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Selected Papers from the

AIR *and* WATER POLLUTION

Conference

November 19, 1957
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The Fourth Annual Air and Water Pollution Conference will be held on the University of Missouri Campus, November 18, 1958.

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Municipal and Industrial Cooperation on Pollution Abatement

*William Q. Kehr**

I SHOULD LIKE to start this discussion with an example of the cooperation between The Metropolitan St. Louis Sewer District and the industries using our facilities which, I think, exemplifies the attitude that should be present between industry and a municipality where they are facing a joint problem.

When the Metropolitan Sewer District started operations we were faced with quite a number of problems. Overnight, the sewer systems and facilities of 86 municipalities and nearly 30 sewer districts were taken over by a single agency. It doesn't require much imagination to visualize our situation. In many areas the sewers were adequate and in others they were not. Some areas had no sewers and were dependent on individual sewage disposal facilities. Maintenance ranged from good to none at all. Only through prior planning and very excellent cooperation was it possible to avoid chaotic conditions.

Among the problems we faced was one of controlling the use of sewers. This might not seem like a very important problem, but there was a wide difference among ordinances that were in effect in the 86 municipalities. The wide variation in the type of ordinance, the restrictions and the penalties resulted in very little or no control in some areas, while in others there was very strict control. The lack of uniformity resulted in many legal questions because the District had to be consistent in its restrictions and controls, and impartial in its enforcement. It was impressed on us very early that if we were to protect the sewers that had been entrusted to us, it would be necessary to develop and place in effect an ordinance which would give us the control required to prevent the abuse of these facilities.

With the model ordinance prepared by a committee of the Federation of Sewage Works Associations as a base, we studied the ordinances that were in effect, not only in the St. Louis area but in other major municipalities. We prepared what we thought was a reasonably good ordinance but we still were not satisfied with it. We recognized that industry also had a stake in this ordinance.

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While the ordinance was not specifically aimed at industry, nevertheless, industrial wastes do constitute a problem in the use of the sewers. Many industrial wastes are toxic or corrosive, and since many of our sewers, particularly the large ones, are made of concrete, they are subject to deterioration when acids or other harmful constituents are present.

A rough draft of the proposed ordinance was sent to the various industries in the area, with a request for comments and suggestions. Industry's reaction to the ordinance was not as great as we had thought it might be, but it did show that industry was interested and, in some cases, seriously concerned about the effect the ordinance might have on their operations. A public hearing had been previously arranged and the various industries invited to have representatives present to give their views. Many industries were represented at the hearing and presented comments worthy of consideration. In order to work out the provisions of the ordinance so it would not be unfair to industry and yet at the same time provide us with the measure of protection that we needed, we asked industry to appoint a group of representatives typical of the various types of industries to meet with representatives of the District to go over the ordinance, article by article, so that we could have the benefit of their knowledge and experience. This was done and the ordinance was amended to incorporate many of their suggestions. As in any case where there are two different points of view, there must necessarily be some compromise but it is important that the compromise does not work out to the disadvantage of either. Such is the ordinance that was finally adopted. We feel that it is a very good ordinance so far and that industry has accepted it very well. We are reasonably sure that amendments will be required. Perhaps some further restrictions will be added or some of the criteria strengthened. Others may be lowered after more knowledge is gained, but we now have a starting point from which to work. We propose to continue to work with industry to the end that while industry is not penalized, at the same time adequate protection is given to the facilities that the public has paid for at a cost of many millions of dollars.

I point to this as an example of cooperation between industry and municipal officials because I think that this same spirit of cooperation is going to be important in the years ahead and particularly in the St. Louis metropolitan area where we are faced with the future problem of constructing sewage treatment works. To the average person, who has not been greatly concerned about pollution abatement, recent events must undoubtedly have shown the handwriting on the wall. The fact that the Federal Water Pollution Law has been strengthened and reenacted with better provision for enforcement and that during the last legislative session the Missouri Legislature adopted a water pollution law, should show to both municipal and industrial officials that the time has come when the government will no longer look upon or tolerate the continuing destruction of one of our greatest resources by undue pollution.

There are, of course, many industries that have and propose to maintain their own separate outlets to the River. They are faced with one problem. For the industries that utilize the facilities of a municipality, the problem is somewhat different. It is primarily to that group of industries that I should like to direct the remarks of the next few minutes. The District and similar municipalities—I don't want to limit it to the St. Louis metropolitan area—are definitely facing the problem of providing adequate sewage treatment for their wastes. Industries, where they are involved, are definitely a part of this problem.

One of the first steps to be taken by such a municipality is to determine what treatment is needed—the degree of treatment, type of treatment, and what facilities such as interceptors, pumping stations, and other auxiliary facilities must become component parts of the improvements. To this end, arrangements must be made of studies of the volume, the characteristics of the wastes, and, in some cases, of industrial wastes to be discharged to the sewers. The capabilities of the receiving stream must receive attention because this is important, too. Many times streams which seem to have adequate capabilities are unable to carry the final load, with the result that supplemental pollution abatement measures must be undertaken. After these studies have been made and analyzed, plans must be prepared giving careful consideration to any unusual industrial wastes which might adversely affect the functioning of the treatment facilities. Finally, of course, comes the financing and the construction of the necessary facilities. When this has been accomplished, there is still another step that must be taken by municipalities where industries are involved. This is to establish charges for the treatment of industrial wastes based on the cost of providing treatment.

This is necessary for three reasons. First, to keep the volume, strength, and cost of treatment to a reasonable minimum. A few careless major industries could conceivably utilize the entire treatment capacity. While many industries are concerned about their wastes because excessive losses are costly, others would find it more convenient and less costly to dispose of waste material directly to the sewer because their wastes are not recoverable or cannot be utilized. If industry pays according to the load it contributes, there is a definite incentive to reduce the waste load to a minimum.

Second, in all fairness, industry should share treatment costs in proportion to its contribution to the problem and to the cost of treating its wastes. Neither size nor valuation is related to the waste treatment problem of an industry. The volume and strength of wastes do and are the fair measure for determining industry's share of costs.

Finally, the ability of a given community to finance both construction and operation is limited. If the costs are out of reason, public support cannot be easily secured, particularly if it is evident that the public is being asked to subsidize industrial waste treatment costs. In major communities this would be less evident, but it is a factor which must be considered in any treatment plant program.

Municipal responsibility does not end with the establishment of a fair and equitable schedule of charges for the treatment of industrial wastes. This must be followed by a continuing program of sampling industrial waste outlets. Through such a program changes in the character and quantity of wastes can be determined as they occur, and records of such sampling programs serve as the basis for forecasting future treatment needs.

The preceding summarizes very briefly the problems faced by a municipality entering a program for treating combined municipal and industrial wastes.

I should like to speak next concerning the responsibilities that are placed on industry in connection with this program. First, we believe that industry should recognize the importance and necessity of the community waste treatment program. We believe industries should, well in advance, begin studying their wastes and conferring with municipal authorities and consulting engineers on special problems. Some of their wastes may involve segregation or specialized treatment of some type in order that they will be amenable to treatment. One of the first steps that industry can take is the installation of sampling manholes at convenient points. Many industries are composed of numerous manufacturing processes in which the wastes are combined before discharge to the sewers. It is sometimes very difficult to sample the waste from a particular process because the need for such a study was not anticipated when the plant was built. Although the need for sampling manholes will vary with the industry, I do want to point out that sometimes a single sampling point at the outlet is not sufficient to locate a waste problem. It may be necessary to study component wastes. Second, industry should institute a study of its wastes and waste disposal problem. Such studies should not be delayed until a municipal waste treatment program is well under way. Delay in making such studies may result in a waste load that is unnecessarily high and penalize the owner by increasing his waste treatment charge. Third, industry should investigate the recovery and reuse of various components of its waste where this is possible. In many cases these components of wastes can be reused or developed into a product that can be sold, if not at a profit, then certainly at less overall cost than the treatment of the wastes.

One example in point came to my attention recently where an industry was faced with a particularly difficult industrial waste disposal problem. After due consideration, it was decided to attempt to recover the component of the wastes that was causing the difficulty. In order to do this it was necessary to install expensive recovery equipment. During the first year the savings to this industry very nearly paid for the cost of the installation and in succeeding years annual saving was estimated in excess of $10,000 a year. You will recall, too, that this morning Mr. Warrick pointed to numerous examples in other industries where savings were accomplished as a result of their efforts to reduce the volume and strength of wastes discharged to streams. Fourth, we believe that waste producing industries should review the possibility and economics of waste reduction through process changes or changes in operating techniques. Such studies could result in considerable reduction in the volume and strength of the wastes that are to be discharged. They may also make unnecessary the construction of some type of preliminary treatment works. Fifth, there are circumstances under which the separation of wastes within an industry may prove the most economical solution to a waste problem. As an example, segregation of a particularly troublesome waste from other plant wastes may make it feasible to recover a usable component or less costly to treat or dispose of separately. Once a small volume of waste is mixed with a much greater volume, the cost of treatment or recovery becomes much greater and more difficult. Sixth, where there is reason to believe that preliminary treatment is necessary for either a segment of waste or for the total waste from an industry, we believe the industry should start immediately the necessary studies to determine the type and capacity of the facility. That is not to say, of course, that the construction of such treatment facilities should be undertaken immediately. It is possible that changes will occur between now and the time when the preliminary treatment would be necessary which would make the facility unnecessary.

The preceding steps suggested to industry are offered in the hope of avoiding future problems. There is little question that when a municipal treatment works are constructed, they must be capable of handling the entire community waste load. If the wastes from a particular industry or a group of industries are such that they would interfere with or prevent the proper operation of these facilities, steps must be taken by the municipality to force immediate removal or treatment of such wastes. The inconvenience to industry and the excessive cost of a crash program can be avoided by advance studies of industrial wastes and proper planning of any needed facilities.

Municipalities and industries together are facing this pollution abatement program. Many municipalities have already faced their problem and now have adequate treatment facilities. New industries, or major expansion in existing plants, may create special problems. By conferring in advance with representatives of the municipality and the state water pollution authorities necessary steps can be taken to avoid interference with existing treatment works. Through cooperation, most of the answers to such problems can be found quickly and easily. Among the things that are most encouraging to us is the fact that industry is now and has for some time shown considerable interest in the waste disposal problems. Many industries have employed engineers who devote full time to these problems. It is not uncommon for these specialized personnel to be a highly profitable investment. Then, too, industries' interest in these problems is shown by increasing representation and participation in meetings such as this and the Federation meetings. It used to be that representatives from industry were quite rare at these meetings. Today they are well represented and I, for one, welcome industries' increasing interest in mutual problems and their cooperation and efforts in finding satisfactory solutions. In the long run, both industry and the people of the country will benefit through clean streams and through additional recreational facilities and other water uses that will be possible only by the protection and improvement of our water resources. As Mr. Warrick pointed out this morning, water is and will be in the future an increasingly precious resource to our nation. It is vital that we keep our water resources in such condition that they will be of greatest use to all.

The National Air Sampling Network

*Elbert C. Tabor**

THE NATIONAL AIR SAMPLING NETWORK of the Public Health Service, established in 1953, is operated in cooperation with local health departments, air pollution agencies and other organizations. By November 1, 1957 the network was composed of 110 stations in major cities in the 48 states, the District of Columbia, Alaska, Hawaii and Puerto Rico, and approximately 30 stations in comparatively remote nonurban areas. A report has been presented on the results of the first three years of operation and on plans for the future of the network (1).

The objectives of the network are to assemble basic data on the nature and extent of the pollution of the air over the United States; to show trend with time, geographical variation, and the influence of topography, population, climate, industry, and other variables; and to provide data against which epidemiological findings may be correlated.

Samples collected for one 24-hour period in each two weeks are mailed to Cincinnati for analysis. The sampling is done on a random schedule determined by statistical methods. The air particulate matter is collected on 8 x 10 inch weighed glass fiber filters, using high-volume samplers which draw approximately 2000 m^3 of air through a filter in an average 24-hour sampling period. Weight of the particulate matter collected varies from a few milligrams to a few grams, depending on the atmospheric loading.

All samples are analyzed for suspended particulate matter, benzene-soluble organics, and β-radioactivity, while selected samples are analyzed for certain inorganic constituents. Reports of findings are sent to the participating agencies at regular intervals. The information in these reports may be used as desired by the individual agency.

After the sample is weighed, the β-radioactivity is measured. Then the filter is cut in such a way that the 7 x 9 inch sample area is divided into equal parts, one of which is used for extraction of organic materials and the other for the

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determination of inorganic constituents. After six circles, each comprising 4% of the total area, have been removed from the second half of the sample for various determinations, the remainder is used for metal analysis.

Suspended Particulate Matter

Since the weight of the collected material is easily determined and the total volume of air sampled can be calculated, the weight of suspended particulate matter per unit volume of air filtered may be obtained. Levels are expressed in micrograms of particulate matter per cubic meter of air. A preliminary report was presented in April, 1955 (2) covering several cities, for 1953, 1954, and early 1955. The frequency distributions of particulate levels of several urban and suburban stations for 1953-1956 are shown in Table 1. The cities in the table are arranged in order of decreasing population. By 1957 all suburban stations were discontinued in favor of nonurban sites more remote from sources of pollution.

TABLE 1. FREQUENCY DISTRIBUTION OF PARTICULATE LEVELS
Percent of Samples

	Range, $\mu g/m^3$					
Stations	0-99	100-199	200-299	300-399	400-499	Over 500
Urban						
Chicago, Ill.	5	24	31	22	8	9
New York, N. Y.	2	30	48	18	1	1
Boston, Mass.	26	61	10	2	1	0
St. Louis, Mo.	0	45	41	7	1	4
Denver, Colo.	20	55	19	5	0	0
Minneapolis, Minn.	39	54	7	0	0	0
Atlanta, Ga.	21	63	13	2	1	0
Tampa, Fla.	62	37	1	0	0	0
Charleston, W. Va.	21	25	11	17	13	12
East Chicago, Ind.	6	32	26	23	10	3
Suburban						
Boston, Mass.	94	6	0	0	0	0
Lakehurst, N. J.	99	1	0	0	0	0
Tampa, Fla.	91	7	2	0	0	0

In general it can be stated that the higher particulate levels are found in the atmosphere of larger cities, except that smaller, heavily industrialized cities may also show high levels. Suburban stations showed considerably lower levels than nearby urban stations.

Organic Matter

The organic portion of the particulate sample is isolated by extraction with the selected solvent in a Soxhlet extractor for 6-8 hours. The solution containing the organic material is filtered through a medium porosity, fritted glass filter, the solvent removed and the weight of the residue determined. The amount of organic matter is reported in micrograms per cubic meter of air.

Originally acetone was used as the solvent because it removed a greater amount of organic matter than any other common solvent. These acetone extracts were difficult to handle when used for further chemical studies, and also contained considerable inorganic matter. Therefore, the use of this solvent was discontinued at the first opportunity. A preliminary report has been presented on the levels of acetone soluble materials from several cities (3).

Since July 1, 1955, all samples have been extracted with redistilled benzene which, while it does not remove all the organic material present, does provide a more useful product for further experimentation. The distribution of benzene soluble organic matter in the atmosphere of several communities is shown in Table 2. This table bears considerable resemblance to Table 1.

TABLE 2. FREQUENCY DISTRIBUTION OF ORGANIC LEVELS

Percent of Samples

Stations	Range, $\mu g/m^3$					
	0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	Over 50
Urban						
Chicago, Ill.	17	34	32	12	4	1
New York, N. Y.	51	41	4	2	2	0
Boston, Mass.	28	63	7	1	0	1
St. Louis, Mo.	26	48	17	4	3	2
Denver, Colo.	38	48	8	6	0	0
Minneapolis, Minn.	72	23	2	2	1	0
Atlanta, Ga.	37	46	7	5	0	5
Tampa, Fla.	73	23	3	0	0	0
Charleston, W. Va.	41	41	7	7	0	4
Suburban						
Boston, Mass.	94	4	2	0	0	0
Lakehurst, N. J.	98	2	0	0	0	0
Tampa, Fla.	94	6	0	0	0	0

In addition to determining the amount of organic material in the atmosphere, considerable effort has been expended on the investigation of the chemical nature of this material. Infrared spectroscopy provides a convenient method of detecting qualitative differences between samples of organic matter. Therefore, infrared spectra of a large number of organic extracts have been obtained. Examples of a few different observations based on these spectra are: variation in the nature of the organic material at different sites within a city, variation in the composition of the organic matter with the seasons, and variation in the nature of the organic matter from city to city. An outstanding demonstration of the value of this technique was the detection of caffeine in samples collected in New Orleans.

Increased interest in the organic portion of suspended particulate matter has led to further chemical studies designed to provide information on the composition of this fraction. A sample of the crude organic matter, obtained by pooling a sufficient number of individual extracts, is easily separated by standard chemical procedures into the following groups of organic compounds: basic, weak acid, strong acid, aliphatic hydrocarbons, aromatic hydrocarbons, and oxygenated neutrals. A preliminary report on the characteristics of atmospheric organic materials has been presented (4). Table 3 shows the results of analysis of a few samples of such materials. Particularly outstanding are the aliphatic fraction from St. Bernard and the acid fraction from Los Angeles. Further work on identification of individual components of the various fractions is in progress.

TABLE 3. PERCENTAGE DISTRIBUTION OF ORGANIC CLASSES IN BENZENE EXTRACTS

Class	St. Bernard, O.	Los Angeles	Philadelphia
Insolubles	2.0	13.3	8.7
Water Solubles	1.0	5.5	2.4
Bases	1.2	0.2	0.6
Weak Acids	2.7	7.0	5.0
Strong Acids	1.1	9.7	3.3
Aliphatics	65.5	19.6	27.5
Aromatics	14.2	14.2	22.2
Oxy-neutrals	6.8	17.6	19.1

Radioactivity

From the beginning, a large proportion of network samples have been measured for β-radioactivity, and a limited number for α-activity. Currently, β-activity determinations are being made on all samples. These β counts are extrapolated to the date of sample collection to correct for decay. Typical results are shown in Table 4.

TABLE 4. RADIOACTIVITY OF SUSPENDED PARTICULATE MATTER

				Activity per Cubic Meter		
Date Collected*	Date Counted	Sample No.	Sta. No.	Alpha** m$\mu\mu$c	Beta** $\mu\mu$c	Beta*** $\mu\mu$c
11/5/54	11/26	1600	A	3	1.09	2.00
11/12	12/13	1926	A	7	2.42	4.00
11/12	12/9	1927	A	11	2.59	4.60
11/18	1/6/55	1928	A	8	1.87	5.20
11/18	1/18	1929	C	7	1.06	3.05

* 24-hour sampling period.
** When counted.
*** Extrapolated to time of collection.

Inorganic Materials

In the early days of the network, analysis of samples for inorganic materials was carried out by the Kettering Laboratory of the University of Cincinnati College of Medicine. Since July, 1955, all such analyses have been done in the network laboratories. The present analytical program calls for the analysis of selected samples for the following: antimony, barium, beryllium, bismuth, cadmium, copper, chromium, cobalt, iron, lead, manganese, molybdenum, nickel, tin, titanium, vanadium, zinc, nitrates, and sulphates. In the past, chlorides were determined for a large number of samples, but the filters now being used contain such a large amount of soluble chlorides that this measurement has been discontinued.

The results of analysis of selected samples from 20 communities for the metals, have been reported (5), while data from 25 others have yet to be evaluated. The metal concentrations are measured by emission spectrographic techniques using a nitric acid extract of the sample which has been heated in a muffle furnace to burn off organic matter prior to the acid extraction.

Iron, zinc, copper, lead and manganese were the metals found in the largest amounts in the samples analyzed. The maximum levels for iron, zinc, copper and lead were well over 10 $\mu g/m^3$ and, except for copper, numerous samples from several cities were well over the 1 $\mu g/m^3$ level. In the case of manganese the maximum level was 3 $\mu g/m^3$ with relatively few samples above 1 $\mu g/m^3$. The method of presentation of typical atmospheric metal data, shown in Table 5, minimizes slight differences in levels and provides a convenient basis for showing trends from year to year.

TABLE 5. FREQUENCY DISTRIBUTION OF LEAD LEVELS
Percent of Samples

Location*	No. of Samples	Range, $\mu g/m^3$ 0-.25**	.25-.63	.63-1.6	1.6-3.9	3.9-9.8	9.8-17.5
All Cities	754	15.6	33.3	34.1	11.5	4.5	0.9
Houston	62	0	15	27	21	27	10
Boston, E. Chicago, Louisville, Salt Lake City	203	8	31	37	17	7	
Chattanooga, Chicago, Denver, E. St. Louis, Houston C, New York, Philadelphia, Portland, Washington	314	9	34	43	14		
Boston C, Ft. Worth, Jersey City, Minneapolis, New Orleans, Paulsboro, Tampa	158	36	46	18			
Lakehurst	17	82	18				

* Nonurban indicated by underline.
** Minimum detectable quantity - .1 $\mu g/m^3$

Barium, bismuth, cadmium, chromium, nickel, tin, titanium, and vanadium were quite widely distributed, but in much smaller quantities than those metals listed in the preceding paragraph. The maximum values, except for barium, were considerably under 1 $\mu g/m^3$ and in many instances the ranges of concentration were quite small. These data have been presented in the same manner as for lead.

The number of samples containing detectable quantities of antimony, beryllium, cobalt and molybdenum was so small and represented so few communities that there is little value in attempting a detailed analysis of the data. The major point is the apparent absence of detectable amounts of these four elements from the atmospheres of a large number of cities.

Variations in maximum levels found among the various communities are shown in Table 6. As was to be expected, most of the high maxima were associated with the more heavily industrialized communities.

TABLE 6. RANGE OF MAXIMUM METAL LEVELS

	Low Level		High Level	
Metal	Location*	$\mu g/m^3$	$\mu g/m^3$	Location*
Zinc	Fort Worth	0.4	49.00	Chicago
Iron	Lakehurst	0.23	30.00	East Chicago
Copper	Washington	0.05	30.00	Boston C
Lead	Lakehurst	0.33	17.00	Boston
Manganese	Lakehurst & Paulsboro	<0.01	3.00	Chattanooga
Barium	Lakehurst & Paulsboro	<0.005	1.5	Houston
Tin	Tampa	0.004	0.8	Boston
Vanadium	Fort Worth	0.002	0.6	Jersey City
Titanium	New Orleans & Tampa	0.01	0.24	East Chicago
Nickel	Houston C	0.005	0.2	East St. Louis New York
Chromium	Lakehurst	<0.002	0.12	East Chicago
Cadmium	Boston	0.002	0.10	East St. Louis
Bismuth	Boston C Minneapolis	<0.002	0.03	New York

* Nonurban indicated by underline.

Sulphates, nitrates and chlorides have been determined on a large number of samples by wet chemical procedures. No report has as yet been presented on the findings. Maximum levels found in several communities are shown in Table 7.

TABLE 7. MAXIMUM LEVELS OF ATMOSPHERIC CHLORIDES, NITRATES AND SULFATES

	$\mu g/m^3$		
Location	Chlorides	Nitrates	Sulfates
Philadelphia	1.2	8.0	85
Charleston, W. Va.	1.0	2.2	37
Atlanta	3.5	2.6	33
Cincinnati	1.3	3.3	27
East Chicago	3.5	6.7	50
San Francisco	43.0	3.4	22
Anchorage - Suburban	0,3	0.2	7
Denver - Suburban	0.3	1.2	7

Summary

The foregoing illustrates the type of information currently being obtained by the National Air Sampling Network.

It is recognized that full assessment of air quality requires more information than can be supplied by analysis of suspended particulate matter collected on filters. A concentrated effort is being made to develop a simple, inexpensive means for sampling and analyzing those gaseous pollutants not caught or absorbed by filters.

Development of an automatic computer program with punched card input and output and direct automatic typing of final data tabulations will expedite the evaluation of the large amount of data being accumulated in the network program. Such tabulations will be incorporated in a detailed report of network operations from 1953 through 1956 which is being prepared.

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Air Pollution Control In Coal Fired Steam-Electric Plants

*John F. McLaughlin**

THE NEED FOR AIR POLLUTION CONTROL in the design and operation of the Steam Power Plant results directly from the combustion process. The effort expended will depend upon where the plants are located, and the type and quantity of fuel burned. Where the fuel is coal, three end products or by-products are of concern—these are smoke, fly ash, and sulphur-dioxide gas. There has been considerable research and discussion in recent years on the oxides of nitrogen. This appears to be of primary concern in the Los Angeles type smog problem. Although we are quite interested in knowing more about what part oxides of nitrogen may play in air pollution, as yet we have no evidence that they have any significance in our particular area. It may come as somewhat of a surprise that we consider smoke still to be a problem. Many undoubtedly believe that the smoke problem was solved some years ago. It is true that the smoke problem has been overcome in most large cities; certainly it has in St. Louis. But for the electric utility system, smoke can still be a major problem in certain plants.

The need for air pollution control comes from the coal burning process. Peculiar to steam-electric plants are the large quantities of coal burned. For example, Union Electric Company in St. Louis burned 2,700,000 tons of coal in the year 1956. Our largest steam power plant burns 5,000 tons of coal a day. There are several steam power plants in the United States that will burn 10,000 tons of coal per day and the largest plant, the Kingston Plant of the TVA System, will burn as much as 15,000 tons of coal a day. Certainly the large quantities involved contribute to the control problem. 5,000 tons of 10% ash coal per day means that 500 tons of ash per day must be handled in one way or the other. Since all of this coal is burned in pulverized form on our system, approximately 80% of the 500 tons per day will be suspended in the flue gas leaving the boiler and must be either collected by dust collectors from the gas stream or it will be discharged into the atmosphere. It is of interest how our attitude has changed in the last 25 years. When pulverized coal firing was first introduced one advantage

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cited over stoker firing was that more ash was discharged from the stack and therefore less ash needed to be handled in the ash handling system. Today, one of the pressing problems of the electric utility industry as a whole is what to do with fly ash after it has been collected. Many utilities with plants located in the heart of large cities are finding the disposal of collected fly ash to be a costly item. This cost of fly ash disposal has lead to the research and development of many uses of fly ash such as a constituent in concrete, for soil stabilization and many others.

In talking about air pollution control in the steam power plants today, I would like to discuss two extremes. I would like to talk very briefly about what we are doing in our new plant, where we can provide, in the design, the best available control facilities. Then I would like to spend some time talking about the more difficult problem; that is the older plant designed before air pollution was given consideration.

Control in the New Plant

Smoke is not a problem in the modern steam power plant. Modern boilers are equipped with highly efficient burners, modern pulverizer equipment, elaborate and responsive combustion control equipment—all have contributed towards eliminating smoke as a problem. Modern plant arrangement, with a large single boiler-turbine-generator unit controlled by one man from a central control room has improved operation and thereby contributed to better stack appearance. One advantage with this arrangement is the elimination of the need to communicate and coordinate operation in separated boiler and turbine switchboard rooms. The large single boiler-turbine-generator unit and the central control room arrangement lends itself and, in fact, requires more complete automation than the older type plant.

High collection efficiency is available today in either the straight electrostatic collector or the combination mechanical-electrical collector. On recent units, we have purchased fly ash collectors designed for 97½% collection efficiency. Figure No. 1 shows the test curve of one of our recent fly ash collectors. Note that collection efficiency decreases as load increases. Since gas velocity thru the fly ash collector is roughly proportional to load, the same curve can be obtained by plotting efficiency against gas velocity. It has been our experience that velocity must be in the order of 6-7 feet per second in order to obtain 97½% efficiency. This high collection efficiency requires an expensive collector installation. With

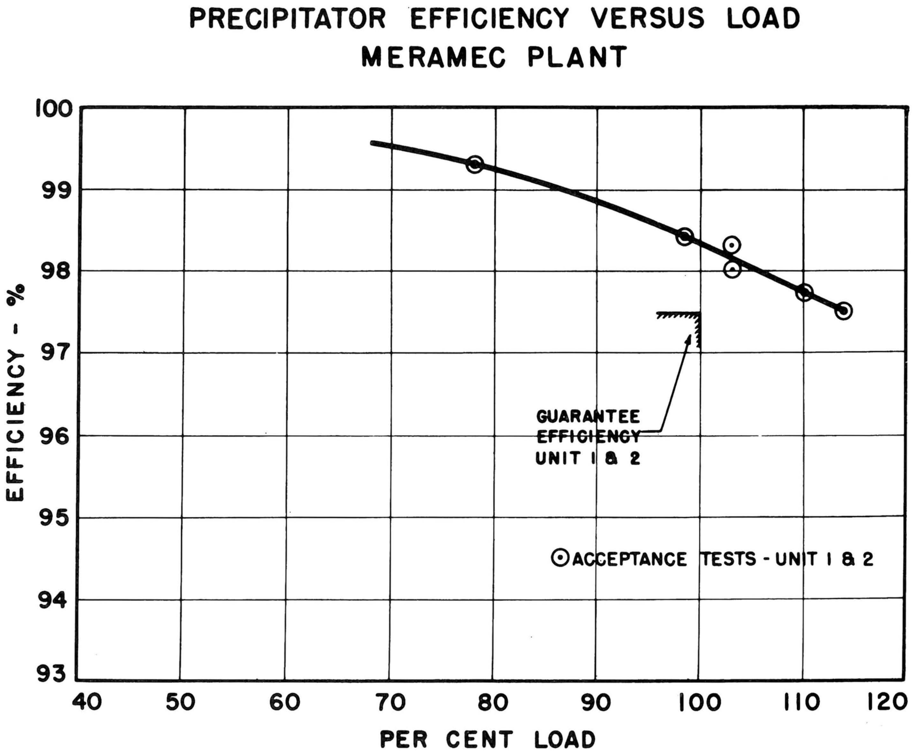

FIGURE 1

97½% efficiency, we are going beyond the requirements of any smoke ordinance in the United States with the possible exception of those in effect in the Los Angeles area. It is of interest that we find that a collector operating at 99% efficiency will give a perfectly clear stack with our pulverized coal boilers. However this efficiency would require a gas velocity in the order of 4½-5 feet per second and would require a collector 25% larger in cross-sectional area.

A problem that our plant designers face today with regard to fly ash collection is the tremendously large size collector required for these high efficiencies. An important cost factor in the design of power plants is the size of the building extension required to house the generating equipment. Working to keep costs of power plants to a minimum in the face of increasing equipment and labor costs, the designer attempts to install more and more generating capacity in proportionally smaller and smaller space. Figure No. 2 shows arrangement of Units 1 and 2 at Meramec Plant in the Union Electric System. Combined capacity of these two units is 280 megawatts. Building length is 256 feet. Shown also is Unit 3, a cross-compound unit with a single boiler and with a twin furnace.

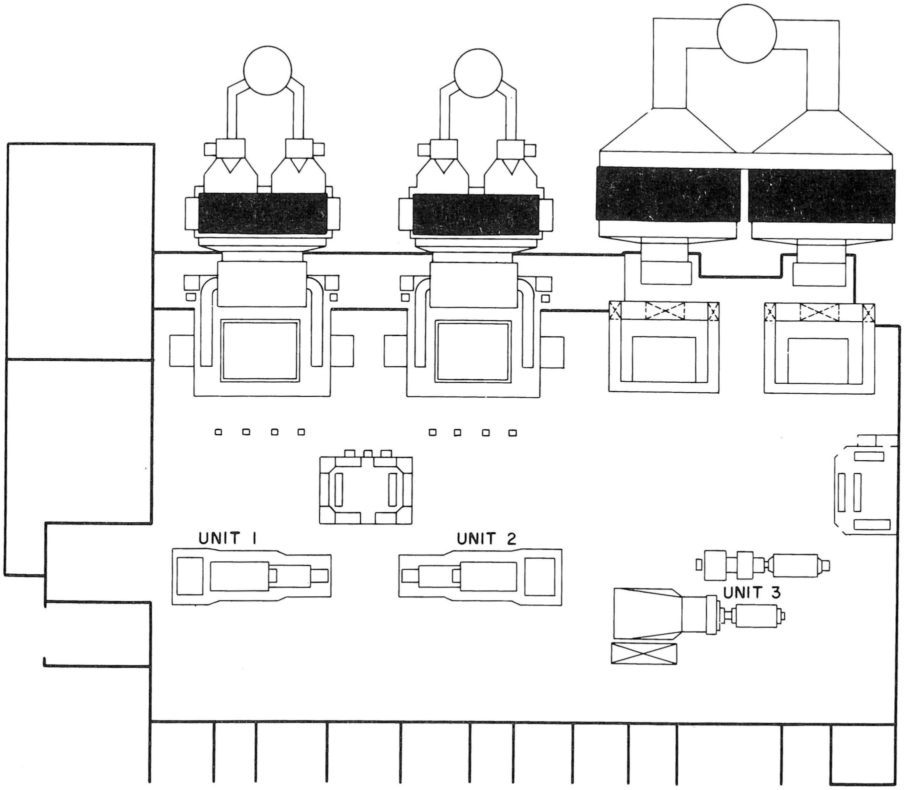

FIGURE 2

Unit 3 generator capacity is also 280 megawatts, but the building length is only 170 feet. Unit 4 now being purchased is 330 megawatts capacity with an expected building length of only 150 feet.

Unfortunately dust collector size has not gone in the same direction as turbine and boiler size. Maximum height is presently limited to about 25′-26′. Based on present design criteria, collector length would continue to increase as unit size increases such that the collector for the next unit would require 170 feet compared to a building length of 150 feet. If this trend were to continue, the following unit, probably of 400 megawatt size, would require a collector 250 foot long. One answer to the problem of space required by dust collectors is to stack two collectors vertically. This proves expensive and it is difficult to distribute the gas evenly to collectors stacked one on top of the other. It seems that the only answer to future development is to build precipitators with high efficiency and higher velocities. We know that the fly ash collector manufacturers are working towards this end.

The only practical solution known at the present time to avoid air pollution from sulphur-dioxide gas is to build the stacks high enough to ensure that the gases never reach the ground. Wind blowing past a plant creates turbulence above and beyond the building and at the stack itself. Normally the stack plume discharges high enough above the building and with enough velocity to escape the turbulent boundary and will gradually rise and disperse in the atmosphere. If the stack is not tall enough or if the gas velocity leaving the stack is not great enough relative to wind velocity, the plume may be entrapped in the turbulent area of wind and will be brought to the ground. This is termed "downwash". Wind tunnel tests were performed at Michigan University to guide us in establishing stack heights for Meramec Unit No. 3. Velocity in the tunnel is held constant and velocity of the stack discharge is varied. Photographs are made of the plumes to record height of the plume above the ground. The effect of various stack nozzles and stack height and the effect of additions to the plant buildings can be studied.

With the knowledge, equipment, and test facilities available today the power plant designer can usually plan and build facilities which will meet today's high standards of air cleanliness. Problems exist, to be sure, and solutions are often expensive. Air control features are usually less expensive, however, when incorporated in the original design rather than added after the plant is in operation.

It is our experience that the more difficult air pollution problem is in the older plant, designed and constructed before atmospheric pollution was given serious consideration and before equipment was available to control it. Cahokia Power Plant, in the Union Electric System, is such a plant. Modern in its day, Cahokia was the first power plant in the United States to be designed exclusively for the use of pulverized coal. The first section began operation in 1924. The last unit was installed in 1937. Typical of most plants constructed in that period, twenty-four boilers were installed without a single fly ash collector.

Control in the Older Plant

Cahokia Power Plant is located on the east bank of the Mississippi River, just south of the East St. Louis City Limits, in the town of Monsanto, Illinois. Plant capacity is 335,000 Kw. Steam conditions are 315 psig and 700° F. There are six turbine-generators ranging in size from 35,000 Kw to 75,000 Kw.

The first two sections of the Cahokia boiler room (16 boilers) were designed with a central pulverizing system. Pulverized coal is transported by compressed air from the central pulverizing system to pulverized coal bins located at the boilers. Boilers are fired with Lopulco vertical burners. Furnaces are almost entirely refractory and are constructed with air cooled sidewalls. Natural draft draws combustion air from the boiler room through the sidewalls and into the furnace through openings in the front wall. Boilers are manually controlled from a firing aisle located 23 feet above ground elevation.

The boilers in the third section of Cahokia were installed with unit pulverizers, horizontal burners, forced and induced draft fans and automatic combustion controls. Boilers are controlled from a firing aisle located at ground elevation. Furnace walls are partially cooled by water wall tubes. Boiler ratings are substantially higher than in the first two sections.

Figure 3 shows the arrangement of the Cahokia boiler room as the final section was completed. Twenty-four boilers supply six turbines; each four boilers discharge into a common stack.

CAHOKIA BOILER ROOM

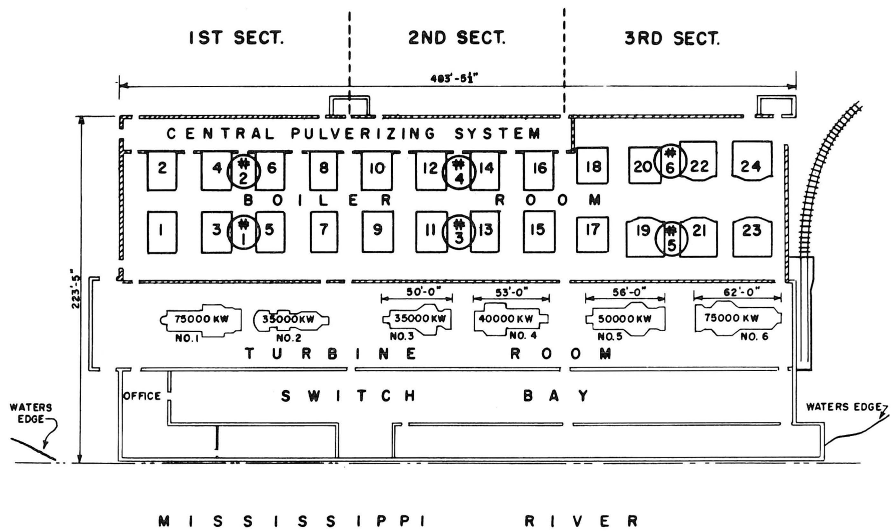

FIGURE 3

In 1940, in cooperation with the air pollution control program of the City of St. Louis, the first fly ash collectors were installed at Cahokia. Because space on the boiler room roof had not been provided for these collectors in the original layout, a steel supporting structure was erected from the ground along the east side of the boiler room. No. 6 stack was equipped with fly ash collectors in

1940. In 1947, fly ash collectors were installed on the four boilers discharging into No. 5 stack. Figure 4 is a photograph of this collector installation. These are electrostatic collectors designed for a collection efficiency of 90%.

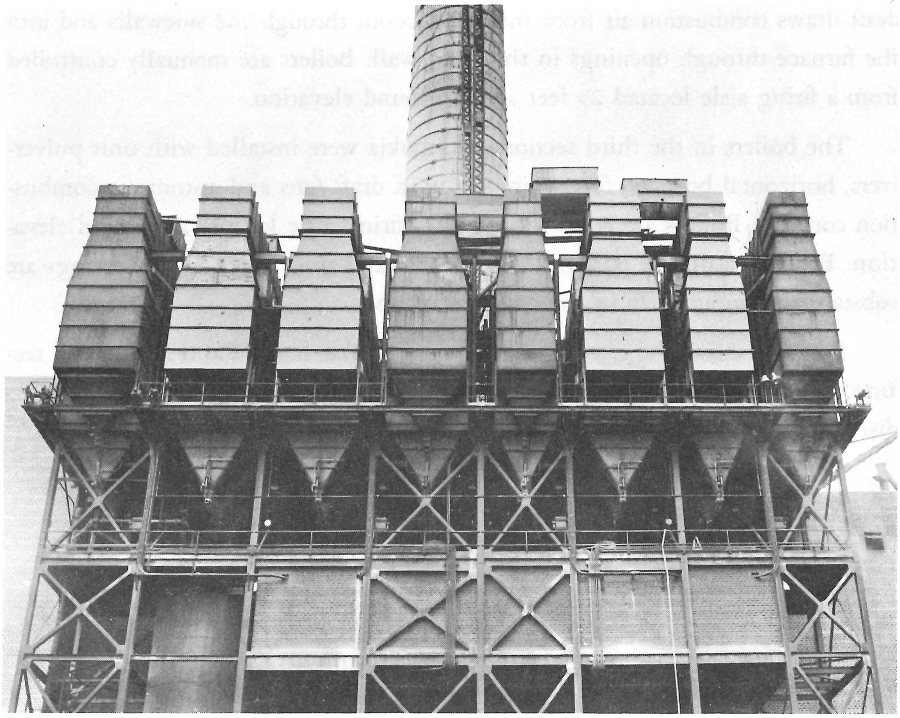

FIGURE 4

In 1949, electrostatic fly ash collectors were installed on boilers 1, 2, 3 and 4. At the same time boilers were converted to a direct fired pulverizer system and were equipped with horizontal circular burners, forced and induced draft fans and furnace wall tubes. Capacity was increased from 110,000 lbs/hr. to 200,000 lbs/hr.

Total cost to purchase and install these twelve fly ash collectors, including the cost of the fly ash disposal system, was $1,150,000.

No further major improvement work was undertaken at Cahokia from 1949 to 1955.

Twelve of the twenty-four boilers were still not equipped with fly ash collectors. Low use factor of these boilers discouraged an expensive fly ash collector installation. Yet operation of only a few of these boilers would give an objectionable stack appearance.

Unfortunately, appearance of the north and south end stacks was frequently objectionable even though all boilers on the south end stacks and half of the boilers on the north end stacks were equipped with fly ash collectors. Often the problem was one of dense smoke emission which the fly ash collectors cannot control. Contributing to the smoke problem was the peaking type of loading experienced at Cahokia as newer, more efficient plants were added to the system.

Effect of Peaking Operation on Stack Appearance

Although the newer plants are better equipped by reason of combustion equipment, controls, and arrangement to handle cycling loads, the economic operation of a system of generating plants requires that the newer plants be base loaded and that the older plants be operated for peaking and reserve. Figure 5

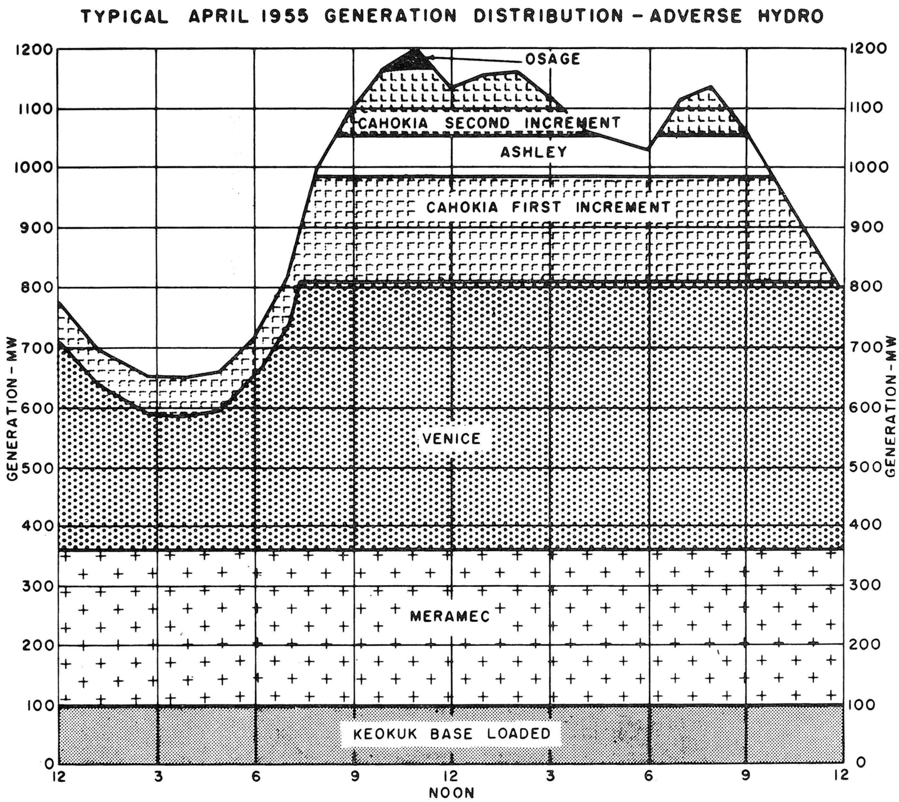

FIGURE 5

illustrates this point showing distribution of generation in the Union Electric system at a time when hydro power usage is at a minimum. Under this condition Cahokia Power Plant, the least efficient of the large steam plants, occupies the position of peaking capacity. This operating condition will obtain for several months during a normal year and will occur more frequently when rainfall is below normal. Figure 6 shows distribution of generation when hydro power is available for peaking use. Under this condition Cahokia generation is relatively constant during the daytime although it is reduced to a minimum at night.

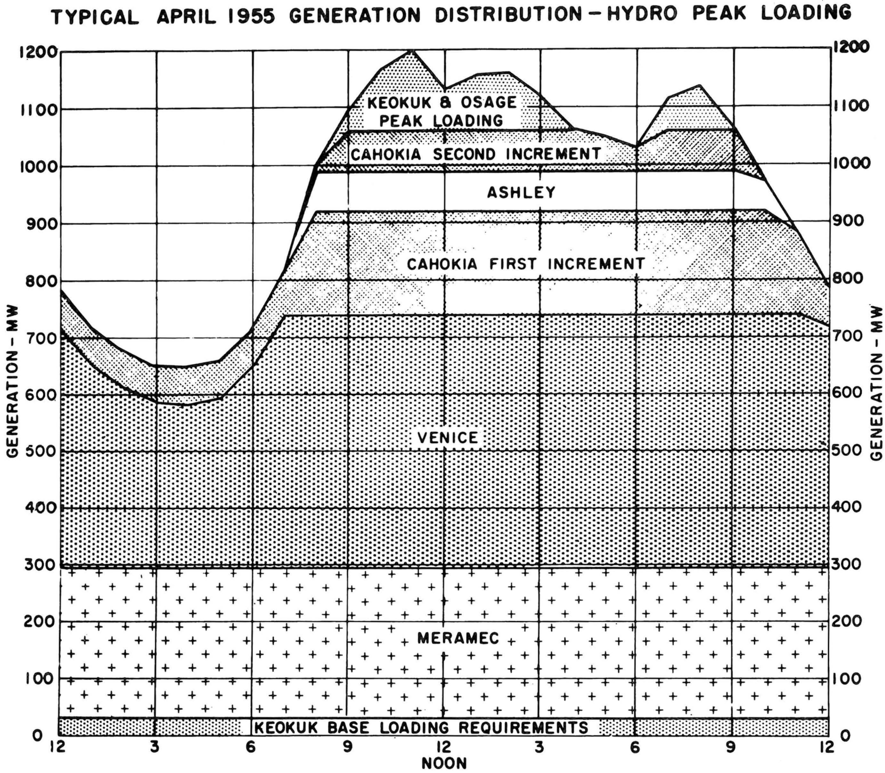

FIGURE 6

On a typical morning, Cahokia generation will increase from a low of 60,000 Kw at 6:00 A.M. to a maximum of 240,000 Kw at 9:00 A.M. with a reserve of 25,000 Kw. To increase generation over this range it would be normal to start three turbines and eight boilers. This would require the starting of 19 pulverizers and the lighting off of 38 burners. Although certain of these boiler operations can take place before plant load increases in the morning, many of these operations must be coordinated with the load increase. Coordination of operation in the boiler room is controlled by one of the boiler operators by means of a public address system. It can be seen that much of the morning scheduled load increase is a manual operation.

This same range of load could be covered by the new Meramec No. 3 unit by starting of two pulverizers, four exhausters and lighting off of sixteen burners. All of these operations would be carried on by one man from one location thus eliminating the need for communication and permitting most of the load increase to be taken on automatic control.

Most of the smoke emission at Cahokia occurs during load increase in the morning and again in the evening at the time of the evening peak. Conservative loading rates of 3 Mw/Min. to 5 Mw/Min. are used to load Cahokia because of the smoke problem.

In February 1955, an Engineering Committee comprised of engineers from the design and operating departments was organized to study the problem of smoke and fly ash emission at Cahokia and to recommend and initiate improvements to existing equipment which would reduce emission to a satisfactory level. As a result of the study and recommendations of this Committee, Management has approved a program of plant improvements for Cahokia Plant which will require a capital expenditure in excess of one million dollars. Although the primary motivation of this program is to improve stack appearance, reduced operating cost and improved efficiency will support a large portion of the expenditure.

Improvement Program

Of the boilers equipped with fly ash collectors, the south end boilers presented the biggest problem to satisfactory control of stack emission. Boilers 19, 21-24 discharge into No. 5 and No. 6 stacks. These are the largest boilers at Cahokia, each capable of a maximum output of 250,000 lbs/hr. Because of their size and because erratic feedwater controls prevented the north end boilers from participating fully in load swings, these five boilers were used for the largest share of load regulation.

Boilers were installed with attrition type pulverizers. Inherent in this type of pulverizer is a decrease in coal fineness as the steel grinding surface wears and as clearance increases between stationary and rotating pegs. Decrease in coal fineness causes an increase in unburned carbon in the fly ash leaving the boiler. High unburned carbon not only represents a loss in boiler efficiency but also adversely affects the performance of the electrostatic fly ash collectors. Collection efficiency drops off rapidly as combustible increases. High carbon content will also result in darker plumes because of the black color of the carbon particles.

Modern attrition type pulverizers frequently are equipped with tungsten carbide wearing parts. The hard tungsten carbide surfaces resist wear, clearances are maintained and coal fineness is held at a high value between overhauls. When tungsten carbide parts are used, a hammer mill pre-crusher is usually installed ahead of the pulverizer to crush the coal before it enters the pulverizer and prevent cracking or chipping of the hard, brittle carbide surface. The cost of the tungsten carbide parts is much higher than steel wearing parts.

As a major improvement, the pulverizers on all five of these large south end boilers have been equipped with the tungsten carbide wearing parts. The original table type feeders have been replaced with a combined feeder-crusher. Coal fineness has increased and carbon in the ash has been reduced from an average of 16% to an average of about 8%. This change in carbon content represents a 1.5% increase in boiler efficiency.

The feeder-crusher uses a drum type feeder designed with a wiper plate which scrapes out the coal from each feeder pocket as the feeder revolves. This feature is particularly helpful when burning a wet or fine coal. Wet and fine coal has a tendency to hang-up in the feeder and discharge to the pulverizer in slugs. This intermittent feed of coal causes boiler fuel-air ratio to become upset and is a source of smoke. By providing a positive and controlled rate of coal feed to the pulverizer, better fuel-air ratio is maintained and smoke is reduced.

Although this installation was undertaken to improve stack appearance, the cost can be economically justified because of improved boiler efficiency and reduced pulverizer maintenance.

Improvements have been made to the fly ash collectors of two of these five boilers. Additional surface was added to the collector by filling the space between sections of the collector with discharge electrodes and collecting plates. Outlet collecting plates were badly warped and were replaced with V-plates. Magnetic impulse, single impact rappers were installed to replace the original swing hammer rappers. The single impact rappers give each section of collecting plates a controlled, relatively light rap, operating in sequence until all sections have been rapped. The rapping cycle goes on continuously and continuously discharges collected ash to hoppers below the collector without causing the familiar rapping puff obtained with the swing hammer rapper.

The combined effect of reducing carbon in the fly ash and the improvements to the fly ash collector resulted in a surprising improvement in collector efficiency. Figure 7 shows test results obtained on No. 24 fly ash collector in 1941 when the collector was first operated and test results after the improvements. Collection efficiency has improved 14 percentage points at the maximum load and 6 percentage points at the normal load.

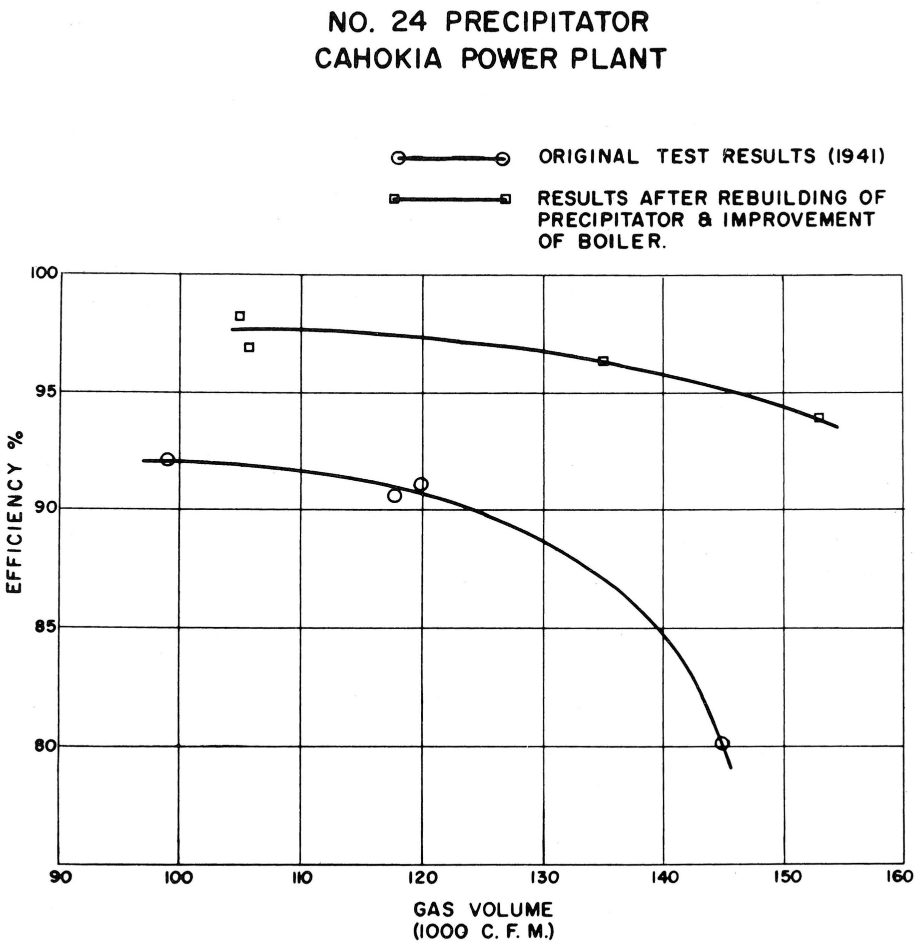

FIGURE 7

Erratic feedwater control can be a cause of smoke. Fuel-air ratio is usually controlled by metering steam flow as an indirect measure of fuel input and by proportioning air to steam flow. A cycling feedwater flow will cause surges in steam flow with no change in fuel flow. Combustion controls will cause air flow to fluctuate with steam flow and fuel-air ratio will alternately be too high and too low. Three-element feedwater controls are being installed on boilers 1-4 to correct an erratic control condition obtained with the present two-element control. It is expected that improved feedwater control will reduce smoke emission from these boilers and will allow a greater amount of regulation than has been heretofore possible.

Smoke recorders are being installed for the guidance of boiler operators and supervisors. The smoke recorder installation is not yet complete at Cahokia. However, experience at the Ashley Plant, in the Union Electric system, is that the smoke recorder is a useful instrument to the boiler operator in his efforts to keep stack density to a minimum.

It is expected that on completion of these improvement projects, Cahokia's fourteen unit mill fired boilers will have the instrumentation, controls, combustion equipment, and collecting equipment to handle the cycling loads required with a minimum of smoke and fly ash emission. Correction of the problems of smoke and fly ash emission from the ten center section boilers will require larger effort and greater expense.

A large number of alternative plans have been studied. Fly ash collectors could be installed. These boilers are natural draft boilers and induced draft fans would be required because of the resistance imposed by the collectors. Total cost would be near $2,000,000.

Load factor at Cahokia is only 40% and load factor of the center section boilers, which are the least efficient boilers, is about 15%. Use of this capacity will continue to decrease as new capacity is added to the system. A large investment in collecting equipment is most unattractive in the face of continuing lower equipment usage, particularly since the expenditure will give no return.

Even though usage is low and will continue to decrease, this 100,000 Kw of capacity has too much value as peaking capacity to permit shutting it down. Capacity would have to be replaced by new steam at about $150/Kw or at a total cost of $15,000,000.

A thorough study of various alternative plans indicated that conversion to oil firing offered the best solution.

The old central coal pulverizing system will be removed. The vertical coal burners are being removed. The front furnace wall of each boiler is being rebuilt to accommodate two horizontal oil fired burners with burner registers and windboxes. Forced draft fans are being installed. To retain side wall cooling the forced draft fans will induce air from the boiler room through the sidewalls to the fan suction. Steam atomization will be used. Push button spark ignitors are being installed to permit quick and safe starting of burners.

Two of the ten boilers have been converted to oil firing. Extensive operating tests were performed on the first boiler converted to oil firing. Tests show that this boiler can be fired from a cold condition, operated at minimum load and loaded quickly to maximum load with a perfectly clear stack. The only exception is that on initial light-off of the first burner, smoke is emitted for a period of about one minute.

Total cost of the conversion to oil firing will be approximately $700,000. Reduced operating and maintenance costs with oil, due primarily to eliminating the antiquated central pulverizing system, will support ninety percent of this expenditure. Fuel cost with oil will be twice that of coal. It is expected that this high cost capacity will be used for reserve and short peak periods only.

Total capital expenditure for the improvements described is approximately $1,000,000. It is estimated that eighty-five percent of this expenditure can be economically justified by lower operating and maintenance costs and improved efficiency. An estimated $150,000 will give no direct return. Fuel cost on the oil fired boilers will be substantially increased and if extended use is required in any year this would represent a major expense. This is not anticipated, however.

Preliminary results of the improvement program have been encouraging. It is expected that on completion of the program next year, the emission of smoke and fly ash from Cahokia stacks will no longer be a problem.

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