Background

21. Mixtures of soil and gravel or stone are used extensively in the construction of foundations, bases, and embankments. As with other earth materials used in construction, the stress-strain and strength characteristics of earth-rock mixtures are controlled by controlling water content and density of placed and compacted fill. Structures being built with earth-rock mixtures must be carefully monitored in real time during construction to ensure that water content and density remain within specified limits around target values; this can be a problem even for the WES Microwave System because of the large masses of material required to ensure representative sampling. For example, the recommendation given by the American Society for Testing and Materials (ASTM) (1988) for minimum specimen sizes in materials containing large particles is given in Table 3. It should be noted that the guidance given by ASTM is in rough agreement with that given in the EM 1110-2-1906 (US Army Corps of Engineers (USACE) 1970), as shown in Table 4. In either case, the minimum mass of wet soil required for materials with a maximum particle size greater than 1/2 in. varies from an amount that is very inconvenient for the present microwave oven system (500 to 1,000 g) to an amount that is not possible with the present system (>1,500 g).

Explosion of Gravel Particles

22. In addition to the inconvenience of handling and drying large specimens of earth-rock mixtures, there is the danger that larger gravel, shale, or stone particles will explode during microwave drying. If particles do explode, it is likely that the test will have to be aborted because the specimen container may be broken or solid material may be ejected from the container. Specimen containers that have the capability to "smother" and contain exploding particles are available (Gilbert 1988), but they are inconvenient to use and may prevent complete soil drying because the container must be closed.

23. Water-saturated soil particles of high brittle strength tend to explode upon drying inside a microwave oven that outputs about 700 w of microwave energy. Particles explode because water vapor is generated more rapidly in the interior of a particle than it can escape through particle

Table 3

ASTM D 2216-80 Minimum Water Content Specimen Sizes

Sieve Retaining More Than About 10% of Sample	Recommended Minimum Mass of Moist Specimen, g
2.0 mm (No. 10) sieve	100 to 200
4.75 mm (No. 4) sieve	300 to 500
19 mm (3/4 in.)	500 to 1,000
38 mm (1-1/2 in.)	1,500 to 3,000
76 mm (3 in.)	5,000 to 10,000

Table 4

EM 1102-2-1906 Minimum Water Content Specimen Sizes

Maximum Particle Size	Minimum Weight of Sample, g
3-in. (76 mm)	6,000
2-in. (51 mm)	4,000
1-in. (25 mm)	2,000
1/2-in. (13 mm)	1,000
Finer than No. 4 sieve	200
Finer than No. 10 sieve	100

pores. Therefore, with time, vapor pressure builds up to a level where the strength of the particle is exceeded and an explosive failure results because of sudden brittle fracture of the particles.

24. The length of path through which vapor must pass to escape to ambient pressure is a function of particle size. Experience has shown that the division between exploding and nonexploding particles (in a 700-w oven) is 1 in. This size was identified by saturating various sizes of gravels known to have a saturated, surface dry water content of about 3 percent and then subjecting the material to microwave drying. The gravels were saturated using vacuum to remove air from the particles and then soaking the particles in water. Some 1-in. gravel particles so treated exploded upon microwave heating. When the fragments of the exploded particles were collected, resaturated, and reheated in the microwave oven, they did not explode. Of course, the particles that resulted from the explosion were less than 1 in. in size.

25. It must be stated that power output is an important consideration in identifying explosion susceptibility of particles. Higher power ovens will vaporize water more quickly. Therefore, ovens with power output levels greater than 700 w will likely cause particles smaller than 1 in. in diameter to explode. Therefore, problems associated with exploding stone particles may be avoided by using any of the following measures:

- a. Do not dry stone and aggregate particles bigger than 1 in. in ovens of about 700-w output power. (Use smaller particles in ovens of higher power.)
- b. Use fractional power application to slowly heat stone particles 1 in. or more in size, thus allowing time for vapor to escape to avoid explosions.
- c. Use containers that will effectively contain and absorb the energy of an explosion.
- d. Recover all the material ejected from specimen containers after an explosion, restore the material to the container, and continue the test. This technique may be used to recover a specific water content test but is not offered as a general satisfactory solution to the problem of exploding particles.

Water Content of Earth-Rock Mixtures

26. The water content of gravel particles resulting from the mechanical breakdown of solid competent parent rock is generally limited to about 3 percent. Table 5 shows percent water absorption (which is the saturated

Table 5

Water Absorption Capacity of Some Coarse Aggregates

Material	Percent Water Absorption	Reference
Crushed limestone	3.0	WES 1955
Crushed limestone, limestone screenings, and fine river bar sand	0.4 (+ No. 4 Fraction)	WES 1956
Uncrushed chert gravel, Natchez Sand, and limestone dust	2.1 (+ No. 4 Fraction)	WES 1956
Porous basalt (Keflavik) aggregate	2.4 (+ No. 4 Fraction)	WES 1956
Blend of slag (+ No. 4), crushed limestone, fine river sand, and limestone dust (- No. 4)	3.6 (+ No. 4 Fraction)	WES 1956
Florida (Brooksville) limestone	3.7 (+ No. 4 Fraction)	WES 1956
Coral: Cooper's Island Quarry, Bermuda	13.9 (+ No. 4 Fraction)	WES 1956
Coral: Bourne Quarry, Bermuda	7.1 (+ No. 4 Fraction)	WES 1956
Porous Basalt from Ririe Dam in Idaho	3.1	This study
Average concrete sand	0 - 2	Troxell et al. 1956
Average gravel; crushed limestone	1/2 - 1	Troxell et al. 1956
Trap rock: granite	0 - 1/2	Troxell et al. 1956
Sandstone	2 - 7	Troxell et al. 1956
Folsom Dam Gravel	2.0	Personal Communication*
Warm Springs Dam Gravel	3.0	Personal Communication**
DeGray Dam Gravel	4.0	Strohm and Torrey 1982

---

* Personal Communication, 1988, R. T. Donaghe, WES, Vicksburg, MS.

** Personal Communication, 1988, D. P. Hammer, ORD, Cincinnati, OH.

surface dry water content) of some coarse aggregate of chert, limestone, basalt, and quartz. Clay, at the other extreme, can exist at water contents that span hundreds of percent. Therefore, when clay, gravel, and intermediate size and plasticity material exist in an earth-rock mixture, logic will suggest that since the water content of the gravel fraction spans such a narrow range, water content of the nongravel will dominate the average water content of the mixture.

27. Simple moment analysis allows derivation of the equation

$$w_{avg} = w_c + X\,(w_g - w_c) \qquad (1)$$

where

w_{avg} = average water content of an earth-rock mixture
w_c = water content of the nongravel fraction in the earth-rock mixture
X = gravel fraction = M_{gd}/M_{td}
M_{gd} = dry mass of gravel in earth-rock mixture
M_{td} = total dry mass of earth-rock mixture
w_g = water content of gravel in the earth-rock mixture

Equation 1 is valuable for a number of reasons. First, it allows a sensitivity analysis of all the factors involved in determining the water content of earth-rock mixtures. For example it may be shown that if the water content of the gravel is bracketed at 3 percent or less, then the influence of the gravel water content on the average water content of the mix is small (if X is also small). Second, Equation 1 allows accurate estimation of the water content of an earth-rock mixture if the water content of the nongravel and the gravel fraction are known. Large size in water content specimens to ensure proper sampling is not necessary if Equation 1 is used. This may be a great advantage in using the microwave oven to determine the water content of earth-rock mixtures since the use of large samples exceeding 1,000 g is often not convenient or possible in the microwave oven. Water content of the nongravel fraction may be measured routinely with the microwave oven system. The water content of the gravel fraction may be estimated (based on judgment or experience), measured (using microwave or conventional oven), or assumed to be zero since the range of the gravel water content is small and its influence on the total water content slight. Once an accurate measure of gravel water content is determined, that value may be assumed to be a constant for subsequent total water content determinations for some period of time or until the gravel source changes since the water content for gravel in a given area is not likely to vary appreciably.

28. The only remaining value necessary for the use of Equation 1 is X , the gravel fraction. The actual value may be computed from the equation

$$X = \frac{M_{gw}}{M_{tw}} \left(\frac{1 + w_{avg}}{1 + w_g} \right) \quad (2)$$

where

M_{gw} = wet mass of gravel
M_{tw} = total wet mass of mixture

However, if the water content of gravel in the mixture is small compared with the water content of the nongravel, then

$$X_{est} = \frac{M_{gw}}{M_{tw}} (1 + w_c) \quad (3)$$

29. As an example of the magnitude of error involved in using Equation 3 for typical proportions of earth-rock mixtures, if the gravel water content, w_g , is 3 percent, clay water content, w_c , is 20 percent, and the gravel fraction, X , is 20 percent, then using Equations 2 and 3

$$\frac{X_{est}}{X} = 1.06$$

This means that about 6-percent error will result in the estimate of gravel fraction. If the true and estimated values of gravel fraction are then used in Equation 1 to compute average water content of a mixture, then for the values given

$$\frac{(W_{avg})_X}{(W_{avg})_{X_{est}}} = 1.01$$

This means that typically about 1-percent error in the computed value of average water content using this system will result from the assumption that water content of the gravel fraction is small compared with water content of the nongravel fraction.

30. The gravel fraction, X , may be fairly easily obtained using

either Equation 2 or 3. An amount of wet material sufficiently large to contain a representative soil and rock mix must be obtained and weighed (M_{tw}). Now if it is determined to define the gravel fraction as the material coarser than the No. 4 sieve, then the wet sample should be screened on the No. 4 sieve, and the clay that adheres to the rock particles dislodged by, for example, blowing with pressurized air. The + No. 4 material should now be weighed to obtain M_{gw}. The microwave oven system may then be used to obtain the water content of the nongravel fraction (and also the water content of the gravel fraction). The gravel fraction may now be determined using Equation 2 or 3, and Equation 1 may be used to compute the water content of the mix. The obvious advantage of using this system is that a large sample which may be representative of the in situ mass (but which is too large to be used in the microwave oven) may be analyzed for water content.

Influence of gravel water content

31. An additional and valuable advantage of Equation 1 is that it allows direct examination of the influence of change in gravel water content on the change in average water content. This can be done by differentiating w_{avg} with respect to w_g. This operation yields

$$\frac{\partial w_{avg}}{\partial w_g} = X \tag{4}$$

This equation written in a slightly different form is

$$\Delta w_{avg} = X \cdot \Delta w_g \tag{5}$$

Equation 5 shows that the change in water content of the mixture is the product of the gravel fraction and the change in gravel water content. For example, if the gravel water content were determined to be in error by 2 percentage points and the gravel content 20 percent, then the error in gravel water content would cause an error in the average water content of 0.4 percent. The range over which gravel water content can vary, combined with examination of Equation 5, shows that the influence of gravel water content on average water content is small.

Conclusions

32. The conclusions which are warranted from the analysis presented in the previous paragraphs of the microwave drying of earth-rock mixture are:

a. Samples of earth-rock mixtures large enough to be statistically representative of the in situ mass would be so large as to be inconvenient or impossible for the microwave system to handle.

b. Stone or rock particles less than about an inch in diameter are not likely to explode in microwave ovens generating about 700 w of output power. Explosions may be avoided by excluding such oversize particles from microwave water content specimens.

c. The saturated surface dry water content of many rock or gravel particles has an upper limit of about 3 percentage points, a value that is small relative to the potential water content of clay soils.

d. Based on c above, the water content of earth-rock mixture may be conveniently computed with sufficient accuracy by determining the gravel content and measuring the water content of the clay fraction (using the microwave oven system).

33. In the next part of the report, the combined effect of these conclusions is tested experimentally where microwave oven water content of gravels and gravelly soils are compared with conventional oven test results.

PART VI: MICROWAVE DRYING OF GRAVELS AND GRAVELLY SOILS

34. Gravels and gravelly soils are important as construction materials in and of themselves and as components in earth-rock mixtures. It has been demonstrated (Gilbert 1988) that the microwave system dries (inorganic) clays and silts effectively and reliably to the conventional oven water content. However, because of the extensive use of earth-rock mixtures, it is important to demonstrate that the system works effectively on clean gravels as well as clay-gravel mixtures. Several materials were obtained for study and evaluation in this investigation, and they are described briefly in the following section.

Materials

35. The materials tested during this phase of the study are described in the following paragraphs.

Folsom Dam gravel

36. Gravel from the site of Folsom Dam was obtained near Sacramento in northern California. The material has a relatively high specific gravity (about 2.9), probably because much of the material is weathered granite and rich in feldspar. The saturated surface dry water content specimens were prepared by soaking the material under water with vacuum applied for 24 hr, after which it was removed from the water and the surface blotted dry.

Warren County clay gravel

37. The Warren County sample is a red clay gravel mixture, 46-percent gravel, 43-percent sand, and 11-percent silt and clay size particles by weight. This soil was obtained from gravel pits in central Mississippi near Vicksburg. The material is geologically 2 to 3 million years old and was water deposited as a much coarser material that weathered under very moist conditions to produce finer gravel, sand, and whatever clay is present. The red color is due to the degradation of an iron compound and is present in the clay in the ferrous state. This material was selected not only because it is a clay gravel, but also because it contains ferrous iron and it is desirable to demonstrate that iron compounds present in soils in normal quantities present no problems for the microwave system.

Warren County pea gravel

38. This material is the washed-gravel faction of Warren County clay gravel between the No. 4 and the 3/8-in. sieve. The material was tested saturated surface dry and prepared like Folsom Dam gravel.

Warner Robbins AFB sand

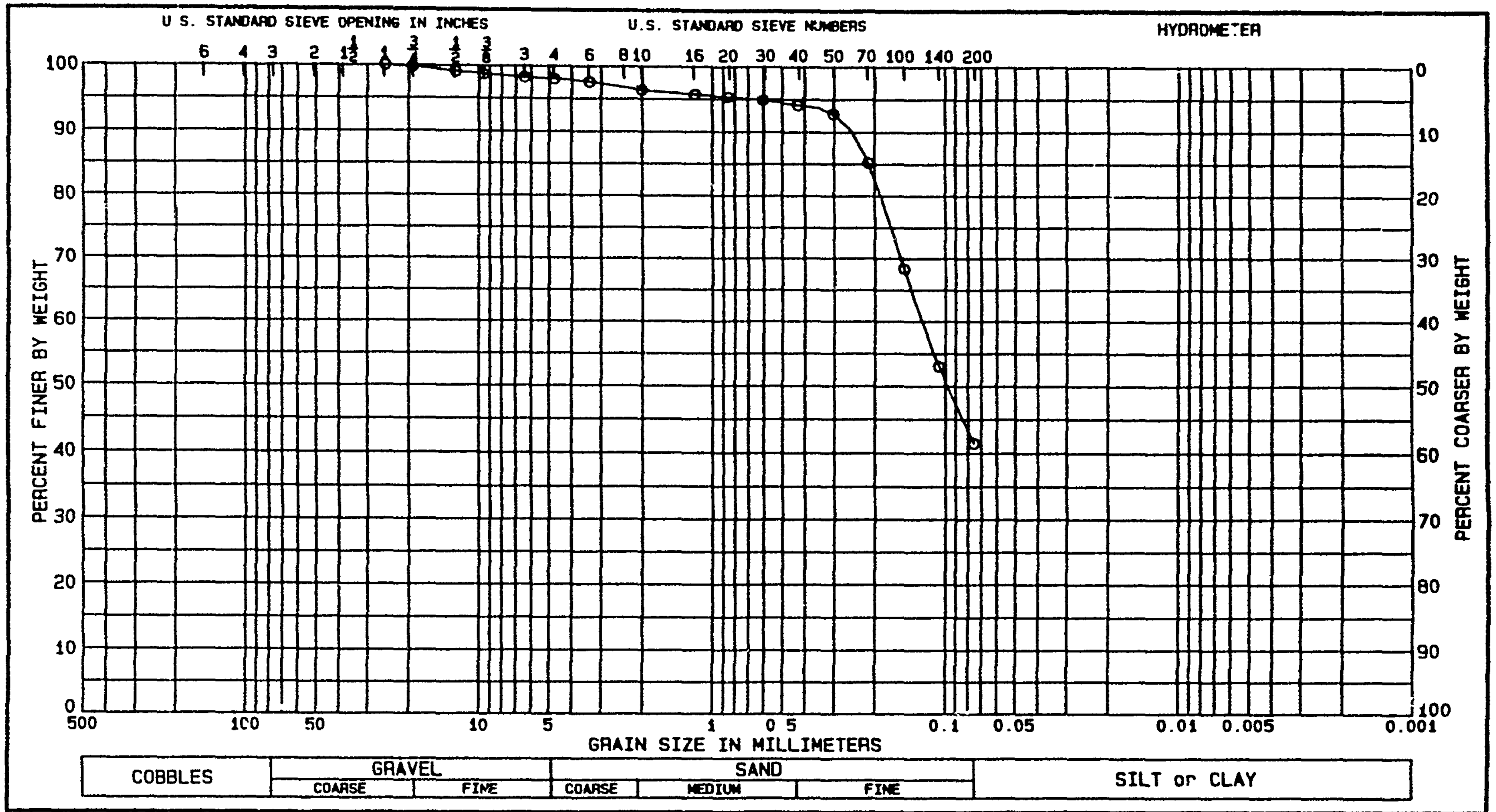
39. Warner Robbins AFB sand is a reddish brown clayey sand from Georgia. The grain size distribution curve of the soil is shown in Figure 4. The material is about 41-percent silt and clay, and the liquid and plastic limits of the silt and clay faction are 23 and 11 percentage points, respectively. This material was chosen (in addition to its high sand content) because it contains a significant amount of ferrous iron compounds.

NPD gravelly clay

40. This material is a brown gravelly clay from the core of Mt. St. Helens Sediment Retention Structure in Washington State located about 20 miles west of the Mt. St. Helens Volcano on the Toutle River. The composition is about 12 to 15-percent gravel and about 35-percent sand by weight. Liquid and plastic limits of the clay fraction are 60 and 30 percentage points, respectively. This material was chosen for testing in the WES Microwave System because uncontrolled microwave systems experienced problems in drying this material to the conventional oven water content.

Fifty-percent gravel mix

41. This soil is a prepared mixture of 50-percent Folsom gravel (No. 4 to 3/8-in. sizes) and 50-percent pullout clay by weight. Pullout clay is an inorganic "Buckshot-like" clay (LL = 53 percent, PI = 19 percent) of medium plasticity. This material was prepared to contain the maximum amount of clay and still be considered a coarse-grained soil. The reason for the preparation and testing of this "border-line" granular material was to determine if any material classified granular by the Unified Soil Classification System (USCS) (USAEWES 1960) should be dried to the same extent that clean sands and gravels are. Clean sands and gravels consist of relatively large particles (>0.074 mm in diameter) and bind and hold little adsorbed water. Clay particles, on the other hand, may bind and hold considerable adsorbed water very tightly because of their highly charged crystal surfaces. Therefore, clays and granular soils react differently to the application of microwave energy. Granular materials give up all water fairly easily as the result of microwave energy exposure, but clays will retain a level of adsorbed water. Different schedules of microwave energy



LL	PL	PI	GS	NAT W,%	
23	11	12	2.69		

CLASSIFICATION
CLAYEY SAND (SC) REDDISH BROWN

GRADATION CURVE

PROJECT RESILIENT MODULUS RESEARCH

BORING NO. SAMPLE NO.
DEPTH/ELEV SUBGRADE DATE 04 DEC 87

Figure 4. Grain size curve of Warner Robbins AFB sand

application are required for the drying of clean granular materials and clays. This fifty-percent gravel mix soil will be used to determine if a "border line" clay/gravel should be dried as a clean granular soil or as a clay.

Fifty-percent sand mix

42. This soil is a prepared mixture of 50-percent Ottawa silica sand and 50-percent pullout clay by weight. This mix is designed to demonstrate for sand what the 50-percent gravel mix demonstrates for gravel.

Results of Tests on Gravels and Gravelly Soils

43. Microwave and conventional oven tests performed on gravels and gravelly soils summarized and compared on Table 6 show that there is good correlation between the microwave system water content and the conventional oven water content. The maximum difference between the two values is less than 1/2 percentage points in all cases, and in most cases substantially less than 1/2 percentage point. All the materials reported on this table were dried in the microwave oven as clean sands, meaning that microwave energy was applied to the soil specimen by the microwave drying system until no decrease in water content occurred over successive 30-sec intervals of microwave heating. This proves to be a more sound procedure for drying for any material classified as coarse grained in the USCS (WES 1960). In the USCS, a coarse-grained material is defined as a soil with 50 percent or less of the particles by weight passing the No. 200 sieve. The results of the last two entries in Table 6 as well as the test on the Warner Robbins AFB sand demonstrate that drying such (coarse-grained) materials to two 30-sec intervals of no weight loss is a valid criterion for terminating the process. This criterion will therefore be incorporated into the controlling software, and it will thus be the responsibility of the user to determine if the material being dried is classified a coarse-grained soil.

44. No explosions were observed in drying the Folsom gravel between 1 and 1-1/2 in. However, this material consisted of hard, strong particles.

Table 6

Summary of Water Content Comparison Tests on Gravels and Gravelly Soils

Material	Initial Mass, g	Drying Time, sec	Water Content, % (1) Microwave	Water Content, % (2) Conventional	Difference (2) - (1), %
Folsom Dam gravel (saturated surface dry)					
No. 4 - 3/8 in.	337.7	473	1.93	2.07	0.14
3/8 in. - 1/2 in.	378.3	534	1.42	1.38	-0.04
1/2 in. - 3/4 in.	656.9	625	1.24	1.34	0.10
3/4 in. - 1 in.	717.3	377	1.38	1.23	-0.15
1 in. - 1-1/2 in.	718.5	566	0.53	0.50	-0.03
Warren County pea gravel (saturated surface dry)	312.5	872	2.69	2.82	0.13
Warren County clay gravel (GC) (46% gravel)	417.3	691	5.27	5.25	-0.02
Warner Robbins AFB sand (SC)	165.2	503	15.92	15.91	-0.01
North Pacific Division gravelly clay (GC)					
No. 30 + 04.7	304.0	811	33.92	33.79	-0.13
No. 24 + 21.2	310.5	781	34.47	34.93	0.46
No. 11 + 02.0	272.3	841	42.04	41.74	-0.30
No. 11 + 02.0a	291.2	811	39.53	39.10	-0.43
50% gravel mix	332.2	721	16.88	16.42	-0.46
50% sand mix	161.3	571	21.00	21.18	-0.18

Conclusions

45. Conclusions from this investigation are:

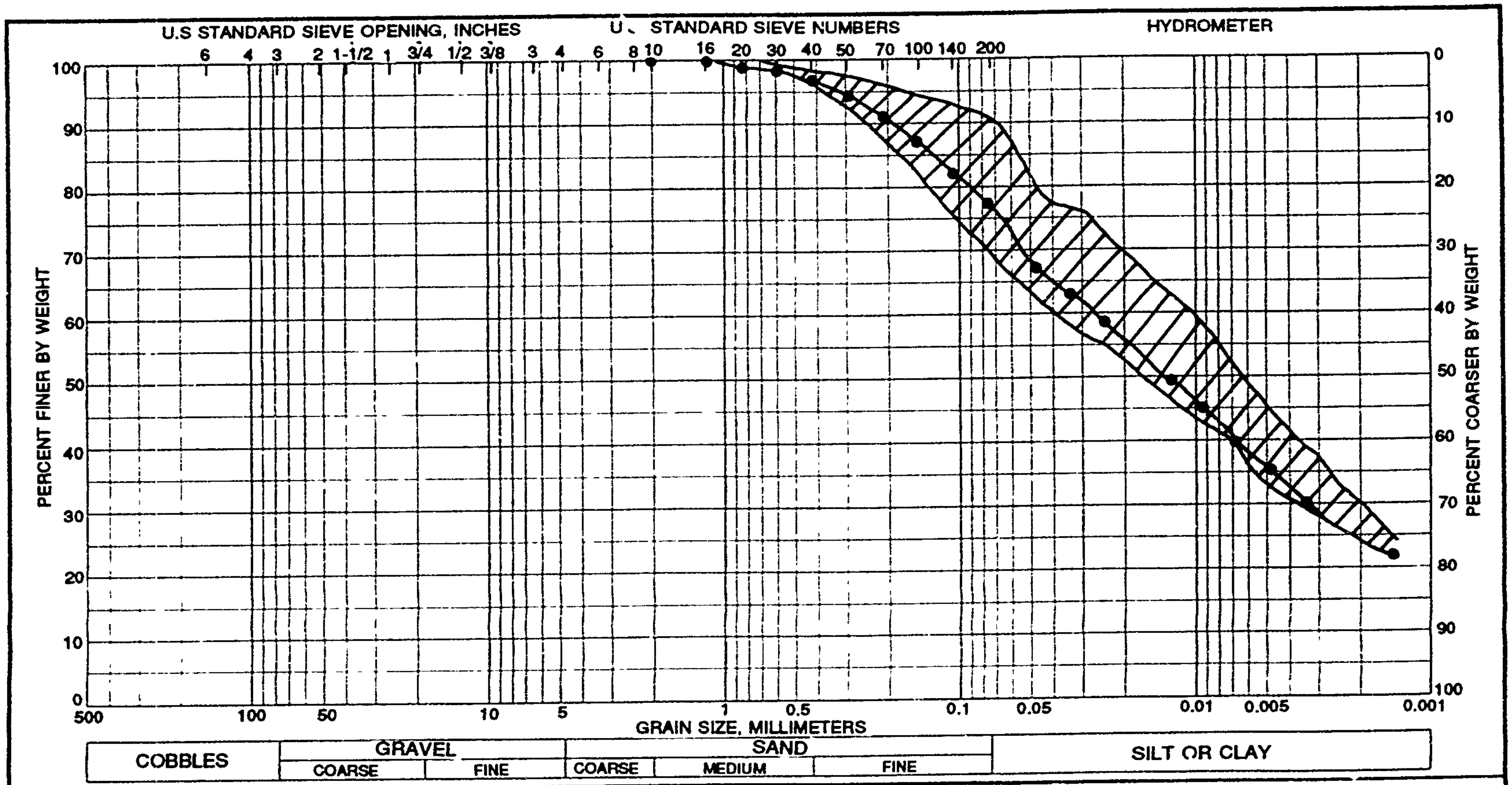
- a. The criterion for termining a microwave test on any coarse-grained soil should be to dry until no weight change occurs during two 30-sec drying intervals.
- b. Hard, strong homogeneous gravel particles are more resistant to exploding than flawed, anisotropic particles.
- c. The microwave system dried soils containing varying amounts of ferrous iron compounds to the conventional oven water content without difficulty.
- d. The microwave system dried all the gravels and gravelly soils tested to the conventional oven water content without difficulty.

PART VII: DREDGED MATERIALS

46. Millions of cubic yards of fine-grained soils having high water content and low strength are dredged from the harbors and navigable waterways of the United States each year. These dredged materials are generally regarded as waste products to the extent that they are deposited in landfills in the hope that they will drain, be reduced in volume by subsequent water loss, gain strength, and ultimately become useful foundations. Because of the fine-grained character of many dredged materials and the typically high field water contents (generally several times the liquid limit), it may be necessary to dry these materials from 30 to 48 hr in a conventional constant temperature oven to determine an accurate water content. Accurate and expedient water content information may be required for strength and stability evaluation and decisions concerning the treatment, management, or storage of dredged material that may be contaminated with toxic chemicals or may contain varying amounts of organic material.

47. Companion tests in the conventional oven and microwave systems were performed on two typical dredged materials obtained for this investigation; one material was taken from Mobile Bay in Alabama, and the other from the Pascagoula River in Mississippi. The range of grain size for the Mobile Bay material is shown on Figure 5, and a single grain size curve for the Pascagoula River material is shown on Figure 6. These figures show that the particles of these particular soils range from medium sand size particles to particles finer than 0.001 mm. Both materials tested in this investigation are classified as highly Plastic Clay (CH) soils. The classifications as well as Atterberg limits and physical description of the materials are given in Figures 5 and 6.

48. It should be noted that no special precautions were required to dry these dredged materials. They were dried as normal inorganic to slightly organic clays with unmodified software and exhibited very unremarkable drying behavior in the oven except that a great deal of vapor and odor were generated. Since some dredged materials may contain toxic chemical contaminants, it will be recommended that when a microwave oven system is used to dry dredged material, the vapors generated should either be discharged underneath a ventilated fume hood or discharged to the outside air.



LL_{AVG} = 96	PL_{AVG} = 28	PI_{AVG} = 68	G_S = 2.7	NT W.%

CLASSIFICATION
SANDY CLAY (CH) GRAY

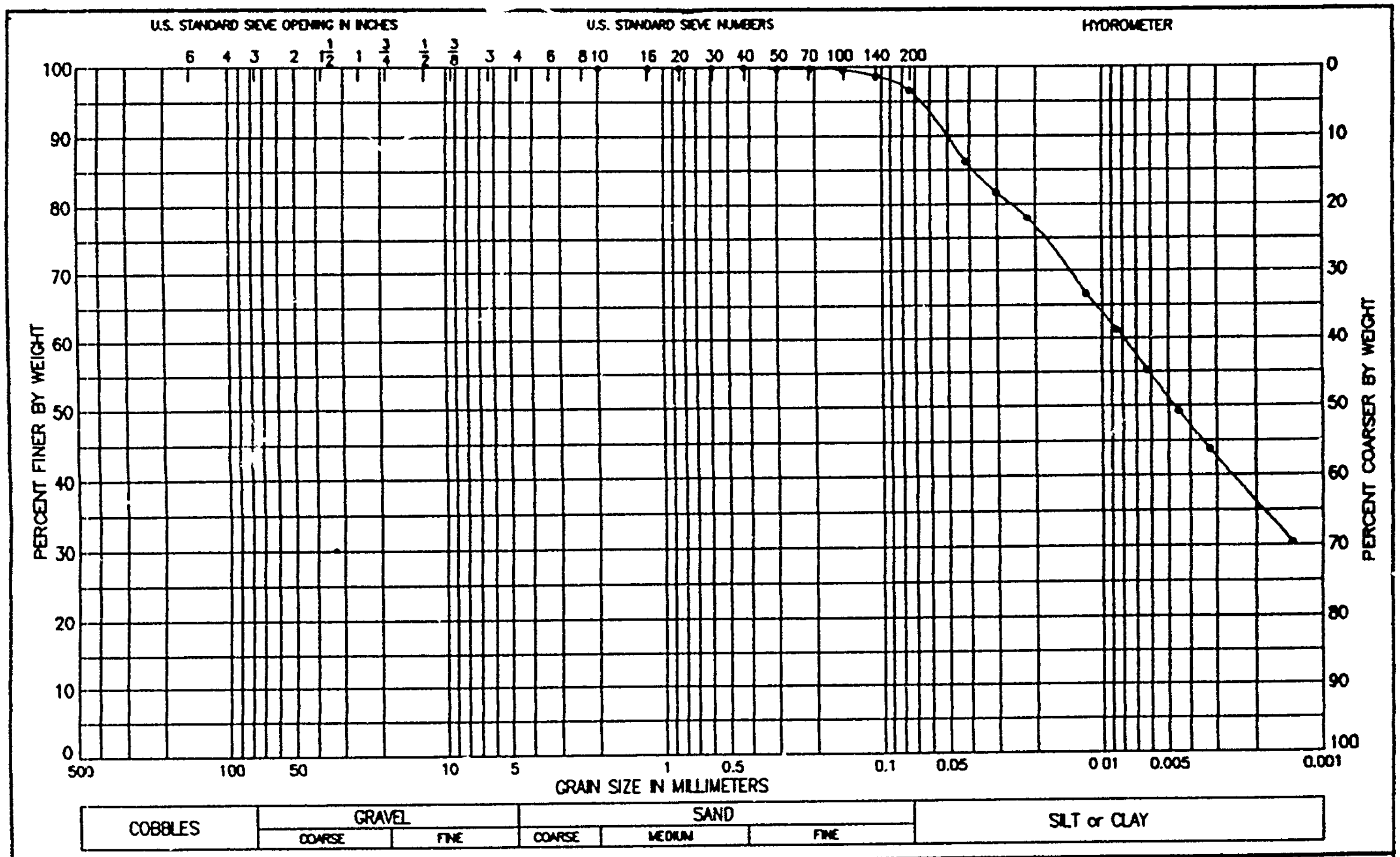
PROJECT SOUTH BLAKELEY ISLAND
MOBILE AL

DATE 09 APR 87

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Figure 5. Grain size distribution for Mobile Bay dredged material



LL 147	PL 32	PI 115	GS 2.65	NAT W,%	

CLASSIFICATION

CLAY (CH) BLACK

GRADATION CURVE

PROJECT PASCAGOULA RIVER

DATE 12 DEC 88

Figure 6. Grain size distribution for Pascagoula River dredged material

49. Microwave and conventional oven tests are summarized and compared on Table 7. It appears that dredged materials normally present no problems for the microwave system. The materials dry unremarkably, and water contents determined correlate well with conventional oven water contents. The only conclusions that can be drawn from the investigation are that (a) the microwave system is particularly advantageous for use with dredged materials since long periods are required to determine water contents in the conventional oven, and (b) large amounts of vapor and odor may be generated during microwave drying of dredged materials. Because of the possible presence of toxic chemicals in the vapor, it should be vented or discharged to outside air.

Table 7

Summary of Water Content Comparison Tests on Dredged Materials

Material	Initial Mass, g	Drying Time, sec	Water Content, % (1) Microwave	Water Content, % (2) Conventional	Difference [(2) - (1)]/W × 100
Mobile River material (CH)	114.5	811	146.76	144.96	-1.24
Pascagoula River material (CH)	127.8	1,112	242.62	242.93	0.13

PART VIII: MICROWAVE DRYING OF FLY ASH

50. Fly ash is the material resulting from the combustion of coal or oil for industrial purposes. This material is often precipitated or filtered from the smokestacks of chemical refineries, foundaries, and power plants. Fly ash is typically fine grained and light grey or tan in color, and it has Pozzolonic properties in that the material hydrates and develops cohesive strength upon exposure to water. The material has commercial value in that it has been used to stabilize liquid chemical wastes and has been used as a partial replacement for portland cement in concrete block and concrete mats used to revet channels and rivers. Standards have been set down for fly ash and approved by ASTM. For example, the material used in this study meets ASTM specification C-618.

51. Fly ash was tested in this investigation to show that the microwave oven system may be used to determine the water content of materials that hydrate, such as portland cement concrete and fly ash. There may even be a certain advantage in using the system to obtain the water content of fresh concrete for the reason that, initially, concrete containing certain admixtures hydrates very quickly and the water of hydration is taken into the crystalline structure of the concrete and bound so tightly that it cannot be removed by heating to 100° C. Fresh concrete will continue to hydrate as it is placed in a conventional oven at 100° C for 24 hr, and some water will be bound by hydration before it is removed by the high temperature. Therefore, not all water that should be removed in a normal content determination is removed, and the water content determined is, to a greater or lesser extent, in error. In the microwave oven system, the test is finished in about 10 min before much water is lost to hydration.

52. Microwave and conventional oven tests are summarized and compared on Table 8. The specimen preparation and test procedure for this investigation were to mix up a specimen uniformly to the desired water content, split it properly, let it cure for the desired period, and then run comparison microwave and conventional oven tests.

53. The fact that fly ash hydrates is shown by examining the second and third entries in Table 8, where it is seen that, even though 10-percent water by weight is added to the dry material, only about 8-percent water content is determined. Two-percent water is evidently lost to hydration and was not recovered by either the microwave system or the conventional oven. Increasing

Table 8

Summary of Water Content Comparison Tests on Fly Ash

Material	Initial Mass, g	Drying Time, sec	Water Content, % (1) Microwave	Water Content, % (2) Conventional	Difference (2) - (1), %
Fly Ash					
Air dry	143.9	223	0.06	0.18	0.12
10% water, tested immediately	173.4	875	8.10	8.09	-0.01
10% water, cured 15 min	217.7	348	8.14	7.98	-0.16
10% water cured 2 days	218.9	1,029	7.30	7.40	0.10
10% water cured 4-5 days	230.4	379	6.07	6.26	0.19

amounts of water are lost to hydration as the material is allowed to cure for longer periods.

54. The microwave and conventional oven water contents correlate well for all tests performed, and the drying process in the microwave system was unremarkable. The conclusion is that the unmodified version of the software dries materials that hydrate safely and predictably and does not drive off water already hydrated. Additionally, it appears from examination of the test results presented in Table 8 that the short drying times effected by the microwave system produced no measurable difference in water content relative to that measured in the conventional oven.

PART IX: DRYING OF GYPSUM RICH SOILS

55. Gypsum is a mineral whose occurrence in fine-grained soils is fairly widespread in the southwestern United States. It is a dihydrate of calcium sulfate, and its chemical composition is $Ca\ SO_4 \cdot 2H_2O$. The water in the chemical composition is bonded water, or water of crystallization and can be shown to be about 21 percent of the weight of gypsum present. Bonded water is rather weakly bound in the crystalline structure of gypsum to the extent that it begins to be driven off at temperatures less than 100° C. This fact is well recognized in that the procedure recommended by ASTM (Test Method D2216-80 1989) is to dry gypsum rich soil to a constant weight either by vacuum desiccation at room temperature (23 - 60° C) or in a constant temperature oven maintained at 60 ± 5° C.

Description of Soil

56. For the purpose of this investigation, a fine-grained pink soil rich in gypsum called Direct Course Soil was obtained from White Sands, New Mexico. The presence of gypsum was determined by X-ray diffraction in a procedure described by Phillips (1986). A dehydration curve of the Direct Course Soil was obtained for this study by drying the soil to a constant weight in a conventional oven maintained at a specific temperature. Figure 7 shows that water begins to be rapidly removed from the soil at a temperature of about 80° C. A stable flat section of the curve is evident up to the shoulder beginning at about 80° C. It may be of interest that one theory of the dehydration of gypsum is that there are two stable hydrates in the system, $Ca\ SO_4 \cdot 2H_2O$ and $Ca\ SO_4 \cdot 1/2\ H_2O$. At temperatures slightly higher than 75° to 80° C, the dihydrate ($Ca\ SO_4 \cdot 2H_2O$) in a sample is converted to hemihydrate ($Ca\ SO_4 \cdot 1/2\ H_2O$) (Hansen and Offutt 1969). This is consistent with the dehydration curve generated for this study (Figure 7) as well as a dehydration curve of a gypsum-rich sand shown by Gilbert (1988) and included here for clarity (see Figure 8), where a sharp rise occurs in the curves immediately after 80° C. The indication by Hansen et al. (1969) is that water can then be slowly and continuously expelled from hemihydrate up to 500° F as it is converted to anhydrite.

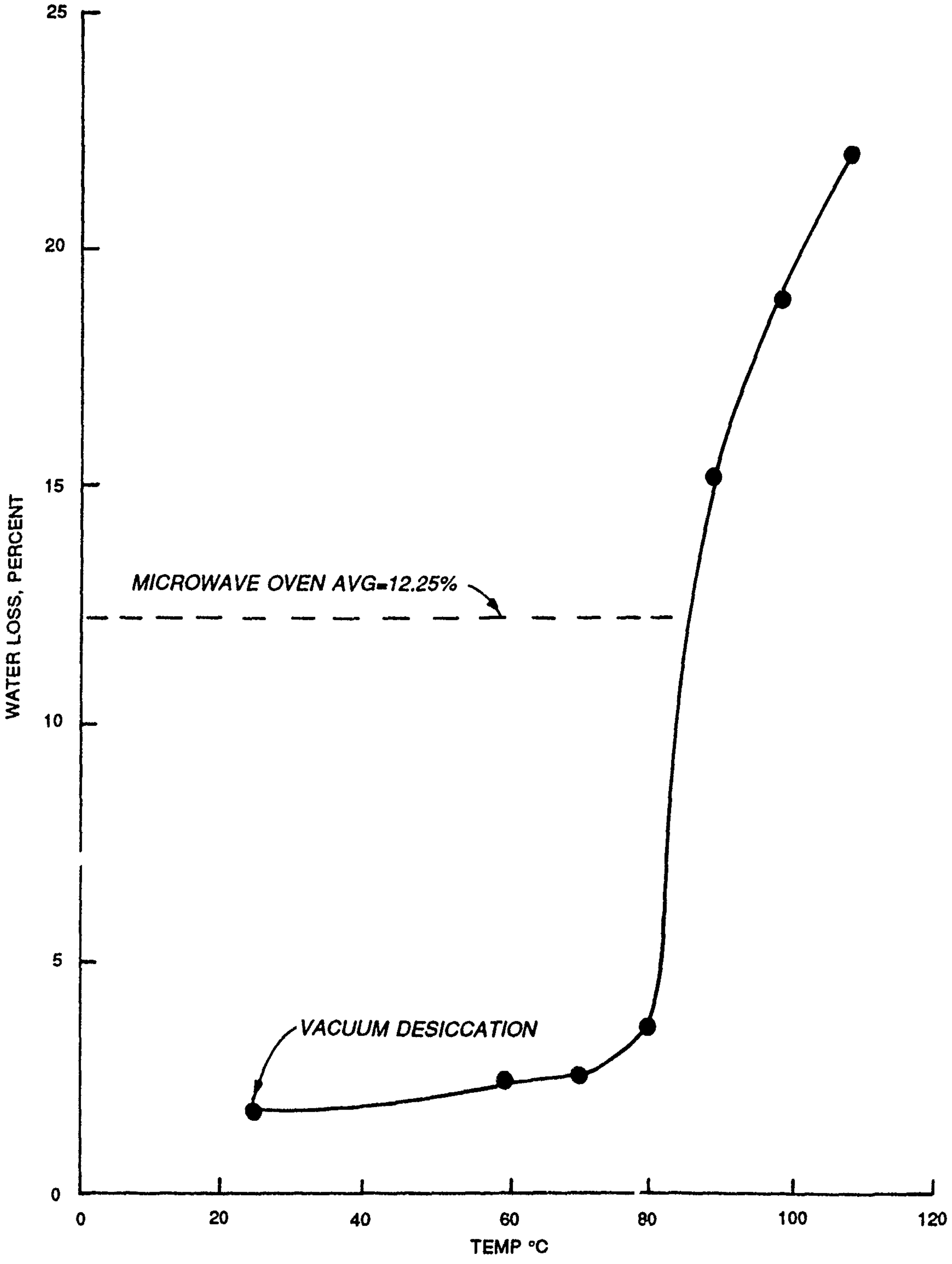


Figure 7. Dehydration relationship of Direct Course Soil

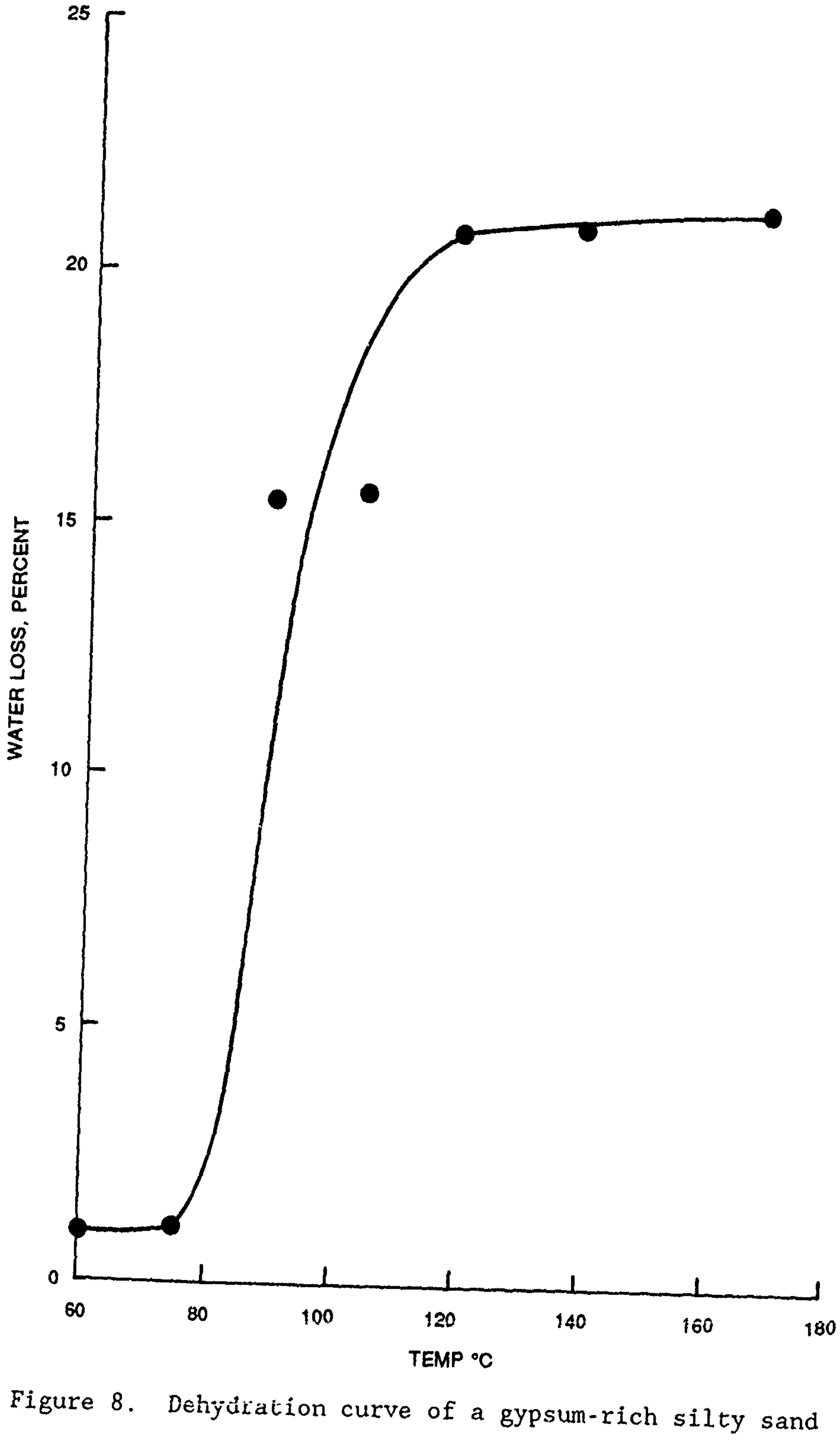


Figure 8. Dehydration curve of a gypsum-rich silty sand

Factors Influencing Dehydration

57. Factors influencing the dehydration characteristics of pure gypsum have been studied by several investigators (Hansen and Offutt 1969, ASTM 1983) and determined to be complex and unpredictable. The dehydration process will be affected not only by relative humidity in the atmosphere surrounding the specimen but also by physical and chemical characteristics of the specimen. A microwave oven dries soil by directing energy to water molecules in a soil sample that ultimately raises the temperature of the soil-water mixture to 100° C and holds this temperature until all free water is vaporized. If the ASTM recommendation of drying gypsum-rich soils at 60 ± 5° C is observed, then it may be inappropriate to use a microwave oven in the manner that it normally functions to dry soil, and nearly impossible to design a controlled process to dry gypsum-rich soil. For example, it may be possible to determine a schedule of energy application to maintain a sample of gypsum-rich soil of a given mass, water content, and gypsum content at 60° C. However, oven load would be determined by the amount of water in the oven, and this is an unknown function of mass, water content, and gypsum content. Therefore, no general schedule of energy application could be designed in light of the unknown gypsum content, water content, and the restriction that the specimen temperature be maintained at 60° C. Even if the complex procedure for drying gypsum soils could be easily devised, there would be no advantage in using a microwave oven over a conventional oven since the same amount of time would be required for either oven. For "normal" soils, the very presence of water limits the temperature of the mixture to 100° C. However, 100° C is too great for gypsum-rich soils and will result in improper dehydration, as can be seen from Figures 7 and 8. To demonstrate this fact with actual data (see Table 9), two microwave dried specimens of Direct Course gypsum using unmodified software resulted in water contents of 12.48 and 12.01 percent. These values are in considerable error when compared with the 60 ± 5° C oven water content of 2.54 percentage points. The indication is that the microwave oven system will produce consistent water content results for a soil with a given gypsum content. However consistent, the values will be incorrect, and the indicated water content will show variation if the gypsum content of the soil (which is generally unknown) changes.

55. Therefore in light of the data and analyses presented above, it is

Table 9

Summary of Water Content Tests on Gypsum Soils

Material	Initial Mass, g	Drying Time, sec	Water Content, % (1) Microwave	Water Content, % (2) Conventional 60 ± 5° C	Difference (2) - (1), %
Direct Course Soil	227.0	961	12.48	2.54	9.94
	163.9	1,124	12.01	2.54	9.47

concluded that factors which are uncontrollable will prevent correct (relative to a 60 ± 5° C oven) microwave oven system water content determination of gypsum-rich soils. It is recommended that the microwave oven system not be used on soils containing gypsum.

PART X: STUDIES OF CALCITE-RICH SOILS

59. Calcite- and carbonate-rich soils occur commonly in the United States. For this reason, it was decided to perform a study on calcite rich soils to determine if problems are encountered in the microwave drying of such materials. It is known that calcite breaks down according to the chemical equation

$$Ca\ CO_3 + Heat \rightarrow Ca\ O + CO_2\uparrow \qquad (6)$$

where it can be shown analytically that with the addition of heat, calcite will lose 44 percent of its weight due to the volatilization loss of carbon dioxide. The temperature that initiates the chemical breakdown of calcite is 620° C (Nutting 1943), and it is not believed that overall temperatures reach this level in microwave specimens; however, local temperatures may indeed reach this level. For this reason, the investigation with calcite was judged to be worthwhile, and calcite-rich soils were obtained from the Cerrillo Dam site near Ponce, Puerto Rico. Ten-bag samples of material were received from the site, and each material was tested in the microwave system and the conventional constant temperature oven.

Material

60. All of the materials received contained varying amounts of calcite or some other calcium carbonate derivative since they all reacted with hydrochloric acid (HCL). A brief visual description of each material by sample number follows.

Sample CBA-WC-#1

61. Sample CBA-WC #1 was a light-brown plastic clay in a matrix of white nodules with a few dark nodules. The white nodules reacted vigorously with dilute HCL and were assumed to be calcite. The composite material was very dense and cohesive and consisted of chunks of material from about 1/2 to 2 in. in diameter.

Sample CBA-WC-#2

62. Sample CBA-WC-#2 was similar to the material of sample CBA-WC-#1 except the material was moister and the individual chunks were softer and more pliable.

Sample CBA-WC-#3

63. This sample was very similar in texture and consistency to CBA-WC-#1 except the materials may have been slightly lighter in color.

Sample CBA-WC-#4

64. The fourth sample was a brown crumbly silty clay with lenses of a white material that reacted with dilute HCL (assumed to be calcite). The bagged material consisted of particles from individual clay size particles up to chunks of material 2 in. or more in diameter.

Sample CBA-WC-#5

65. Sample CBA-WC-#5 was similar in color, texture, and consistency to sample CBA-WC-#4 except there were larger chunks of calcite present.

Sample CBA-WC-#6

66. Sample CBA-WC-#6 was similar to CBA-WC-#1 and CBA-WC-#2 in color, appearance, and texture. There was reaction with HCL, although no large nodules of calcite were observed.

Sample CBA-WC-#7

67. This sample was light brown to yellow crumbly clayey silt with nodules of calcite present. Strong reaction was observed with HCL.

Sample CBA-WC-#8

68. Sample CBA-WC-#8 was similar to CBA-WC-#7 except, perhaps, darker in color.

Sample CBA-WC-#9

69. This sample was similar to CBA-WC-#7.

Sample CBA-WC-#10

70. Sample CBA-WC-#10 was light brown crumbly clayey silt with nodules of calcite and fragments of a darker rock believed to be limestone because of its reaction with dilute HCL.

Test Procedure

71. Specimens for this study were prepared by weighing out about 400 g of wet material, placing it in a clean, dry specimen jar, and sealing it with a screw-on cap. The material was taken into the humid room (which is generally maintained at about 95-percent relative humidity), spread on a clean dry glass plate, and sliced up into small particles with a steel spatula. The material was then replaced in the capped jar and turned several times in an effort to mix the particles thoroughly. Equal amounts of the material were

then poured into specimen containers for the microwave drying test and the control test in the conventional oven; it is believed that a reasonably even split of the material was obtained by using these procedures.

72. It was desired to demonstrate that these materials may be hydrated and dehydrated reversibly and that there is good correlation between the microwave system and conventional oven water contents under conditions of either water added (hydration) or water removed (dehydration). To accomplish this, some specimens were wetted above the natural water content and some specimens were oven dried and then wetted to a water content below the natural water content and tested.

73. For tests on specimens to which it was necessary to add water, materials at the natural water content were placed on a clean dry glass plate in the humid room, and the appropriate amount of water necessary to raise the water content 5 percentage points was added. The soil and water were then thoroughly mixed with a steel spatula, placed in a sealed glass jar, and allowed to cure for about 6 hr. The material in the jar was then split for comparison water content tests.

74. For tests on specimens below the natural water content, the procedure was the same as that previously described except that materials were first dried to a constant weight in an oven at 110 ± 5° C and then brought to a water content about 5 percentage points below the natural water content, cured, split, and tested.

Calcite Test Results and Discussion

75. Results of all tests on the calcite-rich soils are summarized in Table 10, which shows the initial mass of wet soil used in the microwave system, drying time in seconds, a comparison of water contents given by microwave system and conventional oven, and the difference in percentage between the two values.

76. Wet specimen masses were about 200 g, which is recommended to obtain good agreement in fairly short drying times. Drying times were about 600 sec in the microwave system. Agreement between microwave system and conventional oven water contents is reasonably good, the greatest difference being less than 1/2 percentage point. The differences between microwave system and conventional oven water contents are believed to be due, in part, to random sampling and nonhomogeneity of the "identical" specimens. For

Table 10

Summary of Microwave and Conventional Water Content Results on Calcite

Sample Number	Initial Mass g	Drying Time sec	Water Content, % (1) Microwave	Water Content, % (2) Conventional	Difference in Water Content (2) - (1), %
CBA-WC-#1	211.2	566	21.37	20.91	-0.46
CBA-WC-#2	244.1	568	23.78	23.50	-0.28
CBA-WC-#3	226.2	535	20.31	20.25	-0.06
CBA-WC-#4	195.7	568	27.07	26.62	-0.45
CBA-WC-#5	211.5	567	23.97	23.81	-0.16
CBA-WC-#6	212.8	598	24.15	23.70	-0.45
CBA-WC-#7	213.5	504	18.47	18.77	+0.30
CBA-WC-#8	210.4	504	20.43	20.70	+0.27
CBA-WC-#9	221.6	600	27.57	27.15	-0.42
CBA-WC-#10	196.9	568	26.13	26.08	-0.05
CBA-WC-#2 +5%	185.1	599	28.54	28.22	-0.32
CBA-WC-#7 +5%	207.5	598	23.80	23.51	-0.29
CBA-WC-#2 -5%	201.8	503	18.56	18.18	-0.38
CBA-WC-#7 -5%	181.0	440	15.95	15.92	-0.03

example, if more of the larger calcite or limestone particles are randomly placed in one test specimen than the other, then water content differences will be observed because the calcite has a significantly different water content than the soil. In this sense, calcite-rich soils are similar to earth-rock mixtures.

77. In addition to comparison tests performed at the natural water content, tests were performed on specimens that were wetted about 5 percentage points above the natural water content and on specimens that were first oven dried and then wetted up to about 5 percentage points below the natural water content. Only two sets of such tests were performed because the materials fell generally into two groups: clayey soils and silty soils. Clayey soils were CBA-WC-#1, #2, #3, #4, #5, and #6. Silty soils were CBA-WC-#7, #8, #9, and #10. The two soils chosen to demonstrate hydration and dehydration reversibility were CBA-WC-#2 and #7, and these data are shown in the last four entries of Table 1. For specimens wetted above the natural water content, differences between microwave and natural water content are 0.32 and 0.29 percentage points for materials #2 and #7, respectively. For specimens wetted up from the oven dry condition to about 5 percentage points below the natural water content, differences between microwave and conventional oven were 0.38 and 0.03 percentage points, respectively, for materials #2 and #7.

Conclusion

78. Conclusions believed warranted from this study on calcite-rich soils are:

<u>a</u>. The difference between water contents determined in the microwave drying system and the conventional oven for the materials tested is less than 1/2 percentage point and for most cases, substantially less than 1/2 percentage point.

<u>b</u>. The materials may be wetted and dried reversibly with no unexpected influence from the calcite. Water content measurement by the microwave system appeared to be well correlated to the conventional oven for wetted or dried material.

<u>c</u>. Optimum specimen size for the materials was about 200 g wet weight and drying time about 600 sec.

<u>d</u>. The response of these materials to microwave energy was unremarkable, and no problems were encountered in obtaining microwave system water content data that correlated well with conventional oven data.

PART XI: INVESTIGATION OF PEAT

79. Swamp muck deposits containing large amounts of decayed fibrous vegetable matter are called peat. A certain amount of silt or clay may also occur in peat, but this component is usually small compared with the amount of organic matter present, which may be upward of 90 percent as determined by a loss on ignition (LOI) test as described below.

Loss on Ignition Test

80. Loss on ignition tests were performed on two peats, and a highly organic clay was tested in the investigation to determine the volatile solids content. The test was performed by first drying the specimen to a constant weight in an oven maintained at 110 ± 5° C. The specimen was then allowed to cool to room temperature in a desiccator. An amount of 110° C oven dry material was then placed in a quartz crucible and weighed to the nearest milligram, after which the material and crucible were placed in a thermostatically controlled oven maintained at 550° C. The material was allowed to remain in the oven for 4 hr, a period which had been determined to result in the specimen reaching a constant weight. The specimen was then removed, placed in a desiccator to cool to room temperature, and weighed to the nearest milligram. The percent weight loss on ignition was computed, and the loss assumed to be volatile solids.

81. The procedure used in this study is described because it is somewhat different from ASTM designation D 2974 (ASTM 1988), where oven temperatures of 440° C (Method C) and 750° C (Method D) are specified along with certain other minor variations. It is believed that the method described above results in an LOI content that is the same as that determined by ASTM D 2974 Method D.

Material

82. Two tubes of peat were obtained from a Corps levee repair project at Davis Pond on the west bank of the Mississippi River in St. Charles Parish in southern Louisiana. One tube of peat was black in color and consisted chiefly of slightly fibrous vegetable remains and wood fragments with traces of clay and pockets of black amorphous decayed vegetable matter. This

material will be referred to as Davis Pond black peat. The second tube of peat was dark brown in color and consisted of moderately fibrous vegetable matter with some plant remains. Traces of clay were less evident in this soil. This material will be called Davis Pond brown peat. Both these materials are classified Peat (Pt) in the USCS.

83. An additional material, an organic clay, was included and tested for the purpose of comparison with the peat. The material was an organic dark gray clay (CH) from a Corps project called West Bank hurricane protection from a site near the mouth of the Mississippi River at Venice, Louisiana. Properties of all these materials were determined (where possible) and are summarized on Table 11, including three materials classified OH that were tested by Gilbert (1988) and included here for completeness. The last column in the table is the natural water content of the soils.

Table 11

Properties of Peat and Organic Clay

Material	LOI, %	LL,* %	PL,** %	PI,† %	W_{nat}, %
Davis Pond brown peat	82.7	810	--	--	771
Davis Pond black peat	67.6	450	310	140	425
West Bank hurricane soil	14.6	228	63	165	125
San Francisco Bay mud	5.5	88	43	45	90
Wilmington Harbor material 72/2703	36.7	133	53	80	263
Wilmington Harbor material 72/2697	--	184	62	122	91

* LL = Liquid limit.

** PL = Plastic limit.

† PI = Plasticity index.

Conventional Oven Water Content Determination

84. The procedure recommended by ASTM for determining the water content of peat (Standard D 2216-80 1989) is to dry the material in an oven maintained at 60 ± 5° C until it reaches a constant weight. Drying peat in a 110 ± 5° C oven (the temperature for drying inorganic soils) would drive off volatile elements of the soil that should not be removed in a water content determination. To demonstrate sensitivity to drying temperature, a dehydration curve was determined for Davis Pond black peat and is shown on Figure 9. The figure shows that mass will be continually lost at temperatures above 60° C, and the indicated water content at 110° C will be about 34 percent age points higher than that at 60° C.

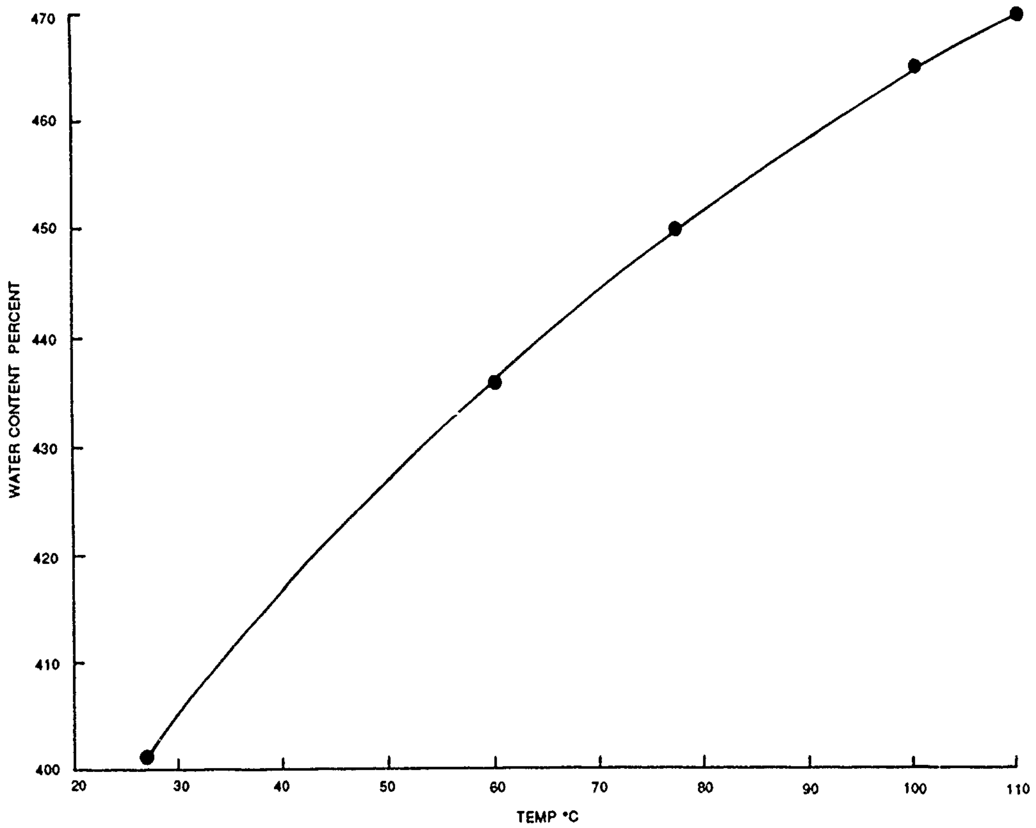


Figure 9. Dehydration curve of Davis Pond black peat

85. Water content by ASTM (Standard D 2216-80 1989) recommended procedure was determined for Davis Pond brown and black peats in a 60° C oven and for the black peat by vacuum desiccation at 27° C. Intermediate values of water content taken with time up to the terminal water content value (Wf) and the results are summarized on Figure 10. Examination of the figure shows that

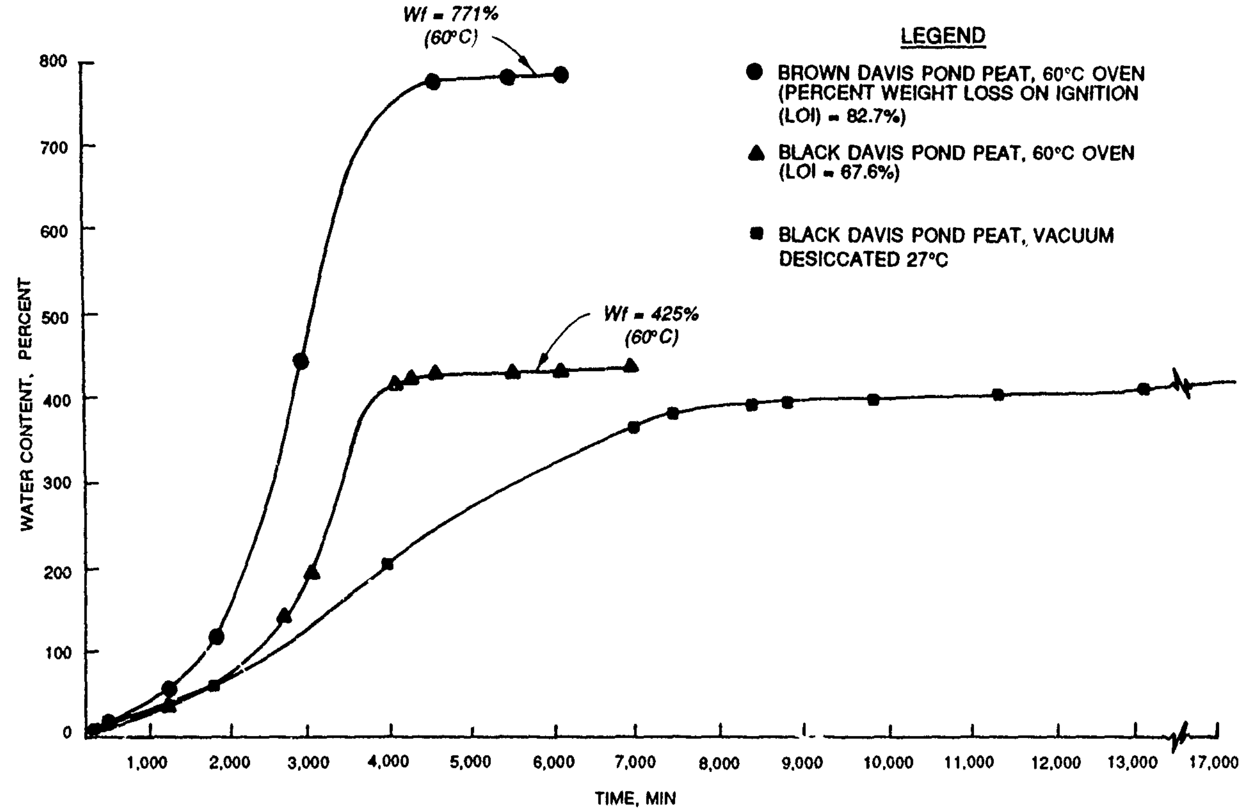


Figure 10. Water content versus drying time of peat

the time required for a terminal water content to be reached in the 60° C oven was more than 3 days (4,500 min) and the time by vacuum desiccation was about 12 days (17,000 min). These very extended periods for correct water content determination suggest the desirability of an accurate and expedient water content method for these materials. Earlier attempts (Gilbert 1974) to dry peat in a microwave oven failed and were abandoned when peat specimens overheated, overdried, and ultimately caught fire. It was determined to develop a procedure for drying peat in the present computer-controlled microwave oven system realizing that the procedure would have to be considerably different from that for drying inorganic soil.

Modification of Controlling Software

86. Volatile organic material may be vaporized and improperly removed from peat during a water content test at 110 ± 5° C inside a conventional oven. For this reason, water content tests on highly organic clay and peat are performed in the conventional oven at a temperature of 60° C to ensure that volatile matter is not improperly removed.

87. Because temperature is not controlled in the microwave drying of soil, the drying of peat could present a problem if the correct schedule of energy is not applied. For example, the software control routine for drying inorganic clay was initially used in an attempt to dry a specimen of black peat from St. Charles Parish in Louisiana. This routine failed when it could not satisfy the necessary condition to complete and pass Stage 1 (see Figure 11) of the drying process. To allow drying in the microwave system, Stage 1 conditions were defeated, but then Stage 2 and 3 conditions failed when the system dried the specimen continuously to the point where first a burning odor was observed coming from the specimen and then the specimen was observed smoking. The test was aborted soon after because the specimen was observed smoking more intensely with time and it was feared that the specimen would soon catch fire (as has been observed in the past (Gilbert 1974)). The "Water Content" versus time relationship for this failed drying attempt of a peat specimen is shown on Figure 12. The correct water content is believed to be about 425 percent, and the test was arrested when the measured water content exceeded 525 percent. It is obvious (from Figure 12) that at the end of

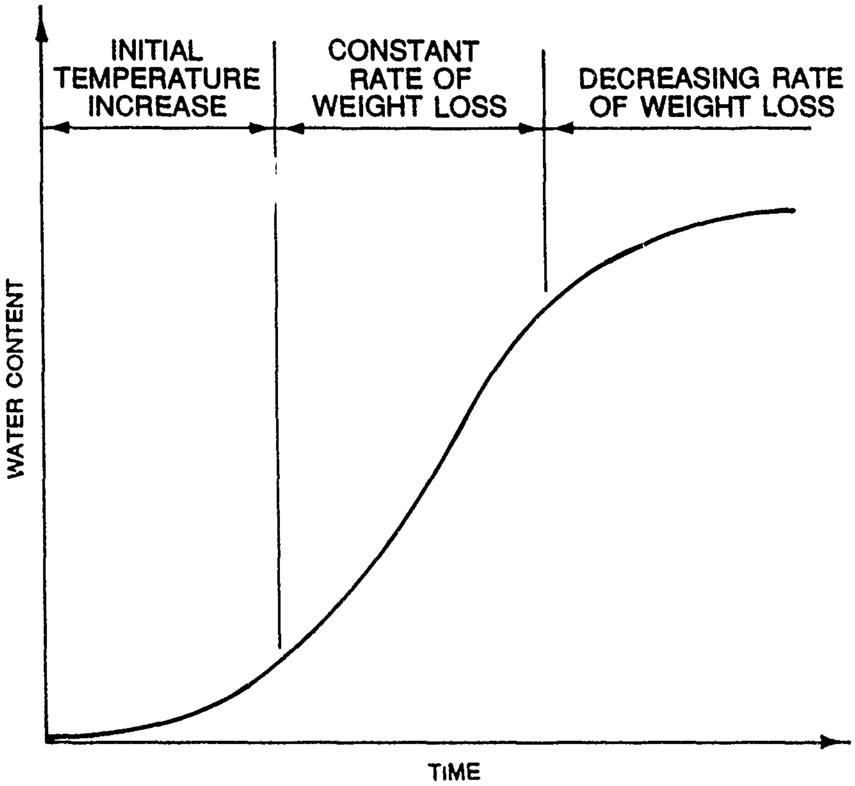


Figure 11. Typical water content/time relationship for microwave heated soil specimens

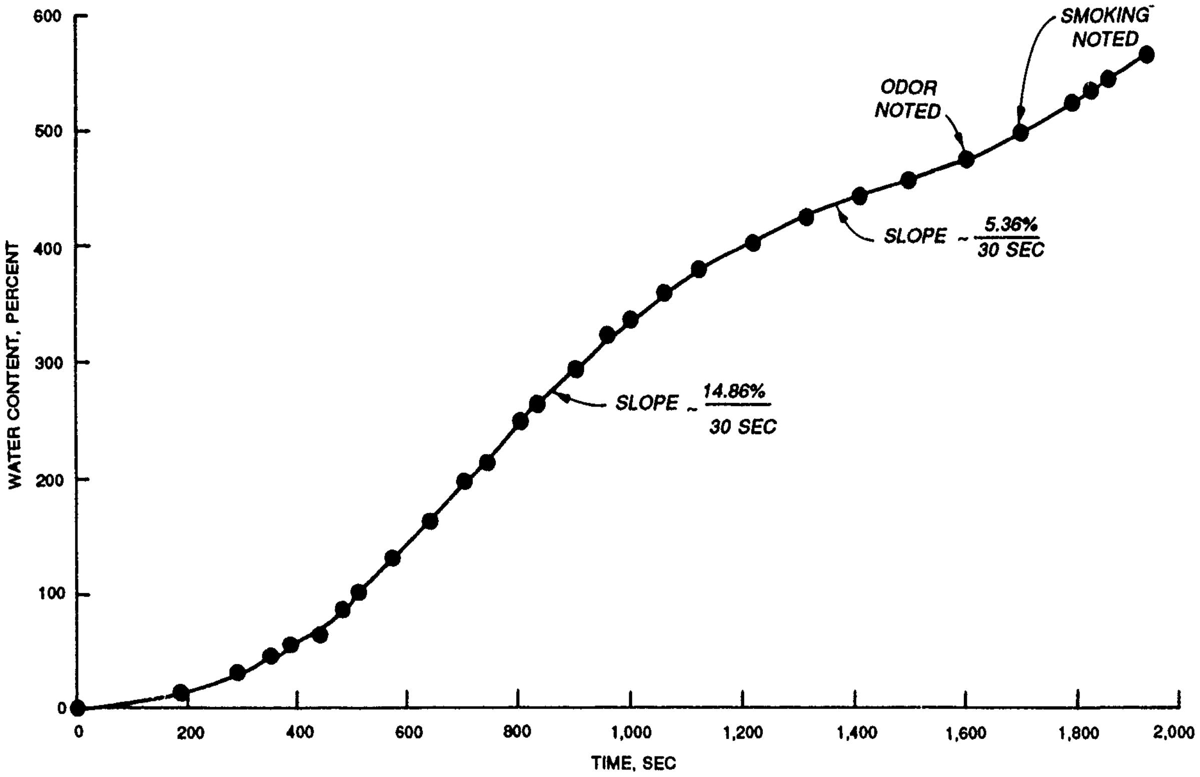


Figure 12. Water content versus time for drying of St. Charles Parish peat

the test, organic material was being burned and removed at an increasing rate to the extent that, instead of converging to a constant weight/slope, the weight of the specimen was continuously decreasing while the slope was increasing.

88. The figure indicates that the specimen was initially brought to a state of fairly rapid weight loss by the application of microwave energy. The slope on Figure 12 corresponding to this condition is 14.86 percent/30 sec. The rate then decreased to 5.36 percent/30 sec but then increased to a higher rate in the precombustion stage.

89. From the experience gained from drying the peat sample and analyses of Figure 12, a procedure for drying peat was determined. Consistent with the procedure for drying inorganic clay and sand, the sequence for drying peat will consist of three stages: (a) The first stage will consist of continuous drying and will continue until a 30-sec increment is sampled when the increase in water content is greater than 10 percent. At that point, stage two begins. (b) The second stage will consist of continuous drying and will continue until a 30-sec increment is sampled when the increase in water content is less than 8 percent. At that point, stage three begins. (c) The third stage consists

of intermittent drying at half power (30 sec of microwave energy application and then 30 sec of rest) until the change in water content over a 30-sec interval is less than 5 percent, at which time the drying process will be terminated. After a 3-min waiting period, final water content will be computed, and the test terminated. It should be mentioned that the variables chosen to control drying of peat (less than 8-percent increase in 30 sec to pass Stage 2, less than 5-percent increase in Stage 3 to terminate) were the results of a fairly extensive calibration. For example, when less than 3-percent increase was investigated to terminate Stage 3, the material consistently overheated and began to burn. The reason for this is obvious; in an attempt to reach this (too small) shut off value, the material began to overheat and give off volatile material that increased the rate of weight loss. At that point, the drying procedure had failed because overheating and continued weight loss would escalate. In this sense, the terminating value in Stage 3 is very important. In drying peat or other highly organic material with this version of the program, the specimen should be observed carefully during testing, and if smoke and/or odor are evident, the test should be aborted. However, the version of the program developed and given in Appendix E proved effective and safe in drying peat with an LOI greater than 60 percent.

Test Results

90. Microwave and conventional oven tests (controls) performed during this investigation are summarized on Table 12. It should be noted that these are the tests performed with the completely modified software (except as indicated). Tests performed to determine appropriate values of process-controlling variables are not reported because many failed and had to be aborted. The last three material entries in Table 12 were experiments performed by Gilbert (1988) on OH soils and are included here for completeness.

91. Certain measured values for peats (Pt), an organic clay (OH), and an inorganic clay (CH) are shown on Table 13 for the purpose of comparison. The first column of the table shows the difference in water content obtained at 110° and 60° C. This difference is, of course, significant for peat with high loss on ignition values but not so significant for moderately organic clays. The indication of the data presented in Tables 12 and 13 is that

Table 12

Summary of Water Content Comparison Tests on Peat and Organic Clay

Material	Initial Mass, g	Drying Time, sec	Water Content, % (1) Microwave	(2) Conventional	Difference (2) - (1)/(2) x 100
Davis Pond brown peat	197.8	1,803	771.36*	770.81	-0.07
(Pt)	78.4	1,382	683.99**	771.73	11.37
	134.8	1,434	697.63*	771.73	9.60
	244.4	1,953	754.54*	770.81	2.11
Davis Pond black peat	118.4	1,248	412.55*	425.09	2.95
(Pt)	157.8	1,280	422.51*	425.09	0.61
	99.7	1,124	419.27*	425.09	1.37
West Bank hurricane soil (OH)	187.0	1,082	126.41**	124.82	-1.27
San Francisco Bay mud†	160.20	803	89.13**	89.32	-0.21
(OH)	163.00	807	90.85**	90.55	0.33
Wilmington Harbor material 72/7203† (OH)	132.87	1,521	257.68**	262.58	-1.86
Wilmington Harbor material 72/2697† (OH)	120.95	996	91.14**	91.07	0.08

* Specimen dried using software modified for peat.
** Specimen dried using unmodified software.
† Experimental work reprinted from Gilbert (1988).

Table 13

Comparison of Organic and Inorganic Soils

Material	$W_{110^\circ \mathrm{C}} - W_{60^\circ \mathrm{C}}$, %	Loss on Ignition, %	Software Used to Control
Davis Pond brown peat (Pt)	59.31	82.7	Modified for peat
Davis Pond black peat (Pt)	34.00	67.6	Modified for peat
West Bank hurricane soil (OH)	3.93	14.6	Inorganic clay and sand
San Francisco Bay mud (OH)	1.22	5.5	Inorganic clay and sand
Pull out soil (CH)	0.86	4.0	Inorganic clay and sand
Wilmington Harbor material 72/7203 (OH)	--	36.7	Inorganic clay and sand
Wilmington Harbor material 72/2697 (OH)	--	--	Inorganic clay and sand

unless a material is actually classified peat, the software modified for peat does not have to be used to dry the material in the microwave oven.

Conclusions

92. Based on observations from the comparison tests and the evaluation of data from Tables 12 and 13, the following conclusions are believed warranted:

- a. Peat specimens of high water content will require large initial masses to determine accurate water contents. This is a problem associated with the resolution of the scales of the system. What may look to be a large initial mass of peat may dry to a few grams of material for which the resolution of the balance is not great enough to give an adequately accurate measurement. This can be seen by considering the second and third specimen of Davis Pond brown peat on Table 12, where poor agreement between control (conventional oven) and the microwave system is due to inadequate specimen size. Therefore, it is recommended that all peat specimens have a minimum of 200 g wet weight.
- b. Because of the large quantities of water involved, more than 30 min may be required for a microwave oven test on peat.
- c. More than 3 days may be required for a conventional oven water content test on peat (in a 60 ± 5° C oven).
- d. Unless a material is actually classified peat, it is not necessary to use the software modified for peat to dry otherwise organic clays.

PART XII: MICROWAVE DRYING OF HAWAIIAN VOLCANIC ASH

Background

93. Tropical soils occur extensively throughout the world. The same type of tropical lateritic soil that occurs in the State of Hawaii also occurs in the Phillippines, New Guinea, Vietnam, Thailand, Indonesia, Burma, India, Australia, Brazil and other equitorial South American countries, and equitorial Africa. Latosol is the name of the soil group containing many of these tropical soils, most of which are iron oxide and aluminum oxide rich, highly weathered clayey soils (Mitchell 1976, Tateishi 1967). Research has shown that the amorphous hydrated colloidal fraction of such tropical soils has a definite influence on physical properties. For example, dehydration of the soil will result in an irreversible change to a material with more granular characteristics.

94. The process of laterization involves the leaching of SiO_2 and the deposition of Fe_2O_3 and Al_2O_3 ; the process is a natural consequence of weathering in hot, wet tropical climates. Grim (1968) reports research which confirms the laterization process just described by pointing out that the weathering of basaltic rock in the Hawaiian Islands is largely a matter of desilication and the removal of bases with the production of large amounts of halloysite and gibbsite along with lesser amounts of various other minerals and amorphous gels. Gibbsite is usually associated with the dehydration of the amorphous gels, but these soils can be and usually are rich in halloysite.

95. The Hawaiian volcanic ash tested in this study is dark red in color (possibly due to the presence of iron compounds), appears to be dry but has a natural water content of about 300 percent, and has a liquid limit and plasticity index of 353 and 238 percentage points, respectively. Interestingly enough, the material is classified MH in that the Atterberg limits plot below the "A" line on the USCS plasticity chart. Upon drying/dehydration, the material degenerates to hard nodules of sandlike particles that can never be rehydrated to the original soil texture. All indications are that this is a classical latosol/halloysite rich material.

96. The standard software for drying inorganic soils had to be modified to dry this tropical soil. The modification consisted of changing the timing sequences to apply microwave energy in 90-sec intervals instead of 30-sec intervals; rest periods during the third stage of drying remain unchanged.

This means that during the third stage of drying, 75-percent power is applied to the specimen rather than 50 percent. It appears that this material is somehow resistant to microwave energy, and 50-percent power applied during the third stage allows the specimen to cool too much, causing the water content to converge to a value that is too small. The controlling software for drying microwave resistant soil is shown in Appendix F.

Test Results

97. Microwave and conventional oven tests are summarized on Table 14. The first three entries in the table show comparison tests performed with the modified software and tests that are considered successful. The last two entries in the table show the results of the first two tests conducted, which were performed with unmodified software. The microwave and conventional test results do not compare favorably for these tests, but valuable lessons were learned. Analysis of these tests shows that (a) the software modification was effective and (b) the size of the specimen is important. Just as with specimens of peat, too small a specimen of Hawaiian volcanic soil will lead to mass resolution problems (because of the balance) toward the end of the test. The result will be a microwave oven water content that converges too quickly and to an apparently incorrect value because it will not correlate well with the companion conventional oven water content. Experience would dictate that a specimen of at least 200 g wet weight be used in the microwave oven system.

Conclusions

98. Conclusions believed to be warranted from this investigation are:

a. Latosol materials may be microwave energy resistant and require higher power levels for effective and complete microwave drying.

b. Specimens of at least 200 g wet weight should be used in the microwave oven system.

c. Typical drying times in the microwave oven system is of the order of 2 hr.

d. The modified software allows the determination of water content values in the microwave system that correlate satisfactorily with those determined in the conventional oven.

e. These latosol soils dehydrate irreversibly becoming hard granular particles upon drying. After dehydration, the original properties and material consistency cannot be regained by rehydration.

Table 14

Summary of Water Content Comparison Tests on Hawaiian Volcanic Ash

Material	Initial Mass, g	Drying Time, sec	Water Content, % (1) Microwave	Water Content, % (2) Conventional	Difference (2) - (1)/(2) × 100
Hawaiian volcanic ash	193.4	5,131	298.76*	295.31	1.15
	120.5	8,244	274.22*	285.58	3.98
	180.7	7,641	291.97*	285.65	2.21
	(110.4)	(4,592)	(251.59)**	(300.04)	(16.15)
	(90.9)	(4,422)	(245.62)**	(307.81)	(20.20)

---

* Specimen dried using software modified for microwave resistant soils.
** Specimen dried using unmodified software.

PART XIII: EVALUATION OF MICROWAVE DRYING SYSTEM

Field Performance of Microwave Oven Systems

99. Two microwave oven drying systems equipped with software designed to dry inorganic soils were delivered to Corps field projects in the Ohio River Division in April 1988. The two projects were the Yatesville Lake Project, where an earth and rockfill dam was being constructed near Huntington, West Virginia, and the Gallipolis Lock System on the Ohio River near Gallipolis, Ohio.

100. Personnel at the project offices used the microwave system as a "rapid moisture detection device" and compared water content results with comparison specimens tested in the conventional constant temperature oven. The procedure used for specimen preparation was to obtain a large sample of the desired material, break it into small particles in a vessel, homogenize the material by thorough mixing, and then split the material into two water content specimens for testing in the two oven systems. Results from field tests were sent to WES as they were obtained for analysis and for incorporation into this report. The Yatesville Lake Project was successfully completed in September 1988, but the Gallipolis Lock System repair continues at this writing.

Field Comparison Studies

101. There were 369 comparison water content test results obtained from Yatesville Lake Project and 301 results from Gallipolis Lock Project. The data were analyzed using a least squares linear fit computer code and are tabulated in Appendix A along with predicted values of water content from the analysis.

102. The coefficients of determination (R^2) of the Yatesville and Gallipolis data are 0.984999 and 0.983984, respectively. However, when the two data sets are combined, the coefficient of determination is 0.985304. This indicates a very good fit of the data and a very reliable correlation.

Microwave Oven System Evaluation by Yatesville

103. Mr. Kenneth E. Zimmerman, Resident Engineer of Yatesville Lake Project, evaluated the WES Microwave Oven System and documented his finding and opinions in a Memorandum for Record (MFR) dated 19 September 1988. This MFR is included in Appendix B, and the main points and observations may be summarized as follows:

a. The system performed satisfactorily on pervious and impervious soils, the typical difference between microwave and conventional oven water content being less than 1/2 percent.

b. Tall beakers or specimen containers caused condensation problems that were solved by using shallow dishes as specimen containers.

c. Dust contamination will occasionally cause a system malfunction which is remedied by resetting the system.

d. Large shale particles will occasionally explode.

e. A 500-g specimen is recommended (over the original 200-g specimen recommendation by this author). This helps to eliminate representative sampling errors.

f. The greatest differences between microwave and conventional water content occurred in large particle materials where it is most difficult to select identical samples with respect to rock content.

g. The smallest differences between comparative specimens occurred in sands. Perhaps this is due to the fact, that in sand, particle size sampling and water content homogeneity (as discussed in Part III) is achieved most easily.

h. Dust protection is recommended for microwave system components in the field.

PART XIV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

104. Based on the results of the present investigation and the 1988 study by Gilbert, the first, and possibly strongest, conclusion which can be drawn is that the subject computer-controlled microwave oven system works safely and reliably for rapid water content determination. The microwave system dries soil specimens and obtains accurate water contents typically within a time frame of 10 to 15 min and therefore will eliminate time lag problems associated with monitoring compacted fill with the conventional oven. Therefore, it would be highly advantageous to use this microwave equipment in Corps field projects for compaction control. Tremendous economic advantages could be gained in terms of construction problems avoided and enhanced safety of the resulting compacted structure. The system has been tested intensively in a laboratory environment and has had considerable use in field environments and has performed well in both situations. Some "shake down" problems were revealed in the field use of the system, but that was, in part, the intent of introducing the system to the field. No serious problems were encountered in field use, and nothing that could not be accommodated.

105. Specific conclusions from the present investigation which are believed warranted are:

a. Samples of earth-rock mixtures large enough to be statistically representative of a compacted fill would generally be too large for use in the microwave oven system.

b. The saturated surface dry water content of stone and gravel aggregates is small compared with the range of water content over which clays can exist. A saturated surface dry water content for several gravel aggregates was determined to be about 3 percent.

c. If the water content of the clay fraction of an earth-rock mixture is known and if the gravel content is known, then accurate water contents of the mixture may be computed by formula from water content of the clay fraction.

d. Rock particles smaller than about 1 in. in size do not explode in the microwave oven system. Measures may, however, be taken to minimize the danger of exploding particles such as reduced power after the first stage of drying or explosion proof containers.

e. The microwave oven system was successfully used without software modification on:

(1) Clean gravels and earth-rock mixtures.

(2) Materials containing iron compounds.

(3) Dredged materials.

(4) Fly ash.

(5) Calcite rich soils.

f. Any material containing 50-percent or more sand and/or gravel should be dried to a constant weight in the microwave oven system (a horizontal mass-time slope).

g. The system will not dry gypsum rich soils to the conventional oven (60° C) water content because of the dehydration characteristics of the material.

h. Peat may be successfully dried in the microwave system using software modified to prevent overheating.

i. Organic soils with loss on ignition contents up to about 15 percent may be dried as inorganic clay with essentially no loss in water content accuracy.

j. Certain tropical soils (latosol soils rich in halloysite) may be microwave energy resistant. Special software to dry such soils was prepared by modifying the existing software to apply higher power levels during the last stage of microwave drying.

k. Adequate wet specimen mass must be used when drying soils of high water content, either organic or inorganic.

l. Preliminary reports indicate that the computer-controlled microwave system performs very satisfactorily at project sites and field situations.

Raw data for all tests performed in this investigation are shown in Appendix H.

Recommendation

106. From consideration of all data acquired during investigation of microwave drying of soil, it may appear that more than rapid water content information is available from the microwave oven system. This information, if available, may be extremely useful to enhance monitoring of compacted earth fills.

107. A material property probably as significant for proper compaction control as water content is soil composition. If, for example, material for placement is being taken from a borrow area that consists of several soil types occurring in layers of variable thickness, then compaction control is made difficult because random and unavoidable mixing in the borrow area will result in many soils with different optimum water contents. Under field

conditions where large volumes of soil are being placed, real-time water content and soil compaction information are essential because if 24 hr or more are required to determine that a layer/lift is unacceptable, then that layer may be buried under several feet of subsequently placed and compacted material when the determination is made. An automated method to precisely identify and classify soil is needed because very often, soils with distinctly different compositions and compaction characteristics will not be visually distinguishable from each other. While a very experienced inspector may be able to use field visual classification techniques to visually identify similar materials with distinctly different compaction characteristics, a less experienced person may not recognize such differences, and problems with compaction will result. In this period when the volume of earthwork being done by the USACE has diminished, the probability of inspectors with less than desired experience is growing, and the need for an automatic device to field classify soils with respect to their compaction performance as a substitute for this lack of experience is increasing.

108. The "family of curves" method was devised to deal with the problem of variable soil composition with <u>two-point compaction</u> as a way to identify a material in question and its compaction characteristics. However, the family of curves method with two-point compaction may require several trial and error compaction specimens for each material in question, and its use does not always result in proper material and curve identification. Material composition has been correlated with certain soil classification parameters such as liquid limit and plasticity index, but these parameters are difficult to obtain in the field, require long periods of time, and are labor intensive. For example, the precise determination of a field water content may require 24 hr, but Atterberg limits to precisely identify and classify a material may require several days. A quick and easy method to identify material composition in the field is needed. If the material composition can be identified, then its optimum water content can likely be determined from a "family of curves" site calibration.

109. It appears highly likely that with certain hardware and software modifications, it may be possible to obtain indices from soil microwave drying characteristics which correlate to certain material classification properties, such as Atterberg limits. For example, soils with different plasticity indices appear to exhibit unique dehydration versus time and temperature versus time "signatures." It is believed that features from these two

"signatures" may be mathematically isolated, identified, and correlated with Atterberg limits.

110. Figure 13 shows the dehydration relationship of materials of different plasticity indices dried in the microwave oven. From this figure, the different shapes may be seen along with the systematic variation in PI. Probability is high that parameters may be devised to correlate curve change with PI. Another dimension which may strengthen the correlation is the quantification and correlation of the temperature versus time relationship. For example, Figure 14 shows temperature rise with time for four materials, a nonplastic sand (PI = 0 percent), two medium plasticity clays (PI = 48 and 54 percent), and a specimen of highly plastic montmorillonite (PI = 643 percent). The temperature of the nonplastic sand appears to level off rapidly with time as the conventional oven water content is reached. Temperature of the two medium plasticity clays increases more sharply than that of the sand as the conventional oven temperature is reached, but temperature slope of the highly plastic montmorillonite is high and increasing at an increasing rate as conventional oven water content is reached. The indication is that there is a definite relationship between shape of the temperature time curve and plasticity characteristics of the material under test.

111. Modification of the microwave system to remotely sense (without contact) specimen temperature would be necessary, and software modification to analyze dehydration and temperature change data would be required as well. However, if successful, estimates of Atterberg limits/material properties would be output along with water content in real time.

112. Real-time material classification indices would significantly enhance the capability to monitor compacted fill. For this reason, it will be recommended that the microwave drying research be extended in the attempt to identify material classification characteristics.

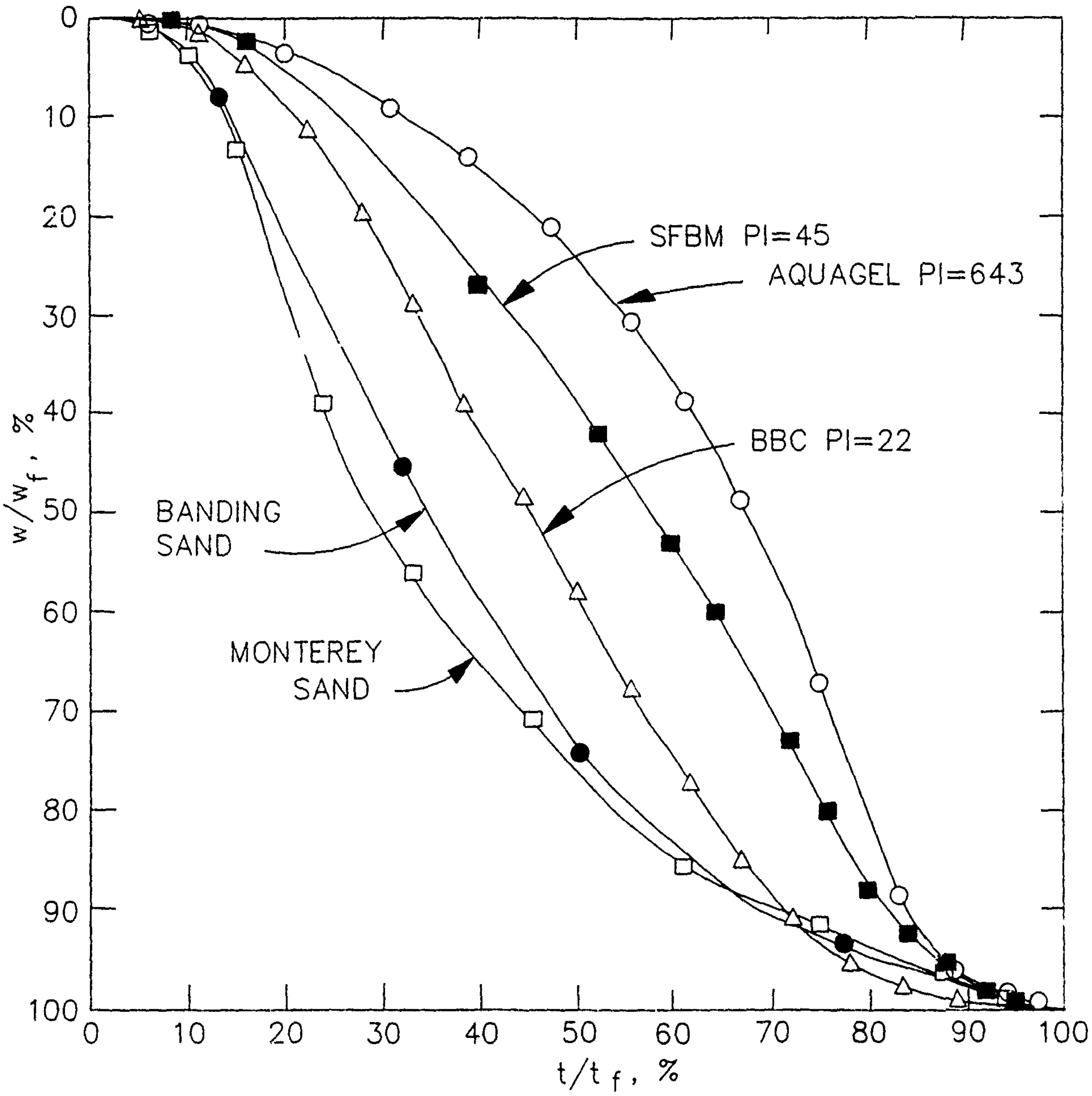


Figure 13. Normalized water content versus time for soils of different PI

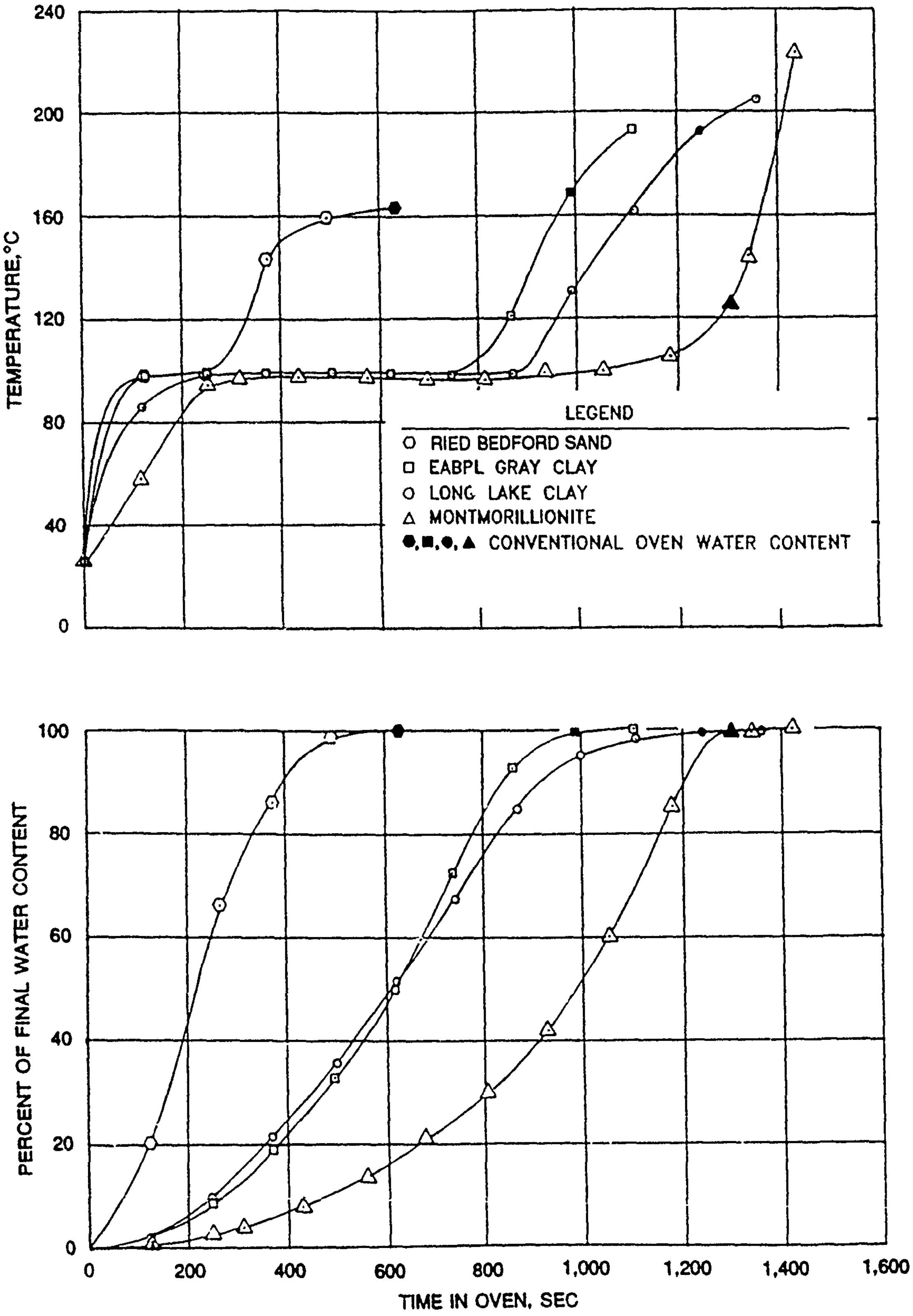


Figure 14. Water content and temperature versus time in microwave oven (from Gilbert 1974)

REFERENCES

American Society for Testing and Materials. 1983. "The Chemistry and Technology of Gypsum," STP 861, R. A. Kuntze, editor, pp 48-56.

__________. 1988. "Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil Aggregate Mixtures," D2216-8.

Gilbert, P. A. 1974 (Aug). "Feasibility Study - Microwave Oven Used for Rapid Determination of Water Contents, Evaluation of Soil Mechanics Equipment," Report 13, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. 1988 (Nov). "Computer Controlled Microwave Oven System for Rapid Water Content Determination," Technical Report GL-88-21, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Grim, R. E. 1968. Clay Mineralogy, McGraw-Hill Book Company, New York, pp 522.

Hansen, W. C., and Offutt, J. S. 1969. "Gypsum and Anhydrite in Portland Cement," United States Gypsum, Chicago, IL.

Mitchell, J. K. 1976. Fundamentals of Soil Behavior, John Wiley and Sons, Inc., New York.

Nutting, P. G. 1943. "Some Standard Thermal Dehydration Curves of Minerals," Professional Paper 197-E, United States Department of the Interior, United States Printing Office, Washington, DC.

Phillips, Bruce R. 1986 (Sep). "Geotechnical Investigation for Direct Course and Related Events, Report 2," Technical Report SL-86-18, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Strohm, W. E., Jr., and Torrey, V. H., III. 1982 (Mar). "Analysis of Field Compaction Data, DeGray Dam, Caddo River, Arkansas," Miscellaneous Paper GL-82-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Tateishi, H. 1967 (Jul). "Basic Engineering Characteristics of High-Moisture Tropical Soils," Proceedings of the WASHO Conference, 12 July 1967, Honolulu, HI.

Troxell, G. E., and Davis, H. E. 1956. Composition and Properties of Concrete, McGraw-Hill Book Company, Inc., New York.

US Army Engineer Waterways Experiment Station. 1955 (Feb). "Tests on an Absorptive Aggregate to Study Effect of Absorption and Gradation on Voids in Compacted Bituminous Paving Mix," Miscellaneous Paper No. 4-118, Vicksburg, MS.

__________. 1956 (Feb). "Cooperative Study of Bulk Impregnated Specific Gravels," Miscellaneous Paper No. 4-152, Vicksburg, MS.

__________. 1960 (Apr). Technical Memorandum No. 3-357, Vicksburg, MS.

US Army Corps of Engineers. 1970 (Nov). "Laboratory Soil Testing," EM 1110-2-1906, Washington, DC.

APPENDIX A

DATA FROM YATESVILLE LAKE PROJECT AND GALLIPOLIS LOCK SYSTEM

Table A1

Water Content Comparison Data from Yatesville Lake Project

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
15.21	15.70	15.33
13.32	13.26	13.44
15.58	15.62	15.69
14.14	14.14	14.26
15.69	15.43	15.80
13.43	13.36	13.55
12.97	13.36	13.10
10.76	10.89	10.90
19.32	19.30	19.41
24.68	24.51	24.74
14.75	14.97	14.87
13.28	13.58	13.40
13.26	13.12	13.38
15.03	15.39	15.14
14.90	15.10	15.02
19.23	19.35	19.32
15.36	14.90	15.47
12.04	12.07	12.17
15.06	14.60	15.17
11.76	11.74	11.89
15.99	16.30	16.10
12.98	13.00	13.11
18.62	19.20	18.72
13.31	13.21	13.43
18.41	18.20	18.51
13.67	13.70	13.79
15.79	16.10	15.90
11.84	11.50	11.97
17.75	18.00	17.85
14.62	14.90	14.74
11.62	11.40	11.75
14.97	15.20	15.09
12.27	12.20	12.40
12.25	12.40	12.38
11.73	11.60	11.86
11.04	11.20	11.18
10.87	11.10	11.01
16.23	16.10	16.34
13.76	13.70	13.88
12.43	12.47	12.56
13.02	13.11	13.15
16.62	17.09	16.73

(Continued)

Table A1 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
17.06	17.29	17.16
16.14	15.93	16.25
15.34	15.51	15.45
14.96	14.88	15.08
14.28	14.28	14.40
14.15	14.23	14.27
12.07	12.09	12.20
18.93	18.83	19.02
16.92	16.91	17.02
18.04	18.07	18.14
17.41	17.42	17.51
14.20	14.30	14.32
11.11	11.36	11.25
17.73	18.17	17.83
15.65	15.65	15.76
16.49	16.90	16.60
14.28	14.25	14.40
15.53	15.94	15.64
13.73	13.72	13.85
12.77	12.98	12.90
12.78	13.02	12.91
16.31	16.29	16.42
13.04	12.89	13.17
15.33	15.57	15.44
13.25	13.45	13.37
15.39	16.01	15.50
12.52	12.58	12.65
12.12	12.20	12.25
10.85	11.10	10.99
14.45	14.58	14.57
12.66	12.83	12.79
21.19	21.26	21.27
18.11	18.59	18.21
17.88	19.10	17.98
17.64	17.90	17.74
17.20	17.90	17.30
14.40	14.67	14.52
22.60	22.71	22.68
19.69	19.57	19.78
20.13	20.65	20.22
17.88	17.98	17.98
22.08	22.35	22.16
17.89	17.92	17.99

(Continued)

Table A1 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
20.45	20.44	20.54
16.47	16.44	16.58
17.57	17.52	17.67
14.17	14.43	14.29
17.24	17.21	17.34
15.11	15.19	15.22
17.06	17.46	17.16
13.90	14.13	14.02
18.20	18.29	18.30
13.54	13.62	13.66
16.04	16.34	16.15
13.79	13.97	13.91
20.08	20.48	20.17
18.03	18.03	18.13
17.33	17.86	17.43
14.49	14.62	14.61
20.59	20.79	20.68
16.80	16.97	16.91
13.09	13.17	13.21
12.83	12.80	12.96
5.91	6.03	6.07
19.42	19.30	19.51
16.68	16.78	16.79
15.86	16.34	15.97
13.91	14.12	14.03
17.72	17.79	17.82
15.42	15.62	15.53
6.33	6.43	6.49
5.02	5.07	5.19
5.02	5.17	5.19
17.81	18.25	17.91
15.52	15.82	15.63
15.68	16.00	15.79
13.49	13.88	13.61
6.61	7.00	6.77
17.24	17.81	17.34
15.54	15.59	15.65
11.55	11.20	11.68
15.34	15.67	15.45
15.17	15.28	15.28
5.93	6.17	6.09
14.70	14.99	14.82
19.32	19.29	19.41
14.64	14.57	14.76

(Continued)

Table A1 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
5.53	5.79	5.69
16.98	17.50	17.08
15.56	15.31	15.67
18.53	18.66	18.63
16.31	16.33	16.42
20.23	20.59	20.32
18.47	18.61	18.57
5.40	5.40	5.57
5.23	5.70	5.40
15.46	15.55	15.57
15.27	15.34	15.38
4.15	4.16	4.33
16.79	16.82	16.90
15.34	15.33	15.45
14.37	14.29	14.49
12.71	12.74	12.84
16.61	17.30	16.72
15.58	15.56	15.69
4.32	4.46	4.49
5.66	5.79	5.82
16.51	16.69	16.62
14.19	14.19	14.31
6.56	6.59	6.72
15.48	16.06	15.59
15.50	15.63	15.61
15.42	15.75	15.53
13.67	13.95	13.79
5.29	5.50	5.46
15.99	15.88	16.10
14.25	14.22	14.37
17.38	17.14	17.48
14.24	14.38	14.36
4.53	4.39	4.70
4.93	5.21	5.10
5.37	5.08	5.54
13.94	13.82	14.06
13.86	13.88	13.98
14.00	15.00	14.12
13.80	13.88	13.92
15.64	15.78	15.75
14.75	14.75	14.87
3.71	3.80	3.88
22.79	22.94	22.86
19.96	19.73	20.05
5.31	5.48	5.48

(Continued)

Table A1 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
18.55	18.77	18.65
17.39	17.35	17.49
19.08	19.02	19.17
14.99	15.07	15.10
16.87	17.02	16.98
16.26	16.47	16.37
4.78	4.82	4.95
18.16	18.83	18.26
13.22	13.46	13.34
15.24	15.23	15.35
13.16	13.36	13.28
16.09	17.00	16.20
14.41	14.61	14.53
5.10	5.15	5.27
3.72	4.09	3.89
14.70	14.80	14.82
14.69	14.65	14.81
15.38	15.73	15.49
15.85	15.93	15.96
15.16	15.26	15.27
14.36	14.19	14.48
4.04	4.12	4.21
18.96	18.87	19.05
17.45	17.53	17.55
5.15	5.17	5.32
20.82	21.01	20.90
17.52	17.65	17.62
18.78	18.87	18.88
15.43	15.51	15.54
19.04	10.36	19.13
18.59	18.52	18.69
6.63	6.68	6.79
19.23	19.78	19.32
14.80	14.83	14.92
5.08	5.20	5.25
15.92	16.03	16.03
14.19	14.31	14.31
20.64	20.70	20.73
18.37	18.55	18.47
5.93	6.07	6.09
16.20	16.72	16.31
14.64	15.19	14.76
20.11	20.74	20.20
17.49	17.41	17.59
8.10	8.30	8.25

(Continued)

Table A1 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
17.04	17.30	17.14
16.36	16.32	16.47
16.94	16.60	17.04
17.51	17.62	17.61
5.71	5.83	5.87
16.16	16.37	16.27
14.45	14.42	14.57
16.28	15.91	16.39
14.48	14.67	14.60
4.60	4.50	4.77
16.55	16.73	16.66
14.49	14.41	14.61
15.97	16.04	16.08
14.07	14.61	14.19
6.05	6.12	6.21
17.82	18.09	17.92
17.25	17.20	17.35
16.50	16.54	16.61
14.64	14.91	14.76
4.85	4.87	5.02
17.14	17.13	17.24
13.59	14.20	13.71
6.50	6.76	6.66
18.48	18.13	18.58
14.56	14.58	14.68
5.87	5.99	6.03
14.26	14.37	14.38
13.86	13.84	13.98
14.70	14.91	14.82
12.99	12.99	13.12
5.59	5.75	5.75
14.35	14.53	14.47
13.28	13.30	13.40
14.97	14.78	15.09
13.38	13.88	13.50
5.57	5.63	5.73
13.39	13.53	13.51
13.77	13.79	13.89
14.12	14.38	14.24
11.53	11.59	11.66
5.81	5.59	5.97
13.98	14.14	14.10
14.05	14.08	14.17
5.27	5.34	5.44
13.86	14.57	13.98

(Continued)

Table A1 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
12.60	12.86	12.73
14.20	14.13	14.32
11.99	12.09	12.12
13.14	13.40	13.26
12.63	12.77	12.76
15.76	15.67	15.87
14.75	14.98	14.87
6.08	6.15	6.24
16.00	16.38	16.11
14.66	14.82	14.78
13.24	13.93	13.36
12.30	12.66	12.43
5.76	5.86	5.92
13.86	13.88	13.98
12.61	13.02	12.74
15.55	15.73	15.66
13.58	13.57	13.70
6.33	6.42	6.49
14.24	14.33	14.36
12.34	12.48	12.47
4.97	5.16	5.14
13.35	14.03	13.47
11.87	12.16	12.00
4.33	4.49	4.50
12.74	12.89	12.87
11.96	12.15	12.09
14.06	14.50	14.18
12.23	12.23	12.36
13.28	14.24	13.40
11.75	12.08	11.88
5.52	5.57	5.68
6.46	6.49	6.62
12.93	13.58	13.06
12.12	12.45	12.25
5.64	5.94	5.80
14.97	14.97	15.09
12.71	12.79	12.84
11.77	12.16	11.90
12.25	12.57	12.38
12.79	13.33	12.92
12.52	12.71	12.65
16.04	15.85	16.15
13.78	13.88	13.90
5.38	5.56	5.55
12.31	12.77	12.44

(Continued)

Table A1 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
11.19	11.72	11.32
13.51	14.00	13.63
12.33	12.42	12.46
4.33	4.35	4.50
15.96	15.99	16.07
14.39	14.33	14.51
14.53	15.00	14.65
13.00	13.12	13.13
13.65	14.88	13.77
13.27	13.48	13.39
6.60	6.53	6.76
5.22	5.33	5.39
14.87	15.40	14.99
13.36	13.42	13.48
13.79	14.46	13.91
13.03	13.12	13.16
6.41	6.79	6.57
14.19	14.67	14.31
13.36	13.62	13.48
15.67	15.68	15.78
13.34	13.32	13.46
4.77	4.89	4.94
13.66	13.66	13.78
11.98	12.14	12.11
13.97	14.07	14.09
12.25	12.27	12.38
16.00	16.45	16.11
14.17	14.22	14.29
5.18	5.30	5.35
15.58	16.30	15.69
14.23	14.41	14.35
12.81	12.91	12.94
18.42	17.22	18.52
6.15	6.36	6.31
4.85	4.86	5.02
6.07	6.30	6.23
18.80	18.70	18.90
16.89	16.93	17.00
4.59	4.78	4.76
15.66	15.71	15.77
13.37	13.53	13.49
14.29	14.08	14.41
12.99	13.08	13.12
4.47	4.77	4.64
15.22	15.44	15.33

(Continued)

Table A1 (Concluded)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
14.31	14.36	14.43
5.44	5.56	5.60
17.00	17.03	17.10
15.33	15.06	15.44
5.30	5.47	5.47
15.91	16.09	16.02
13.00	13.13	13.13
5.30	5.20	5.47
15.56	16.33	15.67
13.87	13.92	13.99
4.98	4.98	5.15
14.72	15.77	14.84
14.01	14.47	14.13
16.09	16.21	16.20
15.00	15.52	15.11

Table A2

Water Content Comparison Data from Gallipolis Lock Repair

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
13.40	13.90	13.59
12.80	13.30	12.99
10.70	11.10	10.91
14.90	15.40	15.08
15.20	14.90	15.37
12.60	12.40	12.79
19.80	19.90	19.94
19.00	19.50	19.15
16.30	16.70	16.47
14.60	14.70	14.78
14.50	15.10	14.68
16.10	16.60	16.27
13.70	13.60	13.88
12.20	12.60	12.40
14.00	14.60	14.18
16.00	16.40	16.17
14.70	15.10	14.88
12.80	13.00	12.99
14.60	15.00	14.78
14.40	14.70	14.58
12.00	12.50	12.20
13.40	13.90	13.59
12.80	13.30	12.99
10.70	11.10	10.91
14.90	15.40	15.08
15.00	15.20	15.18
12.40	12.60	12.59
13.00	13.30	13.19
14.90	15.10	15.08
17.40	17.80	17.56
16.90	17.10	17.06
14.40	14.40	14.58
11.90	12.20	12.10
11.50	11.80	11.70
13.40	13.90	13.59
17.40	17.50	17.56
16.20	16.80	16.37
18.70	18.90	18.85
15.70	15.80	15.87
13.90	14.30	14.08
16.10	16.50	16.27
14.90	15.00	15.08
12.70	13.00	12.89
23.00	23.70	23.12
17.90	18.80	18.06

(Continued)

Table A2 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
18.30	18.80	18.45
19.50	19.50	19.65
17.80	18.20	17.96
19.30	19.50	19.45
18.70	18.50	18.85
17.30	17.30	17.46
16.60	16.40	16.76
15.50	15.30	15.67
15.20	15.60	15.37
16.20	16.70	16.37
18.90	18.60	19.05
22.40	22.30	22.53
21.10	21.50	21.23
18.20	18.30	18.35
20.70	21.20	20.84
23.10	23.90	23.22
17.80	18.10	17.96
18.00	18.20	18.16
18.00	17.50	18.16
15.50	15.60	15.67
23.30	23.60	23.42
19.80	20.00	19.94
23.00	22.90	23.12
20.60	20.00	20.74
18.00	18.10	18.16
16.40	16.60	16.57
17.40	17.70	17.56
17.90	17.90	18.06
19.00	19.40	19.15
13.50	13.70	13.69
13.40	13.70	13.59
13.30	13.80	13.49
11.10	11.40	11.30
15.30	15.30	15.47
13.30	13.60	13.49
11.70	11.80	11.90
14.40	14.20	14.58
13.70	14.00	13.88
15.20	15.50	15.37
16.80	16.60	16.96
15.60	16.10	15.77
13.80	14.00	13.98
13.30	13.30	13.49
13.20	13.30	13.39
14.30	14.50	14.48

(Continued)

Table A2 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
13.90	13.70	14.08
13.40	13.60	13.59
15.40	15.50	15.57
14.60	14.70	14.78
15.00	15.20	15.18
14.30	14.50	14.48
11.70	11.80	11.90
16.40	16.30	16.57
16.70	16.90	16.86
15.30	15.50	15.47
17.20	17.00	17.36
15.50	15.80	15.67
14.40	14.40	14.58
12.90	12.80	13.09
12.70	12.90	12.89
14.50	14.80	14.68
15.50	15.70	15.67
15.00	15.50	15.18
13.00	13.40	13.19
13.70	13.70	13.88
13.40	13.60	13.59
16.10	16.20	16.27
16.00	15.60	16.17
14.70	14.90	14.88
13.20	13.40	13.39
17.50	17.30	17.66
16.70	16.90	16.86
15.40	15.60	15.57
15.50	15.70	15.67
14.00	14.30	14.18
12.50	12.80	12.69
15.00	14.70	15.18
14.00	14.20	14.18
12.00	12.20	12.20
15.60	15.70	15.77
14.90	14.80	15.08
12.80	12.60	12.99
15.00	15.60	15.18
14.30	14.80	14.48
12.40	12.20	12.59
18.50	17.80	18.65
16.90	17.10	17.06
15.50	15.90	15.67
11.90	11.70	12.10
11.60	11.80	11.80

(Continued)

Table A2 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
14.00	14.30	14.18
14.20	14.50	14.38
13.70	13.90	13.88
14.90	15.10	15.08
16.20	16.50	16.37
15.00	15.50	15.18
13.50	13.90	13.69
12.50	12.80	12.69
14.30	14.60	14.48
13.20	14.00	13.39
19.50	19.40	19.65
17.70	18.20	17.86
15.30	15.50	15.47
14.90	14.60	15.08
14.60	14.70	14.78
12.40	12.10	12.59
16.80	17.10	16.96
12.40	12.90	12.59
14.80	15.60	14.98
19.10	19.80	19.25
19.40	19.70	19.55
17.30	17.10	17.46
16.20	15.70	16.37
15.80	16.30	15.97
13.00	13.40	13.19
15.80	15.80	15.97
16.30	16.80	16.47
14.30	14.50	14.48
14.70	15.30	14.88
13.90	14.00	14.08
11.80	12.00	12.00
14.60	14.40	14.78
15.70	15.70	15.87
13.20	13.40	13.39
14.40	13.80	14.58
13.40	13.90	13.59
11.50	12.10	11.70
13.70	14.20	13.88
13.80	14.10	13.98
12.00	12.40	12.20
14.40	14.70	14.58
12.80	13.20	12.99
16.70	16.30	16.86
14.20	14.40	14.38
12.10	12.60	12.30

(Continued)

Table A2 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
17.50	18.10	17.66
14.50	14.80	14.68
12.50	12.40	12.69
15.10	15.30	15.28
14.30	14.50	14.48
12.10	12.50	12.30
15.10	15.50	15.28
14.20	14.00	14.38
12.70	12.90	12.89
22.20	22.60	22.33
19.60	19.50	19.74
18.20	18.40	18.35
14.60	13.90	14.78
13.40	13.50	13.59
11.00	10.80	11.20
16.80	17.20	16.96
15.50	15.70	15.67
13.70	13.80	13.88
15.30	15.50	15.47
13.90	13.20	14.08
12.90	12.80	13.09
14.30	14.90	14.48
13.90	14.00	14.08
11.60	11.70	11.80
18.60	18.60	18.75
18.20	18.20	18.35
15.60	16.90	15.77
16.30	16.00	16.47
14.40	14.60	14.58
11.90	11.80	12.10
16.90	16.90	17.06
13.30	13.30	13.49
11.20	11.50	11.40
16.50	16.40	16.67
15.50	15.70	15.67
13.30	13.40	13.49
17.10	17.60	17.26
14.80	15.00	14.98
12.40	12.50	12.59
15.80	16.00	15.97
15.50	15.80	15.67
13.20	13.10	13.39
15.90	16.20	16.07
16.50	16.60	16.67
13.80	13.80	13.98

(Continued)

Table A2 (Continued)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
16.40	15.50	16.57
14.00	14.10	14.18
11.50	11.30	11.70
14.20	13.90	14.38
13.20	13.30	13.39
11.40	11.70	11.60
15.80	15.60	15.97
14.90	15.10	15.08
12.60	13.00	12.79
15.80	15.70	15.97
15.80	16.10	15.97
13.10	13.40	13.29
16.40	16.80	16.57
16.60	16.60	16.76
14.20	14.00	14.38
14.10	14.40	14.28
14.00	14.30	14.18
12.00	12.40	12.20
14.40	14.50	14.58
13.80	14.10	13.98
15.10	15.50	15.28
17.60	16.90	17.76
16.80	17.10	16.96
14.90	14.90	15.08
13.50	13.10	13.69
14.40	14.80	14.58
15.60	16.30	15.77
16.00	16.10	16.17
15.70	16.20	15.87
13.60	14.10	13.79
13.20	13.20	13.39
13.00	13.40	13.19
10.40	10.60	10.61
16.60	16.50	16.76
15.20	15.60	15.37
13.30	13.60	13.49
15.00	15.10	15.18
12.80	13.10	12.99
15.70	16.10	15.87
13.00	13.20	13.19
16.30	16.80	16.47
14.90	15.00	15.08
12.00	12.30	12.20
15.40	15.00	15.57
15.10	15.30	15.28

(Continued)

Table A2 (Concluded)

Microwave Water Content (%)	Conventional Oven Water Content (%)	Predicted Water Content (%)
12.90	12.40	13.09
14.40	14.70	14.58
14.20	14.20	14.38
11.90	11.30	12.10
14.20	14.00	14.38
13.40	13.90	13.59
11.80	11.90	12.00
14.00	14.50	14.18
12.10	12.60	12.30
15.10	15.00	15.28
13.70	14.00	13.88
11.20	11.60	11.40
14.40	14.30	14.58
14.00	13.90	14.18
11.40	11.90	11.60
17.70	17.80	17.86
16.10	16.40	16.27
13.80	14.20	13.98
13.90	13.70	14.08
14.60	14.90	14.78
13.10	13.30	13.29
11.20	11.70	11.40
16.20	16.50	16.37
14.60	14.90	14.78
12.20	12.60	12.40
12.60	12.90	12.79
13.90	14.20	14.08
14.40	14.60	14.58
15.30	15.50	15.47
14.60	14.80	14.78
12.00	12.20	12.20

APPENDIX B

EVALUATION OF US ARMY ENGINEER WATERWAYS EXPERIMENT STATION MICROWAVE OVEN SYSTEM BY YATESVILLE LAKE PROJECT PERSONNEL

CEORH-CD-YBC
19 September 1988

SUBJECT: Using a Microwave Oven to Measure Soil Moisture at Yatesville Lake Project

1. Background. From 28 April to 9 September 1988, a microwave oven was used to measure the moisture content of soil at the Yatesville Lake Project. At the same time, a conventional oven was used to determine field and one-point moisture content. Throughout this experiment, the microwave was designated the "rapid moisture-detection device," while the conventional oven remained the primary method of field control for determining moisture and dry density.

2. Subjective Evaluation. A comparative statistical analysis of the results of this experiment is being conducted by WES. The impression of those who used the microwave method, however, is that it proved to be an adequate field control for both pervious and impervious material. The differences in the results obtained using the microwave and the conventional oven appear to be within the tolerance normally associated with small variations between samples. Such variations appear to be more pronounced in rocky or shaley material because it's difficult to select identical samples with respect to rock content. With respect to clean sand, however, test results suggest that there is virtually no difference between the microwave and conventional-oven methods. Except for obvious errors, discussed below, the difference between these methods was generally less than 0.5 percent.

3. Problem Areas. During the early tests it was noticed that the microwave's breakers stayed cool while the soil sample was being heated. Because of this difference in temperature, moisture condensed on the tall, vertical sides of the beaker and was visible even though the computer indicated that the sample and beaker were oven-dry. This problem was solved by using shallow dishes with sloping sides as sample containers.

For reasons that remain unexplained, the system occasionally loses track of the moisture content. When this happens the error is easily detected and the results easily corrected, and so construction work isn't significantly affected. Similar problems with another prototype in operation at Gallipolis were traced to a loose pedestal mount, but a check of the unit at Yatesville showed that the pedestal mount was secure. The dusty conditions found at any soils lab, including the lab at Yatesville, are now thought to be the predominant cause.

A third problem area concerns the retention, during testing, of materials containing shale particles. Occasionally these particles exploded with a force sufficient to eject portions of sample from the sample container. Tests were salvaged by carefully sweeping the loose particles from the microwave and weighing the recovered sample. However, this isn't considered an appropriate solution.

4. Recommendations

a. Recommended Sample Size. Because our experienced materials technician determined that the recommended 100- to 200-gram sample size was too small, the sample size was increased to about 500 grams. Subsequent testing confirmed that a sample this size reduces the errors associated with obtaining a representative sample--particularly in rocky material. We therefore recommend adoption of the 500-gram sample size as the new recommemded size for tests using microwave methods.

b. Preparation and Sample Selection. As in any sample selection, the sampling process itself must be performed carefully. Accordingly, to ensure accurate results using a microwave, prepare one-point and field material properly using appropriate methods for selecting representative samples.

c. Dust-Proofing. Dust-proof microwave components to ensure reliable long-term operation.

d. Modifications or Additions. Suitably modify or supplement the sample container, or perhaps provide a "shale cycle" at reduced power, to either preclude or effectively contain exploding shale particles.

Kenneth E. Zimmerman
KENNETH E. ZIMMERMAN
Resident Engineer

APPENDIX C

DEHYDRATION CHARACTERISTIC TABLES OF SOME MINERALS

Table C1

Weight Ratios for Materials Showing Slight Variations at Different Temperatures

Temperature, °C	Q	S	A	M	R	D	L
50	1.00544	1.0560	1.0408	1.2020	1.0832	1.0825	1.1690
100	1.00468	1.0415	1.0375	1.1666	1.0458	1.0475	1.1332
150	1.00402	1.0341	1.0290	1.1356	1.0388	1.0406	1.1150
200	1.00345	1.0297	1.0161	1.1100	1.0333	1.0356	1.1024
300	1.00251	1.0215	1.0077	1.0730	1.0283	1.0272	1.0816
400	1.00180	1.0135	1.0039	1.0484	1.0242	1.0192	1.0620
500	1.00120	1.0058	1.0020	1.0260	1.0122	1.0110	1.0420
600	1.00072	1.0021	1.0009	1.0160	1.0076	1.0050	1.0220
700	1.00032	1.0006	1.0003	1.0080	1.0045	1.0021	1.0116

Note: Q = Powdered quartz and felspar, anhydrous crystalline minerals.
S = Amorphous silica, dried silica gel.
A = Volcanic ash, amorphous glasses.
M = Amorphous material having the composition of montmorillonite.
R = Isotropi silica resolve remaining after extraction of bases from bentonite.
D = Diatoms.
L = Synthetic magnesium silicate, "Magnesol."

Table C2

Weight Ratios for Hydrous Oxides and Zeolites

Temperature, °C	A_1	A_2	H_1	H_2	O	S	T	C	P
50	1.365	1.575	1.277	1.530	1.0871	1.1790	1.1686	1.265	1.1972
100	1.268	1.430	1.236	1.422	1.0813	1.1535	1.1200	1.226	1.1797
150	1.203	1.354	1.217	1.321	1.0615	1.1424	1.0795	1.163	1.1160
200	1.168	1.303	1.199	1.244	1.0393	1.1332	1.0582	1.114	1.0965
300	1.103	1.233	1.163	1.150	1.0130	1.1030	1.0374	1.062	1.0596
400	1.0610	1.167	1.095	1.086	1.0058	1.0700	1.0272	1.0341	1.0315
500	1.0242	1.131	1.028	1.047	1.0039	1.0507	1.0183	1.0164	1.0240
600	1.0150	1.025	1.015	1.023	1.0027	1.0370	1.0100	1.0056	1.0220
700	1.0052	1.003	1.005	1.008	1.0011	1.0166	1.0038	1.0000	1.0010

Note: A_1, A_2 = Allophanes (from Kentucky).
H_1, H_2 = Aluminum Hydroxide.
O = Mexican Opal.
S = Sepiolite (from Asia minor).
T = Ptilolite (from Utah).
C = Chabazite (from Oregon).
P = Phillipsite (from Victoria, Australia).

Table C3

Weight Ratios for Hydrous Oxides and Related Silicates

Temperature, °C	A_1	G	D	L	T	B	I	R	F
50	1.089	1.545	1.167	1.134	1.122	1.465	1.0765	1.1010	1.1035
100	1.086	1.529	--	1.128	--	--	1.0552	1.0736	1.1035
150	1.083	1.525	--	1.120	1.115	--	1.0413	1.0684	1.1035
200	1.077	1.345	1.165	1.096	1.112	1.460	1.0354	1.0674	1.1035
250	1.069	1.150	--	1.040	1.100	1.458	1.0317	1.0684	1.1035
300	1.055	1.105	--	1.014	1.050	1.430	1.0275	1.0684	1.1010
350	1.031	1.090	1.163	1.008	1.015	1.080	1.0080	1.0660	1.0712
400	1.014	1.084	1.162	--	1.010	1.030	1.0042	1.0544	1.0408
450	1.006	1.079	1.160	1.004	--	--	1.0038	1.0250	1.0245
500	1.003	1.027	1.015	1.002	--	1.010	1.0030	1.0064	1.0142
600	1.001	1.003	1.005	--	1.004	--	1.0019	1.0002	1.0033

Note: A_1 = Analcime (from Wyoming).
G = Gibbsite.
D = Diaspore (from Rolla, Missouri).
L = Limonite (from Avery, North Carolina).
T = Geothite.
B = Brucite (from Nevada).
I = Inesite (from Quinault, Washington).
R = Rectorite (from Hot springs, Arkansas).
F = Dufrenite (from Cherokee County, Alabama).

Table C4

Weight Ratios for Kaolin Group

Temperature, °C	A_1	A	A_2	K_1	K_2	Pontiac, N.C.	Jerome, Ariz.	Stillwater, Mont.	D_1	Brand, Saxony	Pikes Peak, Colo.
100	1.140	1.150	1.163	1.164	1.163	1.169	1.165	1.161	1.149	1.173	1.149
200	1.137	1.146	1.163	1.164	1.163	1.168	1.165	1.160	1.149	1.173	1.149
300	1.134	1.144	1.162	1.164	1.163	1.167	1.165	1.159	1.149	1.167	1.149
400	1.127	1.136	1.153	1.160	1.160	1.062	1.161	1.158	1.149	1.167	1.147
450	1.078	1.096	1.105	1.155	1.157	1.056	1.159	1.157	1.149	1.163	1.146
475	1.033	1.050	1.083	1.152	1.154	1.051	1.156	1.156	1.148	1.157	1.145
500	1.012	1.020	1.046	1.147	1 149	1.041	1.087	1.152 1.086	1.147	1.134	1.144
525	1.008	1.012	1.029	1.018	1.085	1.020	1.076 1.032	1.052	1.143	1.096	1.143
550	1.005	1.008	1.019	1.013	1.021	1.016	1.023	1.031	1.135	1.075	1.138 1.106
575	1.003	1.005	1.014	1.009	1.014	1.014	1.019	1.021	1.119	1.062	1.075
600	1.001	1.003	1.011	1.007	1.012	1.012	1.015	1.015	1.070	1.050	1.066
650	1.000	1.000	1.007	1 004	1.009	1.009	1.009	1.006	1.012	1.016	1.057 1.028
700	1.000	1.000	1.002	1.001	1.006	1.006	1.004	1.002	1.003	1.009	1.007

Note: A_1 = from the Mokelumne River, California.
A_2 = from Franklin, North Carolina.
A = from Ione, California.
K_1 = from Ione, California.
K_2 = from Bishop, California.
D_1 = from Pennsylvania.

Table C5

Weight Ratios for Montmorillonites

Temperature, °C	S	C	B	Y	T	U	O	F
100	1.0860	1.0483	1.0552	1.0492	1.1090	1.0635	1.0555	1.1290
200	1.0610	1.0449	1.0408	1.0449	1.0815	1.0585	1.0470	1.0870
300	1.0555	1.0437	1.0380	1.0424	1.0784	1.0551	1.0408	1.0555
400	1.0500	1.0426	1.0356	1.0398	1.0753	1.0518	1.0348	1.0316
500	1.0444	1.0411	1.0326	1.0372	1.0715	1.0484	1.0234	1.0154
550	1.0395	1.0340	1.0243	1.0320	1.0650	1.0462	1.0108	1.0118
600	1.0225	1.0122	1.0122	1.0130	1.0400	1.0316	1.0058	1.0092
700	1.0014	1.0015	1.0020	1.0013	1.0030	1.0020	1.0020	1.0045

Note: S = Pure bentonitic montmorillonite (from Polksville, Mississippi).
C = High potash bentonite (from Suifu, China).
B = High potash bentonite (from High Bridge, Kentucky).
Y.= High sodium bentonite (from Upton, Wyoming).
T = Bentonite (from Whitewright, Texas).
U = Bentonite (fropm Upton, Utah).
O = Fuller's Earth (from Olmstead, Illinois).
F = Fuller's Earth (from Florida).

Table C6

Weight Ratios for the Montmorillonite Group

Temperature, °C	B	G	R	N	H	I	T
50	1.148	1.145	1.182	1.186	1.188	1.083	1.113
100	1.120	1.134	1.139	1.080	1.174	1.069	1.085
150	1.107	1.126	1.123	1.059	1.169	1.065	1.077
200	1.100	1.119	1.117	1.053	1.166	1.062	1.070
300	1.093	1.105	1.109	1.048	1.157	1.056	1.070
350	1.089	1.097	1.104	1.046	1.151	1.050	1.069
400	1.084	1.090	1.096	1.039	1.145	1.034	1.067
450	1.067	1.083	1.072	1.017	1.138	1.019	1.065
500	1.036	1.064	1.029	1.009	1.029	1.010	1.061
550	1.020	1.034	1.017	1.006	1.017	1.005	1.055
600	1.011	1.018	1.011	1.003	1.011	1.002	1.045
700	1.003	1.004	1.003	1.000	1.003	1.000	1.011

Note: B = Beidellite (from Pontotoc, Mississippi).
G = Beidellite (from West Chester, Pennsylvania).
R = Beidellite (from Utah).
N = Nontronite (from Santa Rita, New Mexico).
H = Halloysite (from Liege, Belgium).
I = Illite.
T = Saponite (from Hector, California).

Table C7

Weight Ratios for Chlorites and Related Silicates

Temperature, °C	S	L	N	C	P	K	V	G
50	1.196	1.168	1.151	1.142	1.133	1.141	1.107	1.068
100	1.188	1.165	1.150	1.139	1.130	1.121	1.074	1.048
150	1.184	1.164	1.149	1.138	1.128	1.114	1.062	1.048
200	1.181	1.163	1.148	1.137	1.127	1.085	1.058	1.045
300	1.178	1.161	1.146	1.136	1.125	1.077	1.052	1.042
400	1.175	1.159	1.145	1.134	1.122	1.054	1.050	1.033
500	1.172	1.158	1.140	1.132	1.120	1.025	1.030	1.015
550	1.170	1.152	1.066	1.080	1.119	1.020	1.033	1.009
600	1.161	1.074	1.033	1.069	1.060	1.015	1.027	1.005
650	1.080	1.064	1.030	1.059	1.012	1.006	1.022	1.002
700	1.015	1.058	1.027	1.047	1.003	1.001	1.020	1.000
800	1.000	1.043	1.013	1.017	1.000	1.000	1.010	1.000

Note: S = Serpentine.
L = Clinochlore (from Chester County, Pennsylvania).
N = Penninite (from Paradise Range, Nevada).
C = Chlorite (from Danville, Virginia).
P = Picrolite (from Baltimore, Maryland).
K = Paligorskite)from Montana).
V = Vermiculite (from North Carolina).
G = Glauconite (from Lyons Wharf, Maryland).

Table C8

Weight Ratios for Micas

Temperature, °C	P	L	N	T	R	S	M	B
100	1.0014	1.0000	1.0000	1.0000	1.0030	1.0000	1.0000	1.0000
200	1.0014	0.9989	1.0000	1.0000	1.0018	1.0000	0.9998	1.0000
300	1.0000	0.9978	1.0000	1.0000	1.0007	1.0000	0.9945	1.0000
400	1.0000	0.9969	1.0000	1.0000	1.0000	1.0000	0.9935	1.0000
500	0.9980	0.9955	0.9921	1.0000	1.0000	1.0000	0.9908	1.0000
600	0.9850	0.9912	0.9921	1.0000	1.0000	0.9980	0.9846	1.0000
700	0.9595	0.9739	0.9921	1.0000	1.0000	0.9880	0.9805	0.9983
800	0.9496	0.9705	0.9921	0.9925	0.9997	0.9675	0.9805	0.9885
900	0.9486	0.9705	0.9800	0.9572	0.9936	0.9630	0.9800	0.9787
1000	0.9486	0.9705	0.9460	0.9552	0.9788	0.9630	0.9750	0.9765

Note: P = Pyrophyllite (from Hemp, North Carolina).
L = Lepidolite (from Manotoba).
N - Taeniolite (from Magnet Cone, Arkansas).
T - Talc.
R = Tremolite asbestos (from Baltimore, Maryland).
S - Sericite (from Prince Rupert, British Columbia).
M = Biotite (from Philadelphia, Pennsylvania).
B = Beryl (from Warren Depot, Maine).

Table C9

Weight Ratios for Carbonates

Temperature, °C	C	D	M	H	N
50	1.000	1.000	1.000	1.000	1.000
100	1.000	1.000	1.000	1.000	0.825
150	1.000	1.000	1.000	1.000	0.736
200	1.000	1.000	1.000	0.998	0.691
250	1.000	1.000	1.000	0.900	0.661
300	1.000	1.000	1.000	0.837	0.643
400	1.000	1.000	0.975	0.467	0.330
500	1.000	0.956	0.540	0.445	0.310
600	0.995	0.528	0.508	0.435	0.300
700	0.552	0.528	0.508	0.433	0.300

Note: C = Calcite.
D = Dolomite (from Cockeysville, Maryland).
M = Magnesite (from Cote St. Paul, Quebec).
H = Hydromagnesite (from Luna, New Mexico).
N = Nesquehonite (Synthetic).

APPENDIX D

INTERNATIONAL BUSINESS MACHINES VERSION OF MICROWAVE CONTROL PROGRAM FOR INORGANIC SOIL DRYING

```
4  COLOR 7, 1: CLS
5  INPUT "HIT RETURN TO CONTINUE"; E$
8  OUT &H303, &H80
9  OUT &H300, 0
10 WO = 0: TW = 0: W = 0: WN = 0: F2% = 0: TT = 0
20 CLS
30 OUT &H300, 56
40 REM FOR J = 1 TO 1000: NEXT J: REM DELAY
50 PRINT "MICROWAVE OVEN PROGRAM"
60 PRINT "INITIALIZING:STANDBY"
65 REM ON ERROR GOTO 5050
67 OPEN "COM1:600,E,7,1,CS" FOR RANDOM AS #1
71 GOSUB 6000
72 DIM A$(100): REM DIMENSION A$
76 GOSUB 5000
78 IF FLAG = 1 THEN GOTO 100
80 FOR J = 1 TO 5000: NEXT J: REM DELAY
90 PRINT #1, "P": REM SCALE POWER ON
100 FOR J = 1 TO 15000: NEXT J: REM DELAY
105 IF FLAG <> 1 THEN GOTO 72
110 PRINT #1, "R": REM RESET SCALE
120 FOR J = 1 TO 5000: NEXT J: REM DELAY
140 GOSUB 8000: REM READ ZERO
150 IF F <> 0 THEN GOTO 110
160 CLS
170 PRINT "PLACE TARE ON SCALE"
180 INPUT "PRESS ANY KEY AND RETURN"; E$
190 IF E$ = "" THEN 180
195 FOR J = 1 TO 1000: NEXT J
200 GOSUB 8000: REM GO AND READ TARE
210 TW = W
220 TARE = (INT(TW * 100)) / 100
230 CLS
240 PRINT "FILL TARE WITH 100-200"
250 PRINT "GRAMS OF MOIST SOIL, PLACE"
260 INPUT "ON PAN, PRESS ANY KEY AND RETURN"; E$
270 IF E$ = "" THEN 260
275 FOR J = 1 TO 1000: NEXT J
280 GOSUB 8000: REM READ INITIAL WEIGHT
292 IF F2% = 0 GOTO 300
295 OPEN "LPT1:" FOR OUTPUT AS #3
296 IF F2% = 1 THEN GOSUB 7000
297 PRINT #3, "TARE WEIGHT = "; TARE
300 WXYZ = W
305 PRINT "TARE WEIGHT = "; TARE
```

```
310 WETW = (INT(WXYZ * 100)) / 100
320 PRINT "WET WEIGHT = "; WETW
323 IF F2% = 0 GOTO 340
325 PRINT #3, "WET WEIGHT = "; WETW
328 REM IF F2%=1 THEN GOSUB 7100
340 CL = 16: T = 0: NI = 24: RS = 56
350 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
360 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
370 OUT &H300, T: FOR J = 1 TO 1000: NEXT J
380 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
390 FOR K = 1 TO 4
400 OUT &H300, NI: FOR J = 1 TO 1000: NEXT J
410 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
420 NEXT K
430 INPUT "CLOSE DOOR, PRESS ANY KEY AND RETURN"; E$
440 IF E$ = "" THEN 430
443 CLS
445 GOSUB 7095
450 GOSUB 8000
460 ABCD = W
470 OFFSET = WXYZ - ABCD
480 TUVW = ABCD + OFFSET
500 SR = 32: RS = 56
510 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
520 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
530 L = 0
540 N = 1
550 G0 = 0
560 TI = TIMER
570 X = TIMER - TI: IF X < 30 THEN 570
580 IF N = 1 THEN WO = TUVW
590 GOSUB 2000: REM GET WEIGHT
600 WN = W
610 G = ((WO - TW) ^ 2 - (WN - TW) ^ 2) / 60
620 WC = ((TUVW - WN) / (WN - TW)) * 100
630 G = (INT(G * 10000)) / 10000
640 WN = (INT(WN * 100)) / 100
650 WC = (INT(WC * 1000)) / 1000
651 TT = TT + X
652 ET = TT
653 IF F2% = 0 THEN GOTO 660
654 PRINT #3, USING "  ####"; ET;
655 PRINT #3, USING "        ####"; TT;
656 PRINT #3, USING "          ###.#"; WN;
657 PRINT #3, USING "         ###.##"; WC
660 PRINT USING "  ####"; ET;
662 PRINT USING "           ####"; TT;
```

```
664 PRINT USING "             ###.#"; WN;
666 PRINT USING "            ###.##"; WC
670 N = N + 1
680 WO = WN
700 IF G < G0 AND L = 1 THEN GOTO 820
710 IF G >= G0 THEN G0 = G: GOTO 560
720 IF G < G0 THEN L = 1: GOTO 560
820 TI = TIMER
830 X = TIMER - TI: IF X < 30 THEN 830
840 WO = WN
850 GOSUB 2000
860 WN = W
870 WC = ((TUVW - WN) / (WN - TW)) * 100
880 DW = (TUVW - TW) * (1 / (WN - TW) - (1 / (WO - TW)))
890 DW = (INT(DW * 1000000!)) / 1000000!
900 WN = (INT(WN * 100)) / 100
910 WC = (INT(WC * 1000)) / 1000
911 TT = TT + X
912 ET = TT
913 IF F2% = 0 THEN GOTO 920
914 PRINT #3, USING "  ####"; ET;
915 PRINT #3, USING "         ####"; TT;
916 PRINT #3, USING "           ###.#"; WN;
917 PRINT #3, USING "          ###.##"; WC
920 PRINT USING "  ####"; ET;
922 PRINT USING "           ####"; TT;
924 PRINT USING "           ###.#"; WN;
926 PRINT USING "          ###.##"; WC
930 IF DW > .02 THEN 820
940 MW = 56577!: SP = 8: RS = 56
950 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
960 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
970 WO = WN
980 TI = TIMER
990 X = TIMER - TI: IF X < 30 THEN 990
995 ET = ET + X
1000 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
1010 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1020 TI = TIMER
1030 X = TIMER - TI: IF X < 30 THEN 1030
1035 ET = ET + X
1040 GOSUB 9000
1050 WN = W
1060 WC = ((TUVW - WN) / (WN - TW)) * 100
1070 DW = (TUVW - TW) * (1 / (WN - TW) - (1 / (WO - TW)))
1080 DW = (INT(DW * 1000000!)) / 1000000!
```

```
1090 WN = (INT(WN * 100)) / 100
1100 WC = (INT(WC * 1000)) / 1000
1101 TT = TT + X
1102 IF F2% = 0 THEN GOTO 1110
1104 PRINT #3, USING "  ####"; ET;
1105 PRINT #3, USING "         ####"; TT;
1106 PRINT #3, USING "           ###.#"; WN;
1107 PRINT #3, USING "          ###.##"; WC
1110 PRINT USING "  ####"; ET;
1112 PRINT USING "           ####"; TT;
1114 PRINT USING "           ###.#"; WN;
1116 PRINT USING "          ###.##"; WC
1120 IF DW > F1 THEN GOTO 970
1130 SP = 8: RS = 56
1140 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
1150 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1160 TI = TIMER
1170 X = TIMER - TI: IF X < 180 THEN 1170
1180 GOSUB 8000
1190 WN = W
1200 FOR K = 1 TO 25
1210 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
1220 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1230 NEXT K
1240 Z = ((TUVW - WN) / (WN - TW)) * 100
1250 Z = (INT(Z * 100) / 100)
1252 IF F2% = 0 THEN GOTO 1269
1253 PRINT #3, USING "  ####"; ET + 180;
1254 PRINT #3, USING "         ####"; TT;
1255 PRINT #3, USING "           ###.#"; WN;
1256 PRINT #3, USING "          ###.##"; Z
1257 PRINT USING "  ####"; ET + 180;
1258 PRINT USING "           ####"; TT;
1259 PRINT USING "           ###.#"; WN;
1260 PRINT USING "          ###.##"; Z
1263 PRINT #3, "WATER CONTENT ="; Z; "%"
1264 PRINT #3, "FINAL WEIGHT ="; WN; "G"
1269 PRINT "WATER CONTENT ="; Z; "%"
1270 PRINT "FINAL WEIGHT ="; WN; "G"
1280 FOR J = 1 TO 5000: NEXT J
1290 MW = 56577!: CL = 16: RS = 56
1300 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
1310 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1320 PRINT #1, "P": REM SCALE POWER OFF
1330 PRINT "TEST IS OVER!"
1340 PRINT "REMOVE CONTAINER"
```

```
1360 PRINT "CAUTION!-CONTAINER IS HOT"
1365 CLOSE #3
1366 CLOSE #1
1367 INPUT "PRESS RETURN TO RESET FOR NEXT TEST"; E$
1368 GOTO 10
1370 END
2000 REM SUBROUTINE TO READ THE SCALE
2003 MW = 56577!: SP = 8: RS = 56
2005 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
2007 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
2020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
2040 LINE INPUT #1, A$(3)
2050 IF A$(3) = "" THEN 2040
2070 IF A$(3) = CHR$(103) THEN A$(3) = CHR$(71)
2080 B$ = LEFT$(A$(3), 2)
2090 DT$ = MID$(A$(3), 5, 11)
2100 IF B$ = "US" THEN GOTO 2020
2105 F = VAL(DT$)
2110 W = 1! * F
2113 SR = 32: RS = 56
2115 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
2117 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
2120 RETURN
5000 PRINT #1, "Q": FOR J = 1 TO 250: NEXT J
5020 FOR I = 1 TO 100
5021 A = INP(&H3F8): FOR J = 1 TO 100: NEXT J: IF A <> 10
AND A <> 255 AND A <> 0 THEN FLAG = 1: LINE INPUT #1,
A$(2): GOTO 5050
5023 NEXT I
5030 FLAG = 0
5050 RETURN
6000 REM OPERATOR INPUT
6010 INPUT "PLEASE INPUT DATE OF TEST"; D$
6020 INPUT "WHAT IS THE PROJECT NUMBER?"; P$
6030 INPUT "WHAT IS THE JOB NUMBER?"; J$
6040 INPUT "IS THIS A CLEAN SAND?"; I$
6045 F1 = .002
6050 IF I$ = "Y" THEN F1 = 0!: GOTO 6080
6060 IF I$ <> "N" THEN GOTO 6040
6080 INPUT "ARE YOU USING A PRINTER?"; I$
6085 F2% = 0
6090 IF I$ = "Y" THEN F2% = 1: GOTO 6110
6100 IF I$ <> "N" THEN GOTO 6080
6110 RETURN
7000 REM HEADER INFO
7010 PRINT #3, "       MICROWAVE OVEN"
```

```
7020 PRINT #3, " WATER CONTENT DETERMINATION"
7030 PRINT #3, "DATE: "; D$
7040 PRINT #3, "PROJECT NO: "; P$
7050 PRINT #3, "JOB NUMBER: "; J$
7065 REM HEADER INFO
7070 PRINT "       MICROWAVE OVEN"
7075 PRINT " WATER CONTENT DETERMINATION"
7077 PRINT "DATE: "; D$
7080 PRINT "PROJECT NO: "; P$
7085 PRINT "JOB NUMBER: "; J$
7090 RETURN
7095 IF F2% = 0 THEN GOTO 7200
7100 PRINT #3, "  ELAPSED      DRYING          WEIGHT
      WATER"
7110 PRINT #3, "TIME (SEC)   TIME (SEC)        (G)
   CONTENT (%)"
7120 PRINT #3, "__________   __________   __________
               "
   _____________
7130 PRINT #3, USING "   ###"; ZERO;
7132 PRINT #3, USING "          ###"; ZERO;
7134 PRINT #3, USING "           ###.#"; WETW;
7136 PRINT #3, USING "          ###.##"; ZERO
7200 PRINT "  ELAPSED        DRYING         WEIGHT
    WATER"
7210 PRINT "TIME (SEC)     TIME (SEC)        (G)
  CONTENT (%)"
7220 PRINT "__________     __________     __________
            "
_____________
7225 ZERO = 0
7230 PRINT USING "   ###"; ZERO;
7232 PRINT USING "            ###"; ZERO;
7234 PRINT USING "           ###.#"; WETW;
7236 PRINT USING "          ###.##"; ZERO
7240 RETURN
8000 REM SUBROUTINE TO READ THE SCALE
8010 FOR J = 1 TO 5000: NEXT J
3020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
8040 LINE INPUT #1, A$(2)
8050 IF A$(2) = " " THEN 8040
8070 IF A$(2) = CHR$(103) THEN A$(2) = CHR$(71)
8080 B$ = LEFT$(A$(2), 2)
8100 IF B$ = "US" THEN GOTO 8020
8102 DT$ = MID$(A$(2), 5, 11)
8105 F = VAL(DT$)
8110 W = F
8120 RETURN
```

```
9000 REM SUBROUTINE TO READ THE SCALE
9003 MW = 56577!: SP = 8: RS = 56
9005 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
9007 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
9020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
9040 LINE INPUT #1, A$(4)
9050 IF A$(4) = "" THEN 9040
9070 IF A$(4) = CHR$(103) THEN A$(I) = CHR$(71)
9080 B$ = LEFT$(A$(4), 2)
9090 DT$ = MID$(A$(4), 5, 11)
9100 IF B$ = "US" GOTO 9020
9105 F = VAL(DT$)
9110 W = 1! * F
9120 RETURN
```

APPENDIX E

INTERNATIONAL BUSINESS MACHINES VERSION OF MICROWAVE CONTROL PROGRAM FOR DRYING PEAT

```
4  COLOR 7, 1: CLS
5  INPUT "HIT RETURN TO CONTINUE"; E$
8  OUT &H303, &H80
9  OUT &H300, 0
10 WO = 0: TW = 0: W = 0: WN = 0: F2% = 0: TT = 0
20 CLS
30 OUT &H300, 56
40 REM FOR J = 1 TO 1000: NEXT J: REM DELAY
50 PRINT "MICROWAVE OVEN PROGRAM"
60 PRINT "INITIALIZING:STANDBY"
65 REM ON ERROR GOTO 5050
67 OPEN "COM1:600,E,7,1,CS" FOR RANDOM AS #1
71 GOSUB 6000
72 DIM A$(100): REM DIMENSION A$
76 GOSUB 5000
78 IF FLAG = 1 THEN GOTO 100
80 FOR J = 1 TO 5000: NEXT J: REM DELAY
90 PRINT #1, "P": REM SCALE POWER ON
100 FOR J = 1 TO 15000: NEXT J: REM DELAY
105 IF FLAG <> 1 THEN GOTO 72
110 PRINT #1, "R": REM RESET SCALE
120 FOR J = 1 TO 5000: NEXT J: REM DELAY
140 GOSUB 8000: REM READ ZERO
150 IF F <> 0 THEN GOTO 110
160 CLS
170 PRINT "PLACE TARE ON SCALE"
180 INPUT "PRESS ANY KEY AND RETURN"; E$
190 IF E$ = "" THEN 180
195 FOR J = 1 TO 1000: NEXT J
200 GOSUB 8000: REM GO AND READ TARE
210 TW = W
220 TARE = (INT(TW * 100)) / 100
230 CLS
240 PRINT "FILL TARE WITH 100-200"
250 PRINT "GRAMS OF MOIST SOIL, PLACE"
260 INPUT "ON PAN, PRESS ANY KEY AND RETURN"; E$
270 IF E$ = "" THEN 260
275 FOR J = 1 TO 1000: NEXT J
280 GOSUB 8000: REM READ INITIAL WEIGHT
292 IF F2% = 0 GOTO 300
295 OPEN "LPT1:" FOR OUTPUT AS #3
296 IF F2% = 1 THEN GOSUB 7000
297 PRINT #3, "TARE WEIGHT = "; TARE
300 WXYZ = W
305 PRINT "TARE WEIGHT = "; TARE
```

```
310 WETW = (INT(WXYZ * 100)) / 100
320 PRINT "WET WEIGHT = "; WETW
322 IF F2% = 0 GOTO 340
325 PRINT #3, "WET WEIGHT = "; WETW
327 REM IF F2%=1 THEN GOSUB 7100
340 CL = 16: T = 0: NI = 24: RS = 56
350 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
360 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
370 OUT &H300, T: FOR J = 1 TO 1000: NEXT J
380 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
390 FOR K = 1 TO 4
400 OUT &H300, NI: FOR J = 1 TO 1000: NEXT J
410 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
420 NEXT K
430 INPUT "CLOSE DOOR, PRESS ANY KEY AND RETURN"; E$
440 IF E$ = "" THEN 430
443 CLS
445 GOSUB 7095
450 GOSUB 8000
460 ABCD = W
470 OFFSET = WXYZ - ABCD
480 TUVW = ABCD + OFFSET
500 SR = 32: RS = 56
510 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
520 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
530 WO = TUVW
560 TI = TIMER
570 X = TIMER - TI: IF X < 30 THEN 570
590 GOSUB 2000: REM GET WEIGHT
600 WN = W
620 WC = ((TUVW - WN) / (WN - TW)) * 100
630 DW = (TUVW - TW) * (1 / (WN - TW) - (1 / (WO - TW)))
640 WN = (INT(WN * 100)) / 100
650 WC = (INT(WC * 1000)) / 1000
651 TT = TT + X
652 ET = TT
653 IF F2% = 0 THEN GOTO 660
654 PRINT #3, USING "  ####"; ET;
655 PRINT #3, US1NG "        ####"; TT;
656 PRINT #3, USING "          ###.#"; WN;
657 PRINT #3, USING "         ###.##"; WC
660 PRINT USING "  ####"; ET;
662 PRINT USING "          ####"; TT;
664 PRINT USING "          ###.#"; WN;
666 PRINT USING "         ###.##"; WC
668 WO = WN
```

```
670 IF DW < .1 THEN GOTO 560
680 WO = WN
820 TI = TIMER
830 X = TIMER - TI: IF X < 30 THEN 830
840 WO = WN
850 GOSUB 2000
860 WN = W
870 WC = ((TUVW - WN) / (WN - TW)) * 100
880 DW = (TUVW - TW) * (1 / (WN - TW) - (1 / (WO - TW)))
890 DW = (INT(DW * 1000000!)) / 1000000!
900 WN = (INT(WN * 100)) / 100
910 WC = (INT(WC * 1000)) / 1000
911 TT = TT + X
912 ET = TT
913 IF F2% = 0 THEN GOTO 920
914 PRINT #3, USING "  ####"; ET;
915 PRINT #3, USING "         ####"; TT;
916 PRINT #3, USING "           ###.#"; WN;
917 PRINT #3, USING "          ###.##"; WC
920 PRINT USING "  ####"; ET;
922 PRINT USING "           ####"; TT;
924 PRINT USING "           ###.#"; WN;
926 PRINT USING "          ###.##"; WC
930 IF DW > .08 THEN 820
940 MW = 56577!: SP = 8: RS = 56
950 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
960 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
970 WO = WN
980 TI = TIMER
990 X = TIMER - TI: IF X < 30 THEN 990
995 ET = ET + X
1000 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
1010 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1020 TI = TIMER
1030 X = TIMER - TI: IF X < 30 THEN 1030
1035 ET = ET + X
1040 GOSUB 9000
1050 WN = W
1060 WC = ((TUVW - WN) / (WN - TW)) * 100
1070 DW = (TUVW - TW) * (1 / (WN - TW) - (1 / (WO - TW)))
1080 DW = (INT(DW * 1000000!)) / 1000000!
1090 WN = (INT(WN * 100)) / 100
1100 WC = (INT(WC * 1000)) / 1000
1101 TT = TT + X
1102 IF F2% = 0 THEN GOTO 1110
1104 PRINT #3, USING "  ####"; ET;
```

```
1105 PRINT #3, USING "         ####"; TT;
1106 PRINT #3, USING "           ###.#"; WN;
1107 PRINT #3, USING "          ###.##"; WC
1110 PRINT USING "  ####"; ET;
1112 PRINT USING "           ####"; TT;
1114 PRINT USING "           ###.#"; WN;
1116 PRINT USING "          ###.##"; WC
1120 IF DW > F1 THEN GOTO 970
1130 SP = 8: RS = 56
1140 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
1150 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1160 TI = TIMER
1170 X = TIMER - TI: IF X < 180 THEN 1170
1180 GOSUB 8000
1190 WN = W
1200 FOR K = 1 TO 25
1210 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
1220 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1230 NEXT K
1240 Z = ((TUVW - WN) / (WN - TW)) * 100
1250 Z = (INT(Z * 100) / 100)
1252 IF F2% = 0 THEN GOTO 1265
1255 PRINT #3, "WATER CONTENT ="; Z; "%"
1260 PRINT #3, "FINAL WEIGHT ="; WN; "G"
1265 PRINT "WATER CONTENT ="; Z; "%"
1270 PRINT "FINAL WEIGHT ="; WN; "G"
1280 FOR J = 1 TO 5000: NEXT J
1290 MW = 56577!: CL = 16: RS = 56
1300 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
1310 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1320 PRINT #1, "P": REM SCALE POWER OFF
1330 PRINT "TEST IS OVER!"
1340 PRINT "REMOVE CONTAINER"
1360 PRINT "CAUTION!-CONTAINER IS HOT"
1365 CLOSE #3
1366 CLOSE #1
1367 INPUT "PRESS RETURN TO RESET FOR NEXT TEST"; E$
1368 GOTO 10
1370 END
2000 REM SUBROUTINE TO READ THE SCALE
2003 MW = 56577!: SP = 8: RS = 56
2005 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
2007 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
2020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
2040 LINE INPUT #1, A$(3)
2050 IF A$(3) = "" THEN 2040
```

```
2070 IF A$(3) = CHR$(103) THEN A$(3) = CHR$(71)
2080 B$ = LEFT$(A$(3), 2)
2090 DT$ = MID$(A$(3), 5, 11)
2100 IF B$ = "US" THEN GOTO 2020
2105 F = VAL(DT$)
2110 W = 1! * F
2113 SR = 32: RS = 56
2115 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
2117 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
2120 RETURN
5000 PRINT #1, "Q": FOR J = 1 TO 250: NEXT J
5020 FOR I = 1 TO 100
5021 A = INP(&H3F8): FOR J = 1 TO 100: NEXT J: IF A <> 10
AND A <> 255 AND A <> 0 THEN FLAG = 1: LINE INPUT #1,
A$(2): GOTO 5050
5023 NEXT I
5030 FLAG = 0
5050 RETURN
6000 REM OPERATOR INPUT
6010 INPUT "PLEASE INPUT DATE OF TEST"; D$
6020 INPUT "WHAT IS THE PROJECT NUMBER?"; P$
6030 INPUT "WHAT IS THE JOB NUMBER?"; J$
6045 F1 = .05
6080 INPUT "ARE YOU USING A PRINTER?"; I$
6085 F2% = 0
6090 IF I$ = "Y" THEN F2% = 1: GOTO 6110
6100 IF I$ <> "N" THEN GOTO 6080
6110 RETURN
7000 REM HEADER INFO
7010 PRINT #3, "       MICROWAVE OVEN"
7020 PRINT #3, " WATER CONTENT DETERMINATION"
7030 PRINT #3, "DATE: "; D$
7040 PRINT #3, "PROJECT NO: "; P$
7050 PRINT #3, "JOB NUMBER: "; J$
7065 REM HEADER INFO
7070 PRINT "       MICROWAVE OVEN"
7075 PRINT " WATER CONTENT DETERMINATION"
7077 PRINT "DATE: "; D$
7080 PRINT "PROJECT NO: "; P$
7085 PRINT "JOB NUMBER: "; J$
7090 RETURN
7095 IF F2% = 0 THEN GOTO 7200
7100 PRINT #3, "  ELAPSED      DRYING         WEIGHT
      WATER"
7110 PRINT #3, "TIME (SEC)   TIME (SEC)        (G)
   CONTENT (%)"
```

```
7120 PRINT #3, "__________   __________    __________
 _____________"
7130 PRINT #3, USING "   ###"; ZERO;
7132 PRINT #3, USING "          ###"; ZERO;
7134 PRINT #3, USING "           ###.#"; WETW;
7136 PRINT #3, USING "          ###.##"; ZERO
7200 PRINT "  ELAPSED        DRYING         WEIGHT
    WATER"
7210 PRINT "TIME (SEC)     TIME (SEC)        (G)
 CONTENT (%)"
7220 PRINT "__________   __________   __________
_____________"
7225 ZERO = 0
7230 PRINT USING "   ###"; ZERO;
7232 PRINT USING "          ###"; ZERO;
7234 PRINT USING "         ###.#"; WETW;
7236 PRINT USING "        ###.##"; ZERO
7240 RETURN
8000 REM SUBROUTINE TO READ THE SCALE
8010 FOR J = 1 TO 5000: NEXT J
8020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
8040 LINE INPUT #1, A$(2)
8050 IF A$(2) = " " THEN 8040
8070 IF A$(2) = CHR$(103) THEN A$(2) = CHR$(71)
8080 B$ = LEFT$(A$(2), 2)
8100 IF B$ = "US" THEN GOTO 8020
8102 DT$ = MID$(A$(2), 5, 11)
8105 F = VAL(DT$)
8110 W = F
8120 RETURN
9000 REM SUBROUTINE TO READ THE SCALE
9003 MW = 56577!: SP = 8: RS = 56
9005 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
9007 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
9020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
9040 LINE INPUT #1, A$(4)
9050 IF A$(4) = "" THEN 9040
9070 IF A$(4) = CHR$(103) THEN A$(I) = CHR$(71)
9080 B$ = LEFT$(A$(4), 2)
9090 DT$ = MID$(A$(4), 5, 11)
9100 IF B$ = "US" GOTO 9020
9105 F = VAL(DT$)
9110 W = 1! * F
9120 RETURN
```

APPENDIX F

INTERNATIONAL BUSINESS MACHINES
VERSION OF MICROWAVE SYSTEM CONTROL PROGRAM
FOR DRYING MICROWAVE RESISTANT SOILS

```
4  COLOR 7, 1: CLS
5  INPUT "HIT RETURN TO CONTINUE"; E$
8  OUT &H303, &H80
9  OUT &H300, 0
10 WO = 0: TW = 0: W = 0: WN = 0: F2% = 0: TT = 0
20 CLS
30 OUT &H300, 56
40 REM FOR J = 1 TO 1000: NEXT J: REM DELAY
50 PRINT "MICROWAVE OVEN PROGRAM"
60 PRINT "INITIALIZING:STANDBY"
65 REM ON ERROR GOTO 5050
67 OPEN "COM1:600,E,7,1,CS" FOR RANDOM AS #1
71 GOSUB 6000
72 DIM A$(100): REM DIMENSION A$
76 GOSUB 5000
78 IF FLAG = 1 THEN GOTO 100
80 FOR J = 1 TO 5000: NEXT J: REM DELAY
90 PRINT #1, "P": REM SCALE POWER ON
100 FOR J = 1 TO 15000: NEXT J: REM DELAY
105 IF FLAG <> 1 THEN GOTO 72
110 PRINT #1, "R": REM RESET SCALE
120 FOR J = 1 TO 5000: NEXT J: REM DELAY
140 GOSUB 8000: REM READ ZERO
150 IF F <> 0 THEN GOTO 110
160 CLS
170 PRINT "PLACE TARE ON SCALE"
180 INPUT "PRESS ANY KEY AND RETURN"; E$
190 IF E$ = "" THEN 180
195 FOR J = 1 TO 1000: NEXT J
200 GOSUB 8000: REM GO AND READ TARE
210 TW = W
220 TARE = (INT(TW * 100)) / 100
230 CLS
240 PRINT "FILL TARE WITH 100-200"
250 PRINT "GRAMS OF MOIST SOIL, PLACE"
260 INPUT "ON PAN, PRESS ANY KEY AND RETURN"; E$
270 IF E$ = "" THEN 260
275 FOR J = 1 TO 1000: NEXT J
280 GOSUB 8000: REM READ INITIAL WEIGHT
292 IF F2% = 0 GOTO 300
295 OPEN "LPT1:" FOR OUTPUT AS #3
296 IF F2% = 1 THEN GOSUB 7000
297 PRINT #3, "TARE WEIGHT = "; TARE
300 WXYZ = W
305 PRINT "TARE WEIGHT = "; TARE
310 WETW = (INT(WXYZ * 100)) / 100
```

```
320 PRINT "WET WEIGHT = "; WETW
322 IF F2% = 0 GOTO 340
325 PRINT #3, "WET WEIGHT = "; WETW
327 REM IF F2%=1 THEN GOSUB 7100
340 CL = 16: T = 0: NI = 24: RS = 56
350 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
360 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
370 OUT &H300, T: FOR J = 1 TO 1000: NEXT J
380 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
390 FOR K = 1 TO 4
400 OUT &H300, NI: FOR J = 1 TO 1000: NEXT J
410 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
420 NEXT K
430 INPUT "CLOSE DOOR, PRESS ANY KEY AND RETURN"; E$
440 IF E$ = "" THEN 430
443 CLS
445 GOSUB 7095
450 GOSUB 8000
460 ABCD = W
470 OFFSET = WXYZ - ABCD
480 TUVW = ABCD + OFFSET
500 SR = 32: RS = 56
510 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
520 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
530 L = 0
540 N = 1
550 G0 = 0
560 TI = TIMER
570 X = TIMER - TI: IF X < 90 THEN 570
580 IF N = 1 THEN WO = TUVW
590 GOSUB 2000: REM GET WEIGHT
600 WN = W
610 G = ((WO - TW) ^ 2 - (WN - TW) ^ 2) / 180
620 WC = ((TUVW - WN) / (WN - TW)) * 100
630 G = (INT(G * 10000)) / 10000
640 WN = (INT(WN * 100)) / 100
650 WC = (INT(WC * 1000)) / 1000
651 TT = TT + X
652 ET = TT
653 IF F2% = 0 THEN GOTO 660
654 PRINT #3, USING "  ####"; ET;
655 PRINT #3, USING "         ####"; TT;
656 PRINT #3, USING "           ###.#"; WN;
657 PRINT #3, USING "          ###.##"; WC
660 PRINT USING "  ####"; ET;
662 PRINT USING "           ####"; TT;
```

```
664 PRINT USING "          ###.#"; WN;
666 PRINT USING "         ###.##"; WC
670 N = N + 1
680 WO = WN
700 IF G < G0 AND L = 1 THEN GOTO 820
710 IF G >= G0 THEN G0 = G: GOTO 560
720 IF G < G0 THEN L = 1: GOTO 560
820 TI = TIMER
830 X = TIMER - TI: IF X < 90 THEN 830
840 WO = WN
850 GOSUB 2000
860 WN = W
870 WC = ((TUVW - WN) / (WN - TW)) * 100
880 DW = (TUVW - TW) * (1 / (WN - TW) - (1 / (WO - TW)))
890 DW = (INT(DW * 1000000!)) / 1000000!
900 WN = (INT(WN * 100)) / 100
910 WC = (INT(WC * 1000)) / 1000
911 TT = TT + X
912 ET = TT
913 IF F2% = 0 THEN GOTO 920
914 PRINT #3, USING "  ####"; ET;
915 PRINT #3, USING "         ####"; TT;
916 PRINT #3, USING "           ###.#"; WN;
917 PRINT #3, USING "          ###.##"; WC
920 PRINT USING "  ####"; ET;
922 PRINT USING "          ####"; TT;
924 PRINT USING "          ###.#"; WN;
926 PRINT USING "         ###.##"; WC
930 IF DW > .02 THEN 820
940 MW = 56577!: SP = 8: RS = 56
950 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
960 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
970 WO = WN
980 TI = TIMER
990 X = TIMER - TI: IF X < 30 THEN 990
995 ET = ET + X
1000 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
1010 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1020 TI = TIMER
1030 X = TIMER - TI: IF X < 90 THEN 1030
1035 ET = ET + X
1040 GOSUB 9000
1050 WN = W
1060 WC = ((TUVW - WN) / (WN - TW)) * 100
1070 DW = (TUVW - TW) * (1 / (WN - TW) - (1 / (WO - TW)))
1080 DW = (INT(DW * 1000000!)) / 1000000!
```

```
1090 WN = (INT(WN * 100)) / 100
1100 WC = (INT(WC * 1000)) / 1000
1101 TT = TT + X
1102 IF F2% = 0 THEN GOTO 1110
1104 PRINT #3, USING "  ####"; ET;
1105 PRINT #3, USING "         ####"; TT;
1106 PRINT #3, USING "           ###.#"; WN;
1107 PRINT #3, USING "          ###.##"; WC
1110 PRINT USING "  ####"; ET;
1112 PRINT USING "           ####"; TT;
1114 PRINT USING "           ###.#"; WN;
1116 PRINT USING "          ###.##"; WC
1120 IF DW > F1 THEN GOTO 970
1130 SP = 8: RS = 56
1140 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
1150 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1160 TI = TIMER
1170 X = TIMER - TI: IF X < 180 THEN 1170
1180 GOSUB 8000
1190 WN = W
1200 FOR K = 1 TO 25
1210 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
1220 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1230 NEXT K
1240 Z = ((TUVW - WN) / (WN - TW)) * 100
1250 Z = (INT(Z * 100) / 100)
1252 IF F2% = 0 THEN GOTO 1265
1255 PRINT #3, "WATER CONTENT ="; Z; "%"
1260 PRINT #3, "FINAL WEIGHT ="; WN; "G"
1265 PRINT "WATER CONTENT ="; Z; "%"
1270 PRINT "FINAL WEIGHT ="; WN; "G"
1280 FOR J = 1 TO 5000: NEXT J
1290 MW = 56577!: CL = 16: RS = 56
1300 OUT &H300, CL: FOR J = 1 TO 1000: NEXT J
1310 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
1320 PRINT #1, "P": REM SCALE POWER OFF
1330 PRINT "TEST IS OVER!"
1340 PRINT "REMOVE CONTAINER"
1360 PRINT "CAUTION!-CONTAINER IS HOT"
1365 CLOSE #3
1366 CLOSE #1
1367 INPUT "PRESS RETURN TO RESET FOR NEXT TEST"; E$
1368 GOTO 10
1370 END
2000 REM SUBROUTINE TO READ THE SCALE
2003 MW = 56577!: SP = 8: RS = 56
```

```
2005 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
2007 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
2020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
2040 LINE INPUT #1, A$(3)
2050 IF A$(3) = "" THEN 2040
2070 IF A$(3) = CHR$(103) THEN A$(3) = CHR$(71)
2080 B$ = LEFT$(A$(3), 2)
2090 DT$ = MID$(A$(3), 5, 11)
2100 IF B$ = "US" THEN GOTO 2020
2105 F = VAL(DT$)
2110 W = 1! * F
2113 SR = 32: RS = 56
2115 OUT &H300, SR: FOR J = 1 TO 1000: NEXT J
2117 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
2120 RETURN
5000 PRINT #1, "Q": FOR J = 1 TO 250: NEXT J
5020 FOR I = 1 TO 100
5021 A = INP(&H3F8): FOR J = 1 TO 100: NEXT J: IF A <> 10
AND A <> 255 AND A <> 0 THEN FLAG = 1: LINE INPUT #1,
A$(2): GOTO 5050
5023 NEXT I
5030 FLAG = 0
5050 RETURN
6000 REM OPERATOR INPUT
6010 INPUT "PLEASE INPUT DATE OF TEST"; D$
6020 INPUT "WHAT IS THE PROJECT NUMBER?"; P$
6030 INPUT "WHAT IS THE JOB NUMBER?"; J$
6040 INPUT "IS THIS A CLEAN SAND?"; I$
6045 F1 = .02
6050 IF I$ = "Y" THEN F1 = 0!: GOTO 6080
6060 IF I$ <> "N" THEN GOTO 6040
6080 INPUT "ARE YOU USING A PRINTER?"; I$
6085 F2% = 0
6090 IF I$ = "Y" THEN F2% = 1: GOTO 6110
6100 IF I$ <> "N" THEN GOTO 6080
6110 RETURN
7000 REM HEADER INFO
7010 PRINT #3, "        MICROWAVE OVEN"
7020 PRINT #3, " WATER CONTENT DETERMINATION"
7030 PRINT #3, "DATE: "; D$
7040 PRINT #3, "PROJECT NO: "; P$
7050 PRINT #3, "JOB NUMBER: "; J$
7065 REM HEADER INFO
7070 PRINT "        MICROWAVE OVEN"
7075 PRINT " WATER CONTENT DETERMINATION"
7077 PRINT "DATE: "; D$
```

```
7080 PRINT "PROJECT NO: "; P$
7085 PRINT "JOB NUMBER: "; J$
7090 RETURN
7095 IF F2% = 0 THEN GOTO 7200
7100 PRINT #3, "  ELAPSED      DRYING         WEIGHT
      WATER"
7110 PRINT #3, "TIME (SEC)   TIME (SEC)        (G)
   CONTENT (%)"
7120 PRINT #3, "__________   __________    __________
  _____________"
7130 PRINT #3, USING "   ###"; ZERO;
7132 PRINT #3, USING "          ###"; ZERO;
7134 PRINT #3, USING "           ###.#"; WETW;
7136 PRINT #3, USING "          ###.##"; ZERO
7200 PRINT "  ELAPSED        DRYING         WEIGHT
   "
7210 PRINT "TIME (SEC)     TIME (SEC)        (G)
 CONTENT (%)"
7220 PRINT "__________    __________    __________
____________"
7225 ZERO = 0
7230 PRINT USING "   ###"; ZERO;
7232 PRINT USING "           ###"; ZERO;
7234 PRINT USING "          ###.#"; WETW;
7236 PRINT USING "         ###.##"; ZERO
7240 RETURN
8000 REM SUBROUTINE TO READ THE SCALE
8010 FOR J = 1 TO 5000: NEXT J
8020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
8040 LINE INPUT #1, A$(2)
8050 IF A$(2) = " " THEN 8040
8070 IF A$(2) = CHR$(103) THEN A$(2) = CHR$(71)
8080 B$ = LEFT$(A$(2), 2)
8100 IF B$ = "US" THEN GOTO 8020
8102 DT$ = MID$(A$(2), 5, 11)
8105 F = VAL(DT$)
8110 W = F
8120 RETURN
9000 REM SUBROUTINE TO READ THE SCALE
9003 MW = 56577!: SP = 8: RS = 56
9005 OUT &H300, SP: FOR J = 1 TO 1000: NEXT J
9007 OUT &H300, RS: FOR J = 1 TO 1000: NEXT J
9020 PRINT #1, "Q": FOR J = 1 TO 500: NEXT J
9040 LINE INPUT #1, A$(4)
9050 IF A$(4) = "" THEN 9040
```

```
9070 IF A$(4) = CHR$(103) THEN A$(I) = CHR$(71)
9080 B$ = LEFT$(A$(4), 2)
9090 DT$ = MID$(A$(4), 5, 11)
9100 IF B$ = "US" GOTO 9020
9105 F = VAL(DT$)
9110 W = 1! * F
9120 RETURN
```

APPENDIX G

ENHANCED VERSION OF COMMODORE 64 CONTROL PROGRAM FOR INORGANIC SOIL DRYING

```
4   PRINT "{CLR}"
5   INPUT "HIT RETURN TO CONTINUE"; E$
8   POKE 808, 39: POKE 809, 254
10 WO=0: TW=0: W=0: WN=0: F2%=0: TT=0
20 PRINT "{CLR}"
30 GOSUB 3000
40 FOR J=1 TO 1000: NEXT J: REM DELAY
50 PRINT "MICROWAVE OVEN PROGRAM"
60 PRINT "INITIALIZING:STANDBY"
70 OPEN 2, 2, 0, CHR$(7+32)+CHR$(32+64)
71 GOSUB 6000
72 DIM A$(17): REM DIMENSION A$
76 GOSUB 5000
78 IF FLAG=1 THEN GOTO 100
80 FOR J=1 TO 100: NEXT J: REM DELAY
90 PRINT #2, "P": REM SCALE POWER ON
100 FOR J=1 TO 500: NEXT J: REM DELAY
110 PRINT #2, "R": REM RESET SCALE
120 FOR J=1 TO 100: NEXT J: REM DELAY
140 GOSUB 8000: REM READ ZERO
150 IF F <> 0 THEN GOTO 110
160 PRINT "{CLR}"
170 PRINT "PLACE TARE ON SCALE"
180 INPUT "PRESS ANY KEY AND RETURN"; E$
190 IF E$="" THEN 180
200 GOSUB 8000: REM GO AND READ TARE
210 TW=W
220 TARE=(INT(TW*100))/100
230 PRINT "{CLR}"
240 PRINT "FILL TARE WITH 100-200"
250 PRINT "GRAMS OF MOIST SOIL, PLACE"
260 INPUT "ON PAN, PRESS ANY KEY AND RETURN"; E$
270 IF E$="" THEN 260
275 FOR J=1 TO 500: NEXT J
280 GOSUB 8000: REM READ INITIAL WEIGHT
292 IF F2%=0 GOTO 300
295 OPEN 4,4
296 IF F2%=1 THEN GOSUB 7000
297 REM PRINT #4, "TARE WEIGHT="; TARE
300 WXYZ=W
305 PRINT "TARE WEIGHT="; TARE
310 WETW=(INT(WXYZ*100))/100
320 PRINT "WET WEIGHT="; WETW
322 IF F2%=0 GOTO 330
324 PRINT #4, CHR$(16); CHR$(52); CHR$(49);
325 PRINT #4, " Wet Weight + Tare (g): "; WETW: PRINT #4,
```

```
326 IF DD$="Y" THEN PRINT #3, "DENSITY SPECIMEN VOLUME IN
CUBIC FEET="; VVV
327 IF DD$="Y" THEN PRINT #3, "DENSITY SPECIMEN WET
WEIGHT IN GRAMS ="; WWW
328 REM IF F2%=1 THEN GOSUB 7100
340 MW=56577: CL=16: T=0: NI=24: RS=56
350 POKE MW, CL: FOR J=1 TO 100: NEXT J
360 POKE MW, RS: FOR J=1 TO 100: NEXT J
370 POKE MW, T: FOR J=1 TO 100: NEXT J
380 POKE MW, RS: FOR J=1 TO 100: NEXT J
390 FOR K=1 TO 4
400 POKE MW, NI: FOR J=1 TO 100: NEXT J
410 POKE MW, RS: FOR J=1 TO 100: NEXT J
420 NEXT K
430 INPUT "CLOSE DOOR, PRESS ANY KEY AND RETURN"; E$
440 IF E$="" THEN 430
443 PRINT "{CLR}"
445 GOSUB 7095
450 GOSUB 8000
460 ABCD=W
470 OFFSET=WXYZ-ABCD
480 TUVW=ABCD+OFFSET
500 MW=56577: SR=32: RS=56
510 POKE MW, SR: FOR J=1 TO 100: NEXT J
520 POKE MW, RS: FOR J=1 TO 100: NEXT J
530 L=0
540 N=1
550 G0=0
560 TI$="000000"
570 X=VAL(TI$): IF X<30 THEN 570
580 IF N=1 THEN WO=TUVW
590 GOSUB 2000: REM GET WEIGHT
600 WN=W
610 G=((WO-TW)^2-(WN-TW)^2)/60
620 WC=((TUVW-WN)/(WN-TW))*100
630 G=(INT(G*10000))/10000
640 WN=(INT(WN*100))/100
650 WC=(INT(WC*1000))/1000
651 TT=TT+VAL(TI$)
652 ET=TT
653 IF F2%=0 THEN GOTO 660
654 PRINT #4, "    "; ET; CHR$(16); CHR$(49); CHR$(53);
TT; CHR$(16); CHR$(50); CHR$(57); WN;
655 PRINT #4, CHR$(16); CHR$(52); CHR$(54); WC
660 PRINT TT; TAB(16); WN; TAB(30); WC
670 N=N+1
```

```
680 WO=WN
700 IF G<G0 AND L=1 THEN GOTO 820
710 IF G>=G0 THEN G0=G: GOTO 560
720 IF G<G0 THEN L=1: GOTO 560
820 TI$="000000"
830 X=VAL(TI$): IF X<30 THEN 830
840 WO=WN
850 GOSUB 2000
860 WN=W
870 WC=((TUVW-WN)/(WN-TW))*100
880 DW=(TUVW-TW)*(1/(WN-TW)-(1/(WO-TW)))
890 DW=(INT(DW*1000000!))/1000000!
900 WN=(INT(WN*100))/100
910 WC=(INT(WC*1000))/1000
911 TT=TT+VAL(TI$)
912 ET=TT
913 IF F2%=0 THEN GOTO 920
915 PRINT #4, "    "; ET; CHR$(16); CHR$(49); CHR$(53);
TT;CHR$(16); CHR$(50); CHR$(57); WN;
916 PRINT #4, CHR$(16); CHR$(52); CHR$(54); WC
920 PRINT TT; TAB(16); WN; TAB(30); WC
930 IF DW>.02 THEN 820
940 MW=56577!: SP=8: RS=56
950 POKE MW, SP: FOR J=1 TO 100: NEXT J
960 POKE MW, RS: FOR J=1 TO 100: NEXT J
970 WO=WN
980 TI$="000000"
990 X=VAL(TI$): IF X<30 THEN 990
995 ET=ET+X
1000 POKE MW, SR: FOR J=1 TO 100: NEXT J
1010 POKE MW, RS: FOR J=1 TO 100: NEXT J
1020 TI$ "000000"
1030 X=VAL(TI$): IF X<30 THEN 1030
1035 ET = ET+X
1040 GOSUB 9000
1050 WN=W
1060 WC=((TUVW-WN)/(WN-TW))*100
1070 DW=(TUVW-TW)*(1/(WN-TW)-(1/(WO-TW)))
1080 DW=(INT(DW*1000000!))/1000000!
1090 WN=(INT(WN*100))/100
1100 WC=(INT(WC*1000))/1000
1101 TT=TT+VAL(TI$)
1102 IF F2%=0 THEN GOTO 1110
1105 PRINT #4, "
";ET;CHR4(16)CHR$(49)CHR$(53);TT;CHR$(16)CHR$(50)CHR$(5
7);WN;
```

```
1106 PRINT #4,CHR$(16)CHR$(52)CHR$(54);WC
1110 PRINT TT;TAB(16);WN;TAB(30);WC
1120 IF DW>F1 THEN GOTO 970
1130 MW=56577:SP=8:RS=56
1140 POKE MW,SP:FOR J=1 TO 100: NEXT J
1150 POKE MW,RS:FOR J=1 TO 100: NEXT J
1160 TI$="000000"
1170 X=VAL(TI$): IF X<180 THEN 1170
1180 GOSUB 8000
1190 WN=W
1200 FOR K=1 TO 25
1210 POKE MW,CL:FOR J=1 TO 100: NEXT J
1220 POKE MW,RS:FOR J=1 TO 100: NEXT J
1230 NEXT K
1240 Z=((TUVW-WN)/(WN-TW))*100
1245 ET=ET+180
1250 Z=(INT(Z*100)/100)
1251 IF DD$="Y" THEN DDD=(WWW*.0022046)/(VVV*(1+Z/100))
1252 IF F2%=0 THEN GOTO 1265
1253 PRINT #4,"
";ET;CHR$(16)CHR$(49)CHR$(53);TT;CHR$(16)CHR$(50)CHR$(5
7);WN;
1254 PRINT#4,CHR$(16)CHR$(52)CHR$(54);WC
1255 PRINT#4,"WATER CONTENT =";Z;%"
1256 PRINT#4
1260 PRINT#4, "FINAL WEIGHT ="; WN; "G"
1261 PRINT#4
1262 PRINT#4,"TOTAL ELAPSED TIME = ";ET;" SEC":PRINT#4
1263 PRINT#4," TOTAL DRYING TIME = ";TT;" SEC":PRINT#4
1264 PRINT#4,"        TECHNICIAN : ";TECH$
1265 PRINT"WATER CONTENT =";Z;"%"
1266 DDD=INT(DDD)*10)/10
1267 IF DD$ = "Y" THEN PRINT #4, "DRY DENSITY = ";DDD;"
PCF"
1269 PRINT "WATER CONTENT ="; Z; "%"
1270 PRINT "FINAL WEIGHT ="; WN; "G"
1280 FOR J=1 TO 5000: NEXT J
1290 MW=56577!: CL=16: RS=56
1300 POKE MW,CL: FOR J=1 TO 100: NEXT J
1310 POKE MW,RS: FOR J=1 TO 100: NEXT J
1320 PRINT #2, "P": REM SCALE POWER OFF
1330 PRINT "TEST IS OVER!"
1340 PRINT "REMOVE CONTAINER"
1360 PRINT "CAUTION!-CONTAINER IS HOT"
1365 CLOSE 4
1366 CLOSE 2
```

```
1367 INPUT "PRESS RETURN TO RESET FOR NEXT TEST"; E$
1368 GOTO 10
1370 END
2000 REM SUBROUTINE TO READ THE SCALE
2003 MW=56577!: SP=8: RS=56
2005 POKE MW,SP: FOR J=1 TO 100: NEXT J
2007 POKE MW,RS: FOR J=1 TO 100: NEXT J
2020 PRINT #2, "Q": FOR J=1 TO 500: NEXT J
2030 FOR J=1 TO 17
2040 GET #2,A$(J)
2050 IF A$(J)="" THEN 2040
2060 NEXT J
2070 IF A$(J)=CHR$(103) THEN A$(3) = CHR$(71)
2080 B$=A$(1)+A$(2)
2                  0                  9                  0
DT$=A$(5)+A$(6)+A$(7)+A$(8)+A$(9)+A$(10)+A$(11)+A$(12)+
A$(13)
2100 IF B$="US" THEN GOTO 2020
2105 F=VAL(DT$)
2110 W=1! * F
2113 MW=56577: SR=32: RS=56
2115 POKE MW,SR: FOR J=1 TO 100: NEXT J
2117 POKE MW,RS: FOR J=1 TO 100: NEXT J
2120 RETURN
3000 REM SUBROUTINE TO INITIALIZE
3010 REM I/O PORT FOR MICROWAVE
3020 REM OVEN CONTROL
3030 Y=PEEK(56579)
3040 Y=Y OR 56
3050 POKE 56579,Y
3060 POKE 56579,56
3070 POKE 56579,8
3080 FOR J=1 TO 100: NEXT J
3090 POKE 56577,56
3100 RETURN
5000 PRINT #2, "Q": FOR J=1 TO 50: NEXT J
5010 FOR J=1 TO 17
5020 GET#2,A$(J)
5030 IF A$(J)<>"" THEN FLAG=1
5040 NEXT J
5050 RETURN
6000 REM OPERATOR INPUT
6002 INPUT "WHAT IS THE DISTRICT: "; DS$
6010 INPUT "WHAT IS THE DATE: "; D$
6020 INPUT "WHAT IS THE PROJECT: "; P$
6022 INPUT "WHAT IS THE CONTRACT: "; CTR$
```

```
6030 INPUT "WHAT IS THE LOCATION: "; LO$
6035 INPUT "WHAT IS THE TIME: "; TM$
6037 INPUT "WHAT IS THE SAMPLE NO.: "; SN$
6038 INPUT "WHAT IS THE CLASSIFICATION: "; CL$
6039 INPUT "TECHNICIAN: "; TECH$
6040 INPUT "IS THIS A CLEAN SAND?"; I$
6045 F1=.002
6050 IF I$="Y" THEN F1=0!: GOTO 6080
6060 IF I$<>"N" THEN GOTO 6040
6080 INPUT "ARE YOU USING A PRINTER?"; I$
6085 F2%=0
6090 IF I$="Y" THEN F2%=1: GOTO 6110
6100 IF I$<>"N" THEN GOTO 6080
6110 INPUT "WANT TO COMPUTE DRY DENSITY?"; DD$
6112 IF DD$="Y" THEN INPUT "ENTER DENSITY SPECIMEN VOLUME
IN CUBIC FEET: ", VVV
6115 IF DD$="Y" THEN INPUT "ENTER DENSITY SPECIMEN WET
WEIGHT IN GRAMS: ", WWW
6120 IF DD$<>"N" AND DD$<>"Y" THEN GOTO 6110
6130 RETURN
7000 REM HEADER INFO
7010 PRINT#4,"                                   MICROWAVE
OVEN":PRINT#4
7020 PRINT#4,"                           WATER CONTENT
DETERMINATION":PRINT#4
7022 PRINT#4,"      DISTRICT. ";DS$
7024 PRINT#4,CHR$(16)CHR$(50)CHR$(57);"PROJECT: "P$;
7025   PRINT#4,CHR$(16)CHR$(53)CHR$(52);"CONTRACT:
";CTR$:PRINT#4
7027 PRINT#4,"      LOCATION: ";LO$;
7030 PRINT#4,CHR$(16)CHR$(51)CHR$(50);"DATA: "D$
7032 PRINT#4,CHR$(16)CHR$(53)CHR$(50);"TIME: "TM$:PRINT#4
7035 PRINT#4,"    SAMPLE NO.: ";SN$;
7040  PRINT#4,CHR$(16)CHR$(50)CHR$(50);"CLASSIFICATION:
";CL$;
7050 PRINT#4,CHR$(16)CHR$(52)CHR$(55);"TARE WEIGHT (G):
";TARE
7065 REM HEADER INFO
7070 PRINT"       MICROWAVE OVEN"
7075 PRINT" WATER CONTENT DETERMINATION"
7077 PRINT"DATE: "; D$
7080 PRINT"PROJECT NO: "; P$
7085 PRINT"JOB NUMBER: "; J$
7090 RETURN
7095 IF F2%=0 THEN GOTO 7200
```

```
7100 PRINT#4, "  ELAPSED       DRYING           WEIGHT
     WATER"
7110 PRINT#4, "TIME (SEC)    TIME (SEC)         (G)
  CONTENT (%)"
7120 PRINT#4, "__________    __________     __________
          "
 _____________
7129 PRINT#4,        0          0";
7                  1                  3                  0
PRINT#4,CHR$(16)CHR$(50)CHR$57);WETW;CHR$(16)CHR$(52)CH
R$(54)" 0"
7200 PRINT"TOTAL TIME      WET WEIGHT     WATER"
7210 PRINT"   SEC                G            %"

7220 PRINT" _______         _______      ______  "
7230 PRINT " 0";TAB(16);WETW;TAB(31);"0"
7240 RETURN
8000 REM SUBROUTINE TO READ THE SCALE
8010 FOR J=1 TO 17:GET #2,A$(J):NEXT J
8020 PRINT #2, "Q": FOR J=1 TO 500: NEXT J
8030 FOR J=1 TO 17
8040 GET #2,A$(J)
8050 IF A$(J)=" " THEN 8040
8060 NEXT J
8070 IF A$(I)=CHR$(103) THEN A$(I)=CHR$(71)
8080 B$=A$(1)+A$(2)
8                  0                  9                  0
DT$=A$(5)+A$(6)+A$(7)+A$(8)+A$(9)+A$(10)+A$(11)+A$(12)+
A$(13)
8100 IF B$="US" THEN GOTO 8020
8105 F=VAL(DT$)
8110 W=F
8120 RETURN
9000 REM SUBROUTINE TO READ THE SCALE
9003 MW=56577!: SP=8: RS=56
9005 POKE MW,SP: FOR J=1 TO 100: NEXT J
9007 POKE MW,RS: FOR J=1 TO 100: NEXT J
9020 PRINT #2, "Q": FOR J=1 TO 500: NEXT J
9030 FOR J=1 TO 17
9040 GET #2,A$(J)
9050 IF A$(J)="" THEN 9040
9060 NEXT J
9070 IF A$(I)=CHR$(103) THEN A$(I)=CHR$(71)
9080 B$=A$(1)+A$(2)
```

```
9                  0                  9                  0
DT$=A$(5)+A$(6)+A$(7)+A$(8)+A$(9)+A$(10)+A$(11)+A$(12)+
A$(13)
9100 IF B$="US" GOTO 9020
9105 F=VAL(DT$)
9110 W=!*F
9120 RETURN
```

APPENDIX H

DATA TABLES

TABLE H1

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 5/31/88
PROJECT: FOLSOM GRAVEL #4-3/8 INCH FRACTION
TARE WEIGHT: 97.0 G
WET WEIGHT: 434.7 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	434.7	0.00
32	434.6	0.03
64	434.6	0.03
96	434.4	0.09
128	433.9	0.24
160	433.0	0.50
192	431.8	0.87
224	430.8	1.17
256	430.0	1.41
287	429.4	1.59
318	429.0	1.72
349	428.8	1.78
380	428.6	1.84
411	428.5	1.87
442	428.4	1.90
473	428.4	1.90

FINAL WATER CONTENT = 1.93 %
FINAL WEIGHT = 428.3 G

TABLE H2

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 5/31/88
PROJECT: FOLSOM GRAVEL 3/8-1/2 INCH FRACTION
TARE WEIGHT: 97.0 G
WET WEIGHT: 475.3 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	475.3	0.00
32	475.2	0.03
64	475.1	0.05
96	474.8	0.13
128	474.2	0.29
160	473.5	0.48
192	472.8	0.67
224	472.1	0.85
255	471.5	1.01
286	471.1	1.12
317	470.9	1.18
348	470.7	1.23
379	470.5	1.28
410	470.4	1.31
441	470.3	1.34
472	470.2	1.37
503	470.1	1.39
534	470.1	1.39

FINAL WATER CONTENT = 1.42 %
FINAL WEIGHT = 470.0 G

TABLE H3

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/1/88
PROJECT: FOLSOM GRAVEL 1/2-3/4 INCH FRACTION
TARE WEIGHT: 169.4 G
WET WEIGHT: 826.3 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	826.3	0.00
32	826.2	0.01
64	826.1	0.03
96	825.6	0.11
128	825.1	0.18
160	824.5	0.27
191	823.5	0.43
222	822.6	0.57
253	821.8	0.69
284	821.2	0.78
315	820.6	0.88
346	820.2	0.94
377	819.8	1.00
408	819.5	1.04
439	819.2	1.09
470	819.0	1.12
501	818.8	1.15
532	818.7	1.17
563	818.5	1.20
594	818.4	1.22
625	818.4	1.22

FINAL WATER CONTENT = 1.24 %
FINAL WEIGHT = 818.2 G

TABLE H4

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/1/88
PROJECT: FOLSOM GRAVEL 3/4-1 INCH FRACTION
TARE WEIGHT: 169.4 G
WET WEIGHT: 886.7 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	886.7	0.00
32	886.6	0.01
64	886.4	0.04
96	885.9	0.11
128	884.9	0.25
160	883.7	0.42
192	882.4	0.60
224	881.4	0.74
256	880.6	0.86
288	880.0	0.94
319	879.0	1.09
350	878.5	1.16
381	878.1	1.21
412	877.8	1.26
443	877.6	1.28
474	877.5	1.30
505	877.3	1.33
536	877.2	1.34
567	877.1	1.36
598	877.0	1.37
629	877.0	1.37

FINAL WATER CONTENT = 1.38 %
FINAL WEIGHT = 876.9 G

TABLE H5

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/16/88
PROJECT: FOLSOM GRAVEL 1-1.5 INCH FRACTION
TARE WEIGHT: 169.4 G
WET WEIGHT: 887.9 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	887.9	0.00
32	887.9	0.00
64	887.8	0.01
96	887.5	0.05
128	887.2	0.10
160	886.8	0.15
192	886.4	0.21
224	886.0	0.26
256	885.6	0.32
287	885.2	0.38
318	885.0	0.41
349	884.9	0.42
380	884.7	0.45
411	884.6	0.46
442	884.5	0.47
473	884.4	0.49
504	884.3	0.50
535	884.2	0.52
566	884.2	0.52

FINAL WATER CONTENT = 0.53 %
FINAL WEIGHT = 884.1 G

TABLE H6

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/8/88
PROJECT: WARREN COUNTY PEA GRAVEL
TARE WEIGHT: 158.1 G
WET WEIGHT: 470.6 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	470.6	0.00
32	470.5	0.03
64	470.4	0.06
96	470.4	0.06
128	470.3	0.10
159	470.1	0.16
190	469.9	0.22
221	469.6	0.32
252	469.2	0.45
283	468.7	0.61
314	468.1	0.81
345	467.5	1.00
376	466.9	1.20
407	466.4	1.36
438	465.8	1.56
469	465.3	1.73
500	464.9	1.86
531	464.5	1.99
562	464.2	2.09
593	463.9	2.19
624	463.6	2.29
655	463.4	2.36
686	463.2	2.42
717	463.0	2.49
748	462.8	2.56
779	462.7	2.59
810	462.6	2.63
841	462.5	2.66
872	462.5	2.66

FINAL WATER CONTENT = 2.69 %
FINAL WEIGHT = 462.4 G

TABLE H7

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/23.88
PROJECT: WARREN COUNTY RED CLAY GRAVEL
TARE WEIGHT: 142.2 G
WET WEIGHT: 559.5 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	559.5	0.00
32	559.5	0.00
64	559.3	0.05
96	558.9	0.14
128	557.5	0.48
160	554.4	1.24
192	551.1	2.05
224	548.4	2.73
256	546.2	3.29
288	544.5	3.73
319	543.1	4.09
350	542.0	4.38
381	541.1	4.61
412	540.4	4.80
443	539.9	4.93
474	539.5	5.03
505	539.2	5.11
536	539.0	5.17
567	538.9	5.19
598	538.8	5.22
629	538.7	5.24
660	538.6	5.27
691	538.6	5.27

FINAL WATER CONTENT = 5.27 %
FINAL WEIGHT = 538.6 G

TABLE H8

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/24/88
PROJECT: WARNER ROBBINS AFB / GEORGIA RED CLAY
TARE WEIGHT: 59.1 G
WET WEIGHT: 224.3 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	224.3	0.00
32	224.1	0.12
64	222.7	0.98
96	218.4	3.70
128	214.7	6.17
160	211.4	8.47
192	208.6	10.50
224	206.3	12.23
255	204.7	13.46
286	203.6	14.32
317	202.8	14.96
348	202.3	15.36
379	201.9	15.69
410	201.8	15.77
441	201.7	15.85
472	201.6	15.93
503	201.6	15.93

FINAL WATER CONTENT = 15.92 %
FINAL WEIGHT = 201.6 G

TABLE H9

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 9/7/88
PROJECT: NPD MATERIAL STATION 30+04.7 ON CL
TARE WEIGHT: 129.1 G
WET WEIGHT: 433.1 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	433.1	0.00
30	433.1	0.00
60	433.0	0.03
90	432.4	0.23
120	429.3	1.26
150	423.6	3.22
180	417.7	5.34
210	411.9	7.50
240	406.4	9.63
270	400.9	11.85
300	395.7	14.03
330	390.7	16.21
361	385.8	18.43
391	381.4	20.49
421	377.2	22.53
451	373.4	24.44
481	370.3	26.04
511	367.5	27.52
541	365.0	28.87
571	363.0	29.97
601	361.2	30.98
631	359.7	31.83
661	358.6	32.46
691	357.8	32.92
721	357.3	33.22
751	356.9	33.45
781	356.5	33.69
811	356.3	33.80

FINAL WATER CONTENT = 33.92 %
FINAL WEIGHT = 356.1 G

TABLE H10

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 9/7/88
PROJECT: NPD MATERIAL STATION 24+21.2 ON CL
TARE WEIGHT: 140.7 G
WET WEIGHT: 451.1 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	451.1	0.00
30	451.1	0.00
60	451.0	0.03
90	450.6	0.16
120	447.8	1.07
150	442.2	2.95
180	436.1	5.08
210	430.3	7.18
240	424.5	9.37
270	418.9	11.57
300	413.5	13.78
330	408.3	15.99
361	403.3	18.19
391	398.6	20.35
421	394.2	22.44
451	390.1	24.45
481	386.6	26.22
511	383.6	27.78
541	381.1	29.11
571	378.9	30.30
601	377.0	31.34
631	375.5	32.18
661	374.2	32.92
691	373.3	33.43
721	372.7	33.78
751	372.2	34.07
781	371.9	34.24

FINAL WATER CONTENT = 34.47 %
FINAL WEIGHT = 371.5 G

TABLE H11

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 9/7/88
PROJECT: NPD MATERIAL STATION 11.02
TARE WEIGHT: 129.1 G
WET WEIGHT: 401.4 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	401.4	0.00
30	401.4	0.00
60	401.4	0.00
90	401.0	0.15
120	397.4	1.49
150	391.5	3.77
180	385.7	6.12
210	379.9	8.57
240	374.3	11.05
270	368.9	13.55
300	363.5	16.17
330	358.3	18.80
361	353.3	21.45
391	348.6	24.05
421	344.1	26.65
451	340.0	29.11
481	336.4	31.35
511	333.2	33.41
541	330.5	35.20
571	328.3	36.70
601	326.5	37.94
631	325.0	39.00
661	323.8	39.86
691	322.9	40.51
721	322.3	40.94
751	321.8	41.31
781	321.5	41.53
811	321.2	41.75
841	321.0	41.90

FINAL WATER CONTENT = 42.04 %
FINAL WEIGHT = 320.8 G

TABLE H12

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 9/7/88
PROJECT: NPD MATERIAL STATION 11.02
TARE WEIGHT: 142.2 G
WET WEIGHT: 433.4 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	433.4	0.00
30	433.3	0.03
60	433.2	0.07
90	433.0	0.14
120	429.9	1.22
150	424.3	3.22
180	418.5	5.39
210	412.2	7.85
240	407.0	9.97
270	401.5	12.30
300	396.1	14.69
330	390.9	17.09
361	385.8	19.54
391	380.9	21.99
421	376.3	24.39
451	372.0	26.72
481	368.1	28.91
511	364.5	30.99
541	361.6	32.72
571	359.2	34.19
601	357.2	35.44
631	355.5	36.52
661	354.1	37.42
691	353.0	38.19
721	352.3	38.60
751	351.9	38.93
781	351.4	39.20
811	351.1	39.40

FINAL WATER CONTENT = 39.53 %
FINAL WEIGHT = 350.9 G

TABLE H13

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 9/9/88
PROJECT: 50% PEA GRAVEL AND PULLOUT CLAY
TARE WEIGHT: 149.7 G
WET WEIGHT: 481.9 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	481.9	0.00
30	481.8	0.03
60	481.4	0.15
90	478.6	1.00
120	473.5	2.59
150	467.5	4.53
180	461.6	6.51
210	456.1	3.42
240	451.2	10.18
270	447.2	11.66
300	443.9	12.92
330	441.1	14.00
361	438.9	14.87
391	437.3	15.51
421	436.1	15.99
451	435.4	16.27
481	435.0	16.44
511	434.7	16.56
541	434.5	16.64
571	434.4	16.68
601	434.3	16.73
631	434.2	16.77
6[illegible]1	434.1	16.81
6[illegible]	434.0	16.85
721	434.0	16.85

FINAL WATER CONTENT = 16.88 %
FINAL WEIGHT = 433.9 G

TABLE H14

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/23/88
PROJECT: 50% SAND AND PULLOUT CLAY
TARE WEIGHT: 101.6 G
WET WEIGHT: 262.9 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	262.9	0.00
30	262.8	0.06
60	261.0	1.19
90	256.6	4.06
120	251.9	7.32
150	254.9	10.25
180	244.6	12.80
210	242.0	14.89
240	240.0	16.55
270	238.4	17.91
300	237.3	18.86
330	236.5	19.57
361	235.9	20.10
391	235.6	20.37
421	235.3	20.64
451	235.2	20.73
481	235.1	20.82
511	235.0	20.91
541	234.9	21.00
571	234.9	21.00

FINAL WATER CONTENT = 21.00 %
FINAL WEIGHT = 234.9 G

TABLE H15

MICROWAVE OVEN
WATER CONTENT DETERMINATION

DATE: 8/22/88
PROJECT: MOBILE BAY DREDGE MATERIAL
TARE WEIGHT: 59.0 G
WET WEIGHT: 173.5 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	173.5	0.00
30	172.9	0.53
60	171.3	1.96
90	169.3	3.81
120	166.5	6.51
150	163.2	9.88
180	159.8	13.59
210	156.2	17.80
240	152.6	22.33
270	148.8	27.50
300	145.0	33.14
330	141.2	39.29
361	137.3	46.23
391	133.5	53.69
421	129.7	61.95
451	126.1	70.64
481	122.7	79.75
511	119.5	89.26
541	116.5	99.13
571	113.8	108.94
601	111.2	119.35
631	109.0	129.00
661	107.4	136.57
691	106.4	141.56
721	105.8	144.66
751	105.5	146.24
781	105.4	146.77
811	105.4	146.77

FINAL WATER CONTENT = 146.76 %
FINAL WEIGHT = 105.4 G

TABLE H16

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/24/88
PROJECT: PASCAGOULA RIVER DREDGE MATERIAL
TARE WEIGHT: 96.9 G
WET WEIGHT: 224.7 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	224.7	0.00
30	224.4	0.23
60	223.5	0.95
90	222.5	1.75
120	220.6	3.31
150	218.4	5.18
180	216.0	7.30
210	213.4	9.70
240	210.6	12.40
270	207.8	15.24
300	204.9	18.33
330	201.9	21.71
361	198.8	25.42
391	195.6	29.48
421	192.3	33.96
451	188.9	38.91
481	185.4	44.41
511	181.7	50.71
541	178.0	57.58
571	174.3	65.12
601	170.6	73.40
631	166.8	82.83
661	163.0	93.34
691	159.3	104.81
721	155.7	117.35
751	152.2	131.10
781	148.9	145.77
811	145.8	161.35
841	142.7	179.04
871	140.2	195.15
901	137.8	212.47
931	136.2	225.19
961	135.3	232.81
991	134.8	237.20
1022	134.5	239.89
1052	134.3	241.71
1082	134.2	242.63
1112	134.2	242.63

FINAL WATER CONTENT = 242.62 %
FINAL WEIGHT = 134.2 G

TABLE H17

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/16/88
PROJECT: FLY ASH-AIR DRY
TARE WEIGHT: 167.2 G
WET WEIGHT: 311.1 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	311.1	0.00
32	311.1	0.00
64	311.1	0.00
96	311.0	0.07
128	311.0	0.07
160	311.0	0.07
192	311.0	0.07
223	311.0	0.07

FINAL WATER CONTENT = 0.06 %
FINAL WEIGHT = 311.0 G

TABLE H18

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/22/88
PROJECT: FLY ASH TESTED IMMEDIATELY AFTER MIXING
TARE WEIGHT: 97.4 G
WET WEIGHT: 270.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	270.8	0.00
32	270.8	0.00
64	270.6	0.12
96	270.2	0.35
128	268.1	1.58
160	266.0	2.85
192	264.4	3.83
224	263.1	4.65
255	262.3	5.15
286	261.7	5.54
317	261.2	5.86
348	260.8	6.12
379	260.5	6.32
410	260.2	6.51
441	259.9	6.71
472	259.7	6.84
503	259.5	6.97
534	259.3	7.10
565	259.1	7.24
596	258.9	7.37
627	258.7	7.50
658	258.6	7.57
689	258.4	7.70
720	258.3	7.77
751	258.2	7.84
782	258.1	7.90
813	258.0	7.97
844	257.9	8.04
875	257.9	8.04

FINAL WATER CONTENT = 8.10 %
FINAL WEIGHT = 257.8 G

TABLE H19

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/16/88
PROJECT: FLY ASH CURED 15 MINUTES
TARE WEIGHT: 167.3 G
WET WEIGHT: 385.0 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	385.0	0.00
32	384.9	0.05
64	384.7	0.14
96	382.1	1.35
128	378.5	3.08
160	375.6	4.51
192	373.4	5.63
224	371.7	6.51
255	370.6	7.08
286	369.8	7.51
317	369.3	7.77
348	369.0	7.93

FINAL WATER CONTENT = 8.14 %
FINAL WEIGHT = 368.6 G

TABLE H20

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/24/88
PROJECT: FLY ASH CURED 2 DAYS
TARE WEIGHT: 97.5 G
WET WEIGHT: 316.4 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	316.4	0.00
32	316.2	0.09
64	316.1	0.14
96	315.3	0.50
128	312.8	1.67
160	310.7	2.67
192	309.2	3.40
223	308.4	3.79
254	307.8	4.09
285	307.2	4.39
316	306.6	4.69
347	306.2	4.89
378	305.7	5.14
409	305.3	5.34
440	304.9	5.54
471	304.6	5.70
502	304.3	5.85
533	304.0	6.00
564	303.7	6.16
595	303.5	6.26
626	303.2	6.42
657	303.0	6.52
688	302.8	6.62
719	302.6	6.73
750	302.5	6.78
781	302.3	6.88
812	302.2	6.94
843	302.1	6.99
874	302.0	7.04
905	301.9	7.09
936	301.8	7.15
967	301.7	7.20
998	301.6	7.25
1029	301.6	7.25

FINAL WATER CONTENT = 7.30 %
FINAL WEIGHT = 301.5 G

TABLE H21

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/22/88
PROJECT: FLY ASH CURED 4.5 DAYS
TARE WEIGHT: 140.0 G
WET WEIGHT: 370.4 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	370.4	0.00
32	370.3	0.04
64	370.1	0.13
96	368.8	0.70
128	366.0	1.95
160	363.7	2.99
192	362.0	3.78
224	360.8	4.37
255	359.9	4.77
286	359.2	5.11
317	358.6	5.40
348	358.1	5.64
379	357.7	5.83

FINAL WATER CONTENT = 6.07 %
FINAL WEIGHT = 357.2 G

TABLE H22

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/20/88
PROJECT: DIRECT COURSE GYPSUM RICH SOIL
TARE WEIGHT: 97.2 G
WET WEIGHT: 368.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	368.8	0.00
30	368.8	0.00
60	368.5	0.13
90	367.7	0.49
120	366.2	1.16
150	364.6	1.88
180	363.1	2.58
210	361.7	3.23
240	360.4	3.84
270	359.1	4.46
300	358.1	4.95
330	357.2	5.39
361	356.3	5.83
391	355.4	6.27
421	354.5	6.72
451	353.8	7.07
481	353.0	7.48
511	352.2	7.89
541	351.5	8.25
571	350.8	8.61
601	350.2	8.93
631	349.5	9.29
661	348.9	9.61
691	348.3	9.93
721	347.7	10.25
751	347.2	10.52
781	346.7	10.78
811	346.2	11.06
841	345.7	11.33
871	345.3	11.55
901	344.8	11.82
931	344.4	12.04
961	344.1	12.21

FINAL WATER CONTENT = 12.48 %
FINAL WEIGHT = 343.6 G

TABLE H23

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/8/88
PROJECT: DIRECT COURSE GYPSUM RICH SOIL
TARE WEIGHT: 141.8 G
WET WEIGHT: 261.3 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	261.3	0.00
32	261.3	0.00
64	261.2	0.06
96	260.8	0.31
128	259.9	0.86
160	258.8	1.55
192	257.9	2.12
224	257.0	2.69
256	256.1	3.27
287	255.3	3.80
318	254.7	4.19
349	254.1	4.59
380	253.5	4.99
411	253.0	5.33
442	252.4	5.73
473	251.9	6.08
504	251.4	6.42
535	251.0	6.70
566	250.5	7.05
595	250.0	7.39
628	249.6	7.68
659	249.1	8.03
690	248.7	8.32
721	248.3	8.60
752	247.9	8.89
783	247.5	9.18
814	247.1	9.47
845	246.7	9.77
876	246.4	9.99
907	246.1	10.21
938	245.7	10.51
969	245.4	10.73
1000	245.1	10.95
1031	244.8	11.18
1062	244.5	11.40
1093	244.2	11.63
1124	244.0	11.78

FINAL WATER CONTENT = 12.10 %
FINAL WEIGHT = 243.7 G

TABLE H24

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/29/88
PROJECT: CERRILLOS SOIL #1
TARE WEIGHT: 99.3 G
WET WEIGHT: 310.5 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	310.5	0.00
32	310.4	0.05
64	309.8	0.33
96	305.3	2.53
128	299.6	5.44
160	294.4	8.25
192	289.9	10.81
224	285.9	13.18
256	282.8	15.10
287	280.3	16.68
318	278.5	17.86
349	277.0	18.85
380	275.9	19.59
411	275.2	20.07
442	274.6	20.48
473	274.2	20.75
504	273.9	20.96
535	273.6	21.17
566	273.4	21.31

FINAL WATER CONTENT = 21.37 %
FINAL WEIGHT = 273.4 G

TABLE H25

MICROWAVE OVEN
WATER CONTENT DETERMINATION

DATE: 7/28/88
PROJECT: CERRILLOS SOIL #2
TARE WEIGHT: 101.6 G
WET WEIGHT: 345.7 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	345.7	0.00
32	345.6	0.04
64	344.6	0.45
96	349.9	2.01
128	335.0	4.58
160	329.2	7.25
192	323.8	9.85
224	318.9	12.33
256	314.6	14.60
288	310.8	16.68
320	307.6	18.50
351	305.3	19.83
382	303.5	20.90
413	302.1	21.75
444	301.1	22.35
475	300.3	22.85
506	299.7	23.22
6537	299.3	23.47
568	299.0	23.66

FINAL WATER CONTENT = 23.00 %
FINAL WEIGHT = 78.0 G

TABLE H26

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/29/88
PROJECT: CERRILLOS SOIL #3
TARE WEIGHT: 101.6 G
WET WEIGHT: 327.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	327.8	0.00
32	327.8	0.00
64	326.8	0.44
96	322.8	2.26
128	318.0	4.53
160	312.7	7.15
192	308.0	9.59
224	303.9	11.81
256	300.4	13.78
287	297.7	15.35
318	295.6	16.60
349	294.0	17.57
380	292.7	18.37
411	291.8	18.93
442	291.1	19.37
473	290.6	19.68
504	290.2	19.94
535	289.9	20.13

FINAL WATER CONTENT = 20.31 %
FINAL WEIGHT = 289.6 G

TABLE H27

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/28/88
PROJECT: CERRILLOS SOIL #4
TARE WEIGHT: 98.2 G
WET WEIGHT: 293.9 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	293.9	0.00
32	293.9	0.00
64	293.7	0.10
96	290.0	2.03
128	284.4	5.10
160	279.0	8.24
192	274.0	11.32
224	269.6	14.18
256	265.7	16.83
288	262.4	19.18
320	259.7	21.18
351	257.6	22.77
382	256.0	24.02
413	254.8	24.97
444	253.9	25.69
475	253.3	26.18
506	252.9	26.50
537	252.6	26.75
568	252.4	26.91

FINAL WATER CONTENT = 27.07 %
FINAL WEIGHT = 252.2 G

TABLE H28

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/28/88
PROJECT: CERRILLOS SOIL #5
TARE WEIGHT: 99.3 G
WET WEIGHT: 310.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	310.8	0.00
32	310.8	0.00
64	310.4	0.19
96	306.0	2.32
128	300.3	5.22
160	294.9	8.13
192	290.1	10.85
224	285.9	13.34
256	282.3	15.57
288	279.2	17.57
319	276.9	19.09
350	275.1	20.31
381	273.7	21.27
412	272.5	22.11
443	271.7	22.68
474	271.1	23.11
505	270.6	23.47
536	270.3	23.68
576	270.1	23.83

FINAL WATER CONTENT = 23.97 %
FINAL WEIGHT = 269.9 G

TABLE H29

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/28/88
PROJECT: CERRILLOS SOIL #6
TARE WEIGHT: 97.0 G
WET WEIGHT: 309.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	309.8	0.00
32	309.7	0.05
64	308.9	0.42
96	304.6	2.50
128	299.0	5.35
160	293.6	8.24
192	288.6	11.06
224	284.3	13.61
256	280.6	15.90
288	277.6	17.83
319	275.3	19.35
350	273.6	20.50
381	272.3	21.39
412	271.2	22.16
443	270.4	22.72
474	269.8	23.15
505	269.3	23.50
536	269.0	23.72
567	268.7	23.94
598	268.5	24.08

FINAL WATER CONTENT = 24.15 %
FINAL WEIGHT = 268.4 G

TABLE H30

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/29/88
PROJECT: CERRILLOS SOIL #7
TARE WEIGHT: 97.0 G
WET WEIGHT: 310.5 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	310.5	0.00
32	310.5	0.00
64	310.3	0.09
96	305.8	2.25
128	300.4	4.97
160	295.6	7 50
192	291.4	9.82
224	287.9	11.84
256	285.0	13.56
287	283.0	14.78
318	281.4	15.78
349	280.2	16.54
380	279.3	17.11
411	278.5	17.63
442	278.0	17.95
473	277.6	18.22
504	277.3	18.41

FINAL WATER CONTENT = 18.47 %
FINAL WEIGHT = 277.2 G

TABLE H31

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/28/88
PROJECT: CERRILLOS SOIL #8
TARE WEIGHT: 97.3 G
WET WEIGHT: 307.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	307.8	0.00
32	307.7	0.05
64	307.4	0.20
96	302.6	2.53
128	296.9	5.46
160	291.8	8.23
192	287.4	10.74
224	283.7	12.94
256	280.6	14.85
287	278.4	16.24
318	276.6	17.41
349	275.3	18.27
380	274.2	19.00
411	273.4	19.55
442	272.9	19.89
473	272.5	20.16
504	272.3	20.30

FINAL WATER CONTENT = 20.43 %
FINAL WEIGHT = 272.1 G

TABLE H32

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/29/88
PROJECT: CERRILLOS SOIL #9
TARE WEIGHT: 98.3 G
WET WEIGHT: 319.9 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	319.9	0.00
32	319.9	0.00
64	319.8	0.05
96	316.4	1.60
128	310.4	4.48
160	304.5	7.47
192	298.9	10.47
224	293.8	13.35
256	289.2	16.08
288	285.3	18.50
320	282.0	20.63
352	279.3	22.43
383	277.3	23.79
414	275.7	24.92
445	274.6	25.69
476	273.7	26.34
507	273.1	26.77
538	272.6	27.14
569	272.3	27.36
600	272.1	27.50

FINAL WATER CONTENT = 27.57 %
FINAL WEIGHT = 272.0 G

TABLE H33

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/28/88
PROJECT: CERRILLOS SOIL #10
TARE WEIGHT: 93.2 G
WET WEIGHT: 290.1 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	290.1	0.00
32	289.9	0.10
64	289.6	0.25
96	284.4	2.98
128	278.6	6.20
160	273.2	9.39
192	268.5	12.32
224	264.4	15.01
256	260.9	17.41
288	258.0	19.48
320	255.7	21.17
351	254.0	22.45
382	252.7	23.45
413	251.7	24.23
444	250.9	24.86
475	250.3	25.33
506	249.9	25.65
537	249.6	25.90
568	249.4	26.06

FINAL WATER CONTENT = 26.13 %
FINAL WEIGHT = 249.3 G

TABLE H34

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/1/88
PROJECT: CERRILLOS SOIL #2 HYDRATED 5%
TARE WEIGHT: 99.3 G
WET WEIGHT: 284.4 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	284.4	0.00
32	284.3	0.05
64	283.4	0.54
96	278.9	3.06
128	273.9	6.38
160	268.1	9.66
192	263.4	12.80
224	259.2	15.76
256	255.6	18.43
288	252.7	20.66
320	250.2	22.66
351	248.4	24.14
382	247.0	25.32
413	245.9	26.26
444	245.2	26.87
475	244.7	27.30
506	244.2	27.74
537	243.9	28.01
568	243.6	28.27
599	243.4	28.45

FINAL WATER CONTENT = 28.54 %
FINAL WEIGHT = 243.3 G

TABLE H35

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/1/88
PROJECT: CERRILLOS SOIL #7 HYDRATED 5%
TARE WEIGHT: 101.7 G
WET WEIGHT: 309.2 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	309.2	0.00
32	309.2	0.00
64	209.0	0.10
96	304.9	2.12
128	299.2	5.06
160	293.9	7.96
192	289.2	10.67
224	285.0	13.20
256	281.5	15.41
288	278.5	17.36
319	276.3	18.84
350	274.6	20.01
381	273.2	20.99
412	272.1	21.77
443	271.2	22.42
474	270.6	22.85
505	270.1	23.22
536	269.8	23.44
567	269.5	23.66
598	269.4	23.73

FINAL WATER CONTENT = 23.80 %
FINAL WEIGHT = 269.3 G

TABLE H36

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/2/88
PROJECT: CERRILLOS SOIL #2 DEHYDRATED 5%
TARE WEIGHT: 98.3 G
WET WEIGHT: 300.1 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	300.1	0.00
32	3.0	0.05
64	299.1	0.50
96	293.9	3.17
128	288.6	6.04
160	284.0	8.67
192	280.2	10.94
224	277.1	12.86
255	274.8	14.33
286	273.1	15.45
317	271.8	16.31
348	270.8	16.99
379	270.1	17.46
410	269.6	17.81
441	269.2	18.08
472	268.9	18.29
503	268.7	18.43

FINAL WATER CONTENT = 18.56 %
FINAL WEIGHT = 268.5 G

TABLE H37

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/2/88
PROJECT: CERRILLOS SOIL #7 DEHYDRATED 5%
TARE WEIGHT: 101.6 G
WET WEIGHT: 282.6 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	282.6	0.00
32	282.5	0.05
64	281.6	0.56
96	276.7	3.37
128	272.1	6.16
160	268.2	8.64
192	265.2	10.64
223	263.1	12.07
254	261.5	13.19
285	260.3	14.05
316	259.4	14.70
347	258.8	15.14
378	258.3	15.51
409	258.0	15.73
440	257.8	15.88

FINAL WATER CONTENT = 15.95 %
FINAL WEIGHT = 257.7 G

TABLE H38

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/5/88
PROJECT: DAVIS POND BROWN PEAT (LARGER SAMPLE)
TARE WEIGHT: 157.0 G
WET WEIGHT: 354.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	354.8	0.00
30	354.8	0.00
60	354.8	0.00
90	354.6	0.10
120	354.2	0.30
150	353.1	0.87
180	349.7	2.65
210	344.7	5.38
240	339.6	8.32
270	334.4	11.50
300	329.3	14.80
330	324.2	18.30
361	319.2	21.95
391	314.1	25.91
421	309.1	30.05
451	304.1	34.47
481	299.1	39.20
511	294.2	44.17
541	289.2	49.62
571	284.4	55.26
601	279.5	61.47
631	274.7	68.05
661	269.9	75.20
691	265.2	82.81
721	260.4	91.29
751	255.7	100.40
781	251.1	110.20
811	246.5	121.00
841	241.9	132.98
871	237.4	146.02
901	233.0	160.26
931	228.6	176.26
961	224.2	194.35
991	219.9	214.47
1021	215.5	238.12
1052	211.1	265.62
1082	207.1	294.81
1112	203.2	328.14
1142	199.9	361.07

(continued)

TABLE H38 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1172	196.9	395.74
1202	194.3	430.29
1232	191.9	466.76
1262	189.8	503.05
1292	188.1	536.01
1322	186.9	561.54
1352	185.8	586.80
1382	185.0	606.43
1412	184.3	624.54
1442	183.7	640.82
1472	183.1	657.85
1502	182.6	672.66
1532	182.2	684.92
1562	181.9	694.38
1592	181.6	704.06
1622	181.3	713.99
1652	181.0	724.17
1682	180.8	731.09
1712	180.5	741.70
1743	180.3	748.93
1773	180.1	756.28
1803	180.0	760.00

FINAL WATER CONTENT = 771.36 %
FINAL WEIGHT = 179.7 G

TABLE H39

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/5/88
PROJECT: DAVIS POND BROWN PEAT (SMALL SAMPLE SIZE)
TARE WEIGHT: 97.3 G
WET WEIGHT: 175.7 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	175.7	0.00
30	175.6	0.13
60	175.2	0.64
90	173.2	3.29
120	169.1	9.19
150	164.8	16.15
180	160.6	23.85
210	156.4	32.66
240	152.3	42.54
270	148.1	54.33
300	144.0	67.88
330	139.9	84.04
361	135.8	103.64
391	132.1	125.29
421	128.9	149.10
451	126.0	173.17
481	123.2	202.70
511	120.9	232.20
541	118.8	246.65
571	117.2	293.97
601	115.8	323.78
631	114.7	350.57
661	113.8	375.15
691	113.0	399.60
721	112.3	422.67
751	111.8	440.69
781	111.3	460.00
811	110.9	476.47
841	110.5	493.94
871	110.1	512.50
901	109.8	527.20
931	109.5	542.62
961	109.3	553.33
991	109.1	564.41
1022	108.9	575.86
1052	108.7	587.72
1082	108.5	600.00
1112	108.3	612.73
1142	108.2	619.27

(continued)

TABLE H39 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1172	108.0	632.71
1202	107.9	639.62
1232	107.8	646.67
1262	107.7	653.85
1292	107.6	611.16
1322	107.5	668.63
1352	107.4	676.24
1382	107.4	676.24

FINAL WATER CONTENT = 683.99 %
FINAL WEIGHT = 107.3 G

TABLE H40

MICROWAVE OVEN
WATER CONTENT DETERMINATION

DATE: 8/3/88
PROJECT: DAVIS POND BROWN PEAT
TARE WEIGHT: 98.2 G
WET WEIGHT: 233.0 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	233.0	0.00
32	232.9	0.07
64	232.8	0.15
96	231.8	0.90
128	227.5	4.25
160	221.7	9.15
192	215.9	14.53
224	210.2	20.36
256	204.6	26.69
288	199.0	33.73
320	193.8	41.00
352	188.6	49.12
384	183.5	58.03
416	178.6	67.66
448	173.9	78.07
480	169.3	89.59
512	164.9	102.10
544	160.6	116.03
576	156.4	131.62
608	152.1	150.09
640	147.8	171.77
672	143.5	197.57
704	139.5	226.39
736	136.0	256.61
768	132.9	288.47
800	130.2	321.25
832	127.6	358.50
864	125.4	395.59
896	123.6	430.71
928	122.2	461.67
960	121.1	488.65
992	120.3	509.95
1024	119.5	532.86
1056	118.9	551.21
1088	118.4	567.33
1120	117.9	584.26
1152	117.6	594.84
1184	117.1	613.23
1216	116.8	624.73

(continued)

TABLE H40 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1248	116.6	632.61
1279	116.2	648.89
1310	116.0	657.30
1341	115.8	665.09
1372	115.6	674.71
1403	115.4	683.72
1434	115.4	688.30

FINAL WATER CONTENT = 697.63 %
FINAL WEIGHT = 115.1 G

TABLE H41

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 9/26/88
PROJECT: DAVIS POND BROWN PEAT
TARE WEIGHT: 141.7 G
WET WEIGHT: 386.1 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	386.1	0.00
30	386.1	0.00
60	386.0	0.04
90	385.8	0.12
120	385.1	0.41
150	383.9	0.91
180	382.1	1.66
210	378.7	3.12
240	373.6	5.39
270	368.0	8.00
300	362.5	10.69
331	357.0	13.52
361	351.4	16.55
391	345.9	19.69
421	340.5	22.94
451	335.0	26.43
481	329.5	30.14
511	324.1	33.99
541	318.8	38.00
571	313.4	42.34
601	308.0	46.96
631	302.7	51.80
661	297.4	56.97
691	292.2	62.39
721	286.9	68.32
751	281.7	74.57
781	276.6	81.17
811	271.4	88.43
841	266.3	96.15
871	261.2	104.52
901	256.2	113.45
931	251.2	123.20
961	246.2	133.88
991	241.3	145.38
1022	236.4	158.08
1052	231.5	172.16
1082	226.7	187.56
1112	221.9	204.74
1142	216.8	225.43

(continued)

TABLE H41 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1172	212.1	247.16
1202	207.3	272.56
1232	202.8	300.00
1262	198.4	331.04
1292	194.5	362.88
1322	191.1	394.74
1352	188.0	427.86
1382	185.3	460.55
1412	182.9	493.20
1442	180.8	525.06
1472	179.1	553.47
1502	177.7	578.89
1532	176.5	602.30
1562	175.6	620.94
1592	174.8	638.37
1622	174.1	654.32
1652	173.5	668.55
1683	173.0	680.83
1713	172.6	690.94
1743	172.2	701.31
1773	171.9	709.27
1803	171.5	720.13
1833	171.3	725.67
1863	171.1	731.29
1923	170.7	742.76
1953	170.6	745.67

FINAL WATER CONTENT = 754.54 %
FINAL WEIGHT = 170.3 G

TABLE H42

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/25/88
PROJECT: DAVIS POND BLACK PEAT (8%/5%)
TARE WEIGHT: 97.0 G
WET WEIGHT: 215.4 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	215.4	0.00
32	215.3	0.08
64	215.1	0.25
96	213.3	1.80
128	208.1	6.57
160	202.3	12.44
192	196.7	18.76
224	191.1	25.82
256	185.6	33.63
287	180.8	41.29
318	176.3	49.31
349	171.7	58.50
380	167.1	68.90
411	162.5	80.76
442	158.1	93.78
473	154.0	107.72
504	150.3	122.14
535	147.0	136.80
566	143.8	152.99
597	141.1	168.48
628	138.3	186.68
659	135.9	204.37
690	133.6	223.50
721	131.6	242.20
752	130.0	258.79
783	128.6	274.68
814	127.4	289.47
845	126.4	302.72
876	125.5	315.44
907	124.7	327.44
938	124.1	336.90
969	123.5	346.79
1000	122.9	357.14
1031	122.5	364.31
1062	122.1	371.71
1093	121.7	379.35
1124	121.4	385.24
1155	121.1	391.29
1186	120.8	397.48

(continued)

TABLE H42 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1217	120.5	403.83
1248	120.4	405.98

FINAL WATER CONTENT = 412.55 %
FINAL WEIGHT = 120.1 G

TABLE H43

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/20/88
PROJECT: DAVIS POND BLACK PEAT (8%/5%)
TARE WEIGHT: 140.1 G
WET WEIGHT: 297.9 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	297.9	0.00
32	297.9	0.00
64	297.8	0.06
96	297.2	0.44
128	294.8	2.00
160	289.3	5.76
192	283.5	10.04
224	277.8	14.60
256	272.1	19.55
288	266.5	24.84
319	261.6	29.88
350	256.8	35.22
381	252.1	40.89
412	247.4	47.06
443	242.8	53.65
474	238.2	60.86
505	233.6	68.77
536	228.9	77.70
567	224.3	87.41
598	219.6	98.49
629	214.8	111.24
660	210.1	125.43
691	205.6	140.92
722	201.3	157.84
753	197.3	175.87
784	193.6	194.95
815	190.2	214.97
846	187.2	235.03
877	184.3	257.01
908	181.9	277.51
939	179.9	296.48
970	178.3	313.09
1001	176.9	328.80
1032	175.8	342.02
1063	174.8	354.76
1094	173.9	366.86
1125	173.2	376.74
1156	172.6	385.54
1187	172.0	394.67

(continued)

TABLE H43 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1218	171.6	400.95
1249	171.1	409.03
1280	170.8	414.01

FINAL WATER CONTENT = 422.51 %
FINAL WEIGHT = 170.3 G

TABLE H44

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 7/19/88
PROJECT: DAVIS POND BLACK PEAT (8%/5%)
TARE WEIGHT: 97.4 G
WET WEIGHT: 197.1 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	197.1	0.00
32	197.0	0.10
64	169.7	0.40
96	195.3	1.84
128	191.6	5.84
160	186.8	11.52
192	181.8	18.13
224	177.0	25.25
256	172.3	33.11
287	168.1	41.02
318	164.2	49.25
349	160.3	58.51
380	156.4	68.98
411	152.7	80.29
442	149.0	93.22
473	145.4	107.71
504	141.9	124.04
535	138.5	142.58
566	135.3	163.06
597	132.3	185.67
628	129.7	208.67
659	127.7	229.04
690	125.9	249.82
721	124.5	267.90
752	123.4	283.46
783	122.4	298.80
814	121.6	311.98
845	120.8	326.07
876	120.2	337.28
907	119.6	349.10
938	119.1	359.45
969	118.6	370.28
1000	118.2	379.33
1031	117.8	388.73
1062	117.5	396.02
1093	117.1	406.09
1124	116.9	411.28

FINAL WATER CONTENT = 419.27 %
FINAL WEIGHT = 116.6 G

TABLE H45

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 8/5/88
PROJECT: HAWAIIAN VOLCANIC ASH
TARE WEIGHT: 149.2 G
WET WEIGHT: 342.6 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	342.6	0.00
90	342.3	0.16
180	336.6	3.20
270	326.4	9.14
360	316.4	15.67
450	305.5	23.74
540	296.3	31.48
630	287.5	37.85
720	283.0	44.54
810	277.1	51.21
900	271.0	58.78
990	264.8	67.30
1080	258.5	76.94
1170	252.5	87.22
1260	246.7	98.36
1350	241.3	109.99
1440	236.9	120.52
1530	233.4	129.69
1620	230.6	137.59
1710	228.3	144.50
1800	226.4	150.52
1890	224.7	156.16
1980	223.2	161.35
2070	221.7	166.76
2161	220.4	171.63
2251	219.2	176.29
2341	217.9	181.51
2431	216.8	186.09
2521	215.6	191.26
2611	214.5	196.17
2701	213.5	200.78
2791	212.4	206.01
2881	211.4	210.93
2971	210.3	216.53
3061	209.4	221.26
3151	208.4	226.69
3241	207.4	232.30
3331	206.5	237.52
3421	205.5	243.52

(continued)

TABLE H45 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
3511	204.7	248.47
3601	203.8	254.21
3691	203.1	258.81
3781	202.4	263.53
3871	201.8	267.68
3961	201.3	271.21
4051	200.7	275.53
4141	200.3	278.47
4231	199.9	281.46
4321	199.5	284.49
4411	199.2	286.80
4501	198.9	289.13
4591	198.7	290.71
4681	198.4	293.09
4771	198.3	293.89
4861	198.1	295.50
4951	198.0	296.31
5041	197.8	297.94
5131	197.8	297.94

FINAL WATER CONTENT = 298.76 %
FINAL WEIGHT = 197.7 G

TABLE H46

MICROWAVE OVEN
WATER CONTENT DETERMINATION

DATE: 7/8/88
PROJECT: HAWAIIAN VOLCANIC ASH
TARE WEIGHT: 93.1 G
WET WEIGHT: 213.6 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	213.6	0.00
102	213.5	0.08
204	212.6	0.84
306	208.5	4.42
408	203.5	9.15
510	199.1	13.68
612	194.6	18.72
714	189.3	25.26
816	184.4	31.98
918	180.1	38.51
1020	176.1	45.18
1122	172.8	51.57
1124	169.7	57.31
1326	167.2	62.62
1428	164.9	67.83
1530	162.8	72.88
1632	161.0	77.47
1734	159.4	81.75
1836	157.9	65.96
1938	156.6	89.76
2040	155.3	93.73
2142	154.1	97.54
2244	153.0	101.17
2346	152.0	104.58
2448	151.0	108.12
2550	150.1	111.40
2652	149.3	114.41
2754	148.4	117.90
2856	147.7	120.69
2958	146.9	123.98
3060	146.1	127.36
3162	145.4	130.40
3264	144.7	133.53
3366	144.1	136.27
3468	143.4	139.56
3570	142.8	142.45
3672	142.1	145.92
3774	141.5	148.97
3876	140.8	152.62

(continued)

TABLE H46 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
3978	140.2	155.84
4080	139.5	159.70
4182	138.9	163.10
4284	138.6	166.59
4386	137.6	170.79
4488	137.0	174.49
4590	136.4	178.29
4692	135.8	182.20
4794	135.2	186.22
4896	134.6	190.36
4998	134.1	193.90
5100	133.5	198.27
5202	133.1	201.25
5304	132.6	205.06
5406	132.1	208.97
5508	131.7	212.18
5610	131.3	215.45
5712	130.8	219.63
5814	130.4	323.06
5916	130.1	325.67
6018	129.7	229.23
6120	129.4	231.96
6222	129.0	235.65
6324	128.7	238.48
6426	128.5	240.40
6527	128.1	244.29
6628	127.8	247.26
6729	127.6	249.27
6830	127.4	251.31
6931	127.1	254.41
7032	126.9	256.51
7133	126.7	258.63
7234	126.5	260.78
7335	126.4	261.86
7436	126.2	254.05
7537	126.1	265.15
7638	125.9	267.38
7739	125.8	268.50
7840	125.7	269.63
7941	125.6	270.77
8042	125.5	271.91
8143	125.4	273.07
8244	125.4	273.07

FINAL WATER CONTENT = 274.22 %
FINAL WEIGHT = 125.3 G

TABLE H47

MICROWAVE OVEN
WATER CONTENT DETERMINATION

DATE: 7/22/88
PROJECT: HAWAIIAN VOLCANIC ASH
TARE WEIGHT: 129.2 G
WET WEIGHT: 309.9 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	309.9	0.00
102	309.8	0.05
204	309.3	0.33
306	302.1	4.51
408	294.4	9.38
510	287.8	13.93
612	281.4	18.73
714	275.7	23.34
816	270.5	27.88
918	265.9	32.19
1020	261.5	36.58
1122	257.5	40.84
1224	253.8	45.02
1326	250.2	49.34
1428	246.7	53.79
1530	243.0	58.79
1632	239.1	64.42
1734	234.7	71.28
1836	230.0	79.26
1938	225.4	87.84
2040	221.0	96.84
2142	217.2	105.34
2244	213.9	113.34
2346	211.2	120.36
2448	209.0	126.44
2550	207.2	131.67
2652	205.6	136.52
2754	204.3	140.61
2856	203.0	144.85
2958	201.8	148.90
3060	200.8	152.37
3162	199.7	156.31
3264	198.7	160.00
3366	197.8	163.41
3468	196.9	166.91
3570	196.0	170.51
3672	195.2	173.79
3774	194.4	177.15
3876	193.5	181.03

(continued)

TABLE H47 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
3978	192.7	184.57
4080	191.9	188.20
4182	191.1	191.92
4284	190.3	195.74
4386	189.5	199.67
4488	188.8	203.19
4590	188.0	207.31
4692	187.2	211.55
4794	186.5	215.36
4896	185.8	219.26
4998	185.0	223.84
5100	184.4	227.35
5202	183.6	232.17
5304	183.0	235.87
5406	182.3	240.30
5508	181.7	244.19
5610	181.1	248.17
5712	180.5	252.24
5814	180.0	255.71
5916	179.5	259.24
6018	179.1	262.12
6120	178.7	265.05
6222	178.3	268.02
6324	177.9	271.05
6426	177.6	273.35
6528	177.3	275.67
6630	177.0	278.03
6732	176.8	279.62
6833	176.5	282.03
6934	176.3	283.65
7035	176.1	285.29
7136	175.9	286.94
7237	175.8	287.77
7338	175.6	289.44
7439	175.5	290.28
7540	175.4	291.13
7641	175.4	291.13

FINAL WATER CONTENT = 291.97 %
FINAL WEIGHT = 175.3 G

TABLE H48

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/21/88
PROJECT: HAWAIIAN VOLCANIC ASH
TARE WEIGHT: 97.4 G
WET WEIGHT: 207.8 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	207.8	0.00
32	207.7	0.09
64	207.7	0.09
128	206.6	1.10
159	204.1	3.47
190	202.0	5.54
221	200.1	7.50
252	198.2	9.52
283	196.2	11.74
314	194.2	14.05
345	192.0	16.70
376	189.7	19.61
407	187.5	22.53
438	185.4	25.45
469	183.3	28.52
500	181.5	31.27
531	179.9	33.82
562	178.4	36.30
593	176.9	38.87
624	175.5	41.36
655	174.1	43.94
686	172.8	46.42
717	171.7	48.59
748	170.6	50.82
779	169.5	53.12
810	168.6	55.06
841	167.6	57.26
872	166.8	59.08
903	165.9	61.17
934	165.3	62.83
965	164.4	64.78
996	163.7	66.51
1027	163.0	68.29
1058	162.3	70.11
1089	161.6	71.96
1120	161.0	71.96
1151	160.3	75.52
1213	159.1	78.93
1244	158.5	80.69

(continued)

TABLE H48 (continued)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1275	158.0	82.18
1306	157.5	83.69
1337	156.9	85.55
1368	156.4	87.12
1339	155.9	88.72
1430	155.4	90.34
1461	154.9	92.15
1492	154.4	93.68
1523	154.0	95.05
1554	153.3	96.79
1585	153.0	98.56
1616	152.6	100.00
1678	151.7	103.31
1709	151.3	104.82
1740	150.9	106.36
1771	150.1	109.49
1833	149.7	111.09
1864	149.4	112.31
1895	149.0	113.95
1926	148.6	115.62
1957	148.3	116.89
1988	147.9	118.61
2019	147.6	119.92
2050	147.2	121.69
2081	146.9	123.03
2112	146.6	124.39
2143	146.2	126.23
2174	145.9	127.63
2205	145.6	129.05
2236	145.3	130.48
2267	145.0	131.93
2298	144.6	133.90
2329	144.3	135.39
2360	144.0	136.91
2391	143.7	138.44
2422	143.4	140.00
2453	143.1	141.57
2484	142.8	143.17
2515	142.5	144.79
2546	142.2	146.43
2577	141.9	148.09
2606	141.6	149.77
2639	141.3	151.48
2670	141.0	153.21
2701	140.7	154.96
2732	140.4	156.77

(continued)

TABLE H48 (continued)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
2763	140.1	158.55
2794	139.8	160.38
2825	139.5	162.23
2856	139.3	163.48
2887	139.0	165.38
2918	138.7	167.31
2949	138.4	169.27
2980	138.1	171.25
3011	137.9	172.59
3042	137.6	174.63
3073	137.4	176.00
3104	137.1	178.09
3135	136.9	179.49
3166	136.6	181.63
3197	136.4	183.08
3228	136.1	185.27
3259	135.9	186.75
3290	135.7	188.25
3321	135.4	190.53
3352	135.2	192.06
3383	135.0	193.62
3414	134.8	195.19
3445	134.6	196.77
3476	134.4	198.38
3507	134.2	200.00
3538	134.0	201.64
3569	133.8	203.30
3600	133.6	204.97
3631	133.4	206.67
3662	133.2	208.38
3693	133.0	210.11
3724	132.9	210.99
3755	132.7	212.75
3786	132.5	214.53
3817	132.3	216.33
3848	132.2	217.24
3879	132.0	219.07
3910	131.8	220.93
3941	131.7	221.87
3972	131.5	223.75
4003	131.4	224.71
4034	131.2	226.62
4065	131.1	227.60
4096	130.9	229.55
4127	130.8	230.54
4158	130.7	231.53

(continued)

TABLE H48 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
4189	130.5	233.53
4220	130.4	234.54
4251	130.3	235.56
4282	130.1	237.61
4313	130.0	238.65
4344	129.9	239.69
4375	129.8	240.74
4406	129.6	242.86
4437	129.5	243.93
4468	129.4	245.00
4498	129.8	246.08
4530	129.2	247.17
4561	129.0	249.37
4592	129.0	249.37

FINAL WATER CONTENT = 251.59 %
FINAL WEIGHT = 128.8 G

TABLE H49

MICROWAVE OVEN
WATER CONTENT DETERMINATION
DATE: 6/17/88
PROJECT: HAWAIIAN VOLCANIC ASH
TARE WEIGHT: 59.1 G
WET WEIGHT: 150.0 G

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
0	150.0	0.00
32	149.9	0.11
64	149.8	0.22
96	149.3	0.78
128	146.8	3.65
160	143.3	7.96
192	140.4	11.81
224	137.9	15.35
256	135.5	18.98
288	133.1	22.84
320	131.0	26.42
352	129.1	29.86
384	127.5	32.89
416	126.2	35.47
448	125.0	37.94
480	123.8	40.49
512	122.7	42.92
544	121.7	45.21
576	120.6	47.80
608	119.6	50.25
640	118.8	52.26
671	118.0	54.33
702	117.3	56.19
733	116.7	57.81
764	116.1	59.47
795	115.5	61.17
826	114.9	62.90
857	114.4	64.38
888	113.8	66.18
919	113.4	67.40
950	112.9	68.96
981	112.4	70.54
1012	111.9	72.16
1043	111.4	73.80
1074	111.0	75.14
1105	110.6	76.50
1136	110.1	78.24
1167	109.7	79.64
1198	109.3	81.07

(continued)

TABLE H49 (continued)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
1229	108.8	82.90
1260	108.4	84.38
1291	108.0	85.89
1322	107.6	87.42
1353	107.1	89.38
1384	106.7	90.97
1415	106.3	92.58
1446	105.8	94.65
1477	105.4	96.33
1508	105.0	98.04
1539	104.5	100.22
1570	104.1	102.00
1601	103.7	103.81
1632	103.2	106.12
1663	102.8	108.01
1694	102.4	109.93
1725	101.9	112.38
1756	101.5	114.39
1787	101.1	116.43
1818	100.7	118.51
1849	100.3	120.63
1880	99.9	122.79
1911	99.6	124.44
1942	99.2	126.68
1973	98.9	128.39
2004	98.5	130.71
2035	98.3	131.89
2066	97.9	134.28
2097	97.7	135.49
2128	97.3	137.96
2159	97.1	139.21
2190	96.8	121.11
2221	96.5	143.05
2252	96.2	145.01
2283	96.0	146.34
2314	95.7	148.36
2345	95.5	149.73
2376	95.2	151.80
2404	95.0	153.20
2438	94.7	155.34
2469	94.5	156.78
2500	94.3	158.24
2531	95.1	159.71
2562	93.8	161.96
2593	93.6	163.48
2624	93.4	165.01

(continued)

TABLE H49 (continued)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
2655	93.2	166.58
2686	93.0	169.14
2717	92.8	169.73
2748	92.6	171.34
2779	92.4	172.97
2810	92.3	173.79
2841	92.1	175.45
2872	91.9	177.13
2903	91.7	178.83
2934	91.5	180.55
2965	91.4	181.42
2996	91.2	183.18
3027	91.0	184.95
3058	90.9	185.85
3089	90.7	187.66
3120	90.6	188.57
3151	90.4	190.41
3182	90.3	191.35
3213	90.1	193.23
3244	90.0	194.17
3275	89.8	196.09
3306	89.7	197.06
3337	89.5	199.01
3368	89.4	200.00
3399	89.3	200.99
3430	89.1	203.00
3461	89.0	204.01
3492	88.9	205.03
3523	88.7	207.09
3554	88.6	208.13
3585	88.5	209.18
3616	88.1	211.30
3647	88.2	212.37
3678	88.1	213.45
3709	88.0	214.53
3740	87.9	215.62
3771	87.7	217.83
3802	87.6	218.95
3833	87.5	220.07
3864	87.3	222.34
3895	87.2	223.49
3926	87.1	224.64
3957	87.0	225.81
3988	86.9	226.98
4019	86.8	228.16
4050	86.7	229.35

(continued)

TABLE H49 (concluded)

DRYING TIME (SEC)	WEIGHT (G)	WATER CONTENT (%)
4081	86.6	230.54
4112	86.2	231.75
4143	86.4	232.97
4174	86.3	234.19
4205	86.2	235.42
4236	86.1	236.67
4267	86.0	237.92
4298	85.9	239.18
4329	85.8	240.45
4360	85.7	241.73
4391	85.6	243.02
4422	85.6	243.02

FINAL WATER CONTENT = 245.62 %
FINAL WEIGHT = 85.4 G