SMOKE INVESTIGATIONS

by

George Reid Calhoun

A THESIS SUBMITTED FOR THE DEGREE OF

BACHELOR OF SCIENCE

CHEMICAL ENGINEERING COURSE

The University of Tennessee

1930

TABLE OF CONTENTS

I. Introduction

A. Method of obtaining field data on smoke survey in the city of Knoxville.

B. Reasons for smoke abatement, with special reference to relation of polluted atmosphere to health.

II. General survey

A. Progression of the smoke nuisance with advancement of industry.

B. Relation to health.

III. Purpose of this investigation

IV. Method of studying relation between atmospheric conditions and health.

V. Conclusions

VI. Appendix

Table I

Soot-fall determination

Table II

Cities to which inquires were sent.

Table III

Cities from which replies were received.

Table IV

Data obtained from various cities.

I. INTRODUCTION

In order to further the investigations of Mr. Martin Quinn, Mr. A. H. Cooper, and Mr. R. C. Burton a continuation of the smoke determinations in the sity of Knoxville was made. This determination was carried out according to the directions recommended by the Mellon Institute of Industrial Research. These directions are headed "Directions for Soot-Fall Study", and are as follows:

Locations of Stations:

"Take a map of your city and select ten or twelve centers, having in mind that you wish to obtain soot-fall samples which, when pooled, will represent average atmospheric conditions. You must not hesitate to select a center in what you know to be the smokiest or, on the other hand, a center which you know to be practically free from smoke. The best plan is to forget what you know of smoke conditions and to consider your city simply as a geographical area.

"When you have the general centers in mind, then select ten or twelve buildings -- school houses, settlement houses, engine houses, or private buildings -- on roofs of which you feel certain that you will be permitted to place soot-fall jars. Do not place a jar on the roof of a building which is between two higher buildings nor near chimneys. Jars should be placed on roofs of buildings which are at least two stories high. Attempt to avoid buildings with gravel roofs.

Jars:

"The jars which are to be used are known as battery jars.

Collection of Jars:

Jars should be placed on buildings on the first of each month. - - - - - - - - - If it takes two days to distribute the jars, make a

note of the fact and at the end of the month collect the jars first which were placed out on the first day. At the end of the month the collector of the jars must carry clean ones with him to put in place of the ones which he collects."

After these jars had been carefully collected they were taken to the chemistry laboratory of the University of Tennessee.

Each sample was carefully filtered through a previously weighed gooch crucible. After carefully washing all of the soot and foreign matter from the har the Gooch crucible, containing the sample, was left in an oven at about 90°C for twelve hours. The Gooch containing the sample was cooled and weighed. The difference in this weight and the weight of the crucible gave the weight of the sample. After weighing, the sample was burnt over a blast lamp for two hours, cooled and weighed again. The difference in the weight of the sample after burning and before burning is the amount of combustible matter in the sample.

The area of each jar is calculated after determining its diameter, and the grams per square inch per month are determined. This is converted into tons of soot per square mile per year. This result is multiplied by the percent of combustible matter, and the tons of combustible matter per square mile per year are obtained.

The results obtained by Mr. R. C. Burton for January, 1930 are given in Table I in the appendix. The February results were not obtained cue to the failure of the city of Knoxville to furnish battery jars for that month. The results for March and April were obtained as a part of this thesis. The results are recorded in Table I. All

measurements were made in the manner approved by the Mellon Institute.

Part B of this investigation deals primarily with the relation of atmospheric conditions to health although other harmful effects of polluted air are considered. Many of these effects are apparent to the engineers, but not to the general public.

Smoke abatement is in all probability the outcome of education. Engineers see the need of some method of overcoming the smoke nuisance, but they can do nothing without the stamp of approval by the general public. If, by showing that smoke is a serious detriment to health, public opinion can be swayed against the output of smoke, and the nuisance will be stopped. Physicians, engineers, law-makers, could do nothing against the pollution of drinking water until they convinced the public that it was the cause of many deaths. Then it was that the pollution was stopped. It is hoped that pollution of the atmosphere will some day die a similar death.

If definite proof can be obtained that there is a relation between the soot-fall and the eye, ear, nose, and throat troubles, the public will begin to think. When this occurs, the smoke nuisance will be short lived. The obstacle is not insourmountable, and it will be overcome when the public demands it and not before.

II. GENERAL SURVEY

A. Progression of the smoke nuisance with the advancements of industry.

Smoke has not been a nuisance until recently. Not many years ago there were not so many factories. Trains were so few that the smoke made by them was insignificant. Power was obtained by water or by manual labor. Cities were not large enough to cause enough smoke from heating purposes to harm anything.

Shortly after steam power began becoming popular little was known of combustion methods. Poor combustion resulted, and this produced excess smoke. There were so few steam power plants at first that the soot produced by them was of little consequence, as the number of plants increased, the knowledge of combustion increase, but they were not in proportion. The smoke turned loose increased in amount until it became a detriment to cleanliness, while, at the same time, it was costing the power consumers in fuel. The large power consumers who generate their own power quickly recognize this waste in fuel and began practicing proper methods of firing and using boilers that would give the maximum efficiency with the minimum of fuel. This naturally gave better combustion with less smoke. Even with this reduction in air pollution by the large factories, the amount of soot-fall increased, because of the large number of inefficient heating plants.

Before any great reduction in the amount of soot-fall can be obtained the smaller heating units must be more efficient, the general public must be educated in firing methods, and a better fuel must be

used in the soft coal districts. Each of these may be done with sufficient study and the proper men interested to handle it. Neither the study nor the men will be forthcoming until the public demands it. The public will not demand it until they are forced to by the facts showing that their health is being impaired by the pollution.

At present a large majority of the larger cities have some smoke abatement ordinance, and many of them have smoke abatement departments. These departments function under many difficulties and are, in general, not considered seriously. They do a wonderful amount of good, but their field of authority is limited, thus cutting down their usefulness. They know their shortcomings, and are trying to overcome them. Their development is destined to be gradual, and their service to the public is and always will be, proportional to the cooperation given them by the public. The only way for them to get and keep the cooperation of the public is by education along the line of soot control. Education consists of facts, and until these facts are obtained and published in a logical, intelligent form the general public will not be interested.

B. Relation to health.

Everyone knows what soot does for cleanliness, although the actual cost that could be attributed to filth caused by soot-fall is not definitely known. Accurate figures along this line would probably appal everyone. Similarly, the toll on health by soot-polluted atmosphere is rarely ever thought of. If there is a relation between the amount of soot in the atmosphere it should be known. If soot could be blamed for a share of the medical cost in a community

it should be known. If this cost could be determined, the community would profit by the determination by setting as its goal a means of reducing the cost thus reducing the amount of soot turned loose in the atmosphere.

The best method of determining this cost would be to find the relation existing between the soot-fall and the number of physicians dealing primarily with diseases that could be caused by soot-polluted atmosphere. This relation would be between the number of persons per physician to the number of tons of soot per square mile per year.

III PURPOSE OF INVESTIGATION

The purpose of this investigation was to continue the soot-fall measurements for Knoxville thru the third quarter of the academic year at the University of Tennessee, and also to determine the relation, if any existed, between the soot-fall and the number of persons per physicians in the community. A high soot-fall and a low number of persons per physician, and a low soot-fall with a high number of persons per physician would tend to indicate some relation between polluted atmosphere and sickness. On the other hand, a high number of persons per physician and a low soot-fall would indicate a lack of relation between soot-fall and sickness. A large number of persons per physician, indicates a healthy community, while a small number of persons per physician indicates poor health. The establishment of a relation between poor health and soot-fall will forcefully bring the curse of poor combustion before the eyes of the public. This will bring about a reaction whereby pollution of the atmosphere will cease. The cessation of this pollution is the purpose for which this investigation is being carried on, and it should be the aim of all movements along this line.

IV. METHOD OF STUDYING RELATION BETWEEN ATMOSPHERIC CONDITIONS AND HEALTH.

The method of determining a relationship between soot-fall and sickness offers a perplexing problem. Who knows anything about it? Where will any relation between the two show itself? Just how will this determination be made? These and many more perplexing problems had to be confronted.

The number of physicians dealing with diseases that could be attributed to soot-polluted atmosphere were limited who specialized in eye, ear, nose, and throat troubles. This limitation may or may not be sufficient, but it is the only method of separating the mass of physicians from those who deal especially with cases that might be caused by soot-fall. Obviously this excludes the many cases of eye, ear, nose, and throat troubles, that are treated by general practitioners and other doctors that do not come in any of the classes mentioned above. This is a problem that will lie considered as a constant error, and no method for correcting will be used. Any correction used will be a guess, and it will be better to use incorrect figures that are known to be incorrect than to use figures that are supposed to be correct but that are in reality only guesses.

The air pollution was expressed by the average tons of soot-fall per square mile per year. This determination is not available at present in many cities, The method of proceedure used in Knoxville and some other cities is given in the introduction.

In addition to soot much animal and vegetable matter is blown or falls into the containers, and can not be separated. This goes on record as combustible matter and enters in as an error in the amount of actual soot in the air.

It can readily be seen that where then is much wind there will be more dust and grit blown into the containers than when there is only a small amount of wind. (By amount of wind is meant velocity of wind in miles per hour.) Likewise the animal and vegetable matter will be more prevalent in the containers in windy seasons than in calm ones.

Rainfall naturally curtails the grit and dust pollution in the atmosphere, and it probably precipitates some of the soot in the atmosphere. This would tend to decrease the amount of soot-fall except close to the point where the soot was set free. On the other hand it may increase the amount of soot-fall by precipitating some particles of soot that are being held in suspension by the atmosphere and would not precipitate or fall into the container except by the aid of some other precipitation.

Conditions most suitable For the most accurate determination of the actual amount of soot-fall would be a gentle rain with a slight wind blowing. The wind would blow the pollution about, thus distributing it, while the rainfall would precipitate it.

If expense were not to be considered a more accurate method of determining the soot-fall or the pollution of the atmosphere would be in pounds per cubic yard. This could be done by connecting a suitable air filter with a meter to determine the amount of atmosphere passed through the filter. In this case correction could be made for the water lost in passing the filter by determining the humidity before and after filtering. The cost of such an apparatus would be

prohibitive, and the benefit obtained from its use would not warrant the expenditure for its purchase.

To obtain the above information, questionaries were sent to one hundred and seventy five cities -- at least two in every state. The method of picking the cities to send the questionaries to was to send one to each city of fifty-thousand or more inhabitants, according to the 1920 census. Some few states had no cities of over fifty thousand population, while other had only one city that large. Where such conditions were found the largest or best known cities were chosen until at least wo cities in each state were sent questionaries. If data could be received from those cities to which requests were sent a very good distribution for the whole United States would be obtained.

These questionaries were sent to the secretaries of the Chambers of Commerce in the respective cities. Much interest was created by the questionaires, but very few cities had more than part of the information needed for a thorough study of the situation. The Chambers of Commerce were very courteous and were very liberal with all the information they could find, and their cooperation was an invaluable aid in the study of the question at hand.

V. CONCLUSIONS

In all there were one hundred and seventy questionaires sent out to different cities throught the United States. From there a return of eighty replies have been received. Of these eighty replies forty-one gave part of the information asked for. The others did not have the data available. Each of the forty one replies in which there was some information gave the population and the number of specialists in the city. There were twenty one of this group who gave any information at all concerning the soot-fall. Many of them stated that there had never been any soot-fall survey in their city.

There were only six cities in the entire group from which any definite soot-fall statistics were obtained. These were: Chicago, Boise, Idaho, Terre Haute, Indiana, Asheville, North Carolina, Knoxville, and Nashville, Tennessee. These cities could be grouped into two general districts with respect to location and climatic conditions. Chicago, Terre Haute, and Boise are not very close together, but their climates are somewhat similar, and, with respect to the whole United States, they are grouped close together. Nashville, Knoxville, and Asheville are very similar in location and climate.

The soot-fall data received from Chicago was given in per cent of Sulfuric acid in the air and could not be satisfactorily used for ous purpose.

Boise, Idaho, had a comparatively high tonnage of pure carbon

-- being 324 tons per square mile per year. Their population per specialist was extremely low being only four thousand. This would indicate a relation between the soot-fall and the number of persons per specialist.

Terre Haute had 462 tons of pure carbon in 770 tons of soot-fall per square mile per year. There were 10,430 persons per specialist in Terre Haute. With a higher number of specialist and a higher soot-fall than Boise the relation of soot-fall to eye, ear, nose, and throat specialists does not hold.

In Asheville the annual average soot-fall is low, but the number of persons per specialist is also low. The soot-fall is only 240 tons per square mile per year. There are twenty seven specialists in Asheville which has only thirty-five thousand inhabitants. The low population per specialist may be explained by the fact that Asheville is a noted resort, and many people go there for special treatments.

Nashville has four times as much soot-fall as Asheville, but they have almost seven times as many persons per specialist as Asheville has.

Knoxville has less soot-fall than Nashville and a greater amount than Asheville, while they have fewer persons per specialist than Nashville and more than Asheville.

East Saint Louis, Illinois, and Roanoke, Virginia, report a very heavy soot-fall, but they did not have any figures available. East Saint Louis has 9,000 persons per specialist, and Roanoke has 6.090 persons. Erie, Pennsylvania and Little Rock, Arkansas both report light soot-fall, but they have only 5,400 and 6,370 persons

per specialist respectively. El Paso, Dallas, and San Antonio, Texas each reports the use of natural gas and electric power with a very light soot-fall. The persons per specialist for these three cities are 8,500, 13,440, and 7,950 respectively.

From the above, and from a close examination of Table III of the appendix, the only conclusion that one can reach is that there is no definite relation between the amount of soot-fall and the number of eye, ear, nose, and throat specialists in a community. There are too many other considerations to be taken into account to make it possible to correlate the two.

VI. APPENDIX

TABLE I

March 1930.

Station	Tons per sq. mi. per year.	% Combustible Matter	Tons combustible Matter
1	617	44.	274.
2	950	40.5	385
3	339	28.7	97.3
4	102.4	6.35	6.5
5	268.5	46.4	124.5
6	437.	37.8	165.1
7	1060.	57.1	605
8	765	32.2	24.6
9	272	48	130.5
10	317.5	37.4	132.2
11	687.4	47.6	327
12	879*	26.1	226.8
13	424.9	46.8	207.5
14	389	36.5	142
15	790	15.9	125
16	177.5	39.8	69.6
17	249	46.1	114.9
18	227.7	50.8	115.3
19	183.5	42.9	78.7
2o	622.5	42.1	262
21	780	40.8	318.5
22	333	45.9	153
22	226	34.9	78.4
24	976*	20.3	198.5

* Much grit in sample.

TABLE II.

(continued)

April 1930

Station	Tons per sq. mi. Per year.	% Combustible Matter	Tons combustible Matter
1			
2			
3	209	231	50.5
4			
5	91.4	61.2	60.4
6	767	38.1	293
7	172.5	15.7	27
8	393	27.7	109
9	183	37.8	69.2
10			
11			
12	1740	18,95	329.4
13	520	34.9	183195.1
14	860	12.1	68.8
15	215.3	31.9	50.1
16	167.5	30.	72.1
17	181.2	38.	64.0
18	182.5	35.1	49.7
19	187.5	27.5	113
20	391	28.8	139
21	231	60.2	
22			39.2
23	154.4	25.3	96.5
24	320	30.1	

TABLE I (continued)

January 1930.

Station	Tons per sq. mi. Per year.	% Combustible Matter.	Tons combustible Matter.
1	274	50.1	137.5
2	290.4	45.7	133
3	200*	40	80
4	130*	45	58.5
5	159	48	76.4
6	1282	45.1	579
7	764	50.5	378
8	250*	40	100
9	160	45.3	90.1
10	203	47.8	97
11	279	56.4	157.3
12	500*	35	175
13	319.5	56.5	180
14	400*	40	160
15	250*	45	112.5
16	210*	45	94.5
17	225	45	101.2
18	250*	45	112.5
19	275*	40	110
20	200*	45	90
21	104.8	36.1	37.8
22	225*	40	90
23	190*	40	76
24	650*	45	292.5

* Estimate. Note: This month taken from R. C. Burton.

TABLE I (continued).

Note: Index to stations in Table I.

1. Maple Hurst Park (Kappa Sigma House)
2. Gulf Refining Co.
3. Flenniken School (Maryville Pike)
4. Lindbergh Forrest. (Woodlawn Pike)
5 Island Home Pike (Texaco Refining Co.)
6. Riverside Lumber Co.
7. Atkin Hotel
8. U. of T. Farm
9. 2025 Ogden Ave.
10. Melrose Place (Dr. Hill's).
11. Seventeenth and Laurel (Apts.)
12. Mississippi and Western
13. Appalachain Marble Co. (Middlebrook Pike)
14. Baxter and Wray
15. Knoxville Appartments (Magnolia Ave.)
16. 2800 Magnolia Ave.
17. Knoxville High School
18. Moses School (Deadrick and Carrick).
19. Beaumont School
20. Oakwood School
21. Pershing and Chickamauga
22. Bell Morris School
23. Brownlow School
24. Colored High School (Standpipe Hill).

TABLE II.

Cities over 50,000 (U. S. Census 1920)

New York
- Albany
- Binghampton
- Buffalo
- New York
- Rochester
- Schenectady
- Syracuse
- Troy
- Utica
- Yonkers

Pennsylvania
- Allentown
- Altoona
- Bethlehem
- Chester
- Erie
- Harrisburgh
- Johnstown
- Lancaster
- Philadelphia
- Pittsburgh
- Reading
- Scranton
- Wilkes-Barre

Illinois
- Chicago
- East St. Louis
- Peoria
- Rockford
- Springfield

Ohio
- Canton
- Cincinnati
- Cleveland
- Columbus
- Dayton
- Springfield
- Toledo
- Youngstown

Texas
- Dallas
- El Paso
- Fort Worth
- Houston
- San Antonio

Missouri
- Kansas City
- St. Joseph
- St. Louis

TABLE II (continued)

Massachusetts

- Boston
- Brockton
- Cambridge
- Fall River
- Haverhill
- Holyoke
- Lawrence
- Lowell
- Lynn
- New Bedford
- Somerville
- Springfield
- Worcester

Michigan

- Detroit
- Flint
- Grand Rapids
- Lansing
- Saginaw

California

- Berkely
- Long Beach
- Los Angeles
- Oakland
- Sacramento
- San Francisco

New Jersey

- Atlantic City
- Bayonne
- Camden
- East Orange
- Elizabeth
- Hoboken
- Jersey City
- Newark
- Paterson
- Trenton

Indiana

- Evansville
- Ft. Wayne
- Gary
- Indianapolis
- South Bend
- Terre Haute

Georgia

- Atlanta
- Augusta
- Macon
- Savannah

Wisconsin

- Milwaukee
- Racine

TABLE II (continued)

North Carolina
- Winston Salem
- Asheville

Kentucky
- Covington
- Luisville

Iowa
- Davenport
- Des Moines
- Sioux City

Minnesota
- Duluth
- Minneapolis
- St. Paul

Alabama
- Birmingham
- Mobile

Tennessee
- Chattanooga
- Knoxville
- Memphis
- Nashville

Virginia
- Norfolk
- Portsmouth
- Richmond
- Roanoke

Louisiana
- New Orleans
- Baton Rouge

Mississippi
- Jackson
- Visksburg

Kansas
- Kansas City
- Topeka
- Wichita

Arkansas
- Little Rock

South Carolina
- Charleston

West Virginia
- Huntington
- Wheeling

Maryland
- Baltimore

Connecticut
- Bridgeport
- Hartford
- New Britain
- New Haven
- Waterbury

TABLE II (continued)

Washington	Rhode Island
Seattle	Pawtucket
Spokane	Providence
Tacoma	Montana
Nebraska	Anaconda
Lincoln	Great Falls
Omaha	Utah
Florida	Salt Lake City
Jacksonville	Ogden
Tampa	New Hampshire
Colorado	Manchester
Denver	Idaho
Pueblo	Twin Falls
Oregon	Boise
Portland	New Mexico
Salem	Albuquerque
Maine	Santa Fe
Portland	Vermont
Lewiston	Barre,
North Dakota	Burlington
Fargo	Arizona
Minot	Phoenix,
South Dakota	Douglas
Sioux Falls	Tucson
Aberdeen	

TABLE II (Continued)

Delaware

Wilmington

New Castle

Wyoming

Casper

Cheyenne

Nevada

Reno

Winnemucca

TABLE III

Cities from which replies were received

New York
- Syracuse
- Troy
- Albany
- Buffalo
- New York

Pennsylvania
- Harrisburh
- Wilkes-Barre
- Philadelphia
- Erie

Illinois
- East St. Louis
- Peoria
- Chicago

Ohio
- Cleveland
- Canton
- Toledo
- Youngstown
- Cincinnati
- Springfield

Texas
- El Paso
- Dallas
- San Antonio
- Houston
- Fort Worth

Massachusetts
- Haverbill
- Lynn
- Somerville
- New Bedford
- Springfield

Michingan
- Flint
- Grand Rapids

California
- Long Beach
- Los Angeles

Missouri
- Saint Louis

New Jersey
- Newark

TABLE III (continued)

Indiana

Terre Haute

Georgia

Savannah

Wisconsin

Racine

North Carolina

Asheville

Kentucky

Louisville

Iowa

Des Moines

Davenport

Sioux City

Minnesota

Duluth

Alabama

Mobile

Birmingham

Tennessee

Memphis

Nashville

Knoxville

Chattanooga

Virginia

Roanoke

Norfolk

Richmond

Oklahoma

Tulsa

Oklahoma City

Louisiana

New Orleans

Mississippi

Jackson

Kansas

Topeka

Kansas City

Wichita

Arkansas

Little Rock

West Virginia

Wheeling

Connecticut

Hartford

Washington

Tacoma

Florida

Tampa

TABLE III (continued)

Colorado

Pueblo

Denver

Oregon

Portland

Maine

Lewiston

North Dakota

Fargo

Rhode Island

Providence

Montana

Anaconda

Utah

Salt Lake City

New Hamphsire

Manchester

Idaho

Boise

Twin Falls

New Mexico

Santa Fe

Arizona

Phoenix

Douglas

Tucson

Nevada

Winnemucca

TABLE IV.

Data received from cities:

No.	City	State	No. Specialists	Pop.	Pop. per Spec.	Soot-fall
1	Troy, NyY.		7-	73,000	10,430	
2	Sious City, Ia.		12	85,000	7,000	
3	Wilkes Barre, Pa		15	93,000	6,200	
4	Youngstown, Ohio		8	189,000	23,800	
5	Erie, Pa.		25	135,000	5,400	(light Soot fall)
6	Somerville, Mass.		11	104,000	10,550	
7	Haverhill, Mass		3	50,000	16,700	(Light Soot Fall)
8	Tacoma, Washington		12	97,000	8,090	
9	El Paso, Texas		12	102,000	8,500	(Natural Gas)
10	Dallas Texas		23	308,000	13,400	(practically
11	San Atonio, Texas		29	230,000	7,950	no Soot Fall)
12	Newark, New Jersey		40	485,000	12,125	
13	Jackson, Miss.		4	46,000	11,500	
14	Duluth, Minn.		20	124,000	6,200	
15	Tampa, Florida		12	140,000	12,800	(Light Soot Fall)
16	Chattanooga, Tenn.		16	110,000	6,880	
17	Nashville, Tenn.		17	150,000	8,930	(1050 T. Sq. Mi Yr)
18	Knoxville, Tenn		16	105,000	6,570	(365 T.Sq.Mi./Yr.)
19	Portland, Oregon		46	357,000	7,750	
20	Little Rock, Arkansas		16	102,000	6,370	(Health Resort)
21	Asheville, N. C.		27	35,000	1,300	(240 t. sq. mi. p yr)
22	Anaconda, Montana		1	12,000	12,000	(light. S-Fall)

TABLE IV (continued)

No.	City	State.	No. Spec.	Pop.	Pop. p. Spec.	S. F.
23	Wheeling,	W. Va.	10	75,000	7,500	
24	Savannah,	Georgia	4	100,000	25,00	
25	Lewiston,	Maine	5	35,000	7,000	(Hydro-electric)
26	Salt Lake City,	Utah	18	144,000	8,000	(Light Soot-Fall)
27	Topeka,	Kansas	9	64,000	7,110	
28	Kansas City,	Kansas	8	130,000	16,250	
29	Terre Haute,	Ind.	7	73,000	10,430	(462 Tons Pure C) (770 T sq. Mi. Yr S)
30	Tucson,	Arizona	9	45,000	5,000	(Health Resort L. S. F)
31	Boise,	Idaho	7	38,000	4,000	(324 Tons Pure C.)
32	Flint,	Michigan	10	160,000	16,000	(
33	Santa Fe,	New Mexico	2	8,000	4,000	(No Soot Fall)
34	East St. Louis,	Ill.	8	72,000	9,000	(Heavy Soot Fall)
35	Peoria,	Ill.	15	113,000	7,530	
36	Chicago,	Ill.				
37	Roanoke,	Va.	12	73,000	6,090	(Heavy Soot Fall)
38	Norfolk,	Va.	11	192,000	17,450	
39	Mobile,	Alabama	10	69,000	6,900	
40	Birmingham,	Alabama	27	291,000	10,800	
41	Tulsa,	Oklahoma	20	180,000	9,000	(Natural Gas)/

APPROVAL.

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Name Judson H. Robertson

Title Professor of Chemistry