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HIGH-RATE SLUDGE DIGESTION

BY CLAIR N. SAWYER,* *Member,* AND HAROLD E. SCHMIDT**

(Presented at a meeting of the Sanitary Section, BSCE, held on October 6, 1954.)

THE search for less troublesome, speedier and more economical ways of accomplishing desired objectives continues relentlessly. This is just as true in the field of sewage treatment as in the most highly organized industry. During the past two decades, we have witnessed the development and almost universal acceptance of the high-rate filter as a secondary purification device. Subsequent to and somewhat as a result of the competition offered by the high-rate filter, we have seen the conventional activated sludge process altered to yield a variety of high-rate processes under the names of "Modified," "Stepped Aeration," "Biosorption" and "Super." Reports from Switzerland (1) and Holland (2) tell of similar developments in European countries. Indications are that even greater developments await improvements in aeration technique to satisfy the tremendous demands for oxygen.

Today we are witnessing the evolution of improved methods of operation of anaerobic digestion units which increases their capacity to such a degree that the term high-rate, in this day of superlative adjectives, does not seem quite adequate.

OLD CONCEPTS

With the development of the so-called heated digester about 30 years ago, it appeared that the ultimate in anaerobic digestion had been reached. They were such an advance over the unheated digestion units that, in retrospect, a 30 year rest on our laurels appears merited. The digestion unit of that day, which includes practically all single stage units that are in existence today, was designed to oper-

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ate as a three layer tank as shown in Figure 1. In such tanks, the biochemical activity is restricted largely to the upper part of the sludge layer in the bottom of the tank. Probably not over 25 per cent

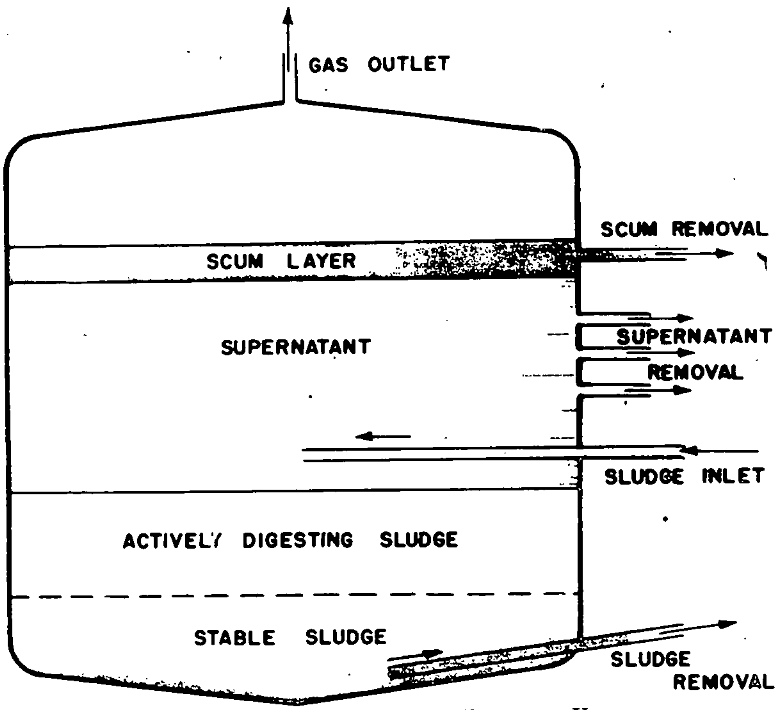

FIG. 1.—CONVENTIONAL SLUDGE DIGESTION UNIT.

of the tank volume is associated with the biochemical degradation of the sludge. The remainder of the tank is utilized primarily as a dewatering device.

EVOLUTIONARY STEPS

Over the course of the years, several major shortcomings of single stage digestion units have become evident as they have been subjected to a wide variety of waste problems and organic loadings. The principal ones are:

1. Scum problems, particularly at high loadings or with inclusion of certain industrial wastes.
2. Inability to always produce a well clarified supernatant liquor.
3. Thermal stratification.

Attempts to overcome the first and the last problems have aggravated the second. As a result the use of two stage digestion units became quite popular, the first stage is operated on a 6-8 day detention period without regard to separation of supernatant liquor, while the secondary digester is used largely as a dewatering device. Under such conditions, mechanical mixers, recirculation and the use of external heat exchangers involving recirculation became common practice. During the same period important developments had occurred in the anaerobic stabilization of industrial wastes. Bloodgood (3) applied anaerobic treatment to high B.O.D. wastes containing low suspended solids using continuous agitation of the digester contents and recycling of a part of the solids captured from the overflow mixed liquor. Fullen (4) has applied this principle to treatment of animal packing house wastes and shown a detention period of about 24 hours to be adequate.

A sublimation of all the newer concepts in regard to anaerobic digestion of sewage sludge and industrial wastes had led to the premise: that the contents of a digestion tank should be continuously agitated or thoroughly mixed at all times, thereby making active use of 100 per cent of the tank volume. This premise serves as the basis for the current developments in high-rate digestion.

High-Rate Systems

The success of any high-rate sludge digestion system depends upon two basic considerations, namely:

1. Maintaining the contents of the digester in constant turmoil and of uniform character from top to bottom.
2. Overflow or withdrawal of mixed liquor in volume equal to the volume of sludge fed.

The most important of these considerations is that of using 100 per cent of the digestion tank capacity for active degradation of the organic matter by keeping the contents constantly agitated. To date this has been accomplished by two methods:

1. Recirculation of gas.
2. Recirculation of sludge assisted by a high rate of gas evolution per unit volume as a result of feeding thickened sludge.

Pearth Process

Although the Pearth Process (5) developed at Washington, D. C., has not been claimed as a high-rate system, it does involve recirculation of gas for the expressed purpose of scum control. The gas is introduced immediately below the scum layer, as shown in Fig. 2. Since scum problems are usually associated with overloaded diges-

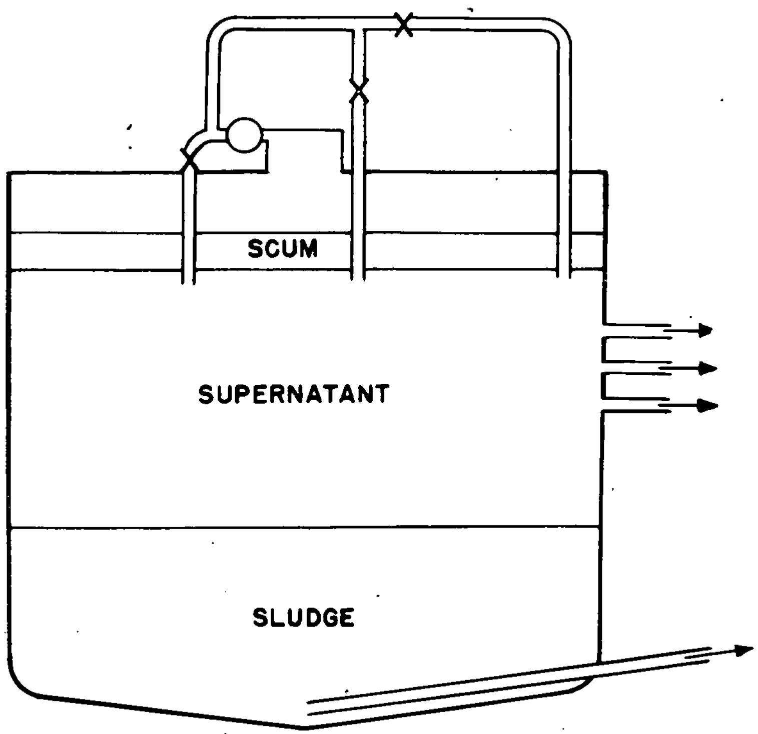

FIG. 2.—PEARTH PROCESS FOR SCUM CONTROL.

tion units, control of scum and maintenance of good conditions for digestion results in accommodating higher sludge loadings. Fuhrman (5) states: "Application of the method will allow appreciable increases in digestion tank loadings. It is believed that loadings of at least 0.12 to 0.15 lb. of volatile solids per cubic foot per day could be applied to modern heated digestion tanks properly equipped with this method of scum control."

CRP Process

The so-called "Catalytic Reduction Process," developed by the Chicago Pump Company through laboratory and pilot plant studies by Prof. Morgan of the University of Iowa (6), employs recirculation of gas in a manner to agitate the entire contents of the digestion unit and, therefore, fulfills the major requirements of a high-rate unit, Fig. 3. Pilot plant studies conducted at the Iowa City sewage treat-

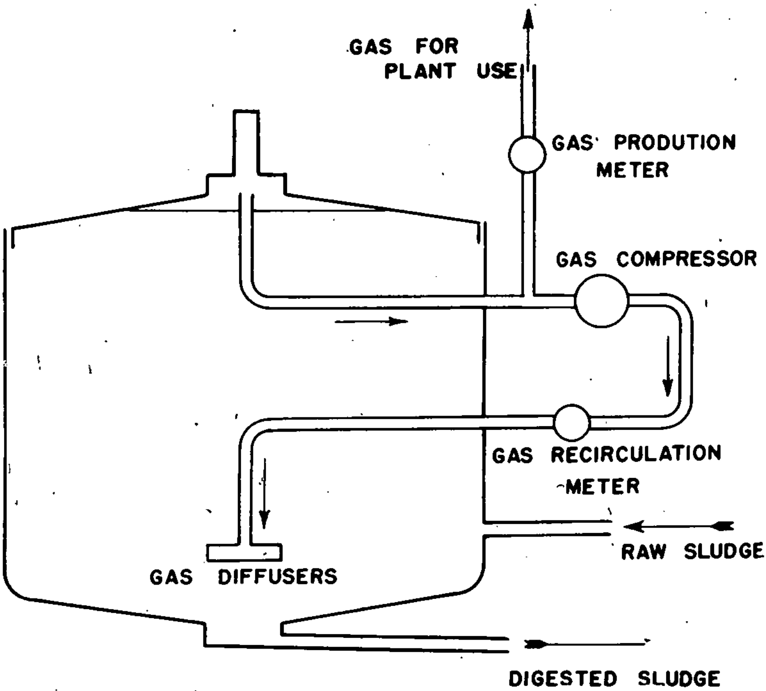

FIG. 3.—C. R. P. OR "CATALYTIC REDUCTION PROCESS."

ment plant demonstrated volatile solids loadings of 0.345 lb. per day per cu. ft. (10.3 lb. per month) could be handled continuously at 95° F.

Blodgett (7) has demonstrated the practical application of the CRP process in one of the 70 foot digesters at the Columbus, Ohio, sewage treatment plant. Gas was recirculated continuously at the very low rate of 76 c.f.m. and solids loading was 3.36 times that on similar separate tanks operating under conventional conditions. Gas production per unit of solids charged to the digester filterability of the sludge remained essentially the same.

Sludge Recirculation and Thickened Sludge

The circulation of the contents of a digester by recycling of sludge to maintain a uniform mixture within the digesting mass does not appear to be a practical method because of the great volumes of recirculated material needed. However, Torpey (8) has met with considerable success at the Bowery Bay plant of New York City where one digestion tank is now accomplishing the work formerly requiring the use of four tanks, which were included in the original design.

According to Torpey, there are three factors which are all important in the successful operation of high-rate sludge digestion units as developed at New York City. These are:

1. Continuous recirculation of sludge.
2. As near continuous feeding of raw sludge, as possible, with the raw sludge being intimately mixed with the recirculated sludge before reaching the digestion unit.
3. Thickening of the raw sludge to such an extent (approx. 10 per cent solids) that the gas evolution per unit volume of digester space is violent enough to keep the total contents well mixed.

It would seem that the last consideration is perhaps the most critical of all and the success of the process would depend upon satisfaction of this item to a great extent. Fig. 4 shows the essential details of the system as used at New York City.

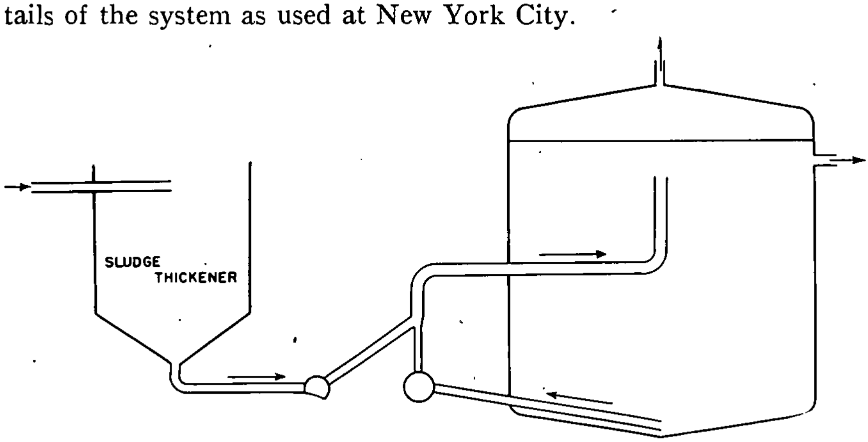

FIG. 4.—NEW YORK CITY SYSTEM—TORPEY.

Combinations of primary sludge with modified aeration solids and primary sludge with activated sludge have both been digested under high-rate conditions at the Bowery Bay plant. During an eight month period when modified aeration was used at the plant, the solids loading to the digester varied from 5.9 to 7.2 lb. per cu. ft. per month. The detention period ranged from 26-36 days as a result of the concentrated sludge (8.3-11.6% solids) which was fed to the digester. During a 5 month period when stepped aeration was used at the plant producing a normal activated sludge, the solids loading varied from 6.6 to 7.8 lb. per cu. ft. per month. The detention period ranged from 11 to 27 days, depending upon the solids concentration of the feed sludge which ranged from 4.6 to 9.0 per cent solids. During these studies, all sludge was handled in one digester which provided only 0.5 cu. ft. of capacity per capita.

Torpey reports that, while the plant scale tests were under way, a pilot scale study was made on the same sludges using a digester equipped with internal mixing. Loadings three times those applied in the full scale unit were satisfactorily handled. The digester capacity corresponded to 0.17 cu. ft. per capita.

Investigations at the Massachusetts Institute of Technology

During the fall of 1952, the junior author enrolled at the Institute as a graduate student. Having worked with Prof. Morgan at the University of Iowa and later for the Chicago Pump Company on development of the CRP process of high-rate sludge digestion, he had well defined ideas of areas of needed research. Because of the lack of knowledge concerning the relative significance of organic loadings versus detention time as limiting factors in sludge digestion, he chose as his thesis problem (9) an investigation of these two factors under conditions of high-rate digestion. The results of these studies substantiate and extend much of the information reported by Morgan (6) and Torpey (8) and add some fundamental information which seems worthy of placing in the published record.

Method of Study

All raw sludge used in the studies was obtained from the primary settling tanks of the Nut Island treatment plant, Boston, Mass. Sludge was obtained on 9 separate occasions in sufficient quantities to last for periods of 7 to 10 days. The volatile solids content of the sludges varied from 69.1 to 81.2 per cent, averaging 75.1 per cent. The sludges were concentrated in the laboratory to at least 8 per cent solids and then diluted to yield stock sludges containing 2, 4, 6 and 8 per cent solids. The stock supplies of sludge were kept under refrigeration at 5°C.

Four sludge digestion units were used as shown in Fig. 5. These consisted of 9.5 liter tall form Pyrex bottles equipped with facilities for adding raw sludge, removal of mixed liquor, and collection of the

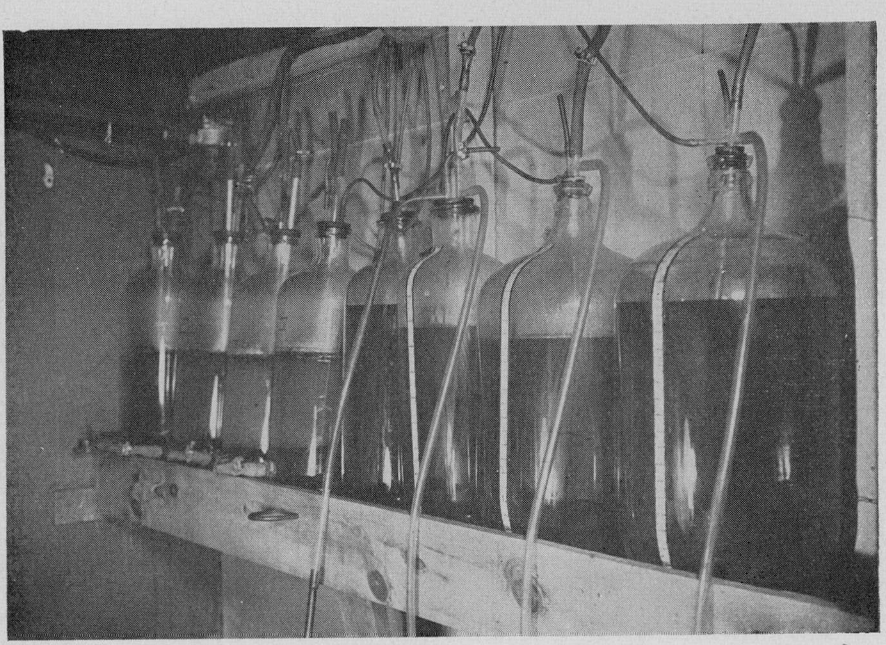

Fig. 5.—Sludge Digesters in Incubator.

gas produced. Stirring by recirculation of gas was tried but, due to lack of adequate facilties, was abandoned in favor of thorough hand shaking following each addition of sludge and, also, prior to the removal of mixed liquor. Mixed liquor in volume equal to the feed sludge was removed prior to each feeding and served as material for chemical analyses. Six liters of sludge mixture were maintained in each digester and feedings were made twice each day at 12 hour intervals. Equal portions of the stock supplies were fed to the proper digesters after warming to 35°C. Thus, No. 1 digester received 2 per cent sludge, No. 2 digester 4 per cent sludge, No. 3 digester 6 per cent sludge, and No. 4 digester 8 per cent sludge at all times. The volume of sludge fed was controlled to give theoretical detention periods of 14, 11, and 8 days. The studies were conducted at each detention time sufficiently long to produce approximately two complete displacements of the digester contents. Digested sludge obtained from the Leominster, Mass., sewage treatment plant was used to seed the digestion units originally, mixtures containing 2, 4, 6 and 8 per cent solids were used.

Experimental Results

14 Day Detention Period

Each digester containing 6 L. of sludge was fed 430 ml. per day of sludge having the proper concentration of total solids for a period of 25 days. Although the digestion units behaved in a somewhat erratic manner during the first week of feeding they soon leveled off in behavior and it was unnecessary to relieve the load applied at any time. A summary of the data obtained is given in Table I.

TABLE I

High-Rate Digestion Studies—14 Day Detention

	Digester 1	Digester 2	Digester 3	Digester 4
Solids in feed, %	2	4	6	8
Loading				
Lbs. total solids/ft^3/mo.	2.7	5.4	8.3	10.5
Lbs. vol. solids/ft^3/mo.	2.0	4.1	6.2	8.0
Solids in digested sludge, %	1.35	2.67	3.86	5.20
V_m in digested sludge, %	58.8	58.7	57.9	58.5
pH	7.05	7.10	7.15	7.25
Volatile Acids, ppm.	100	150	150	380
Gas Production				
Liters per day	3.66	8.28	11.3	17.1
cu. ft./lb. V_m dest.	16.6	17.8	16.6	18.4
Reduction of V_m, %	56.7	56.9	58.3	57.2

The sludge fed during this period averaged 76.7 per cent volatile matter. Reduction of volatile matter was about 58 per cent and gas production varied from 16.6 to 18.4 cu. ft. per lb. of volatile matter destroyed. The solids loading on the digesters varied from 2.7 to 10.5 lb. of total solids and from 2.0 to 8.0 lb. of volatile solids per cu. ft. per month, depending upon the solids in the sludges fed to the digesters.

The pH, volatile acids, gas yield, and volatile matter destruction data all indicate the digesters operated smoothly and without distress, regardless of the loadings or concentration of sludge applied.

11 Day Detention Period

On the 26th day of the study, the amount of sludge fed to the digesters was increased from 430 to 535 ml. per day to give a theoretical detention period of 11 days. Feeding was continued at this rate for 20 days to correspond to approximately two displacements of digester contents. A summary of the results obtained during this period is given in Table II.

TABLE II

High-Rate Digestion Studies—11 Day Detention*

	Digester 1	Digester 2	Digester 3	Digester 4
Solids in feed, %	2	4	6	8
Loading				
Lbs. total solids/ft^3/mo.	3.3	6.7	10.3	13.5
Lbs. Vol. solids/ft.^{3}/mo.	2.5	5.1	7.8	10.2
Solids in digested sludge, %	1.14	2.22	3.45	4.90
V_m in digested sludge, %	58.4	57.7	58.0	58.6
pH	6.70	6.95	7.05	7.15
Alkalinity, ppm.	1250	2300	3200	4350
Volatile Acids, ppm.	90	125	135	260
Gas Production				
Liters per day	4.58	8.90	13.25	19.60
Cu. ft./lb. V_m, dest.	16.4	15.5	15.5	17.5
Reduction of V_m, %	54.6	56.1	55.4	54.2

*Cubic feet per lb. of volatile solids charged to digestion units.

The increased load, ranging from 3.3 to 13.5 lb. of total solids or from 2.5 to 10.2 lb. of volatile solids per cu. ft. per month, applied during the eleven day detention studies was assimilated by all digestion units without difficulty. The sludge fed during this period averaged 75.6 per cent volatile matter. The pH, volatile acids, gas yield and volatile matter information all indicate the digesters were operating satisfactorily. This was substantiated by no indication of deterioration as the run progressed.

The data in Table II point up some information in regard to how the per cent solids in the sludge fed to a digester determines to a great degree the conditions within the digesting mass. For example the pH ranged from a low of 6.7 in the digester fed a 2 per cent sludge to a high of 7.15 in the digester fed an 8 per cent sludge. The alkalinity was found to vary in almost direct proportion to the solids content of the sludge fed, also.

A comparison of the data in Tables I and II shows the pH to have declined with the shortened detention time, volatile matter increased in the digested sludge and an appreciable reduction in volatile matter destruction occurred. These data illustrate that the pH of digesting sludge will be a function of the solids content in the feed sludge and the degree of volatile matter destruction as influenced by detention time or other factors which affect the destruction of organic matter such as temperature.

8 Day Detention Period

After 45 days of operation, the amount of sludge fed to each digestion unit was increased to 750 ml. per day to yield a theoretical detention of 8 days. The digesters were fed at this rate for 16 days at which time the investigation was concluded. A summary of the data obtained is given in Table III.

TABLE III

High Rate Digestion Studies—8 Day Detention

	Digester 1	Digester 2	Digester 3	Digester 4
Solids in feed, %	2	4	6	8
Loading				
Lbs. total solids/ft.^{3}/mo.	4.6	8.9	14.3	19.3
Lbs. Vol. solids/ft.^{3}/mo.	3.4	6.5	10.5	14.2
Solids in digested sludge, %	1.24	2.16	3.33	5.06
V_m in digested sludge, %	58.8	56.3	55.8	56.2
pH	6.40	6.75	6.95	6.85
Alkalinity, ppm.	1080	1820	2600	3580
Volatile Acids, ppm.	660	800	300	1780
Gas Production				
Liters per day	4.50	11.2	16.9	24.3
Cu. ft./lb./V_m dest.	13.6	15.4	15.0	16.6
Reduction of V_m, %	48.3	53.2	54.2	53.6

During this study the first evidences of distress were noticed. After 11 days of feeding at the 750 ml. per day rate, the pH began to decline in Digesters 1 and 4, receiving the 2 and 8 per cent sludges. Digesters 2 and 3 remained in a stable condition. The volatile acids increased in all digesters but only in Digester 1 receiving the 2 per cent sludge did the gas production decline unduly. This was probably a result of the low pH which developed, occasioned by the low alkalinity which was unable to properly buffer the volatile acids released. Volatile solids destruction was significantly lower in Digester 1, also. This reflects the inability of the organisms, under the conditions which developed in Digester 1, to keep pace with those in the other digesters.

From the results of the 8 day detention studies, it would appear that it would be hazardous to attempt operation of digestion units on such a short detention period under conditions used in this experiment, namely feeding twice daily followed by short term thorough agitation.

Discussion

Solids Loading vs. Detention Time

This investigation has shown that a 14 day and even a 11 day detention period provide sufficient time for a stable operation of digestion units at 95°F, regardless of the concentration of solids in the raw sludge (range 2 to 8 per cent), with twice daily feeding and thorough mixing of the digester contents following each feeding. With a detention period of 8 days, operation would be unreliable under the conditions cited. Indications are that difficulty would be most apt to develop with low concentration sludges. This supports the contention that detention time is more important than solids loading and is, probably, the important consideration in high-rate digestion. This is supported by the uniform per cent of volatile matter destruction at the 14 day and at the 11 day detention periods as shown in Fig. 6. These conclusions are in agreement with Rankin (10) who concluded from a review of digester operating data from 17 plants that detention time and not solids loading was the most important consideration.

Destruction of Volatile Matter

The data in Fig. 6 show the effect which decreased detention time has upon volatile matter destruction. The results were, undoubtedly, influenced to some degree by the lower amount of volatile matter in the feed sludge as the detention time decreased. One of the limiting factors concerning the application of high-rate digestion is volatile solids reduction. These data would indicate that detention periods of 10 days should provide a well stabilized sludge with a reasonable degree of volatile solids destruction.

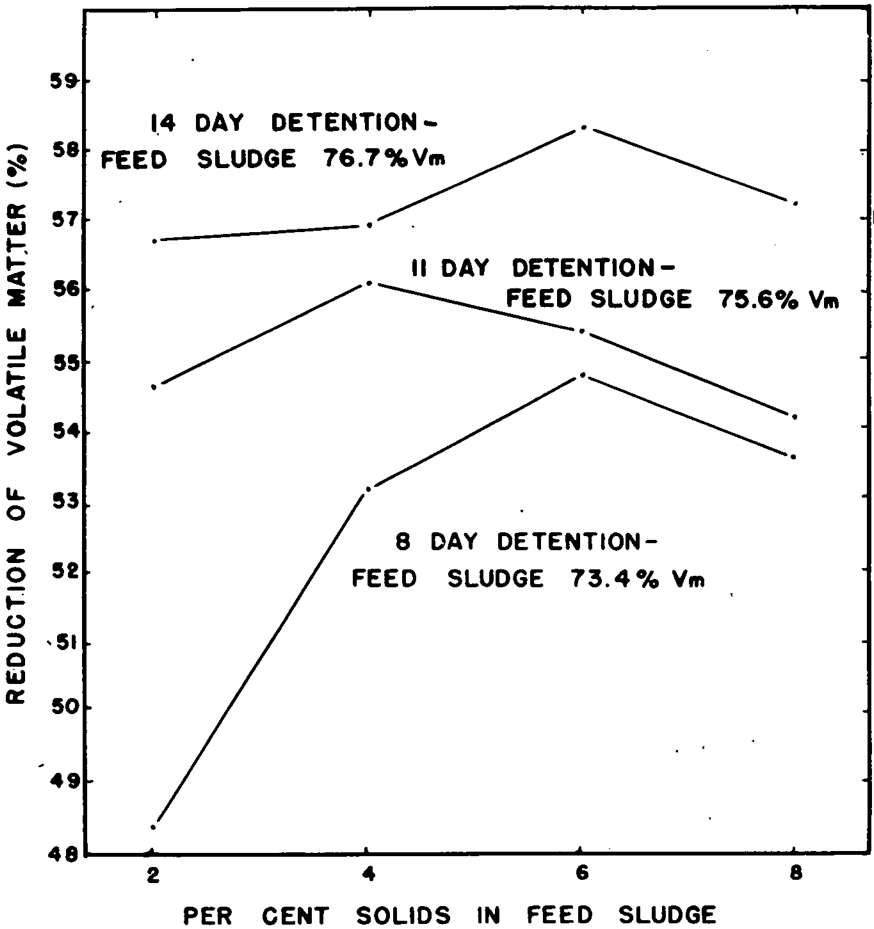

FIG. 6.—DESTRUCTION OF VOLATILE SOLIDS VERSUS DETENTION TIME.

Gas Production

The economical operation of many treatment plants depends upon utilizing the sludge gas produced to the fullest extent. One important question which may be raised concerning high-rate digestion concerns how it will affect gas production and the quality of the gas produced. Unfortunately, no studies were made of gas quality during the studies at M. I. T. However, gas production data were obtained and are summarized in Table IV.

TABLE IV

Gas Production Versus Detention Time*

	2% Sludge	4% Sludge	6% Sludge	8% Sludge	Avg.
14 Day Detention	9.4	10.1	9.7	10.5	9.9
11 Day Detention	9.0	8.7	8.6	9.5	9.0
8 Day Detention	6.6**	8.2	8.1	8.9	8.4

*Cubic feet per lb. of volatile solids charged to digestion units.
**Excluded from Average.

The data in Table IV indicate that gas production with an 8 day detention period would be only 85 per cent of that with a 14 day detention period. Thus, it may be concluded that gas yield will suffer seriously as the detention period approaches and falls below 15 days. This factor could very well be the one which determines the practical detention time in many situations and not biochemical limitations.

Torpey (8) has indicated about 93 per cent of the normally available gas was produced from a high-rate digester operating with a 26 to 36 day detention period, 88 per cent at 22 days, and 83 per cent at 11 days. These values appear low in view of the data given in Table IV and indicate the need for further work to evaluate gas yield with respect to detention time.

Alkalinity and pH

The data shown in Tables I, II and III illustrate some very pertinent information concerning the relationships which exist between pH, alkalinity, concentration of sludge solids and detention time. These relationships are shown in Fig. 7 and demonstrate that the pH of an operating digester will be determined to a great degree by the solids content of the feed sludge and the detention time. The alkalinity will vary in almost direct proportion to the solids content of the sludge fed to the digester and will rise and fall with increase or decrease in detention time.

Survival of Pathogenic Organisms

One of the big questions which may be asked about digestion concerns the survival of pathogenic organisms. It has been commonly accepted that sludges subjected to conventional sludge digestion can be safely dried on open beds and, with certain precautions, used as fertilizer. Will the same be true of sludges from a high-rate process?

It seems highly probable that the sanitary quality of sludges produced in high-rate digestion processes will be rather poor. There are two major reasons for such an assumption. First, the short term deten-

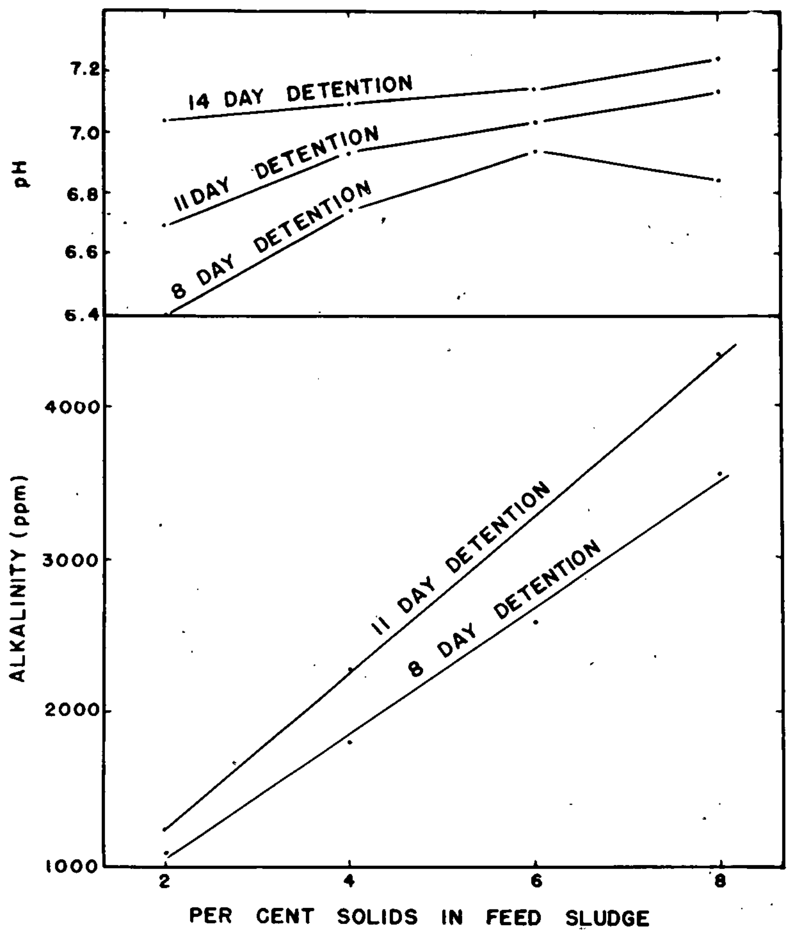

FIG. 7.—ALKALINITY AND pH IN RELATION TO SOLIDS CONCENTRATION AND DETENTION TIME.

tion of possibly 10 days, is bound to be less effective in destroying pathogenic organisms. Second, with the contents of the digestion units being maintained in a so-called "mixed liquor" condition with more-or-less continuous additions and overflow of sludge, the sludge leaving the digestion unit will always contain a percentage of raw solids and some 1, 2, 3, etc. days old. In other words the sludge leaving the digestion unit will consist of a relatively large amount of sludge having had a very short detention time under anaerobic conditions. It becomes pertinent then to evaluate the survival of pathogenic organisms under conditions of high-rate sludge digestion to ascertain the sanitary quality of the sludge produced. Such a study has been initiated at M. I. T. under sponsorship of the National Institute of Health.

Conclusions

1. Detention time is the most important consideration in the operation of high-rate sludge digestion units. Satisfactory operation was obtained with detention periods as short as 11 days.

2. Permissible solids loadings are a function of the concentration of solids in the sludge fed to the digester because of limitations imposed by detention time. For a sludge with about 75 per cent volatile matter and digestion temperature of 95°F., the following maximum loadings are indicated.

2 per cent sludge— 3.3- 4.6 lb. per cu. ft. per month
4 per cent sludge— 6.7- 8.9 lb. per cu. ft. per month
6 per cent sludge—10.3-14.3 lb. per cu. ft. per month
8 per cent sludge—13.5-19.3 lb. per cu. ft. per month

3. Volatile solids destruction will decline considerably with decreasing detention time and gas production will suffer accordingly.

4. The pH and alkalinity of digestion mixtures increases as the total solids increases in the feed sludge.

5. pH and alkalinity are a function of detention time, decreasing with shortened detention periods.

6. High-rate sludge digestion will find practical application in locations where facilities are available for more or less continuous handling of the mixed liquor which is displaced by additions of raw sludge.

7. Most satisfactory operation will be obtained by feeding thickened sludges which will produce a mixed liquor overflow of at least 4 per cent total solids. Thickened sludges are necessary to obtain sufficiently long detention periods (15 days) to allow satisfactory reduction of volatile solids, maximum gas production and elimination of supernatant liquor. Where adequate thickening of sludges

(8-10% solids) cannot be obtained, secondary units for dewatering of the digested sludge will be required.

8. Elutriation of digested sludges prior to chemical conditioning for vacuum filtration will become a necessity because all biochemical degradation products contributing to alkalinity will be concentrated in the sludge liquor.

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BACKGROUND AND HIGHLIGHTS OF THE INTERIM REPORT OF THE COMMITTEE ON EVALUATION OF ENGINEERING EDUCATION

By Harold L. Hazen*

(Presented as part of a Symposium on the Education of the Future Engineer at a meeting of the Boston Society of Civil Engineers, held on September 29, 1954.)

From the fact that the last program of the Boston Society of Civil Engineers devoted to engineering education was held in March 1931, I make the assumption that the audience this evening consists predominantly of practicing engineers. I see a few professors scattered here and there, but as for the rest of you, I must express a certain admiration of your fortitude in exposing yourselves voluntarily to an entire program on engineering education, conducted primarily by pedagogues. I trust that you are aware of the hazard you incur in such an exposure. Perhaps your college days have receded into such a dim distance that you have forgotten how dull a professor can be. But you have asked for it, so on with the show.

First let me state very briefly what the so-called Interim Report covers. The Interim Report expresses the educational philosophy rather widely held by the best thinkers of our engineering faculties and represents the direction in which engineering education will most probably evolve over the next few years.

The Report may be called idealistic and progressive, but actually its conclusions are a recalling of enduring ideals and a reemphasis of fundamentals.

The highlights of its conclusions, as I see them, are these:

(1) The study of science is so important to the engineer that science must take precedence over technology or administration whenever a choice of emphasis must be made; (2) the humanities and the social sciences are a vital part of an engineer's education; (3) good teaching strives less to instruct than to draw out, to inspire a student to develop his own initiative; and finally, the need to recognize that the foundation upon which a good engineering school must build is

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its faculty, for the tone of the school will rise no higher than its faculty.

But where did this Report come from, who wrote it, and what is its significance in engineering education? The Committee on Evaluation of Engineering Education is a committee of the American Society for Engineering Education. The ASEE (we too have fallen for alphabetization) stands with respect to the engineering education in a position quite parallel to that of the American Society of Civil Engineers with respect to Civil Engineering. It is the national society of engineering educators. Its activities are wide-ranging, its annual meeting in June each year attracts well over 2000 people who discuss for a week, in hundreds of sessions, all phases of engineering education. Its membership and activities have a certain quality of universality, including the petty but also including much of the major thinking of the country's leaders in engineering education.

Included among the 40 odd members of the Evaluation Committee are a goodly share of those whose names are associated with the important movements and activities in engineering education in this country. The Interim Report of this committee, issued after two years work and study, greatly assisted by industrial grants, is therefore a document of some significance. Its significance is not diminished by the fact that it benefited from two sets of serious, thoughtful, detailed reports from over 120 engineering-faculty committees in as many institutions. The first set of institutional committee reports was based on a study requested by the Evaluation Committee and stimulated by a series of questions concerning broad problems confronting engineering education. The second set of reports resulted from the consideration of the first, or preliminary, report of the Evaluation Committee. The total volume of material thus made available to the Evaluation Committee was indeed impressive not only for its sheer bulk but for the clear evidence it gave of searching thought and study on the part of the engineering-faculty committees of every one of these 100 odd institutions.

The Evaluation Committee Interim Report is by no means unique in ASEE. The Mann Report of 1918, the Wickenden Report issued in the '30s, the Jackson Report of 1939, the "Aims and Scope of Engineering Curricula" of 1940, the "Engineering Education after the War" of 1944, and others have all been significant studies that have had great influence over the country on the development of engineering education. The Interim Report is a natural sequel to these earlier reports, a rethinking in today's context of fundamental ideals and principles. It responds to the charge of Dean S. C. Hollister, of Cornell, in May 1952 as President of ASEE: "To determine the pattern or patterns that engineering education should take to keep pace with the rapid developments in science and technology, and to educate men who will be competent to serve the needs of, and provide the leadership for, the engineering profession over the next quarter-century."

The Evaluation Committee has had the benefit of very extensive thinking not only of engineering faculties throughout the country, but also of employers of engineers. It is indeed interesting that the emphasis of the industrialists was strongly on the side of science, in contrast to technology or administration, whenever a choice had to be made.

A final report of the Evaluation Committee is expected by next summer. Present trends of thinking across the country suggest that it will differ in no major particulars from the Interim Report.

With the background, let us look at the report itself. Its 28 printed pages are too meaty for me to convey adequately in the time at my disposal. I shall therefore exercise the pedagogical prerogative of attempting primarily to stimulate you to study it carefully yourself. It appears in the September, 1954, issue of the ASEE Journal of Engineering Education. Copies of the report can also be obtained from C. E. Watson, Editor ASEE Journal of Engineering Education, Northwestern University, Evanston, Illinois, for twenty cents each.

The practicing engineer, whose real business is solving the problems of the day and above all getting things done, may regard this report as quite idealistic and somewhat aloof from the work-a-day world of affairs. In this context I would urge two points. The first point is that if you are seriously interested in today's engineering education for tomorrow's problems, you give your educator colleagues the benefit of your observations and reflections. The second point is, and I say this without apology, that you recognize the responsible engineering educators across the country as the real professionals in their field. This carries the implication that even though they sincerely solicit your ideas, they retain the privilege, in view of their total evaluation of the needs of engineering education for the future, of differing from you in some of their mature conclusions. This is said with full respect for educational contributions of the practicing engineer, whose ideas are often thoroughly sound and whose criticisms are frequently all too valid. We must remember, however, that the engineering educator has a wide responsibility to a great variety of users of engineering talent. He must therefore seek in his curricula to achieve for his students a kind of greatest common denominator for all future engineers, usually at the expense of providing specific preparation for particular users of engineering talent. I will go further and say that in the past the great and forward-looking engineering educators have had the vision to see ahead farther than their industrial contemporaries, have gone contrary to them in the sense of insisting upon the fundamental instead of the immediately "practical", and have been proved right by the performance in subsequent decades of their students. I hope you will forgive me for stating this point with some strength and arbitrariness. You are invited to disagree but also to respect the conclusions of the recognized leaders in engineering education.

As I have said before, the practical man may well view this report as an idealistic document. I believe it is, and I believe that it should be. You may find some of the statements in the Report challenging. May I lift a few out of context, which may make them more striking, although I do not believe that it will seriously distort their meaning. For example, from page 10: "The most important goal of engineering education is to motivate the student to learn on his own initiative." Again: "The instructional goals of engineering education include helping the student to learn to deal with new situations in terms of fundamental principles, on his own initiative, and with confidence and sound judgment." Specific skills as an objective are conspicuous by their absence.

The Report does give considerable attention, and indeed quite explicit statements regarding the curriculum content of an adequate undergraduate engineering education, but I believe I am reading the Report correctly when I say that these curricular components are regarded primarily as a medium for developing a kind of quality of mind and a way of thought that will prepare individuals for further development in whatever future environment they find themselves.

A second illustration, to my mind, of the depth of this report is its major emphasis on faculty as the key to quality. On page 4, after mention of a number of factors that influence the effectiveness of engineering education, appears the sentence: "Nevertheless, thoughtful consideration inevitably leads to the conclusion that the character and quality of the faculty are of controlling importance." The first major section of the Report, following a statement of objectives, is therefore entitled "The Selection and Development of an Engineering Faculty." If I may be permitted a personal note, may I say that the cogency and force of this statement concerning the preeminent importance of faculty had been repeatedly and increasingly forced upon my consciousness in my work in connection with the ECPD accreditation program.

As stated earlier, the Interim Report stresses the importance of science and engineering science at the expense, if necessary, of technology and engineering art, and also the importance of the non-scientific components of a liberal education. Both of these ideas, namely the emphasis on science as against technology, and the emphasis on humanities and social science, have characterized the thinking of leaders in the field for many years. It is notable, however, that the institutional responses to the committee have reflected a very important and significant trend toward recognition of these ideas on a much wider front than was characteristic of the thinking in engineering faculties two or three decades ago. This undoubtedly expresses a growing appreciation of the role that the engineer plays, potentially and actually, in the world of affairs, in a technology that is growing in sophistication with accelerated speed, and in a society that is demanding that its professional people be persons increasingly capable of wise, and not merely scientifically competent, decisions.

Some of you may be alarmed by an implication that the good, competent practitioner of technology will no longer be a product of our schools in future years to do the technical jobs on which our industry and economy so heavily depend. This is a big subject, on which I shall comment only briefly. However, I am not worried about the adequacy of supply of this sort of person.

The potential supply of faculty is such that however much we strive for great leadership in our faculties, we shall always have a large, if not indeed predominant, fraction of our professors over the country whose real competence and inspiration of students will lie primarily in the field of technical competence. Experience with the population of students attracted to engineering likewise indicates that a major fraction is intrinsically qualified for, and will be happiest in, work of a primarily technical character.

The Evaluation Committee Report is perhaps saying that the most serious problem in engineering education is to provide opportunity for best development of those students in engineering who give some promise of leadership in their profession, who will move the profession ahead and who will be responsible for the bold, forward-looking innovations. In its Preliminary Report the Evaluation Committee thought seriously of bifurcation, which meant appropriate alternative routes somewhat differentiating between the competent, practicing technologist on the one hand, and on the other, the person who could be encouraged toward a more creative type of leadership in the profession. Neither the faculties nor large segments of the profession would have any of it; they were all for what appeared to them to be the more challenging and more idealistic program.

Finally, the Report in the last section, Evolution of a Common Stem of Engineering Curricula, goes out on a limb, so to speak, in illustrating what it means by a possible common stem by suggesting an approximate allocation of semester hours among the major areas in an engineering education. It did this with some trepidation and with the attempted safeguard of many lines of italics, emphasizing the purely suggestive character of any such tabulation and the great need for experimentation rather than standardization of curricula.

It is hoped that some such broad specification of what indeed constitutes an essential minimum of engineering in a curriculum may be helpful to the Education Committee of ECPD in its work of determining what curricula do, in fact, meet minimum standards to qualify as engineering curricula. This is especially significant in considering so-called "fringe" curricula such as biological engineering or engineering physics.

In conclusion, may I say that I have not touched upon many areas discussed in the Report. I have tried to suggest its spirit and tenor with the hope that some of you will have had your interest sufficiently piqued to go to the Report itself to learn at firsthand what these long haired professors are really thinking about in their work of preparing young men to be the responsible engineers of twenty-five years hence.

THE HUMANISTIC-SOCIAL CONTENT OF ENGINEERING CURRICULA

By William C. White*

(Presented as part of a Symposium on the Education of the Future Engineer at a meeting of the Boston Society of Civil Engineers, held on September 29, 1954.)

It is a pleasant privilege for me to participate in this discussion on "Education of the Future Engineer" and to address my remarks in particular to the non-technical content of engineering curricula.

There has been a growing concern among practicing engineers, industrialists, and engineering educators in recent years for the cultural development of engineering students and a great deal of discussion has taken place as to ways and means for encouraging this to best advantage in the limited time available during the four or five years of study leading to the baccalaureate degree. Considerable impetus was given to the movement for liberalizing engineering curricula about fifteen years ago by the work of Committees of the American Society for Engineering Education under the chairmanship of the late Dean Harry P. Hammond of Penn State College. Reports of his committees in 1940 and again in 1944 pointed out in very definite fashion the objectives of the humanistic-social stem in engineering education and suggested methods of organization to accomplish these objectives. The 1944 report recommended the inclusion of a designed sequence of courses in the social studies and humanities extending throughout the four undergraduate years and requiring a minimum of approximately twenty per cent of the student's educational time.

Although there has been general acceptance of this proposal in principle by engineering faculties throughout the country, it appears to be doubtful that instruction in the humanities and social sciences to the extent recommended and with the effectiveness envisioned by the Hammond Committees has actually been established among engineering schools throughout the country, although there are some notable exceptions. There are many reasons for the lag in this phase of curriculum development, in addition to the normal inertia of edu-

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cational institutions in putting into effect new ideas. Among these are the pressure for more work in mathematics and the engineering sciences, the urge to include additional professional courses in the upper years, the administrative difficulties in getting suitable leadership for an appropriate sequence of courses in the humanistic-social field, the exigencies of World War II, and the tendency to permit substitution of Advanced R.O.T.C. courses for part or all of the liberal subjects in the last two years of the curriculum.

A recent Bulletin* of the U. S. Office of Education prepared by Jennings B. Sanders contains some interesting statistical information on the continued imbalance between technical subjects and the social sciences and humanities. (These data pertain to 112 current curricula in mechanical engineering, but Mr. Sanders also examined representative programs in civil and electrical engineering and reports that the differences in pattern with respect to liberal content are not significant.)

To give you a picture of the present over-all situation with respect to the proportion of the undergraduate program given the social sciences and humanities, I quote from Mr. Sanders' monograph:

"Examination of engineering curricula (some of them over a long period of years), indicates that more than 80 per cent of the student's program is in the three subjects of engineering, mathematics, and physical science. Of an average curriculum of 138 semester hours for five institutions in 1903, these subjects represented 84 per cent and in an average curriculum of 138 semester hours for the same institutions in 1953, they represented 83 per cent. (This does not necessarily mean that curriculum content has remained the same for the last 50 years, but simply that the allotment of time to these segments of the program is essentially unchanged.) Of the average curriculum of 141 semester hours for 112 institutions in 1953, these three subjects accounted for 82 per cent of the total, thus suggesting that engineering educators have long found it difficult to compress the subjects of engineering, mathematics, and physical science into a curricular area as small as that implied in the report of 1944—80 per cent as a maximum. It must be noted, too, that of the 16 to 18 per cent of the curriculum that remains after these three subjects have been subtracted, small portions will be represented by profes-

*Pamphlet No. 114, 1954, General and Liberal Educational Content of Professional Curricula in Engineering—U.S. Department Health, Education, and Welfare.

sionally related courses* and by liberal arts electives that will be chosen in mathematics or physical science.

"From the foregoing it is clear that much less than the minimum 20 per cent of the curriculum as recommended in 1944—in some instances from 0 to 3 per cent is required in those nonprofessional courses in the social sciences and the humanities that might be expected to help equip students for living in an age of complex cultural issues and problems."

So much for the quantitative aspects of the matter. Turning now to the more important question of what is to be done with the time allotted to cultural studies—I would like first to summarize the objectives for this segment of the curriculum recommended by the 1944 Hammond Report to ASEE and then to discuss some approaches that may be serviceable in achieving these aims. There were six specific objectives proposed, comprising in the aggregate quite a large order:

1. To understand how the present organization of society came about and what part science and engineering had in its development.
2. To acquire skill in analyzing social and economic problems for the purpose of forming meaningful judgments regarding them.
3. To develop competence in oral and written expression.
4. To become acquainted with some of the masterpieces of literature and their influence upon the course of civilization.
5. To arrive at a satisfying personal philosophy consistent with the responsibilities of a professional engineer—and
6. To work up enough momentum in the assault upon the five foregoing objectives to sustain a lifelong striving for their achievement.

I submit that an undertaking of this scope and importance cannot wisely be assigned exclusively to any fractional part of the curriculum and that the student's program as a whole should be designed to contribute as effectively as possible to the achievement of these aims. Courses in mathematics, science, and engineering need not be devoid of cultural value, and I am sure that many of us here tonight can testify to the insights into philosophy and ethics that we caught from teachers who were primarily concerned with engineering subject matter.

Dr. Virgil Hancher pointed out eloquently in his address to the

*Such as Construction Finance, Contracts and Agency, Cost Accounting, and Industrial Management.

Association of Land Grant Colleges last year that liberal education in professional curricula can be substantially enhanced if the teacher of technology is alert to the possibilities and interested enough to capitalize upon them. This emphasizes again the paramount importance—brought out in the Interim Report which Dean Hazen highlighted—of providing as members of an engineering faculty, men whose technical competence is matched by breadth of interest and social understanding.

Extra-curricula activities are another source of help that can be brought into play as part of an integrated approach to the development of the student's capacity to take his part in the community as a citizen with professional status and responsibilities. The great advantage here is that the student learns by actually participating rather than by reading a book. He takes part in the musical clubs, writes for the college paper, addresses the student branch, organizes a dance, plans a program for some event, and gains both competence and confidence in the process.

I could mention other factors incidentally useful in furthering the cultural growth of engineering undergraduates, but I shall refrain from doing so for my purpose is simply to point out that the fifth of the curriculum allocated to the humanistic-social studies need not be the only contributor to the objectives of the Hammond Report.

Since there is rather general agreement, however, that over and above the informal and incidental aids to the cultivation of the whole man which may be provided in various ways, there should be some 25 or more semester hours reserved for classroom instruction in the humanities and social sciences, the question arises as to what content and arrangement of subject matter in this segment of the curriculum will yield the most fruitful results. Engineering schools have answered this question in a great variety of ways, and I suspect that a perusal of current undergraduate programs would reveal greater differences from institution to institution in the provision for this aspect of the curriculum than for the scientific technological stem.

Courses in English composition, in effective speaking, and in the principles of economics are usually included, but beyond these the pattern is indistinct. In some schools a carefully planned sequence of courses designed to give students a coordinated view of the historical development of our society has been made a curriculum requirement. The courses build upon each other so that the subject matter and problems considered place increasing demands upon the student as he proceeds through the series. Provision is sometimes made near the culmination of the sequence for the student to choose from among several electives so that he can probe a bit more deeply into an aspect of the program that is of special interest to him.

In other schools the approach seems to be that of permitting the student to choose rather widely among liberal arts courses available at the institution so that he can sample a number of different fields such as literature, art, music, philosophy, sociology, psychology, etc. if he desires to do so. This has the advantage of widening his horizons, but likely means that all of the work will be at an elementary level. Schedule complications usually prevent a student from electing an appropriate series of courses in one field when the program is set up in this way.

Still other schools select certain humanistic-social courses already given at the institution and fix these into the engineering curriculum as a requirement on the theory that the resulting pattern will be more satisfactory than independent choices by the students themselves. There still seems to remain among engineering faculties by and large some skepticism as to the real worth of the cultural disciplines and a feeling that it doesn't make too much difference what goes in to this phase of the curriculum so long as it doesn't encroach unduly upon the student's time.

We shall soon have a much clearer picture of the actual status of humanistic-social studies in engineering schools because the American Society for Engineering Education is now engaged in a research project aimed at determining where we stand 10 years after the Hammond Report.

The central purpose of the Project is to stimulate a continuing search for better ways of helping engineering students benefit from the values resident in the humanities and social sciences. This will require a knowledge of what is actually being done in the teaching of humanistic and social studies and it will involve calling attention to programs that appear to have been signally effective. Chief emphasis will be placed, however, on the use of this accumulated experience in judging ideas or plans that seem to hold promise for fruitful experimentation in the future.

Inquiry will be made into many pertinent facets of the over-all problem: administrative procedures, the training of staff, the support which extra-curricular activities give to the program, the effect of R.O.T.C. on the time allotted to humanistic-social studies, articulation with high school work, plans for post-graduate development, etc. But these matters will be peripheral to what is essentially an intellectual inquiry into the academic content of the humanistic-social courses being offered to engineering students.

The Project is financed by a grant of $30,000 from the Carnegie Corporation and is under the able leadership of Dr. George Gullette of North Carolina State College who has been given a year's leave of absence to direct the field studies. Dr. Edwin Burdell of Cooper Union is chairman of the A.S.E.E. Committee to which the over-all responsibility for the Project has been entrusted.

It is expected that visits to a large number of representative engineering schools will be completed this fall and winter and that a preliminary report will be issued by next June. My belief is that this undertaking is particularly timely, that it is being carried on with high competence, and that its results will be extremely stimulating and serviceable to the cause of liberal education in engineering curricula of the future.

SYNTHESIS IN THE EDUCATION OF THE ENGINEER DURING EARLY TRAINING RATHER THAN LATER OR NOT AT ALL

By John B. Wilbur,* *Member*

(Presented as part of a Symposium on the Education of the Future Engineer at a meeting of the Boston Society of Civil Engineers, held on September 29, 1954.)

Among the mental processes involved in engineering practice, one should differentiate between analysis—in which a total situation is broken down into its parts and examined in a rational and systematic manner, and synthesis—in which the parts of a problem are brought together so as to give a total concept, a process in which the less formal intuitive faculties may play a major role.

To make these terms more definitive, it may be helpful to consider the case of a man looking through a kaleidoscope. As the kaleidoscope is slowly rotated, and as the fragments of glass arrange themselves in various forms, the viewer has a large number of patterns brought before him in a systematic manner; suddenly, however, there may appear a particular pattern that for some reason bears promise of fulfilling the objectives sought by the viewer; he no longer rotates the kaleidoscope, but pauses to consider whether or not the pattern before him may indeed be the one he has been seeking.

Perhaps the kaleidoscope itself may be compared to analysis in thinking—a method of search for the answer to a total situation—but a method that in no sense, by itself, guarantees the finding of the solution; perhaps the recognition of the correct pattern—the synthesis—is something that can spring only from a largely intuitive reaction of the man himself.

The writer has, in recent years, become increasingly concerned with the fact that as engineering education has become what is usually considered more fundamental—in that greater emphasis is placed on basic mathematics and science—the time devoted to total engineering concepts seems of necessity to have been diminished. The importance of mathematics and science to the education of the professional engineer is not questioned, but the penalty that may be paid

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for a firm grounding in these areas may well be sufficiently great to warrant a certain degree of alarm. One has only to consider the importance of over-all concepts—of seeking the best solutions "on the whole"—of the necessity of balancing tangible against intangible factors—to conclude that synthesis plays a basic role in judgment, in broad-scale planning, in administrative work, and—perhaps most important of all, in the boldness and imagination that lead to the new concepts that are the genius of creative engineering.

Figure 1 shows a simplified schematic diagram that represents a typical distribution of time in a typical undergraduate engineering curriculum. As used in this figure, "Science" is interpreted broadly

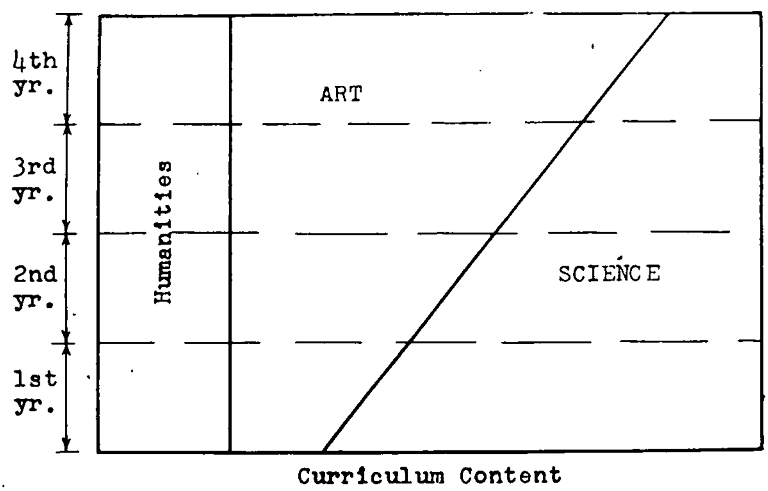

FIGURE I

so as to include mathematics, physics, chemistry, mechanics, etc.—those subjects that are essentially analytical in character. "Art" is also used in a broad sense, and includes subjects such as design and thesis, in which synthesis appears as an important element; it should be emphasized that in this discussion "art" does not mean emphasis on the development of manual skills or on the details of professional practice. Engineering is frequently thought of as being applied science; hence it has appeared to be logical and necessary to give the student a firm grounding in mathematics and science before he attempts to cope with matters that are more truly engineering in character.

The approach to engineering education is so typified by the diagram of Figure 1, that it may at first be difficult for the reader to give serious consideration to a possible alternate approach that constitutes the heart of this presentation. If, however, the shackles of long practice can be set aside, and if one can permit his imagination to do some freewheeling, the kaleidoscope can—figuratively speaking—be turned until a new pattern presents itself for our consideration.

The alternate possible pattern is shown in Figure 2. It will be noted that emphasis in the early part of the curriculum is on art rather than on science, and that in general, science tends to follow

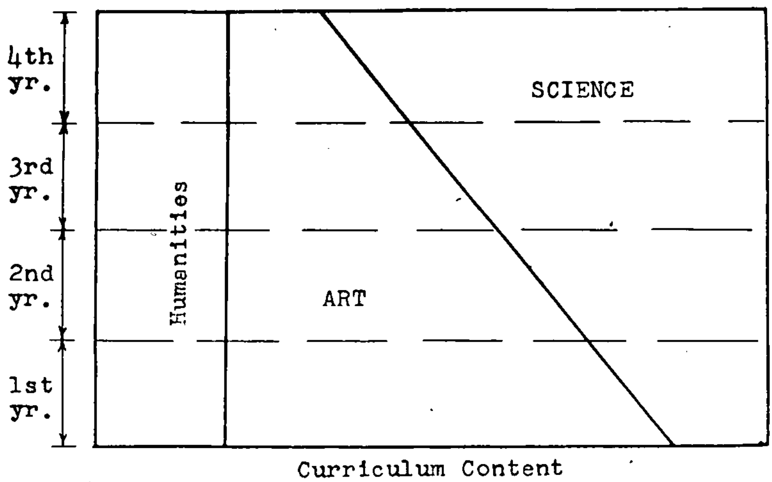

FIGURE II

art rather than to precede it. It is proposed that first-year students be given real comprehensive problems in engineering—not, of course, problems that are completely dependent on advanced mathematics and science, but problems that are nevertheless complex in their coverage, and demanding of a reasonable amount of imagination and some judgment for their solution; as examples, we might consider the location of an expressway through a city, or a study of the economics of a hydroelectric development in a given proposed location. One may immediately claim that such problems are too advanced for first-year students, and perhaps this is true if we are demanding of so-called "correct solutions." But this is scarcely the point: what we should be interested in primarily is getting the student to work out the best total solution of which he is capable at that stage, and to have him discover—with proper but preferably limited guidance, what the essential components of the problem are—how the components can be integrated to achieve the best solution of which he is capable, and how important it is that he master science so that his art may —in the future—be executed more effectively.

The writer believes that this general approach—although admittedly more difficult from the teaching viewpoint than present methods—might well lead to better engineering education, and for reasons such as the following:

1. Synthesis rather than analysis is emphasized as the basic approach to creative engineering. The student is introduced to engineering through total concepts rather than through components. He uses approximate methods first, facilitating physical conception, and brings in the more abstract mathematical procedures at a later stage, applying them to the areas where their use is justified. Science is presented as the tool of engineering, and is not, therefore, confused with engineering itself.

2. Motivation, which is the real key to learning, is heightened. The student is permitted to work on real engineering problems when he begins his engineering education. He discovers for himself that he needs science, and is thereby motivated to study it. This approach, moreover, would require the use of the most experienced and inspiring teachers during the earlier years, when they are most needed by the student.

3. There would be a better selectivity of students. As it is now, elimination through failure to meet standards is based on lack of ability to analyze rather than lack of ability to synthesize whereas the ability to synthesize may be the more important factor in genuine engineering achievement.

4. While it is a personal opinion and cannot be demonstrated as correct, the writer believes that there is something in an introduction to engineering through the exactitudes of analysis that inhibits the student with respect to synthesizing with boldness and imagination at a later date. Both analysis and synthesis are of utmost importance; but it may well be that if analysis comes first, the ability

to synthesize suffers a setback; while if synthesis comes first, the ability to analyze can be taken in stride at a later date.

The writer further believes that science itself might be taught more effectively with the proposed approach, and for reasons such as the following:

1. The student would be somewhat more mature when studying science, and thus able to cope with a more advanced treatment of this important aspect of his education.

2. He would have discovered that he needed the science to perform the art, so that knowing why he needed science, he would be more highly motivated in studying it.

3. Those who continued on for graduate work would benefit by having concentrated on science more recently than under the present system.

It may even be that humanities could be taught more effectively with the proposed approach, since being related more closely to synthesis than analysis, they would not be so much a "thing apart" for first- and second-year students; moreover a broad treatment of comprehensive engineering problems would relate certain subjects of the humanities directly to the total engineering process.

If one were to ask whether or not the suggested inversion is possible, I believe that the answer—at least for Civil Engineering—is in the affirmative, although its implementation is admittedly a most difficult and challenging task.

More pertinent is the question of whether or not the inversion is desirable; it is hoped that this presentation will stimulate thinking along the lines suggested that may lead to a proper evaluation of the factors involved. And in trying to reach a conclusion, it is suggested that one think not only of educating engineers for creative professional engineering, but of educating men to take their place—and preferably places of leadership—in society.

We have gone a long way toward minimizing vocational training in engineering education, but have we made the mistake of limiting our conception of vocational training to manual skills and details of professional practice? Is not the development of skills in carrying out well known processes and applications of science to engineering problems, just another—although possibly higher—type of vocationalism? Is not the judgment and creative imagination that makes use of science to better mankind the highest type of professional expression for which we should strive in engineering education?

THOUGHTS ON AN ENGINEERING EDUCATION

By Oscar S. Bray*

(Presented as part of a Symposium on the Education of the Future Engineer at a meeting of the Boston Society of Civil Engineers, held on September 29, 1954.)

Once there were three blind men, who by chance wandered into a circus lot and there discovered an elephant. None of the three, blind from childhood, had ever seen an elephant, and they examined this one curiously, in the manner of the sightless, with their hands. The first grasped the tail, the second explored the side, and the third ran his fingers over the huge trunk. Later, discussing their experience, they fell into a great argument. "The elephant is like a rope," said No. 1, who had clutched the tail. "Not so," said the second. "The elephant is like a great wall." "I cannot agree with either of you," said the third. "The elephant is like the trunk of a palm tree, upside down."

Like the views of these blind men on the subject of elephants, my thoughts on engineering education result from my own limited observation and experience. This you must keep in mind when evaluating what I shall say to you on the subject. I have one advantage over the elephant inspectors, since this is my second attempt on this subject, the first being some years ago before a Harvard meeting of the Society for the Promotion of Engineering Education. On that occasion, as on this, I was in distinguished company.

There is, I think nothing much wrong with our present engineering education, so far as it goes. My firm employs many young graduates. We try to be selective, but I expect we get no better than a good average cross-section of the crop. Some are fair, some are good, and once in a great while we are fortunate enough to find an outstanding prospect. The differences appear to be as much due to inheritance and breeding as to education, and while we find or think we find better men at one college than another, we really do not have a sufficiently large sampling to justify any firm conclusions on this score.

Judging by what I have seen, today's graduate is suitably prepared to begin an engineering career. His basic mathematics is ade-

*Project Manager, Jackson & Moreland, Boston.

quate, though a little more of it would be useful. He is reasonably competent in design, and is generally abreast of current technical developments. He lacks drafting skill, as is natural, and is likewise unfamiliar with construction practice and the importance of cost. His major shortcoming, perhaps, is his inability to use the English language with precision and effect. On balance, our present engineering education must be rated "good".

But in America, nothing is good enough which can be made better, be it automobiles, concrete or college educations. Our present educational system produces engineering graduates who are about as well taught in technical matters as the limitations of a four-year course and a generally overburdened faculty permit. But we have come, I think, to a point where an adequate technical education is no longer sufficient. The college must be more than a place where the engineering student acquires a set of technical tools. It must also be the place where he learns to understand the world in which he will move, to recognize his place and responsibilities in it, and to live a richer and more complete life, entirely apart from any economic consideration. It must be a place for the opening of new doors, for the stimulation of imagination, and for the planting of the seeds of future progress. Our engineers in the future must be more than very able technicians.

For so long as I can remember, we have talked among ourselves of the engineer's fitness to run the world, and have predicted great influence for the profession in the future. Some of this talk has been at times reminiscent of Kipling's bandar-log, "The Monkey People," who were always going to do great things but never quite got 'round to doing them before rushing off through the tree-tops on some new distraction.

Wide-eyed as some of our more outspoken fellows have been, their utterances contain more than a grain of truth and sound sense. This changing and increasingly complex world does need the engineer's reasoned touch in the guidance of its affairs. The difficulty lies in our lack of formal training outside the rather narrow bounds of engineering theory to move in this larger arena. The engineer cannot hope to operate successfully beyond the technical field until he has a broader understanding of political and economic forces, of finance, of history, and of people. This sort of preparation becomes of increasing importance as free men turn more and more to the new world for the help that once came from the old.

As I have indicated earlier, I think that, on the whole, our colleges today are turning out well prepared technical graduates. After looking over some representative curricula, I do not see how we can do much more or much better in a four-year course, which simply does not contain the time, even with substantial chunks of summer school added. And since present curricula contain very little dead wood, it is not practical to make room for other material by reducing the dose of technical information now being administered.

To me, the conclusion is inescapable: that if we hold to the present 4-year engineering course, we must content ourselves with the production of competent technicians and depend on individual initiative after graduation for the development of the higher skills. If a majority of our engineering graduates are to be equipped to fill the places in the world's councils they should have, more time must be spent in college.

How much more time is a moot question, since there are practical as well as educational questions to consider. I think I would try one extra year, as a starter, with the additional time devoted to such things as history, political science, psychology, philosophy, finance, and further work in English and economics. A second language would also be valuable if it could be worked in, and provided the student had some previous background in it. Much of this sort of thing is now being done in a number of the colleges, which have combined to offer a 5-year course consisting of three years of liberal arts, mathematics and basic science, and two years of technical work for an engineering degree. This sort of thing, new in engineering, has long been standard in the fields of medicine and law.

Adding a year to the education program will mean graduating students at 23 or 24 instead of 22 or 23. Since adding education will not increase working life, the net effect of the 5-year program is apt to be a reduction in the supply of engineers of from 2 to 3 per cent, other factors remaining unchanged. The concomitant effect should be an increase in engineering salaries and a firmer position for engineering as a profession.

The effect of such a program on educational facilities has to be considered. If engineers are to receive their pre-engineering training in the liberal arts colleges, the staffs and facilities of these institutions may well be overtaxed, while the engineering colleges, with only two classes instead of the present four, will be considerably underloaded.

It seems probable that not all students would be interested in or even able to spend 5 years in college. Moreover, not all who are interested in engineering are equipped to benefit sufficiently from a course such as that proposed to justify the expenditure of time and money involved. These are the earnest boys who drop out midway or barely squeak through to graduation, and who in after life never achieve the level of responsibility for which they have sought to prepare themselves. I think that we tend to make too much of a fetish of a college degree, and to attach something of a social stigma to those not possessing it. This is a very wrong and a very bad thing.

Students such as I have just described would be much better served by a sound utilitarian education such as that provided by our technical institutes or by a stripped-down version of the present engineering course, which might be offered in the colleges. Such an education would provide worthwhile economic advantages to the student, reducing his investment in education to a level at which the returns would justify the cost, and enabling him to become a wage earner in from 2 to 3 years after matriculation instead of 4 or 5. It would provide a much-needed flow of trained draftsmen and junior designers, permitting the release of young engineers for higher grade work. In so doing, it would reduce to some extent the engineer shortage induced by the proposed longer course. It would tend to balance the load on the colleges, and finally, it would permit college classes to move at a more rapid pace, relieved of the drag imposed by the slower student.

The principal difficulties to be overcome in putting such a plan into effect are removal of the stigma now attached to anything less than a college degree, and selecting and persuading the students to take part in it. Our great engineering colleges could make a large contribution by offering 2-year concentrated courses leading to a certificate in engineering.

DETERMINATION OF INCIPIENT ROOF FAILURES IN ROCK TUNNELS BY MICRO-SEISMIC DETECTION

By F. J. Crandell,* *Member*

THE lives of the miners, drillers, muckers, engineers, and executives depend upon the safety of the tunnel or mine roof.

For years, the safety of the roof and underground workings has been determined by visual and audible indications, and upon the opinion and experience of the responsible people in charge. The evaluation of these visual and audible indications has been difficult, and all too often has proven to be false. These qualitative determinations have been so grossly in error at times that extremely dangerous and unsafe roof conditions have occurred rapidly enough to escape detection. It was obvious that there was a need for a more quantitative or quasi-quantitative means of determining the safety of underground roof conditions, to improve the environment of the men working in this industry.

A fact well known to mining and tunnelling engineers is that certain types of rock tend to make audible sound under strain, and this type of rock has many times been called "popping rock". It is very easy to imagine that if there are audible sounds at failure, very likely sub-audible sounds have been occurring in the material before the failure occurred.

As a casualty insurance company writing Workman's Compensation insurance, we are primarily interested in the protection of the workmen against injury and death. Fall of rock has been the number one killer in tunnelling and mining.

Before this research was initiated, the U. S. Bureau of Mines experimented with sub-audible apparatus in deep mines subject to bursts.

Tunnel Hazards

There is no problem when the rock and ground conditions are so unstable that it is obvious that they must be supported, or when the ground conditions and rock through which the tunnel is being driven is so uniform and strong that it needs no support.

*Asst. Vice President, Chief Engineer, Liberty Mutual Ins. Co., Boston, Mass.

On the other hand, when the conditions in the tunnel show no visual indications of deterioration and the conditions have been in existence for a matter of weeks or months, what is there to indicate that the roof is safe or unsafe? When the conditions change from hard to soft materials, must the roof be supported, or does it still have strength enough to carry the load above it safely?

Generally speaking, the greatest problem of determining the safety of the roof comes in shales, schists, limestones and sandstones.

Shale

The stability of the roof conditions when shale is encountered depends chiefly upon the character of the shale. This character may range from a sound rock to a swelling clay. The thickness of a shale bed, and the amount of creep that the particular shale may have are factors in failures. In many locations where shales are associated with anhydrite, if the seal of the layers of anhydrite is injured and water percolates through the cracks, the anhydrite gradually changes into gypsum and heavy pressure ensues.

Limestone and Sandstone

Sandstone usually does not present as hazardous a condition as limestone because in contrast to limestone, sandstone is not likely to contain underground channels or reservoirs. However, joints, faults, and thickness of bedding, will have a marked effect upon the strength of these materials.

Schists

In unaltered schists, the rock loads on the roof range from zero to moderate. In addition, the strengths of these schists, for the span encountered, may vary greatly in one hundred yards of tunnel driving.

Figure No. 1 shows four types of rock structures found generally in tunnel driving operations. Our problem is to determine if the immediate roof conditions are safe or unsafe.

A—Indicates the condition that may exist when heavy overbreak occurs due to the use of too much explosive resulting in a very non-uniform dry masonry arch.

B—The horizontal layers of deposit may be safe enough or may be weakened by joints.

C & D—In this type of structure the rock tends to slide into the tunnel.

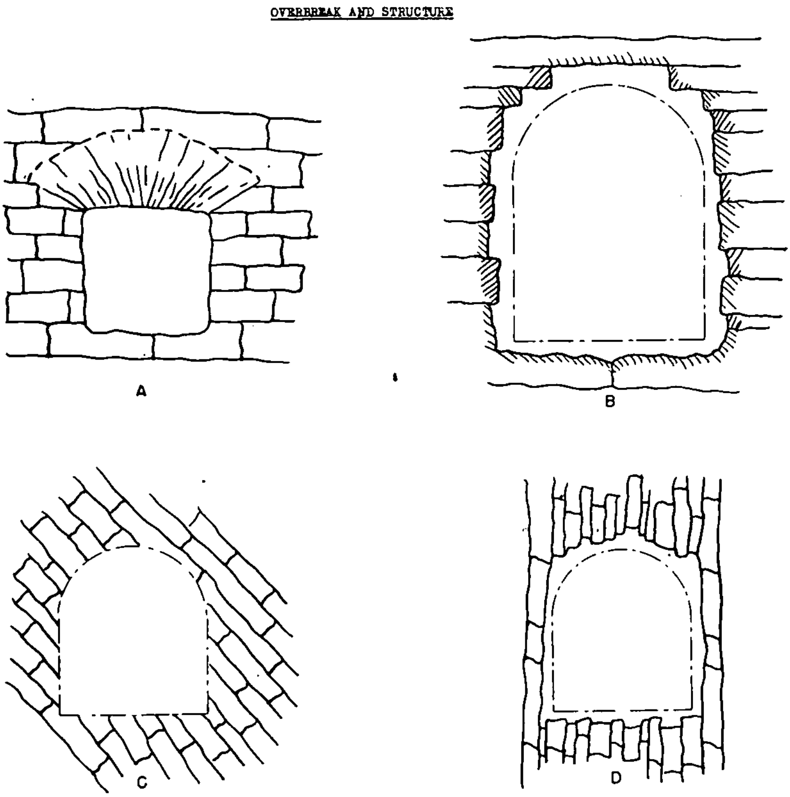

FIG. 1.

OBJECTIVES IN THE FIELD

The objective was to design and build an instrument that could detect minute elastic movements (entitled micro-seismic activity) to

1. Determine the micro-seismic activity of a tunnel roof at varying fractions of rupture stress.
2. Locate areas of impending failure within a practical range.
3. Develop a method of determining roof failure by making micro-seismic measurements in situ.

PROCEDURE

The determination that the micro-seismic rate of a geological specimen under crushing strain increases as it approaches failure had already been established. This has been shown in relatively deep workings and in relatively hard rock.

One of the problems was to determine whether the same basic characteristics could be developed in shallow workings with very minor amounts of pressure upon the roof and in exceedingly soft rocks such as limestone, sandstone, shales and clayey shales. This research was started in the East Delaware tunnel in the section at Roscoe, New York for the Board of Water Supply of the City of New York.

From the attached geological map, (Figure No. 2) it can be seen that the rocks encountered consisted of shales, sandstone, limestone, in many cases jointed, faulted and with varying degrees of shale characteristics.

A 6 ft. hole was drilled in the side of the tunnel in an endeavor to get into solid material. The geophone was inserted in this hole and varying means were used in an endeavor to reduce extraneous noises by plugging the drilled hole with cotton or rubber. A preliminary amplifier was used and connected with a logarithmic amplifier, which in turn was connected to a single channel recorder.

Figure No. 3 shows this equipment including the permanent recording machine being used in Contract 408 of the East Delaware Tunnel, New York. The holes used were numbered and located in accordance with the stationing of the tunnel and the rocks encountered.

In addition to the activities in the tunnel itself, a geophysical laboratory was established on the job, in which samples of the encountered rocks were periodically crushed and their strength determined.

Absorption tests were also made on each sample to determine whether there was a tendency to increase in bulk by the absorption of the moisture from the air in the tunnel. Although some expansion due to moisture was discovered, it was not an important part of the roof control program, and will not be described here.

Each hole was investigated and a record of the micro-seismic activity was recorded. The data were plotted on a micro-seismic activity chart. A sample of this chart is shown which provided data needed to determine whether the activity had increased or stopped completely.

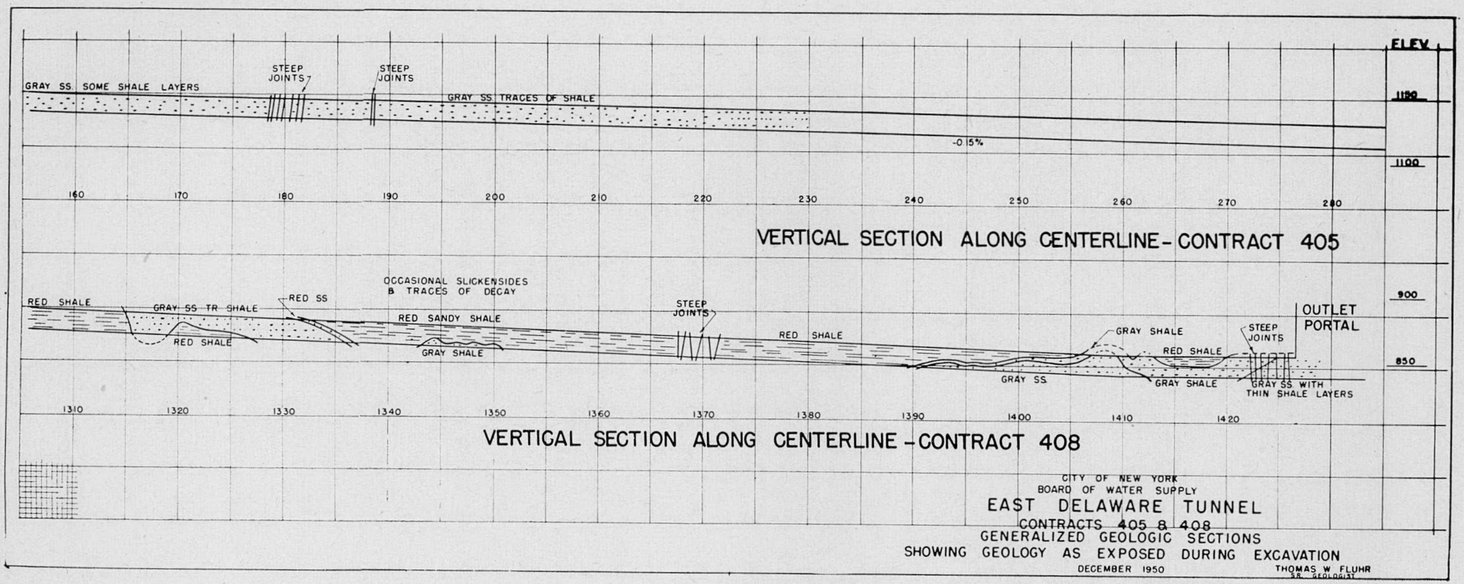
ELEV.
1150
1100
900
850
GRAY SS. SOME SHALE LAYERS
STEEP JOINTS
STEEP JOINTS
GRAY SS. TRACES OF SHALE
-0.15%
160
170
180
190
200
210
220
230
240
250
260
270
280
VERTICAL SECTION ALONG CENTERLINE - CONTRACT 405
OCCASIONAL SLICKENSIDES & TRACES OF DECAY
RED SHALE
GRAY SS TR SHALE
RED SS
RED SANDY SHALE
RED SHALE
GRAY SHALE
STEEP JOINTS
RED SHALE
GRAY SHALE
RED SHALE
STEEP JOINTS
OUTLET PORTAL
GRAY SS.
GRAY SHALE
GRAY SS. WITH THIN SHALE LAYERS
1310
1320
1330
1340
1350
1360
1370
1380
1390
1400
1410
1420
VERTICAL SECTION ALONG CENTERLINE - CONTRACT 408
CITY OF NEW YORK
BOARD OF WATER SUPPLY
EAST DELAWARE TUNNEL
CONTRACTS 405 & 408
GENERALIZED GEOLOGIC SECTIONS
SHOWING GEOLOGY AS EXPOSED DURING EXCAVATION
DECEMBER 1950
THOMAS W. FLUHR
SR. GEOLOGIST

FIG. 2.

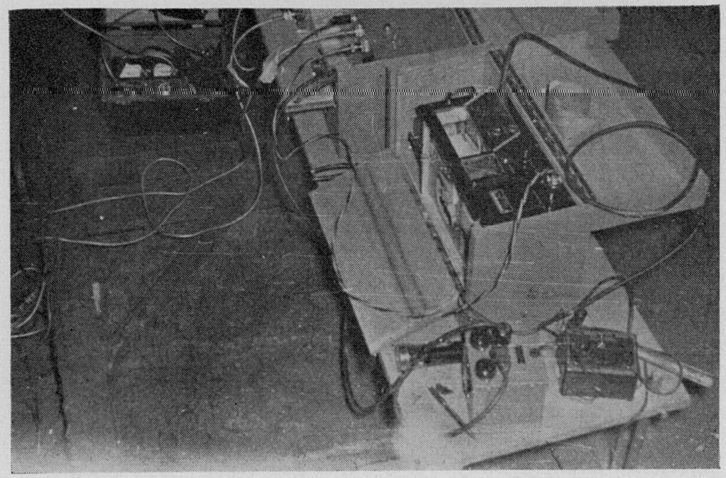

FIG. 3.

DISTURBANCE

In the first six months of investigation, it was discovered that a micro-seismic disturbance could be detected in soft shale and limestone; but in addition, extraneous disturbances were also detected. These included the hum of the trolley on the supply trains, a 60 cycle hum of the electric current running through the tunnel, air going through the high pressure line, the pumps exhausting water from the tunnel, and men talking in the tunnel over 500 ft. away from the listening activities. Such statements as "Joe, hand me that shovel," were clear enough to be distinguished, and of course, overwhelmed any micro-seism that may be coming in at that time.

The most disturbing element in this first set-up was the 60 cycle hum, which at first seemed impossible to eliminate. The result of these first activities proved that in this type of operation, where the listening post is so close to all utilities, power and transportation, the alternating current logarithmic amplifier had to be abandoned.

In addition, believing that a problem in pressure did not exist, it was thought that the laboratory method of crushing a specimen to determine its micro-seismic rate at certain percentages of failure stress was neither necessary nor practical.

Having found that the sub-audible disturbance of these rocks could be amplified to an audible one, it was necessary to overcome the mechanical difficulty and in addition to find the threshold values of a safe or unsafe section of the roof.

Micro-Seismic Detection Apparatus

A micro-seismic detection apparatus was designed to detect the elastic movement under strain long in advance of failure of the geology in question. The pick-up or geophone of this particular micro-seismic detection apparatus uses the piezo-electric action of a quartz crystal to develop a voltage resulting from an elastic movement. The geophone can detect an elastic movement smaller than the diameter of the hydrogen molecule. The amplifier increases the piezo-electric voltage and brings it into the audible range. Figure No. 4 shows the final apparatus, developed as a result of this research program.

Determination of Failure, in Situ

It was assumed that if the micro-seismic rate became zero, the roof was in static equilibrium; if the rate continued to decrease day by day, or from week to week, it was assumed that the area was

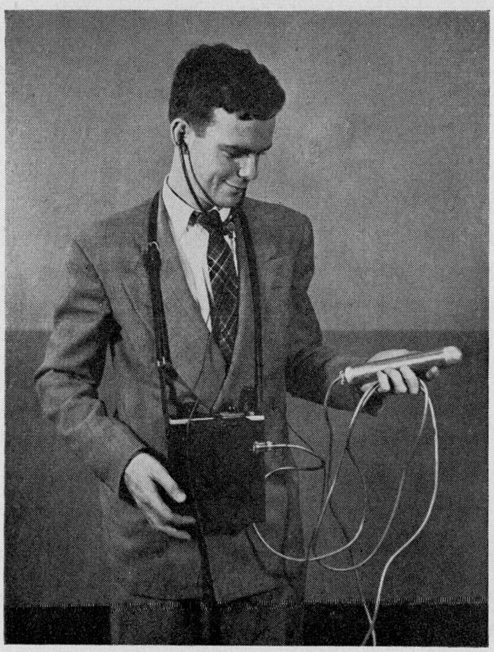

Fig. 4.

approaching equilibrium. On the other hand, if the micro-seismic rate continued to increase from week to week, it definitely indicated that a failure in this section could be expected if it was not supported. This brings up the point of how to establish a threshold of failure of the roof. It was determined that the tests would have to be made in situ to ascertain when the roof was producing sufficient micro-seisms to indicate it was on the point of failure.

Because of the method of operation of the tunnel driving crew, there was never any relatively long period of quiet listening time. Three shifts were worked each day covering the total 24 hour period. However, the last crew of the week shot the heading approximately 8 A.M. on Saturday morning, and then came out of the tunnel. No further actual driving activities were performed until 8 A.M. Monday morning.

The Liberty Mutual Field Safety Engineers therefore inserted the geophone pickup into the hole drilled close to the heading that was to be shot at 8 A.M. on Saturday morning. This geophone pickup was within 8 ft. of the heading, and lead wires were run from it to the amplifier and recording apparatus placed approximately 250 ft. away from the face to be shot. With direct current amplifiers and alternating current recorder, a system was established that could take a record of all micro-seismic activities that would occur at a specific location for 16 hours.

It was assumed that because no scaling would be done directly after the shot, and the tunnel roof would hang until 8 A.M. Monday morning, there were bound to be failures occurring during this period and an analysis of the record would permit determination of the micro-seismic rate that would occur during these failures. In addition, it was believed that such a record would provide information as to how many hours it took these particular rocks to approach static equilibrium if they did at all. Fortunately, this measurement of the micro-seismic activity in situ allowed accurate determination of the rate of activity at failure.

Figure No. 5 shows four samples of the records taken on May 3, 1952, and ending on May 4, 1952, and indicate the types of data that were obtained in situ. It must remembered here that the amplitude of the record was not taken into consideration in this interpretation. The primary interest is in determining the rate of activity, or how many micro-seisms occur in a period of time.

At 9:05 A.M. on May 3, 1952, there is shown a very active micro-seismic rate occurring for about 25 to 30 seconds. This is typical of a failure of a section of the roof.

At 10:06 A.M. another failure occurred and the micro-seismic rate was extremely high and lasted for approximately 35 seconds.

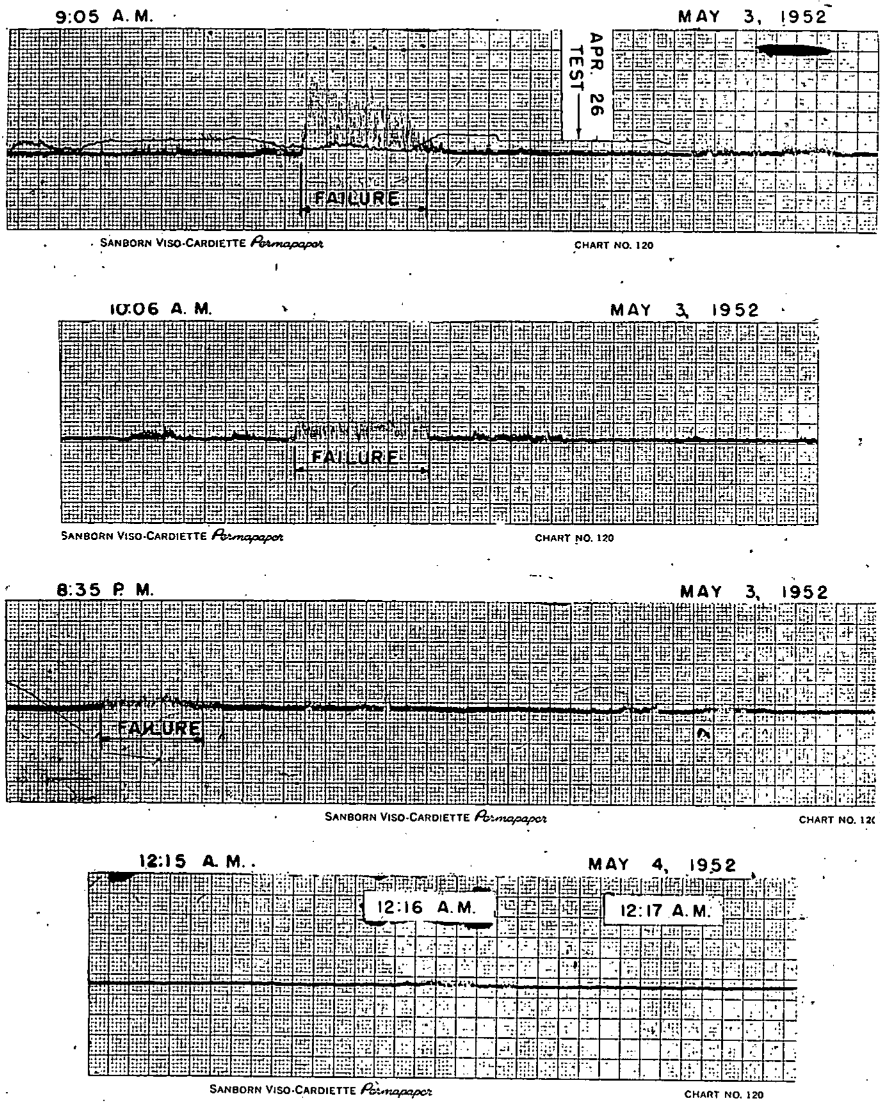

FIG. 5.

At 8:35 P.M., the record shows one large failure and three relatively small failures, but it will be noted that at each time the failure occurred, the micro-seismic rate was extremely high. In order to count the micro-seismic rate, it was necessary to use a high powered magnifying glass.

At 12:16 A.M. on May 4, 1952, another failure occurred, and as can be seen the micro-seismic rate was again extremely high.

Summary of Record Samples

From this continuous record of the unstable roof at the face, the following deductions were made:

1. That the micro-seismic rate of failure was 3 micro-seisms per second, or 180 micro-seisms per minute.
2. That the roof did not become stable in this 16 hour recording, indicating that this was an unstable roof condition.

There were long periods of time while the micro-seismic detection apparatus was running that the roof was quiet, and very few micro-seisms occurred. When this condition existed, the record line was relatively smooth, as can be seen in the last sample at 12:15 A.M. on May 4, 1952.

Micro-Seismic Rate vs. Time of Occurrence of Roof Rock Falls

Figure No. 6 is a recording of the total activity occurring during this measuring time. The ordinate of this chart is the micro-seismic rate in micro-seisms per second. The abscissa is the time of the occurrence. It will be noted that the first four hours were extremely active. From noon time until 1:00 P.M. there was practically no activity at all, and it would appear that the roof had established itself in a stable condition. However, at 3:30 P.M. and between 4:00 P.M. and 5:00 P.M., the rate was of sufficient intensity to produce failures, and even at 10:30 and 11:00 P.M. there were continuing failures in this area.

On the following Monday morning, the roof was sealed and pinned in which 1″ rods, were driven into the roof of the tunnel and small channels were tied to two or more of these pins. The pins have an expansion bolt on the upper end which is usually made active by driving the pin hard into the expansion wedge. On the lower end of this pin, a nut is tightened up with a torque wrench to give sufficient

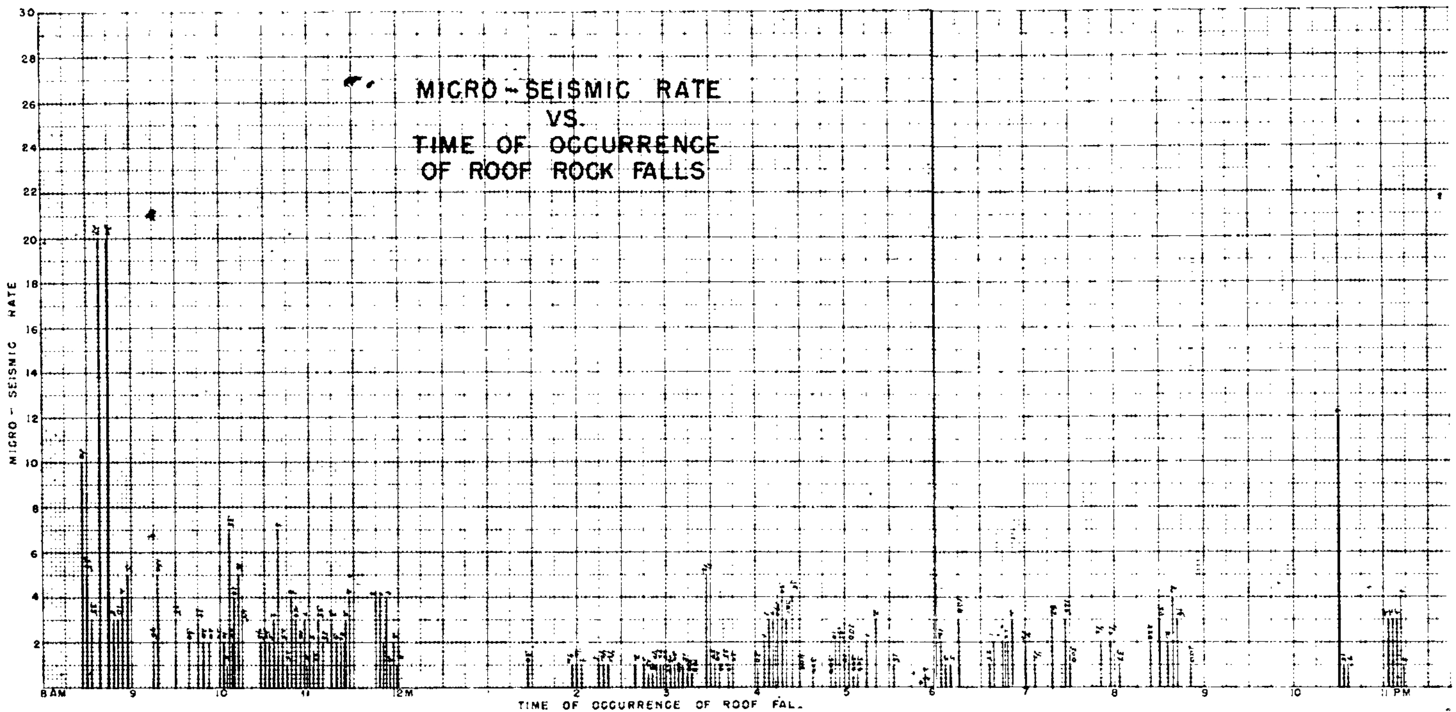
MICRO-SEISMIC RATE
VS.
TIME OF OCCURRENCE
OF ROOF ROCK FALLS
MICRO - SEISMIC RATE
TIME OF OCCURRENCE OF ROOF FAL.
8AM
9
10
11
12M
2
3
4
5
6
7
8
9
10
11 PM

FIG. 6.

tension in the rod to support the loose pieces in the roof. After pinning this section of the roof, the micro-seismic rate reduced from the activity shown in the former data to zero. This demonstrated that equilibrium had been reached and the roof was now safe for the miners.

PROBING

Permanent recording of the micro-seisms required equipment that was cumbersome and heavy. Transportation was needed to get it to the location in question, and this movement of a large amount of equipment became more and more difficult as the length of the tunnel became greater. By the same token, as the tunnel increased in length, the number of probe holes increased.

In order to get the necessary data in a practical manner, the probing method was adapted using only the portable equipment. The prime objective was to determine whether roof conditions were changing from week to week, or month to month, or from year to year.

It was found that the human ear was an excellent analyzer of conditions in situ. The safety engineer could readily distinguish between a micro-seism and talking, air flow, pumping, and locomotive noise where the recording machine made no distinction. Fifteen minutes listening periods were established as a practical time and the engineer counted the micro-seisms heard. The failure rate in situ having been established, the engineer then plotted the rate and determined the fraction of failure stress at each location.

Hole 16A—Station 1350 + 70 was a location that was completely supported by steel arches. Around the first of December, a record was made of the activity even though the section had been supported, and it showed less than 5 micro-seisms per minute during this listening period.

In January of 1951 it was found that lagging over the steel arch had shifted to such an extent that it was necessary to re-block this area. The old lagging had to be removed and new lagging inserted. It was felt that this was an opportunity to determine whether this section was active without steel supports and lagging. When the old lagging was removed, tests showed that the micro-seismic rate increased to approximately 60 micro-seisms per minute. However, at the completion of re-blocking this lagging, the section became relatively stable. This indicated that the steel arch and lagging were working effectively in supporting the roof. Further tests were made in February, March, May, June, July, August and September and a very low micro-seismic rate was obtained. The rate jumped up in October, 1951, but immediately decreased to zero in November and December.

Hole 23—The record of this hole, as shown by the micro-seismic rate chart, (Figure No. 7) was extremely active. This section of the tun-

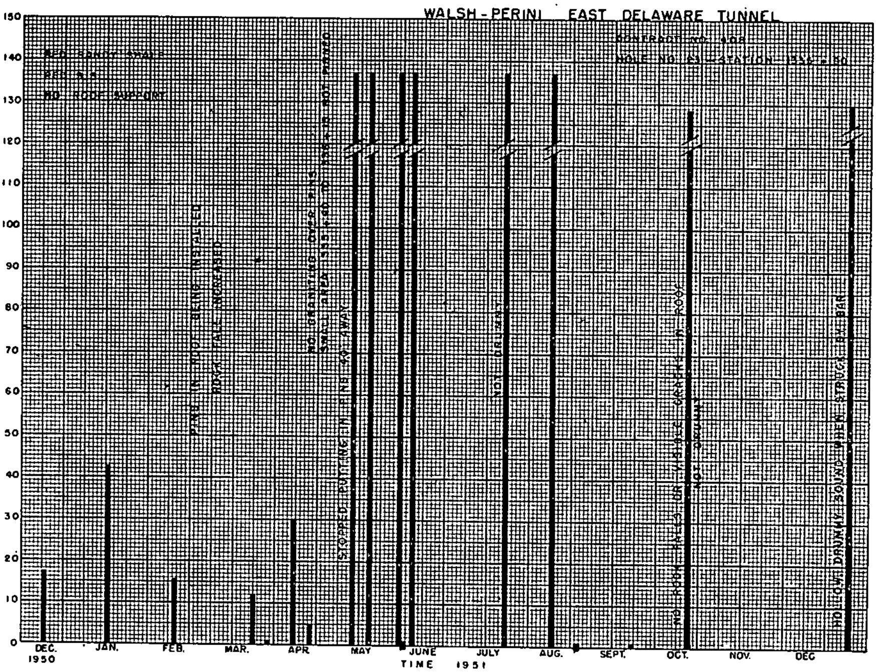

FIG. 7.

nel was unsupported, and the first micro-seismic rate survey made in December, 1950, showed a rate of approximately 17 micro-seisms per minute. In January of 1951, the micro-seismic rate increased up to 42 per minute. Again, there was a decrease until May, 1951, when the micro-seismic rate became extremely high, over 120 micro-seisms per minute, which is approaching 3 per second, or 180 micro-seisms per minute, indicating a probable failure. This section was then partially pinned. The micro-seismic rate remained relatively high through October of 1951 and testing the roof with a steel bar did not produce a drummy sound. However, in December of 1951, the activity had lasted so long that the roof became very drummy. Shortly after this last test, a failure of the roof was noted within approximately 30 to 40 ft. of Hole 23.

After this failure occurred, the hole became inactive and in February and March, May and June, there was practically no activity. July showed an activity of approximately 18 micro-seisms per minute and again dropped off to zero.

Before the assistance of the micro-seismic detection apparatus was available, the conclusion generally accepted was that a roof failure occurred very rapidly, but hole 23 showed that in certain types of material, the activity may last a very long period of time, perhaps a matter of a half year or more, before failure occurred. This statement is not to be taken as a general one that all failures take such a long period of time. Experience has shown that some of the failures are relatively fast and may occur in a matter of hours.

Hole 24—Interpretation of this record (figure No. 8) shows that the micro-seismic rate in December, 1950, was low and that by February

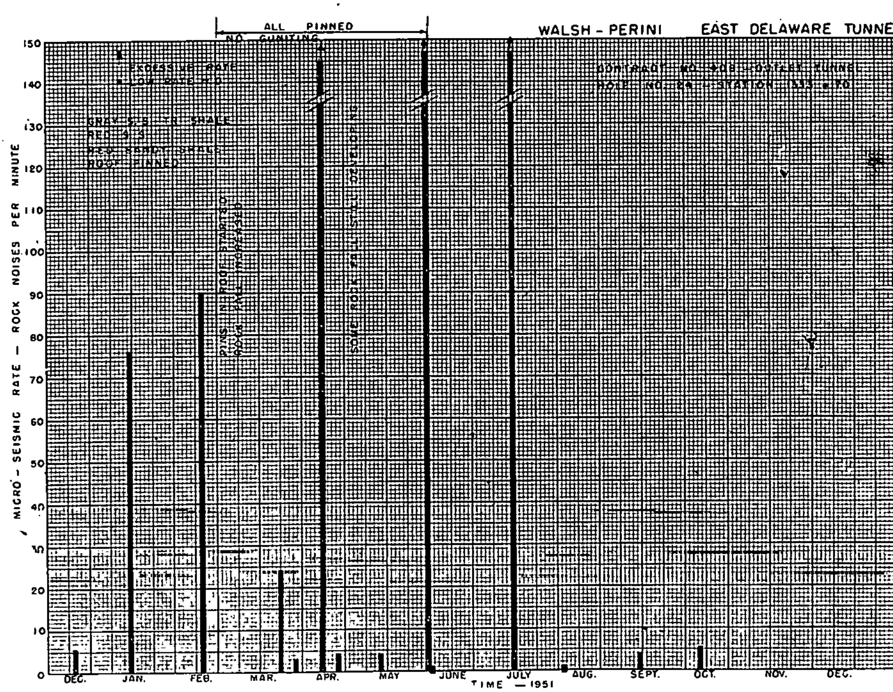

FIG. 8.

of 1951 it became extremely high. There was a distance of 100 ft. between Holes 24 and 25 and between Holes 24 and 23. When it was found that the rate in February was approaching a relatively high one, this roof was then supported by the pinning method described earlier. One hundred feet of tunnel had to be pinned intermittently, and it took a considerable time. The record shows that during the pinning period, the rate was approaching that of failure and some rock falls were developing. When the pinning was completed, the micro-seismic rate immediately decreased, and then approached zero or an average of approximately 5 micro-seisms per minute for the remaining part of the job through December, 1952.

Hole 25—Hole 25 followed the same general course as was found in Hole 24. The micro-seismic rate of the roof in this area was low to begin with and as time went on the activity increased until it became dangerous. After the roof was supported by pins, the rate decreased, indicating that this section of the tunnel was now safe, and further indicated that the pinning of the roof was effective. Further investigation of this area through March, April, May and December of 1952 showed a stable roof at all times.

Location of Activity

Up to this time, the amplitude of the micro-seisms had not been considered. There was evidence throughout the study that the amplitude of the micro-seism increased as the distance from the geophone decreased. It appeared possible that this change in amplitude or intensity of sound, could assist in determining more precisely the location of a weak section of the roof.

In order to confirm this assumption, practical tests were devised using a wooden oak hammer as a source of generating movement in the rock, as follows: The geophone was established at a specific location and 30 blows of the wooden oak hammer were made at 25 intervals from the geophone.

This record (Figure No. 9) gives a visual indication of the decrease in amplitude of the micro-seisms as the distance from the source increases from the geophone.

By plotting the points from a group of these experiments, a relative curve was obtained and is shown in Figure No. 10. Conclusions were drawn that there is a relative relationship between the distance from the source of activity and the amplitude or increased sound intensity of the micro-seism.

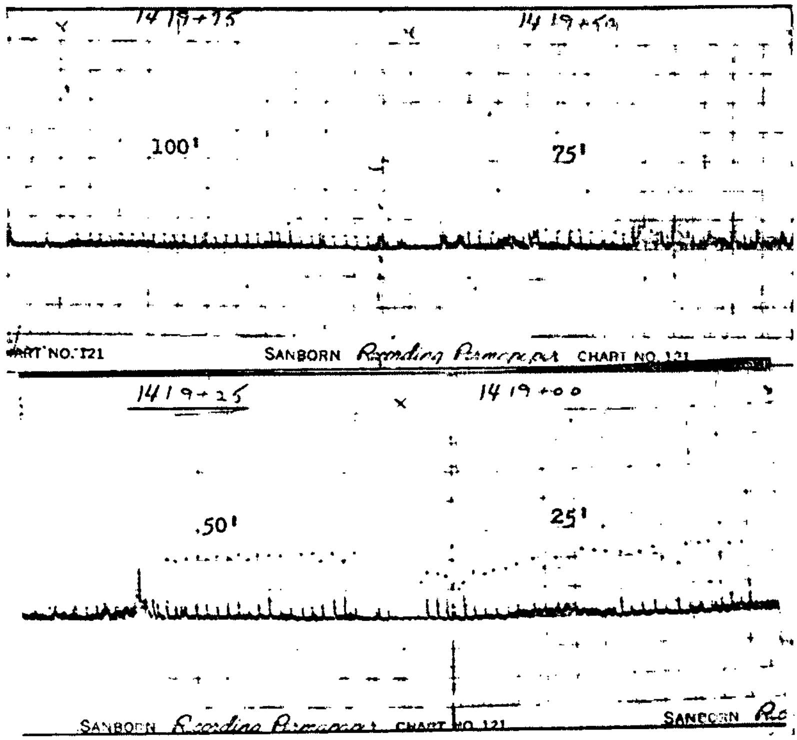

FIG. 9.

These experiments suggested the incorporation of an attenuator into the portable amplifier. Figure No. 11 shows two switches now on the portable amplifier. The one on the left is the main switch to turn the amplifier on, and the one on the right marked from 1 to 8 is the attenuator. When this knob is turned to No. 1, there is no attenuation, and at No. 8, there is maximum attenuation.

By turning the attenuator to a constant setting and moving the geophone, or keeping the geophone at a constant location and changing the attenuation, it was hoped that it would be possible to determine more precisely the active location in the underground workings. In using the portable amplifier and geophone only for locating

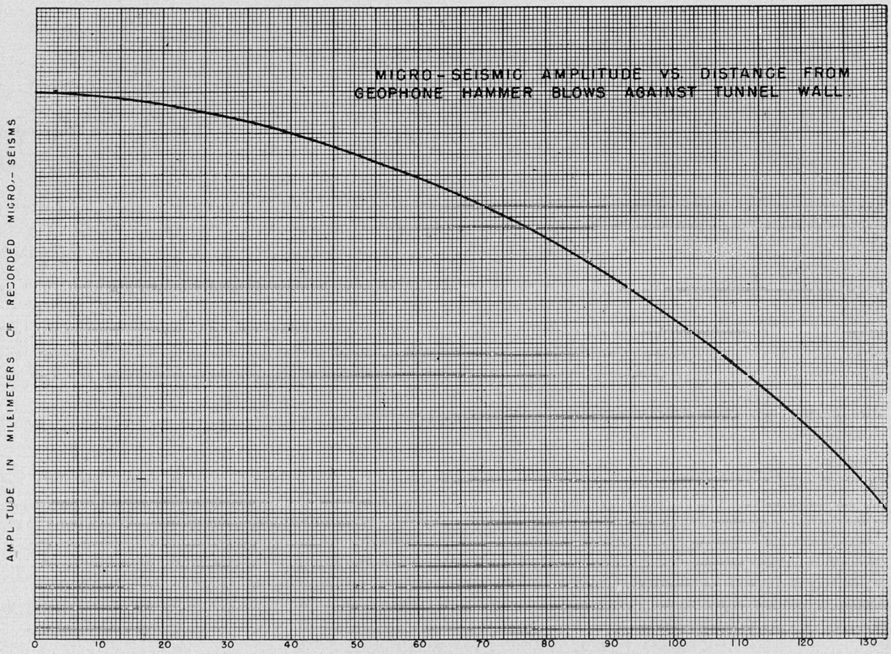
MICRO-SEISMIC AMPLITUDE VS DISTANCE FROM GEOPHONE HAMMER BLOWS AGAINST TUNNEL WALL.
AMPLITUDE IN MILLIMETERS OF RECORDED MICRO-SEISMS
0
10
20
30
40
50
60
70
80
90
100
110
120
130

FIG. 10.

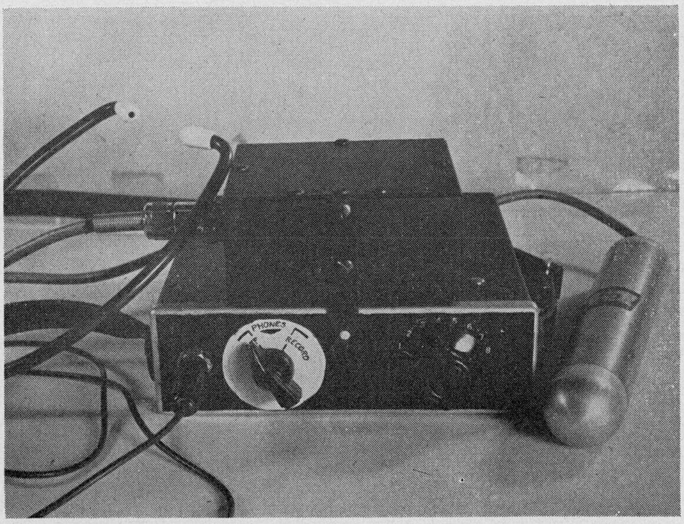
PHONES
RECORD

FIG. 11.

activity, the safety engineer is interested in both intensity and the rate of the micro-seisms. Four results may stem from this type of investigation.

1. If the micro-seismic activity is a great distance away, the character of the noise is likely to be scratchy.

2. If the micro-seismic activity is very close, the character of the noise approaches a tone.

3. If the micro-seismic activity is a long distance from the geophone, the rate is likely to be low, because only the more intense micro-seism will be heard.

4. If the micro-seismic activity is close to the geophone, an increase in rate is likely, because both the weak and strong micro-seism will come through to the geophone.

Simple Distance Test

A simple test was made to determine that the sound travelled and can be picked up by the geophone through gypsum and shale. The geophone was placed in a regular hole as a monitoring station. Pillar centers were tapped by an assistant and a man at the monitoring station recorded at what attentuating station the sound could be heard.

In this experiment, the following was recorded:

Attenuator set at 3 — distance equals 260 ft.
Attenuator set at 4 — distance equals 170 ft.
Attenuator set at 5 — distance equals 60 ft.

It can be readily seen by the use of the attenuator and a stationary monitoring control point that it is possible to determine how far the activity is away from the station. This activity can be in a tunnel on either side of the monitoring station, or in a mine using the room type of excavation, any point 360° from the monitoring station. If the monitoring station is changed to one other location, the direction of the activity can be determined.

General Conclusions

1. The micro-seismic detection apparatus can be used as a quantitative determination of the safety of a tunnel or mine roof or back.

2. It is possible to determine the micro-seismic rate at failure of a tunnel roof in situ.

3. It is possible to get a relative comparison of the micro-seismic rate at failure from laboratory experiments by crushing a sample of the particular rock.

4. The micro-seismic rate is not a continuous frequency impulse, but varies from complete silence to high activity.

5. Because of the intermittent activity, the micro-seismic rate must be averaged over a listening period. The listening period must be determined at location.

6. By varying the attenuation of the instrument, or by varying the location of the geophone, it is possible to locate the area of activity within practical limits.

7. The micro-seismic detection apparatus can be used to determine when the pinning of a roof is safe, or when arch supports and lagging are used, to determine whether they are performing adequately and that the roof is safe. When the supporting members are becoming effective, the micro-seismic rate reduces to zero.

8. With experience, it is possible to determine within practical limits, the time of occurrence of a roof failure.

9. The intensity of a micro-seism varies inversely as the square of the distance from the source.

10. If the micro-seismic activity is a great distance away, the character of the noise is likely to scratchy.

11. If the micro-seismic activity is very close, the character of the noise approaches a tone.

12. If the micro-seismic activity is a long distance from the geophone, the rate is likely to be low, because only the more intense micro-seismic will be heard.

13. If the micro-seismic activity is close to the geophone, an increase in rate is likely, because both the weak and strong micro-seism will come through to the geophone.

Characteristic Sounds

Gypsum—Crushing strength varies between 1700 to 2600 p.s.i. in pure sample.

A. At low percentage of crushing strength, the sounds were gritty, sharp, sandy and extremely intermittent.

B. At failure, the sandy sounds predominated, and it was similar to the sounds of a sandstorm on the beach.

Limestone

A. Sharp, continuous impulses are heard, like ball bearings falling on stone.

B. These sounds have a pattering nature, frequent in occurrence and at times like rain on a window pane.

Shales—Crushing strength from 3600 p.s.i. to 10,000 p.s.i.

A. Sounds resemble creaking of timber, i.e., one or two large intermittent noises.

B. A heavy sound is heard resembling loose coal in a wood chute, almost hollow sounding at times.

Basalt

A. Produces sharp intermittent tube tones, similar to a low pitch of "tube like" door bells.

B. At failure, sharp distinct bell tones are heard.

Halite and Sylvite

A. Produces a crackling sound with no tone, similar to shoes slipping on sand.

B. Sharp crackles are heard much like crushing cellophane or the crunch of stepping on crushed rock pathways.

Sylvanite

A. Produces slight unpleasant tone, similar to knocking two stones together under water. A tunk sound.

B. A sound not as granular as halite produces more tension in the sounds, similar to a spring being twanged, and not musical in quality.

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PROBLEM OF A METROPOLITAN DISTRICT SYSTEM OF REFUSE DISPOSAL INCINERATORS

By C. A. Turner*

(Presented at a meeting of the Sanitary Section, BSCE, held on June 2, 1954.)

This paper concerns the problems of a Metropolitan Incinerator System. At the outset, I believe a few definitions are in order, the first of which is the word "refuse." In this paper this means all forms of material which the householder must dispose of. It, in turn, may be broken down into garbage which, as you probably are all aware, is the residue from the preparation of food and the word "rubbish" which includes all other items of material of which a householder must dispose. This latter includes such things as papers, tin cans, bottles, ashes, old bedsprings, and any other material except garbage. The other definition is that of incinerator capacity. Incinerators are normally rated in the amount of material which they can consume in the period of 24 hours operation; thus, a 200-ton plant is one which can consume 200 tons of refuse in 24 hours of operation.

Before considering the problems of an incinerator system, there is a basic question which immediately arises; namely, why is any public means of the disposal of refuse needed. In the Colonial days this certainly was not so; each householder took care of his own refuse, possibly dumping the material behind the barn, burying it or burning it, depending upon what the refuse was and his own inclination. Today, however, this is obviously impractical due to the increase in population, the population density and the accompanying decrease in the amount of available land for the disposal of refuse. At the same time there has been a steady increase in the amount of refuse produced per person due to the development of more packaging in cartons, cans and bottles. It thus long ago became impossible for the individual to take care of his own problem, for as can be easily understood the city dweller, particularly in apartment buildings, has absolutely no land where he may dispose of this material. Therefore, it becomes necessary that municipalities provide a place for the dumping and, as transportation and living arrangements became more com-

*Chief Mechanical Engineer, Thomas Worcester Inc., Boston.

plicated, for the municipality to also collect this material and transport it to its designated disposal point. The requirements of better housekeeping and more service now demanded by the public have made refuse disposal a municipal chore even outside of densely populated city areas. So, for many years now all except the small towns have been faced with and have coped with this problem.

So, a second question might well be: Well, if they have coped with the problem, why is it necessary for a Metropolitan District to consider it. The answer to this follows much the same pattern on a larger scale. Living is becoming more complicated—available land, scarcer—the cost of construction and operation of disposal facilities, higher, so that it is now beginning to be beyond the practical capabilities of the individual municipality, in the same manner that it outgrew those of the individual householder. So, it seems to be advisable that a Metropolitan District Agency undertake to solve the problem of refuse disposal.

In a similar manner, in 1889 the Metropolitan District Commission took over the sewer system for the district and in 1895 the water distribution system. The State has been aware of this, and in 1950 a bill was passed by the Legislature calling for an investigation of the situation. The investigators, in reporting, recommended that a complete survey and study be made and the Legislature appropriated funds for this in 1951. The report of Thomas Worcester Inc. on the "Advisability of the Construction and Operation of a Metropolitan System of Refuse Disposal Incinerators" is the outcome of this 1951 bill.

Now, let us consider the character of the area. The Metropolitan District, as it now exists, includes some 43 cities and towns which cover an area of approximately 450 square miles. The terrain is not too difficult, not being mountainous and in it are ample sites for disposal facilities. The transportation system of the area is, however, rather complex and difficult at the present time. The new highways now under construction and consideration will alleviate this situation as they are built. These highways, their locations and the accessability to the centers of population materially affect the site choices for disposal facilities.

The population of the District, according to the 1950 census, was 2,120,000 ranging all the way from 1,711 for Dover to 791,000 for Boston, the latter representing one third of the total. Boston, Cambridge, Somerville and Lynn contain one half of the total population of the District and three-quarters of the total is contained in twelve of the communities which, however, cover only one quarter of the total area. Thus, the population density varies from 113 people per square mile in Dover to 26,000 in Somerville. The population density not only affects the seriousness of the situation and the demand that something be done about refuse disposal, but also the method by which the solution is reached. Population trends also have a bearing on this. Records since 1900 show that in the central area, near saturation has been reached and that any solution now made would be relatively permanent. On the other hand, in the fringe areas, where new highway systems and the inclination towards suburban living are showing up in increasing densities, a permanent solution is more difficult. Fortunately, however, it is not necessary that the problems of such areas be solved immediately and more will be known about this trend when the time comes for actual construction.

Out of the 43 communities in the Metropolitan District, there are 14 who do not collect, a few of which who do not even provide a municipal dump. Four of the 43 already have incinerators. These are Waltham, Brookline, Cambridge and Newton. Twenty-five use dumps of one form or another. Of these 25, four are now forced to dump outside their own boundaries, creating an even more serious problem. These four are Somerville, Chelsea, Malden and Boston. There are 14 of the 43 who are actually considering incineration in some form or another. Some of these 14 are in the first group who now provide no service whatsoever.

The collection practices of the various communities are generally similar, although there is some variation as to whether or not they segregate one form of refuse from another. There are those communities where garbage is collected separately in order that it may be sold to hog farmers, thereby giving some revenue to the community, and others who collect non-combustible refuse separately from combustible. This latter is particularly true of those having incinerators as it is not desirable to put ashes, bottles and most non-combustibles through an incinerator, although tin cans are always put through if possible, for it not only sterilizes them but reduces their volume so they take up less space in their final dumping point.

Transportation practices are not greatly different in the various communities. Some use open trucks; some, closed; and still others, both. In a few instances, it is necessary that trucks of one community cross the territory of another in order to reach their dumping ground. This is true of Boston, where trucks from the Brighton District cross Brookline before they reach dumps in the southern part of the City of Boston. This creates a serious problem for at any moment these communities being crossed by the trucks from others could refuse to allow this, thus creating considerable confusion.

Now let us consider the production of refuse. There is a nationally-accepted average figure for refuse production of 2 pounds per day per person. This will vary from 1 to about 3½ depending upon the type of area from which it comes and slightly upon the time of year. The peak is reached in late summer. Lower class areas produce less than the higher class, and business areas are inclined to produce the higher figures; this is particularly true of the Downtown Boston section. This national average of 2 pounds per day per person was checked quite closely when we made a report to the City of Boston not too long ago and actually made weighings of several of the districts considered. There has been a continuing trend for the amount of garbage to be on the decrease, apparently due to the advent of frozen and canned foods as against fresh ones.

This 2 pounds per day per person so adds up in the Metropolitan District that each and every day of the week there are about 2,000 tons of refuse created which must be disposed of, and inasmuch as most disposal systems operate only 5 out of the 7 days this brings the figure up to nearly 3,000 tons per day for the working week. This is certainly a problem of considerable magnitude.

Now let us consider the possible means of the disposal of all this material. Refuse disposal in a broad sense includes not only the disposal itself, but also the transportation and collection of the material. In this discussion we are concerned primarily with the first item, as both the transportation and collection logically remain with the individual municipality and it will only be the disposal itself which will concern the Metropolitan District. It is the point of this disposal, or in other words the location of the facilities, which is affected by the facility of transportation within the surrounding area so that it can be located where it will be of least nuisance and yet not at too costly a distance. This also affects the type of disposal facilities which can be accepted.

There are four general types of refuse disposal; the first of these and the most commonly used is that of dumping. Dumps may be broken down into those wherein the combined garbage and rubbish are disposed of, or in those where only rubbish is taken care of. These may be further broken down into the open dump, which is the most commonly used in this area where the material is merely dumped on the top of the existing surface of the earth. This type of dump, of course, is extremely unsanitary, vermin infested and very subject to fires; therefore, it must be located at a point isolated from the center of population. Accordingly, the cost of transportation of the refuse from the household to the dump is materially increased. The second type of dump is somewhat more satisfactory and is that known as the land-fill type. In this case, the material is either dumped into trenches which have been dug ahead of time, or on the face of a bank. In both cases the refuse is covered with fresh earth at the end of each day. This type of dump, although more expensive to operate, is considerably less subject to fires and somewhat more sanitary, although it still makes an excellent breeding place for rats and other types of vermin. In either case the land being used is unsuitable for other purposes for a long time although eventually, of course, the material will settle sufficiently so that buildings may be placed upon it. It does, however, increase the foundation troubles to some extent.

The second means of disposal of refuse is that of feeding the garbage to hogs, but this also has its disadvantages, as you perhaps all know from having been in the vicinity of a hog farm. In addition, this is an all too easy means of transmitting disease from the garbage to the hogs and back to humans, sufficiently so, that laws have now been passed requiring all garbage fed to hogs to be precooked. This may remove the danger but certainly does not remove the smell, and I understand that the hogs do not care too much for the cooked garbage. As a means of disposing of garbage only, the use of household dispose-alls or mechanical pigs as they are often called is excellent; but somewhat difficult, however, to apply to an entire community although we understand it has been done in some small communities in other parts of the country. They have one advantage over all other means in that the smelly garbage can is banished forever from the household.

The best means of refuse disposal, and it can be used for all types, except non-combustible materials, is that of incineration. It has distinct advantages over most of the others. It is completely sanitary, for the high temperatures in the incinerator furnace sterilize the refuse, eliminate all odors and produce an ash which is not only sanitary but makes excellent fill. Furthermore, the use of incinerators eliminates the necessity of large areas for dumping as the ash is of much smaller volume than the raw refuse. The principal disadvantage of an incinerator is, unfortunately, one of economics.

The present cost of refuse disposal varies from 21 cents per capita per year in the Town of Weston to $4.44 in Arlington. These costs were obtained from municipal reports, they being the best and often the only source of such information. It is impossible in many cases to break down this cost into final disposal as compared to total over-all including transportation and collection. Each municipality has a slightly different bookkeeping system and some do not make any breakdown. However, from 20 of these communities in the District, the evidence indicates the final disposal cost ranges from 8 cents in Needham to 60 cents in Chelsea per person per year, with an average of 23 cents. There is an additional unseen and indeterminable cost connected with present practices and that is the one of land damage due to the nuisance value of a large, smelly, smoky dump.

Incinerators cost between $2600 and $3000 per ton to build, and the operating cost averages between 82 cents and $1.64 per capita per year, this varying with the size of the plant, the hours which it is operated and the labor rates pertaining in a particular area. In the report made for Boston, it was estimated that an incinerator plan at Barry's Ledge would cost 65 cents; one at Southampton Street, 75 cents; and one in Brighton $1.31 per capita per year to operate. The lower figures are somewhat below the 82 cents mentioned above, inasmuch as construction costs were at that time considered to be less than the $2600 above mentioned. In considering the over-all cost of the refuse disposal, transportation must be studied, not only in terms of the distances which must be covered but in the time which would be taken between the collection point and the final disposal point. This is where the characteristics of a highway system must be evaluated.

Although the economics of any such program must be of prime consideration, it still is necessary to weigh the costs against results attained and the demand which is put upon the community by its people. We will discuss this balance at a later point.

In setting up a Metropolitan System for Refuse Disposal, an over-all plan must first be determined, with the locations of disposal points and their relation to the areas to be served and the sizes of the facilities to be constructed carefully considered. There is an infinite number of locations available in the District and one advantage of having the system under the control of a State organization rather than the individual municipalities is that a State Authority would be better able to choose the proper site. The system which we have set up is based on incineration as the only proper solution to the problem. The plants considered were based on a 24-hour day, 5-day-per-week operation. It was decided to leave the present four communities having incinerators out of the picture for the time being. Although not in all cases possible, it is advisable to standardize size of the incinerator plants, and we have tried to do this as far as the demands would allow. The disposal plants must be located near highways and as close as possible to the centers of population, because of the cost of transportation. Studying the situation, it appeared that a 750-ton plant to be located at Southampton Street near the New Market District was the key to the entire Metropolitan District System. This plant recommended in our report to the City of Boston is now in the preliminary design stages by the City. I understand that its actual construction has been delayed until the route of the new Central Artery is definitely decided, emphasizing the effect of transportation upon any solution.

Two basic plans were developed in an attempt to solve this problem and various sites selected for incinerator plants. These sites, of course, are subject to some slight movement which will in no way affect the general over-all picture. Considering these recommended plants in the order of their importance, we come first to the 750-ton one at Southampton Street which we just mentioned. This would be near the egress of the new Central Artery. It would serve Charlestown, the North, West and South Ends of Boston, the Back Bay area, Stuart Street, Elm Hill, Dudley area, Mission Hill, Roxbury and South Boston, three quarters of the Dorchester North area and the Downtown section of Boston, the heaviest per capita producer of refuse in the entire District. I might mention that the names of these various districts are those which have been assigned to them by the City of Boston and they continue to be used as a matter of convenience.

The second plant in order of importance would be located in the Mystic marshes, near the Medford-Somerville line at the junction of the Mystic Valley Parkway and the Fellsway. This area is now becoming largely industrial and the M.D.C. controls a greater part of it; thus, it is an ideal site. This would be a 450-ton plant serving Medford, Malden, Everett and Somerville.

The third plant recommended is one of 300-ton capacity and located either on the Watertown dump or on a site at Wexford Street in Brighton. This plant would serve Brighton, Watertown, Belmont, Arlington and possibly Lexington, if the Town government of Lexington decided to come in on the project. The picture here may be somewhat changed inasmuch as the legislature is, at present, considering a bill to set up an incinerator administration for Watertown and Brighton, with a plant to be built just for these two communities. If this goes ahead, some reshuffling would be necessary to take care of Belmont and Arlington.

We recommended that at Barry's Ledge, off Cummins Highway in Hyde Park, a 400-ton plant be constructed which would take care of the southern half of Boston and part of Milton. This plant would serve 243,000 people.

A fifth site was chosen on Salem Turnpike, crossing the marshes between Revere, Saugus and Lynn. A plant here would serve East Boston, Chelsea, Revere, Saugus, Lynn, Winthrop, Swampscott and Nahant. These latter three communities—Winthrop, Swampscott and Nahant—are somewhat distant from the particular plant, but so they would be from any, due to their isolated geographical location. This would have a capacity of 450 tons. A possible substitute location for this plant might be found in Revere if necessary.

The above five plants would relieve the acute situation now existing in the more densely populated areas of the District and serve 67 per cent of the total population. If the four already in operation were added to these five new ones, 82 per cent of the population would be served. A sixth plant which should be built in the not-too-distant future would serve Quincy, Braintree, Weymouth and one-half of Milton and would be located on the Quincy-Braintree line, with a capacity of about 300 tons. The other fringe areas of the District are not only more dubious from an economic viewpoint, but there is little demand that something be done at present, and they are important only from the viewpoint of sanitation and nuisance as they still have ample territory in which to find dumping facilities. However, eventually a 200-ton plant should be built to serve the towns of Wellesley, Needham, Dedham, Dover, Westwood, Norwood, Walpole, Canton and Stoughton, and another 200-ton one to serve Reading, Woburn, Winchester, Stoneham, Melrose and Wakefield. Obviously, these towns with their present low cost of disposal would not be expected to be overly interested, inasmuch as an economically sized plant to serve them would, of necessity, be somewhat distant from many of them. Thus, these eight plants basically cover the entire Metropolitan District area. As it seemed advisable to offer an alternate solution to the problem, we developed a second plan, with the location for the various incinerators at different sites.

The deeper one got into the problem, the less it seemed possible to depart greatly from Plan I. On the north side of the city, there was only one possible change, that of dividing the Lynn-East Boston district into two; but this was ruled out by economic considerations. However, it did seem feasible to divide the Boston South area between two plants, substituting a 250-ton plant at Gardner Street in West Roxbury and a 400-ton plant at the Neponset River near Granite Street for the one at Barry's Ledge in Plan I and serving South and East Boston, Milton, 90 per cent of Quincy, and 25 per cent of Braintree. Going still further south, in the Whortleberry Pond area in Weymouth, a unit of 150-ton capacity would serve the remaining 10 per cent of Quincy, 75 per cent of Braintree and all of Hingham, Cohasset and Hull. Another change was a 100-ton plant which would serve Westwood, Dover, Norwood, Walpole, Canton, Stoughton and a part of Dedham. Plan II takes nine instead of eight as per Plan I and, therefore, would not be quite as economical, although each could handle basically the same tonnage of refuse and serve the same number of people. It would, of course, under either plan, be possible to expand the hours of operation of the present four incinerator plants, thereby possibly slightly reducing the required new capacity. However, this would be a high-level policy decision and is not contemplated in this report.

Now let us consider the results of these recommendations from the money angle. Although the cost of incinerator construction and operation is not terribly excessive, it is still more than that of dumping; however, in the central higher population density area the two more nearly approach each other. For Plan I, there would be an investment necessary of $8,775,000 for incinerator equipment to serve 1,793,000 of the total population of the district. At the present time, the annual total cost of final disposal is approximately 60 cents per capita per year, which is somewhat less than 94 cents anticipated with the use of incineration. For Plan II, the cost of incineration would be of very little difference—96 cents as against 94. In the central area, where the problem is most acute, the present cost of final disposal is 66 cents and the estimated cost of incineration is 86 and 89 cents respectively for Plans I and II, still higher than the present practice. However, these higher costs are offset by a number of factors. In the first place, the use of incineration will increase property values in the area by the elimination of dumps; secondly, there is the possibility of some revenue to be recovered if steam may be generated in an incinerator plant and sold. This might be possible at the Southampton Street 750-ton plant where there is already a load from the Boston City Hospital available in the immediate vicinity. Furthermore, at the end of the amortization period, incineration becomes cheaper than the present practice, which itself will probably increase in cost as time goes on. And finally, particularly in the central area, it is just a necessity as dumping areas are running out fast.

In conclusion, first we wish to point out that the problem of refuse disposal, now serious, is becoming worse every day, as the population density increases and available sites for dumping becoming scarcer and even non-existent in some localities. Incineration not only seems to be the one possible solution in these dense areas, it is from most viewpoints, a better solution in any area. Individual plants built by single communities are uneconomical, thus making it desirable for the Metropolitan District to take over the problem, and we feel that the central area of the district, including two thirds of the population but covering only one quarter of the total area, should be taken care of as soon as possible with the fringe areas coming later as the demand requires. In other words, there should be five plants built at the present time. First, 750-ton plant at Southampton Street; second, a 450-ton plant at the Mystic marshes; third, a 300-ton plant in Watertown on the dump or at Wexford Street in Brighton; fourth, a 400-ton plant at Barry's Ledge, and fifth, a 450-ton plant in the Revere-Saugus-Lynn area. The cost of these five plants would be approximately $7,000,000.

OF GENERAL INTEREST

INFORMATION WANTED

Information concerning the whereabouts of one of the two specially made transits used in the 1860's by Thomas Doane (1821-1897), Past President of the Boston Society of Civil Engineers, to "run the line" in the Hoosac Tunnel.

One of these twin transits was given to Doane College in the 1890's. The other was thought to be in the Blue Hills Observatory, near Boston. However, no clue to its location could be obtained at the Blue Hills Observatory.

Mr. Thomas Doane Perry, grandson of Thomas Doane, is attempting to trace the instrument because of its historic value and to see that it is properly preserved and labeled. Mr. Perry feels that "it must be somewhere around Boston" and suggests that members of the Boston Society of Civil Engineers "would be the most likely source of information". The Doane Transit has a 2¼" aperture x 24" long, and a plate on the instrument bears the inscription, "J. H. Temple, Maker, Boston, 2". If you have any information concerning the whereabouts of this instrument, please communicate with Mr. Thomas D. Perry, 301 East Main Street, Moorestown, New Jersey.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

SEPTEMBER 29, 1954.—A regular meeting of the Boston Society of Civil Engineers was held this evening at the American Academy of Arts & Sciences, 28 Newbury Street, Boston, Mass., and was called to order by President Miles N. Clair, at 7:05 P.M.

President Clair stated that the Minutes of the May 19, 1954, meeting would be published in a forthcoming issue of the Journal and that the reading of the minutes therefore be waived unless there was objection.

The President announced the death of the following members:—

William N. Parsons, who was elected a member April 5, 1954, and who died June 4, 1954.

Karl T. Compton, who was elected an Honorary Member February 17, 1932, and who died June 22, 1954.

Robinson Abbott, who was elected a member September 15, 1919, and who died June 18, 1954.

Frank H. Stuart, who was elected a member March 19, 1924, and who died July 28, 1954.

Walton H. Sears, who was elected a member December 21, 1927, and who died August 7, 1954.

The Secretary announced:—

The names of applicants for membership in the BSCE.

That the following had been elected to membership on June 16, 1954.

Grade of Member—John K. Hunt.

That the Annual Student Night meeting which is held jointly with the

Northeastern Section of the American Society of Civil Engineers would be held on October 27, 1954, at Harvard University.

President Clair then introduced the speakers of the evening:—

HAROLD L. HAZEN, Dean of the Graduate School, Massachusetts Institute of Technology.
Subject—"Background and Highlights of the Interim Report of the Committee on Evaluation of Engineering Education".

WILLIAM C. WHITE, Vice President of Northeastern University.
Subject — "The Humanistic - Social Content of the Engineering Curricula".

JOHN B. WILBUR, Head of Department of Civil Engineering, Massachusetts Institute of Technology.
Subject—"Synthesis in the Education of the Engineer during Early Training rather than later or not at all".

OSCAR S. BRAY, Project Manager, Jackson & Moreland, Boston.
Subject—"Thoughts on an Engineering Education".

A short discussion period followed after which members gathered in the Lounge, where a collation was served.

A rising vote of thanks was given the speakers.

One hundred and ten members and guests attended the meeting.

The meeting adjourned at 9:05 P.M.

ROBERT W. MOIR, *Secretary*

OCTOBER 27, 1954.—A Joint Meeting of the Boston Society of Civil Engineers with the Northeastern Section of American Society of Civil Engineers was held this date at Harvard University, Cambridge, Mass. Members of Student Chapters and Civil Engineering Students of the New England Colleges were especially urged to attend.

A cafeteria style dinner was held in Harkness Commons, Harvard University, from 5:30 to 6:30 P.M. Student delegations were present from Tufts College, Northeastern University, Harvard, Massachusetts Institute of Technology, University of New Hampshire, Brown University, University of Rhode Island, University of Massachusetts, Dartmouth College and Merrimack College.

President Clair called the meeting to order at 7:00 P.M., and extended a cordial welcome to the Students and expressed appreciation of the cooperation of the officers of the student organizations and of the faculty members in making this event so successful.

President Clair called upon the Secretary to announce the names of applicants for membership in the BSCE.

The Secretary also announced that the following had been elected to membership:—

Grade of Member.—Louis R. Anderson, William E. Haskell, Jr., Guy T. Lewis, Theodore R. Mottola. Robert A. Snowber, Norman K. White, George R. Winters, Luke Capozzoli.

Grade of Junior.—Robert J. Assenzo, James L. Bell, Howard J. Farquharson, Charles H. Flavin, Jr., John J. Gillis, Edwin H. Goodwin, Norman Katziff, John A. Kelch, Robert W. Kwiatkowski, Virginia A. Landry, Philip R. Lindquist, Domenic J. Maio, Robert C. Marini, Kenneth F. Mercier, John W. Meyers, Weedon G. Parris, Jr., James R. Pelkey, Robert F. Pelletier, Charles W. Terenzio.

President Clair introduced John B. Wilbur, President of the Northeastern Section of the American Society of Civil Engineers, and asked him to conduct any necessary business for ASCE at this time.

President Clair then introduced the speaker of the evening, Vice-Admiral Frederick M. Trapnell, USN (Ret.) of Grumman Aircraft, who gave a most interesting talk on "Development of Structural Flight Testing".

A demonstration of Flight Safety

Equipment Used in Jet Aircraft was given by Bruce Tuttle, Test Pilot, and R. S. Moore, Safety Director at Grumman Aircraft Corporation.

A rising vote of thanks was given the speakers.

Two hundred seventy four members and guests attended the meeting.

The meeting adjourned at 9:00 P.M.

ROBERT W. MOIR, *Secretary*

NOVEMBER 17, 1954.—A regular meeting of the Boston Society of Civil Engineers was held this evening at the American Academy of Arts & Sciences, 28 Newbury Street, Boston, Mass., and was called to order by President Miles N. Clair, at 7:00 P.M.

President Clair announced that the Minutes of the October 27, 1954, meeting would be published in a forthcoming issue of the Journal, and that the reading of the minutes would therefore be waived unless there was objection.

The President announced the death of the following members:—

Harry P. Burley, who was elected a member April 20, 1892, and who died August 22, 1954.

Joseph H. Fitch, who was elected a member June 21, 1905, and who died September 25, 1954.

The Secretary announced:—

The names of applicants for membership in the BSCE.

That the following had been elected to membership on November 15, 1954:—

Grade of Member.—John L. Burdick, George C. Wallace, Richard L. Wood.

President Clair then introduced the speaker of the evening:—

Waldo G. Bowman, Editor, Engineering News Record, New York, N. Y., who gave a most interesting talk on "Engineering Ethics".

Prepared discussions were presented by Thomas A. Berrigan, Harry P. Burden, Thomas R. Camp, Thomas E. Needles and Isadore Richmond, and were followed by a general discussion.

At the close of the meeting President Clair announced that a Collation would be served on the floor above.

Ninety one members and guests attended the meeting.

The meeting adjourned at 9:30 P.M.

ROBERT W. MOIR, *Secretary*

STRUCTURAL SECTION

OCTOBER 13, 1954.—A meeting of the Structural Section was held Wednesday evening at the Society Rooms. Dr. Ruth D. Terzaghi, Chairman, opened the meeting at 7:05 P.M.

Professor John M. Biggs, of the Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, was the speaker. His subject was "Buckling Considerations in the Design of Steel Beams and Plate Girders".

Professor Biggs illustrated his talk by a number of slides showing the types of buckling which should be considered by the designer and the critical buckling stress for each as a function of various parameters. In each case he compared the theoretical relations with the corresponding provisions of building codes. He emphasized the fact that the codes have been over-simplified in the matter of provisions to prevent failure by buckling. As a result of this oversimplification, the code provisions do not provide consistent factors of safety. In many instances this leads to unduly large factors of safety, and in certain cases the factor of safety may be somewhat lower than would appear to be desirable.

The speaker also noted that the methods by which the designer determines permissible unit stresses, as influenced by code provisions, are extremely crude in comparison with the methods of analysis for gross internal forces; i.e., thrust, shear and moment. Thus the precision obtained by modern methods of analysis for these gross forces frequently is lost in the subsequent selections of permissible unit stresses. In Professor Biggs' opinion the provisions for safety against buckling could be made more consistent, that is more reflective of the influences of the several significant parameters, without becoming so complex as to unduly burden the designer.

The talk was well received by the 39 members in attendance.

The chairman called attention to the forthcoming joint ASCE-BSCE Student Night at Harvard University on October 27, 1954.

A. L. DELANEY, *Clerk*

NOVEMBER 9, 1954.—The Structural Section held a meeting on Tuesday evening at the Society Rooms. In the absence of Chairman Dr. Ruth D. Terzaghi, Vice-Chairman C. Kray opened the meeting at 7:05 P.M.

Myle J. Holley, Jr., Associate Professor of Structural Engineering at Massachusetts Institute of Technology, spoke on "Relative Strength of Prestressed and Ordinary Concrete". The talk was illustrated by slides.

Professor Holley started by comparing the designs of reinforced concrete sections and prestressed concrete sections in flexure and pointed out the reasons why prestressed concrete appears to have greater resistance in flexure. The advantages and structural characteristics of prestressed concrete were listed, but it was shown that it was not possible to have all these advantages in any single design. For instance, if we wish to take advantage of shallower depths, then it must be at the expense of stiffness. The carrying capacity, stiffness, resisting moment and shear characteristics of the two types were examined and coefficients of resistance and useful load ratio versus span were discussed.

In conclusion Professor Holley stated that prestressed concrete should not be used as a substitute for other materials but only where requirements indicate that it should be used. He feels that there will always be a definite place for reinforced concrete just as there is a place for every material and the proper material should be used in that place.

Sixty-five members were in attendance, and the talk was very well received.

A. L. DELANEY, *Clerk*

SANITARY SECTION

OCTOBER 6, 1954.—Chairman Edward W. Moore called the meeting to order shortly after 7:00 P.M. at the Society Rooms after an informal dinner at Patten's Restaurant. Twenty members and guests attended the dinner and sixty-seven members and guests attended the meeting.

The speaker for the evening was Clair N. Sawyer, Professor of Sanitary Chemistry, Massachusetts Institute of Technology, and he presented a paper entitled "High Rate Sludge Digestion". Professor Sawyer presented a critical review of the current developments in the field of high rate sludge digestion, and then described the results of recent studies made by him and his co-author, Mr. Harold E. Schmidt, at their laboratories at M.I.T. At the conclusion of the paper there was a lively and lengthy discussion between the speaker and Harold Thomas, Frank Flood, Ariel Thomas, and several others.

The meeting was adjourned shortly before 9:00 P.M.

DARRELL A. ROOT, *Clerk*

ADDITIONS

Members

Stuart M. Alexander, c/o Inernational Engr. Co., 74 New Montgomery Street, San Francisco, California

Louis R. Anderson, 80 Central Street, Brookline 46, Mass.

George A. L. Brown, 44 Salem Street, Andover, Mass.

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John J. Dwyer, 109 Fuller Street, Dorchester, Mass.
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William E. Haskell, Jr., 65 Harrison Avenue, Saugus, Mass.
John H. Hession, 228 Slade Street, Belmont, Mass.
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Theodore R. Mottola, 65 Pine Ridge Road, W. Medford, Mass.
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Charles W. Terenzio, 41 Bailey Road, Arlington, Mass.

DEATHS

Harry P. Burley, Aug. 22, 1954
Joseph H. Fitch, Sept. 25, 1954
D. Joseph Hennessy, Nov. 25, 1954
Joseph A. Rourke, Dec. 11, 1954

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