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HYDRAULIC LABORATORIES IN EUROPE

By Lawrence C. Neale,* *Member*

Introduction

As a traveling Freeman scholar during 1955, visits were made to as many European laboratories as the time allotted would allow. Laboratories were visited in France, Italy, Switzerland, Germany, Belgium, Netherlands, Denmark, Sweden, Norway, Scotland and England. The total number of university laboratories seen was 56, while 8 of a governmental nature and 16 under private sponsorship were contacted.

The principal interest was on Hydraulic Laboratories but several facilities concerned with research in allied fields were seen when some particular work or interest was indicated.

In all the countries the reaction was most cordial and information was given freely by the staff members. The descriptions of the laboratories are a combination of data supplied by the activities plus notes and excerpts from conversation and it should be pointed out that with short visits and some language difficulty, there may be inaccuracies in the detailed information as presented.

In retrospect the inspection of these laboratories was an unparalleled opportunity for the author who wishes to express his appreciation to the Freeman Fund Committee of the Boston Society of Civil Engineers and the Alden Hydraulic Laboratory of Worcester Polytechnic Institute for making the opportunity possible.

A detailed description of each of the laboratories visited is on

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file with the Boston Society of Civil Engineers. Since the detailed report could not be published in its entirety, an abbreviated summary is herewith presented. In the case of each laboratory a specific piece of equipment or activity has been described. In several cases the item described is not the most important or more representative but because it seemed unique or filled a particular need representing unusual thought and initiative.

ITALY

In Italy, university hydraulic laboratories were visited in Pisa, Roma, Naples, Bologna, Padua and Milan as well as the machinery laboratory at the Riva plant in Milan.

Pisa

At Pisa, the laboratory under Professor Ruggiero was devoted to basic research and student instruction. A glass-sided steel framed, tilting flume was used for both basic research and instruction. The flume was ½ meter by ½ meter and 8 meters long and could be tilted from —10° to 10° by a manually operated screw jack. The supply from the laboratory constant head tank was in 20-centimeter diameter pipe with flow measurement by a venturi meter. For a refinement on the alignment and smoothness of the flume floor, the flume was set at 0° and a plastic base was flowed on the floor and allowed to set.

Rome

The hydraulic laboratory at the University of Rome was directed by Professor DiRicco and was concerned mainly with student instruction.

A concrete flume 5 meters wide by 18 meters long and 0.50 meters deep was set up to study the mechanics and origin of meandering flow in natural streams. Flow measurements can be made at either end of the flume by volumetric tank or V-notch weir. Different sizes, weights and mixtures of bed material could be used.

Naples

At the University of Naples, the Hydraulics Department was under the supervision of Professor Ippolito while Professor M. Viparelli handled the work of the Hydraulics Laboratory. The laboratory had a wide range of interest and activity with about equal space devoted to student or basic work and the sponsored type of research. For use in the basic program, there was a sloping flume extending from one room to a room on the floor below. The flume was constructed of wood and concrete and was 0.2 meters wide with walls 0.1 meters high and inside surfaces of smooth concrete. Located on steel guides was a pitot type sampling device which takes air or water or various mixtures of air and water to be separated and analysed.

Bologna

In Bologna, two laboratories were visited. The laboratory under Professor Evangelisti was concerned with Hydraulic Construction. The principal piece of test equipment was a steel frame tilting flume 0.5 meters wide by 0.8 meters deep and 17 meters long, with glass panelling on both sides for the entire length. It was supported on two sets of jacks interconnected and driven electrically to maintain alignment over the range of angles. The floor of the flume was machined to give a smooth, straight surface and the head box is attached permanently to the flume so that there is no seal difficulty at the joint between head box and flume with the transition maintained at an optimum design.

The Hydraulics Laboratory under Professor Supino, at Bologna, was concerned with the elementary hydraulics as well as some basic research and outside consulting. The flow meter calibration arrangement in the laboratory was set up to accommodate meters from industry as well as the laboratory meters. The three pipe lines (4″, 8″ and 12″ diameter), leading to the volumetric tank were arranged with a single standard manometer setup. The switching arrangement located just downstream of the nozzle consists of a steel vane which was operated by an electric motor and a heavy fly-wheel. A timing device and an automatic time recorder was connected into the switching device. The volumetric tank had a capacity of 10 cubic meters.

Padua

The hydraulic laboratory at the University of Padua was under the direction of Professor Marzolo, but acting director Professor Ghetti conducted the tour of the facilities. The equipment at the laboratory was largely constructed by the staff of the laboratory and the pieces exhibited the ingenuity of the group in the simplicity and effectiveness in operation. A sample was a surge tank study made up with simple steel pipe, a plexiglass side surge tank and glass tube manometers, all supplied from the laboratory mains.

At the Hydraulic Machinery Laboratory of Professor Medici, the variety of test stands for all the standard types of turbine and pump as well as a number of basic experiments amounted to the largest array of machinery test equipment seen in Italy.

The Maritime Construction Laboratory under Professor Ferro had a large concrete flume with one glass side that was 1 meter wide by 1.2 meters deep and 30 meters long. A vane type wave maker was installed at one end and a rail mounted on the walls for supporting a travelling carriage.

Milan

At Milan, the Institute for Hydraulics and Hydraulic Construction was under the direction of Professor diMarchi. The laboratory has pioneered in many areas over the years. Apparatus was set up at the time of the visit to study the performance of model syphons both to relate the data to a full scale problem and to models of different scale in order to determine the scaling laws for syphons. The models were plastic so that observations and photographs could be made during the tests.

The Industrial Machinery Laboratory of the Riva Company in Milan was outstanding in that the philosophy in arrangement of equipment was to have all the pieces as mobile as possible. This meant that for all the different test equipment, only the heaviest pieces are fixed, thus assuring a maximum of flexibility.

FRANCE

In France, University Laboratories were visited in Toulouse, Grenoble and Lille, while other laboratories, both private and government were seen in Grenoble and Paris.

Toulouse

At Toulouse, Professor Escande had developed a laboratory and staff that had many interests in the field of Hydraulics. One model study on transient flow phenomena included a 25 cm. pipe 30 meters long attached to a trapezoidal flume 60 meters long. The transmission of pressure waves from flow changes in the pipe into the open channel was being studied.

Grenoble

At Grenoble, the Hydraulics Laboratory under the direction of Professor Kravchenko had a program of student instruction and basic research. One research project was a study of the mixing process between concentric jets. The apparatus was arranged with the primary flow in the center section of the test area, and the secondary flow discharging around the primary. The test section was approximately 5 centimeters high by 40 centimeters wide and 1 meter long. The primary flow was a jet discharging under a 5-meter head while the secondary jet discharged under a head of about 0.5 meters. Either discharge could be varied and the resulting flow pattern analysed and photographed with the aid of suspended aluminum dust.

Grenoble—S.O.G.R.E.A.T.H.

At Grenoble, the Laboratory of the S.O.G.R.E.A.T.H. under the direction of Professor Danel is the largest laboratory visited. The problems studied by the capable staff cover the hydraulic machinery, hydraulic structures, irrigation, instrumentation and materials transport fields. A feature of the laboratory supplementing all of these sections was the technical library. This fine effort was the most complete collection of works on hydraulics and allied fields known and was arranged in a unique and seeming more workable form than the average technical library.

Paris

The laboratory of the Electricite de France at Chatou was under the direction of M. Gridel. The laboratory was concerned with the hydraulic problems of the Electricite de France and other governmental agencies. A method of studying and recording the motion of the water surface in harbour models was called the "Starry Sky" method. This involved the use of a large grid of small electric light bulbs mounted over the model. The reflection of the grid on the water's surface was photographed as a time exposure. The trace of particles over the entire area was recorded and could be studied in detail.

Under the direction of Dr. Laurent, the Laboratoire Centrale d'Hydraulique at Mason-Alfort was devoted largely to coastal hydraulics. The laboratory in working on a particular problem did not rely on available data for model reproduction or justification but instead specialized in sending groups into the field to obtain the data that would be used in the model studies which resulted in an unusual continuity in the work.

Lille

At Lille, Professor Martinot-LaGarde had a laboratory in which the sponsored research was devoted in large part to the aeronautical industry. However, a wide variety and large number of experiments were demonstrations of fundamental phenomena aimed at undergraduate instruction. These varied from simple parlor tricks to a variable throat supersonic tunnel. One experiment demonstrating the theory of probability was a simple pinball machine.

SWITZERLAND

In Switzerland, laboratories of the university type were visited in Lausanne and Zurich, while commercial laboratories were in Geneva, Zurich and Winterthur.

Lausanne

At the University of Lausanne, the laboratory under the direction of Professor Stucky was visited, accompanied by his two assistants, Professor Bonnard and Mr. Gardel. In addition to a considerable amount of space within the laboratory devoted to student instruction and to sponsored research there was an interesting installation on the roof of the laboratory. A 150 meter length of pipe was set up to represent a penstock and tunnel system in a hydroelectric scheme. This pipe was connected to model surge tanks within the laboratory. Electronic recording equipment was used to study the operation of various types of surge tank design.

The Machinery Laboratory at Lausanne contained the usual test stands for Kaplan, Francis and Pelton models. In addition a small demonstration stand of a Kaplan runner was in operation. A plexiglass window in the side of a flume allowed observation of the 5-centimeter runner operating under a head of about 25 centimeters. The intake structure, pivot gates and vertical draft tube were included. The water was circulated by a small pump located under the bench of the test stand.

Zurich

At the Technical High School in Zurich, the Civil Engineering Hydraulic Laboratory was under the direction of Professor Schnitter. A large amount of space in the laboratory was devoted to development work for design purposes. However, there were a number of student experiments set up, among which was an interesting test on a chute spillway. The students were able to measure flows, velocities and depths over the entire model. After the data was compiled a second model of the same structure but one-quarter the size of the first was studied. The students were able to get a feeling for model work and some of the limits and advantages thereof.

The Hydraulic Machinery Laboratory was under direction of Professor Gerber, and the entire laboratory was devoted to student instruction. Most of the pieces of equipment represented the common pieces of equipment seen in the hydraulic machinery field. A pair of Kaplan test stands were mounted parallel to one another. Each was set up with head tank, runner, elbow draft tube and DC motor drive. The head tanks at either side of the units were interconnected. Thus it was possible to set up a simple turbine test or a pump turbine arrangement by using both units.

Geneva

The visit to the Atelier Charmilles in Geneva came at an unfortunate time since the old laboratory was being dismantled to be moved into a new building under construction. Although some of the old equipment was in place, it was not operative. It was indicated however, that in addition to the test stands using water for complete turbine models; tests of various sections or parts of turbines were made in air and two dimensional flow studies were also used.

Zurich

The Escher-Wyss Company in Zurich included in its machinery laboratory a new cavitation test stand. In this test stand it was possible to include the complete installation including the intake structure and the draft tube in addition to a runner up to 250 to 300 centimeters in diameter. At the operator's console it was possible to view the runner and the area just below the runner by means of a series of prisms and mirrors. The operator controlled the complete operation of the test stand and also could make all the necessary measurements.

Winterthur

At the Sulzer Brothers Laboratory in Winterthur, the emphasis was on pump testing and at the time of the visit the laboratory was devoted to the work requested by the production department. This situation was to be changed in the near future when a new laboratory will be constructed at some distance from the plant and it will be possible to perform research of a long range type. The routine testing will continue in the present laboratory facilities.

Germany

In Germany, university laboratories were visited in Munich, Stuttgart, Karlsruhe, Aachen, Darmstadt, Hannover, Braunschweig, Gottingen and Hamburg. Commercial laboratories were visited in Heidenheim, Hannover and Gustavsburg.

Munich

At Munich the Aerodynamics Laboratory of Professor Kaufmann was working on analysis of the boundary layer. Equipment was limited to two wind tunnels while other new facilities and in particular instruments were being developed and produced.

The Hydraulic Machinery Laboratory of Professor Hahn was also rebuilding after the war damage. In the plan for the new laboratory was a cavitation test stand and a Pelton wheel test stand to supplement the Kaplan wheel and Francis test stands already in place.

The Civil Engineering Hydraulic Laboratory which was under the direction of Professor Flierl, was in the process of being moved to another building and therefore not in condition to show equipment and apparatus.

Stuttgart

At Stuttgart, the Hydraulic Machinery Laboratory of Professor Hutarew was in a new building with new equipment. The individual pieces to make a machinery laboratory effective were all present. The six concrete volumetric tanks located below the ground floor had a total capacity of 360 cubic meters. The tanks were all interconnected for regulating or measuring flow. Two of the tanks were set up with a switchway for volumetric tests. All six may be operated singly or in parallel or in series as pairs or all together.

The Gas Dynamics Laboratory of Professor Weise is located about 11 kilometers outside the city of Stuttgart. The theme of this laboratory was to produce results in spite of a minimum of special equipment other than that fabricated within the laboratory. The work was basic with at least six major projects under way.

Karlsruhe

At Karlsruhe, the Theodor Rehbock Laboratory was under the direction of Professor Wittman. A new building to house the river models had been constructed having a clear area of 25 meters by 62 meters. The building had radiant heating to reduce air currents that might influence river model results. The water supply was arranged to give a maximum of flexibility to the system with three independent pumped supplies of 500 liters per second.

The Hydromechanics Laboratory under the direction of Professor Boss had been working in the field of water supply and its allied interests. At the time of the visit a conical separator to remove the bed load material from the normal flow of a mountain stream was under test. The material in the bed of the stream was carried through the rotating separator and discharged into the stream below, thus maintaining the normal bed load conditions.

The Hydraulic Machinery Laboratory at Karlsruhe is under the direction of Professor Dickmann. The principal piece of equipment in this laboratory was the turbine test stand for both the Kaplan and Francis types of runner. The test stand was arranged with a few water surface at the intake and outlet of the model so that no vibrations or disturbances, from the pumps located at either end could be transmitted to the test unit. The stand was capable of performing cavitation test work.

Darmstadt

At Darmstadt, Professor Detig indicated that the laboratory had been completely destroyed and was just being re-constructed. The new laboratory will be located in a new setting with all new equipment.

Aachen

In Aachen, Professor Buntru was also in the process of reconstructing the Hydraulics Laboratory. The building now under construction will be occupied for about five years. At the end of that time it is expected that the new Mechanical Engineering building will be completed and the laboratory will be installed in the new building thus leaving the other building.

The Aerodynamics Laboratory under Professor Seewald was interested mainly in supersonic flow. Among the studies being carried on was a spectrum analysis of the Karman vortex trails using a Schlerin optical system and color film to show the variation in density in the trails.

Hannover

At Hannover, the Franzius Institute was under the direction of Professor Hensen. An outdoor model of the Elbe River was under test at the time of the visit. The tide cycle was controlled by a rotating drum on which the tide cycle was formed by an angle offset from the drum. A pair of limit switches to follow either side of the angle were attached to a float and electrically connected to the motor-operated gate to follow the tidal variations. In order to protect this model from the elements a tent of translucent plastic had been erected on a steel tube frame to give a light yet inexpensive covering.

Braunschweig

At Braunschweig, Professor Zimmerman was interested mainly in the irrigation aspects of hydraulics. In this connection a cooperative venture with one of the forward looking farmers in the area was underway with an experimental station on the farm. A laboratory building in the city housed the river model and other types of experimental flow equipment.

The Fluid Machinery Laboratory of Professor Petermann was set up near the power station for the Technical University and had only limited space set aside for experimental work. There was a cavitation test stand set up to study axial flow pumps up to 200 millimeters in diameter. The section in which the pump would normally be installed for test was easily removed for alteration and inspection.

The Aerodynamics Laboratory under the direction of Professor Schlicting was being rebuilt in a new university building and would in the future be dealing mainly with problems in the supersonic flow range.

Gottingen

At the Max Planck Institute for Flow Research in Gottingen, the work under Professor Tollmien is being concentrated in the supersonic range. Also much attention is being given to the design and study of high speed rotary machinery. At the time of the visit, experimental work was in progress on a compressor operating at 50,000 RPM with a rotor only 6 centimeters in diameter, yet developing over 200 HP.

Hamburg

The Institut for Schiffbau at the University of Hamburg under Professor Weinblum was largely interested in ship design problems. A small wind tunnel was driven by a 30 HP motor and had a slotted test section about 1 meter in diameter and 3 meters long. The slots could be varied in position and shape along the centerline to give different velocity profiles in the throat of the tunnel.

Heidenheim

The Hydraulic Laboratory of the J. M. Voith Company in Heidenheim is under the direction of Dr. Dziallars. The water supply at the laboratory was from a spring close to the laboratory that discharges at a rate of about 0.2 cubic meters per second. The water was pumped into a reservoir located on a hill nearby to give a constant head at the laboratory of approximately 68 meters. This supply was used to operate various tests throughout the laboratory and in addition was used in a unique way to regulate pump speed and flow on a test stand. The pump was driven by a turbine which was in turn driven by the water under the reservoir head. Thus by regulating the turbine operation, the pump was controlled over a wide range of speeds.

Gustavsburg

The Hydraulic Laboratory of the Machinenfabrik Augsburg-Nurnberg (M.A.N.) was set up primarily to test hydraulic control structures. The main piece of equipment was a flume 25 meters long by 4.5 meters wide and 1.4 meters deep with glass side panels at various sections along its length. A maximum discharge of 1 meter was measured by a bank of 4 V-notch weirs that were used to give a wide range of discharges.

NETHERLANDS

Delft

The Hydraulic Laboratory in Delft, Holland, under the direction of Professor Thijsse was concerned mainly with the reclamation projects of the Netherlands. A flume about 50 meters by 4 meters by 0.4 meters deep was set up to study waves generated by the wind. This was accomplished by surrounding this flume with a wind tunnel set up in a vertical plane with the return circuit of the wind tunnel mounted above the flume test section. Wind velocities over the water surface up to 20 meters per second were possible.

The Mineral Technological Institute under the direction of Mr. Van der Gaag was devoted to research concerned with the operation and improvement of dredging equipment. The laboratory was sponsored by the dredge manufacturers of Holland. Several flumes are set up with glass walls so that data can be taken by direct observation or by photographic means.

Belgium

In Belgium, University Laboratory visits were made in Ghent and Liege while the State Laboratory in Antwerp was also seen.

Ghent

The laboratory at Ghent was under the direction of Professor Tison. The supply system in the laboratory included three pipes about 15 centimeters in diameter which ran the entire length of the laboratory (50 meters). In these pipe lines it was possible to mount various fittings representing pipe connections such as contractions and expansions, which could be placed in the line to allow the students to measure the different types of head loss. A volumetric tank was used to measure the flows.

Liege

The Hydraulic Laboratory at the University of Liege was under the direction of Professor Schlag and was concerned with basic work on flow meter design and with student instruction. Along this line there were a number of two-dimensional flumes in which flow pattern around objects could be developed and studied using dye and floating particles. It was indicated that these studies had been used to guide several design problems.

The Laboratoire d'Hydraulique Fluvial under the direction of Professor Campus was in the process of being completely revamped with about 100% more room than previously but no equipment was in place and no test work underway.

Antwerp

The Hydraulic Laboratory for the Department of Bridges and Roads in Antwerp under the direction of Dr. Lamoen was located in several large buildings in Antwerp. A fine new laboratory hall for river models was being completed at the time of the visit. The hall had an area of 100 meters by 50 meters with a clear span. It will be possible to have a measured flow of 3 cubic meters across a single river model. An elaborate electrical programming system will allow a total of 200 single events to be programmed through the models automatically.

DENMARK

Copenhagen

The only laboratory visited in Denmark was at the University of Copenhagen under the direction of Professor Bretting. In the office area of the laboratory was a small tilting flume 1 meter long by 10 centimeters wide and 25 centimeters deep to be used for demonstrations. The flume is made up with a steel frame and glass sides with a separate sump and supply pump attached.

SWEDEN

In Sweden, university laboratories were visited in Goteborg and Stockholm, as well as the commercial laboratory at Kristinehamn and government laboratory at Alvkarleby.

Goteborg

The Hydraulics Laboratory at the Chalmers Technical High School in Goteborg under the direction of Professor Erling Reinius had a unique flume constructed at the laboratory. The flume was constructed using precast concrete bents at each panel joint. The bents were made in the form of an "H" with the lower arms of the "H" used as legs and the upper loop used to support the sides and floor of the flume. The sides for most of the length were constructed of glass and the floor was of reinforced concrete. The flume is 15 meters long by 60 centimeters wide by 80 centimeters deep. A steel channel was placed at the top to act as a rail and to stiffen the entire flume.

Stockholm

At the Royal Technical High School in Stockholm, the Hydraulics Laboratory was under the direction of Professor Hellstrom. The laboratory was in the process of being enlarged so that not much was going on at the time of the visit. Professor Hellstrom did have an interesting series of tests under way to determine the effect of various materials, shapes and surfaces on the amount of dew which would be collected in a given time. This would be particularly important to the desert areas of the world.

Alvkarleby

At Alvkarleby, the Swedish State Power Board maintains a Hydraulic Laboratory under the direction of Mr. Angelin. An interesting feature of the work at this laboratory was the preparations for model study in the laboratory. In most cases a river model study was preceded by a small scale model of the area to determine the limits which the larger model should encompass when constructed. This procedure assured the staff that the model will cover the proper reach to provide the necessary design and operating data.

Kristinehamn

The Hydraulic Machinery Laboratory of the WKM Company located at Kristinehamn. In addition to the standard test flumes for turbines and a water tunnel for ships' propellers there was a small flume set aside for exploratory tests. This flume was about 3 meters long and 50 centimeters wide and 50 centimeters deep. In this flume it was possible to test in particular the intake structures of hydraulic turbines. It was indicated that in some cases designs by customers were tested whether or not the tests were requested just to be sure that no improvement in wheel operation was to be gained by changes to the intake.

Norway

Trondheim

In Trondheim three laboratories were visited including the Hydraulic Machinery Laboratory and Civil Engineering Laboratory of the Technical High School and the Ship Model Towing Tank which was connected to the Technical High School.

The Hydraulic Machinery Laboratory under Professor Alming includes the usual machinery test stands, supplied from an excellent system. A "U" shaped channel 1 meter by 1.5 meters in cross section located in the attic and along three walls of the laboratory building, was supplied by a 450 liter pump operating under a head of 15 meters. This channel discharged into a pipe loop 40 centimeters in diameter located approximately a meter under the channel. In addition for the low head tests a 1.2 cubic meter pump operating under a head of 4.2 meters was available.

At the Ship Model Towing Tank a water tunnel was set up with a test section 20 centimeters in diameter. This tunnel had a maximum velocity of 10 meters per second and was driven by a 10 HP pump. The tunnel while being used as a test facility was also a model of a 1.5 meter diameter tunnel in the design stages at the time of the visit.

The Civil Engineering Hydraulics Laboratory under Professor Vidcum was in the process of being moved into a new building and not much in the way of equipment or tests was available at the time of the visit.

Scotland

In Scotland, university laboratories were visited at Dundee, Aberdeen and Glasgow. While the Mechanical Engineering Research Laboratories at East Kilbride were also visited.

Dundee

At Dundee the Mechanical Engineering Department is under the direction of Professor Dick. A study of velocity distribution in turbulent flow was under way at the laboratory. A small plexiglass flume was arranged with a microscope mounted above the flume and a high intensity light beam directed into the flume at right angles to the line of sight. Because of the critical focus of the microscope only a 1/1000 inch thick layer was in focus. By interrupting the line of sight the particles of dirt in the water reflected as streaks of light and the length of the streaks indicated velocity and the direction of the flow at a particular instant.

Aberdeen

In Professor Allen's laboratory at Aberdeen, a tilting flume was set up for various types of research and demonstration. The flume was arranged with an aluminum frame in which were mounted perspex panels for the sides and floor. The flume was 30 feet long by 1 foot deep by 8 inches wide and was supported at each end and at the center point. The maximum slope was 14 inches difference in elevation between ends. A wave generator was built into the intake box.

Glasgow

The Department of Aeronautics and Fluid Mechanics at the University of Glasgow was under the direction of Professor Duncan while the hydraulics was the immediate concern of Dr. Thom. The laboratory was devoted mainly to student instruction and demonstrations. There were a number of tests including one in a flume 10 feet long by 5 inches by 5 inches, for measurement of rift and drag on an airfoil shape. This device consisted of a simple balance mounted on knife edges in a frame clamped to the top edges of the flume. The test shape was mounted on the end of a simple strut so that it was immersed in the flowing water of the flume. The shape was counterbalanced by a weight on the opposite end of the strut and the drag or lift was measured by adding weight to a calibrated beam.

East Kilbride

At the Mechanical Engineering Research Laboratory in East Kilbride under the overall direction of Dr. Sopwith, the Fluid Mechanics section was headed by Dr. Hutton. There were many impressive pieces of new apparatus in this laboratory. Perhaps the most impressive was the cavitation test stand which would accommodate model runners up to 20 inches in diameter, operating at heads up to 200 feet and up to 250 horsepower. The maximum flow was 48 cubic feet per second from either an axial flow or centrifugal pump. A 60 foot re-absorber is located below ground level to maintain a proper air content in the water. It is possible to include in addition to the model turbine, a model intake and an elbow draft tube under the turbine.

England

In England, university laboratories were visited in Durham (Newcastle-on-Tyne), Manchester, Cambridge and Imperial College in London. The Hydraulics Research Station at Wallingford, the English Electric Company Laboratory at Rugby and the British Hydromechanics Research Association at Harlow were also visited.

Durham

The Hydraulic Machinery Laboratory at Newcastle-on-Tyne was under the direction of Professor Burrill, and was primarily interested in ship and propeller design. A towing tank and a water tunnel were the two primary pieces of equipment in the laboratory. A recent development at the laboratory was the technique of casting clear transparent plastic models of ships. With these models it was possible under correct lighting and photographic treatment to accurately plot the wave formation around the hull of a towed model.

The Hydraulics Laboratory was under the direction of Professor Burstall. The laboratory was devoted to student instruction. A series of test setups were maintained including a model Venturi flume in plexiglass to show the hydraulic gradient for various flows. Pressure taps along the profile allowed the students to analyze the pressure distribution.

Manchester

At Manchester University the Hydraulic Laboratory under the direction of Professor Mathieson was set up for student instruction. A water hammer demonstration in a 2″ pipe with a model surge tank upstream of a quick-acting valve was operated by the students. The size of the opening into the surge tank could be varied to study the effect of the different losses at this point in a hydraulic system. The head measurements were made with a pressure gage mounted on the pipe and the supply was direct from the 110 foot head supply of the laboratory.

Cambridge

At Cambridge, the Fluid Mechanics Laboratory under Mr. Binnie was concerned mainly with student instruction. A total of 14 test setups were available to the undergraduate student. For each test a set of complete instructions was available and the students were allowed to elect an average of 6 of these tests during the course. Certain afternoons are set aside when these tests can be performed during the terms. In addition, there were several basic projects under way at the time of the visit.

At the Cavendish Laboratories in Cambridge, under the direction of Sir Geoffrey Taylor, a number of studies concerning the mixing of liquids of different densities were under way. The apparatus for these tests was all simple yet being used in a most effective manner.

London

At Imperial College in London, the Hawksley Hydraulic Laboratory is under the direction of Professor White. A number of demonstration flumes are set up to give the students opportunities to see and study flow phenomena. In addition, there was a tilting flume with a steel frame and glass sides and floor 40 feet long by 1 foot wide and 1 foot deep. The flume was mounted on notched wheels that run on steel wedges set so that the shift in weight as the flume is raised or lowered is automatically taken up and adjusted. The alignment of this flume stays within 0.002 inches over the range of slopes.

Rugby

In the Hydraulic Machinery Laboratory of the English Electric Company at Rugby, there were at least six different test stands for turbines and pump models ranging in size up to 450 HP. In addition, there were three test stands set up to run tests of components of various machines in air. This allowed a more detailed study of a particular vane or strut than would be possible in the water filled test stands.

Wallingford

The Hydraulics Research Station at Wallingford under the direction of Sir Claude Inglis was the Civil Engineering counterpart of the M.E.R.L. at East Kilbride. In addition to a large area devoted to river models and allied open channel work the laboratory had an active instrumentation group. Among the products of this group was a current meter ¾ inch in diameter that depended upon the capacitance principle to indicate velocities under 0.1 feet per second.

Harlow

The Hydraulics Laboratory of the British Hydromechanics Research Association was under the direction of Mr. Prosser. The laboratory was sponsored by industrial members of the association and was available to any group for the study of a wide range of flow problems. At the time of the visit the prime interest was in the transport of solids by fluid flow. In addition to the research work at the station, the staff of the laboratory produces a bulletin every two months carrying reviews of a large number of papers on pertinent fluid flow subjects. In addition, the staff has been responsible for the translation of a number of papers printed in other languages.

Summary

At most of the laboratories the visits lasted only a day or two. In such a short time it was difficult to evaluate reliably the potential of a laboratory. However, after the visits, several overall conclusions were apparent without trying to make comparisons between individual installations.

1. The general caliber of work on basic research in the laboratories visited was at a high level.
2. There was a minimum of electronic equipment in use in the laboratories.
3. The student participation in laboratory experiments for instruction purposes was limited even in laboratories set up solely for student instruction.
4. The classroom instruction load on the teaching staffs at the university laboratories was high.
5. Co-ordination and exchange of ideas from one country to another was good in spite of national and language differences.
6. The approach to problems, as in any laboratory, reflect the attitudes and interest of the director, in particular, and his staff.

The interest and activity on basic research in a majority of the laboratories was at a high level. It would appear also that the caliber of the work going on in this field was good. The variety of detailed projects reflects the varied interests and in many cases needs of the particular area or country.

The equipment in use in the laboratories was of good quality, particularly the apparatus that lent itself to fabrication by the laboratory staff. In general, there seems to be a minimum or even a lack of good electronic test equipment and the necessary personnel to operate and maintain such equipment.

The coordination and exchange of ideas between laboratories on both the national and international level was fair to good. The facility with which most technical personnel handle several languages aided greatly in this interchange.

Undergraduate student participation in laboratory programs either for instruction or research was limited to a small percentage. A majority of the university laboratories have only limited demonstrations for students with no actual handling of equipment by these students.

The instruction load of most university staffs was heavy. The personnel were carrying a full time teaching load in many cases and had to make extra time available for either the basic or sponsored research.

The industrial and governmental laboratories were well staffed and equipped but in general did not have the desired amount of electronic apparatus and trained personnel. These laboratories were contributing a substantial amount of basic research in addition to work in their own fields of interest.

In the industrial laboratories a change in basic policy seemed to be underway. These laboratories indicated that the routine shop test work should be separated from the forward looking research leading to new design. In many cases this means a complete new building and a separate staff to man the laboratory.

DISPOSAL OF ATOMIC POWER PLANT WASTES

By Conrad P. Straub*

(Presented at a meeting of the Sanitary Engineering Section of the Boston Society of Civil Engineers, held on March 6, 1957.)

THE discussion will be in two parts, the first dealing with a description of the Yankee Atomic Power Reactor and the waste problems associated with such a reactor; the second with a brief summary of present practices and research developments in the disposal of radioactive waste materials.

Yankee Atomic Power Reactor, Rowe, Massachusetts**

The plant site is located in the town of Rowe, Massachusetts on the east bank of the Deerfield River at a point approximately three-quarters of a mile south of the Vermont-Massachusetts border adjacent to the Sherman hydroelectric station of the New England Power Company. This location offers advantages to Yankee in cooling water supply, transmission economy, and a favorable land area. According to the 1950 census 28,892 people live within 10 miles of the plant and 104,293 (including North Adams, Massachusetts) live within 20 miles. The basic land use is agriculture and forest products with light industry in Adams and North Adams. No water supplies are listed for the 42 mile reach of the Deerfield River to its confluence with the Connecticut River. Meterological data interpolated from nearby Weather Bureau stations generally indicate the significance of rugged topography in affecting seasonal turbulence and inversions in site-area valleys. Additional meterological studies are underway at the site.

The plant will be similar to a standard steam-electric station except for the boiler equipment. In the Yankee plant the conventional boiler will be replaced by a pressurized water reactor contained

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**The information in this section has been taken from the following documents: (1) Anonymous, "Pressurized Water Reactor for New England—A New American Project," Atomics, Vol. 7, pp. 440-442 and 447, December, 1956; (2) A brochure prepared by the Yankee Atomic Electric company, describing the plant to be constructed at Rowe; (3) Statements contained in the 19th and 20th Semi-Annual Reports of the Atomic Energy Commission to Congress pertaining to the Yankee Reactor; and (4) News releases contained in the February, March, May, July and October, 1956, issues of Nucleonics.

in a large steel sphere. This is the general type of reactor being built at Shippingsport, Pennsylvania by Westinghouse for the Duquesne Power and Light Company, and similar to the unit powering the Nautilus.

The orthodox section of the plant will house a 134,000-kilowatt tandem compound turbine with its condenser and auxiliary equipment. Adjacent to the conventional buildings will be the 125-foot steel sphere known as the vapor container. Inside this steel shell is the actual reactor steam generator with its controls, auxiliaries, and heat exchangers. The heart of the reactor is the core which is cylindrical in shape, about 6 feet in diameter and approximately 8 feet tall. This will stand in a large water filled pressure vessel about 9 feet in diameter and some 30 feet high. Its steel walls will be over 8 inches thick and it will weigh about 175 tons.

Cooling water will enter the top of the vessel from the four coolant pumps, flow downward through the thermal shields, and make a single pass upward through the core heating channels. No penetrations of the reactor vessel are planned below the top of the core, thereby making loss of water covering in the core impossible, except for vessel rupture. Outside the pressure vessel wall is additional radiation shielding consisting of a water-filled thermal shield tank and approximately 8 feet of concrete wall. The reactor core consists of four similar quadrants, each containing 19 fuel assemblies for a total of 76. These assemblies will be made up of over 20,000 stainless steel tubes. Each vertical 8-foot long pencil-sized tube is filled with about 300 pencil eraser-sized pellets of slightly enriched uranium oxide. Some 24 control rods will be located to move up or down inside the pattern of tube assemblies to control the neutron reaction.

Water in the pressure vessel will be heated to 560°F. under 2,000 psi and will return from the heat exchanger at 510°F.; the secondary will make 600 psi steam. High purity for the light water coolant-moderator will be maintained in order to ensure the smallest possible release of activated particles to the waste disposal system. The all stainless steel construction will ensure that the corrosion rate is low, and a hydrogen gas corrosion inhibitor will be used to further reduce corrosion. Furthermore, the use of oxide fuel and the anticipation of a small amount of clad failures will result in only small releases of fission products from the uranium core material.

A purification system consisting of demineralizers will be designed to control loop water purity and to remove activated particles. The demineralizers will be of the "regenerated in place" or "throw away" type based on plant economics and technology of handling waste disposal.

Protective Equipment

Protective equipment and facilities will be provided at the plant to safeguard physical property and for personnel protection. Equipment connected with personnel protection against radioactivity includes the vapor container, radiation shielding, and radiation monitoring.

The design of the vapor container will be such that it will contain the pressure buildup resulting from a maximum credible accident to this particular pressurized water reactor plant. Considering the oxide fuel to be used and the stainless steel cladding, the maximum credible accident has been tentatively chosen as being the pressure buildup resulting from a rupture and the release of the entire volume of the primary loop at average operating temperature.

Radiation shielding during normal plant operation will include a thermal shield tank and the necessary concrete shield to reduce the dose levels at the surface of the vapor container to about 6 mr/hr at full power. The radiation level at continuously manned stations outside the container will be designed below 2 mr/hr at full power. Radiation monitoring will be provided throughout the plant, and in the area surrounding the plant which makes up the site. Plant monitoring will include airborne particle detectors, boiler leak detectors, area monitors, neutron detectors, and gamma detectors.

Fuel Handling and Spent Fuel Storage

Other equipment is that associated with the fuel handling and spent fuel storage. Suitable manipulators, shielding, and underwater storage facilities will be provided to remove and allow spent fuel to decay for the period required prior to shipment in air-cooled container casks. No decladding or reprocessing activities are planned at the facility.

Waste Disposal System

It is reported that a waste disposal system for the temporary holdup and ultimate disposal of activated primary loop and fission product solubles, insolubles, and gases resulting from normal operation or operation with clad failure will be provided. The design will be such that no waste will be discharged from the plant above the permissible levels outlined in National Bureau of Standards Handbook 52. The waste disposal system will include cartridge demineralizers and gas absorbing filters and possible evaporators for the concentration of the waste, such that ultimate disposal in solid form can be accomplished if required. Large volume holdup of liquid waste will be provided by storage tanks. The possibility of plant operation with clad failures will depend on further research on the uranium oxide fuel materials and the adequacy of the waste disposal system.

Waste Disposal Facilities, Shippingsport, Pennsylvania*

Although the Yankee reactor is larger than the Shippingsport pressurized water reactor, having a power level of 500 megawatts heat energy of 134 megawatts electrical energy in contrast to 264 and 60 megawatts, respectively, the waste disposal facilities provided at Shippingsport may be considered as a basis for discussing the waste problem at Yankee. Obviously, there will be differences in the quantities of radioactive wastes produced because of the difference in power levels, but the sources of wastes will be similar. Another difference will result from the types of fuel elements employed; zirconium-enriched uranium, Zircaloy-2 clad elements will be used at Shippingsport whereas uranium oxide pellets clad in stainless steel will be used at Yankee.

The wastes produced at Shippingsport have been categorized into eight types as follows:

Type I. Reactor plant systems spent resins. Spent resin from the mineralizers will be transferred by flushing, in the form of a slurry, directly to underground storage facilities.

Type II. Cold laundry and monitored drains.

Type III. Hot laundry and special monitored drains.

Type IV. Decontamination room waste.

Types II, III, and IV constitute low level wastes, which are processed by holding in service building hold tanks, monitoring and

*This information was given to the writer by Mr. E. D. Harward, Public Health Service, on assignment to the Shippingsport Reactor Project, and by Mr. J. G. Terrill, Jr., Chief, Radiological Health Program, Public Health Service, Washington, D. C., and was taken from the paper, "A Sanitary Engineering Approach to Reactor Waste Disposal," by J. G. Terrill, Jr., and M. D. Hollis, which was presented at the Annual Meeting, American Society of Civil Engineers, October 17, 1956, Pittsburgh, Pennsylvania (5).

release of each into a pair of tanks in the low level waste storage area. These wastes will be evaporated, the evaporator bottoms being discharged to the spent resin storage tanks or packaged for disposal at sea. The vapor condensate will pass to the surge and decay tanks before release into the Ohio River following mixing with condenser stream flow.

Type V. Reactor plant effluent. A portion of the cooling water will be wasted and discharged to the surge and decay tanks for hold-up. The liquid fraction will be passed through ion exchange resins and will feed into the spray recycle tank or into the gas stripper. From the gas stripper the liquid will flow to test tanks where it will be monitored prior to mixing with condenser water and release to the Ohio River. The gases contained in the reactor plant effluent discharge to the vent gas surge drum and into the gas decay drums before release into the atmosphere following monitoring.

Type VI. Combustible waste. This consists of laboratory wipes, contaminated clothing, other contaminated combustible material. It will be burned in an incinerator with the gases passing through a wet gas scrubber before release through the stack, the ash being slurried for disposal in the spent resin storage tanks.

Type VII. Noncombustible wastes such as tools, metal turnings, etc., will be packaged, shielded, and shipped via railroad or truck to a point for disposal at sea.

Type VIII. Noncombustible items too heavy to ship will be disposed of by burial at the site.

In all probability many of the same techniques will be utilized in handling the various wastes produced during the operation of the Yankee atomic power plant.

Waste Disposal in the Atomic Energy Program

Waste materials from the atomic energy industry are gaseous, airborne, liquid and solid and occur in any phase of the industry from the mining of the uranium ore to the ultimate use of a specific radioisotope in industry, research, or medicine. These waste materials differ from those with which we have been concerned in the past in that they are radioactive. Unless properly controlled, they could be damaging to human and other tissues.

Gaseous and Other Airborne Wastes

Gaseous or airborne particulate wastes vary greatly with their origins, and include tiny particles of radioactive material originating from failure of a fuel element in an air-cooled reactor, particulates and iodine from fuel processing plants, and particulates from plutonium fabrication facilities (6). Many of these problems have been solved through the development and use of special high-efficiency filters and iodine gas removal units.

Air used as a coolant for a reactor is prefiltered to remove particulates which would become radioactive when irradiated. High-efficiency filters of glass or kraft paper and asbestos are also used to remove radioactive particulates from gas that has passed through a reactor. Short-lived radioactive isotopes of gases, such as iodine, in the waste streams from chemical processing plants can be released to the atmosphere through dilution from a tall stack under favorable meterological conditions.

Studies in micrometerology have shown that a wide variety of conditions will affect the dispersal of stack discharges, and have indicated what hazards could arise should serious disruptions occur in normal operations involving radioactivity.

Solid Wastes

Solid wastes are divided into two groups: combustible and non-combustible. The latter includes such materials as machine turnings, contaminated equipment, etc., whereas the former includes burnable contaminated trash. In general, the wastes are disposed of by incineration, in the case of combustible materials, and packaging for ocean disposal or direct burial into the ground.

Burial

Five national burial sites, located at the Hanford Works, Washington; National Reactor Testing Station, Idaho; Los Alamos Scientific Laboratory, New Mexico; Oak Ridge National Laboratory, Tennessee; and Savannah River Project, Georgia, are operated by the Atomic Energy Commission for the disposal of solid wastes (7). The physical factors affecting the desirability of any particular site are topography and geology, surface and ground water hydrology, meteorology, soil conditions, and transportation facilities. From results reported by Morgan (7) the costs of operating such disposal sites ranged from \$1.52 to \$9.40 per cu yd of material. These costs did not include sample containers, processing and handling at source, etc., but only capital and operating costs at the site, and may be compared with specific costs at given sites. At Oak Ridge, the annual burial load amounts to about 5 acres per year at a cost of approximately \$2.00/cu yd (8); at the National Reactor Testing Station (9) approximately 3800 cu yds of solid wastes have been disposed of since 1952 from Rocky Flats, Colorado, at a reported cost exclusive of packaging and handling of \$21 to \$35/cu yd (10).

Incineration

Studies to evaluate the effect of incineration waste materials containing P^{32}, Sr^{89}, and I^{131} in an institutional incinerator are described by Geyer *et al.* (11). Their results indicate that of the P^{32} charged into the incinerator, about 12% was retained on the stack wall and 2% was recovered from the stack gas; of the Sr^{89}, 9% was retained on the wall and 1% recovered in the gas; while of the I^{131}, about 11% was deposited on the wall and 80% escaped in the gas. Ash activity was assumed to be the balance of the charge not otherwise accounted for.

The use of a special type of incinerator has been described by Silverman and Dickey (12) for reduction of combustibles contaminated with low level amounts of radioisotopes. Maximum daily load is set at 200 $\mu\mu$c for all isotopes except I^{131} which is set at 500 μc. The stack gas effluents had activity levels of 7×10^{-11} μc/ml. Maintenance costs over a two-year period of operation, during which 3400 lbs of assorted combustibles containing 27,100 μc of activity were handled, amounted to less than \$1/month.

Rodgers and Hampson (13) report operating data on the incinerator designed and built at Argonne National Laboratory to handle 100 $feet^3$ of combustibles daily. Overall decontamination factor (ratio of influent feed to effluent gas concentration) was $2\text{-}3 \times 10^7$. Cost of incineration amounted to \$2.68/ft^3 for 8-hour and \$1.60/ft^3 for 24-hour operation schedules as compared with solid storage costs of \$9.00/ft^3. At present the combustibles are being shipped to Oak Ridge for burial at a cost of \$1.50/ft^3 thus removing the economic justification for incineration.

Liquid Wastes

For convenience, although the breakdown is somewhat arbitrary, the problems of liquid waste management will be considered under three headings: Low, intermediate, and high level wastes. Low level wastes are those which, if decontaminated by a factor of 100 or 1000, would approach permissible limits (14) for human exposure. The range of their activity would be from 10^{-4} to 10^{-3} microcuries per milliliter. High level wastes are those requiring shielding to protect persons handling them from exposure to damaging radiation and may contain 100 or more curies per liter. They are generally associated with the chemical processing of the nuclear fuel for the recovery of the fissionable materials. Intermediate wastes also require shielding and must be handled with considerable care. They may be the high level wastes which have lost a considerable fraction of their activity as a result of decay, the residual wastes following recovery or separation of the strontium or cesium isotopes, the wastes resulting from pilot plant operation, or lower level wastes that may have been concentrated by evaporation.

Low Level Wastes

Low level wastes are those most frequently encountered at the present time at least insofar as release into the environment is concerned. Depending upon their source, they are handled or disposed of in various ways. They may be contained in the residues following the recovery of uranium ore in which case they will contain essentially the daughter products of the uranium itself. Generally, these waste materials are discharged into the stream either directly or from tailings ponds. Studies by the Public Health Service have shown that water, mud, and biological samples collected below uranium mills have activity levels higher than similar samples collected upstream (15). The public health significance of these higher levels has not been evaluated as yet.

Another source of low level wastes results from the use of natural waters as reactor coolants. In passing through the reactor, activity will be induced in the normal constituents of the water as a result of neutron bombardment, and the water may pick up corrosion products and other materials. Most of the activity is relatively short-lived and is associated with the lighter elements. The largest source of such wastes is the Atomic Energy Installation at Hanford where pretreated Columbia River water is used to cool the reactors. Before return to the Columbia River, the water passes through specially designed retention tanks which permit maximum decay of the radioactivity.

Low level wastes are produced in any laboratory where radioactive materials are used. They are extremely variable in composition—both from the standpoint of their chemical as well as radioactive constituents—and are generally released into the environment following limited treatment. At Oak Ridge National Laboratory, for example, they pass through settling basins before release into the Tennessee Valley System through the Clinch River. In general, the activity level in the Clinch River below the plant discharge is at the 10^{-7} microcurie per milliliter level indicated for mixed fission products or activities of unknown composition. Plans are underway to construct a treatment plant for the removal of strontium and other activities present in the wastes during peak activity levels. The plant is flexible in design and will permit the use of either phosphate coagulation or lime-soda ash softening to precipitate the strontium before the wastes are released to the Clinch River.

Brookhaven National Laboratory concentrates its waste by evaporation, mixes it with concrete, places it in steel drums, and carries it out to sea for disposal.

In Great Britain, the low level wastes which arise from the Atomic Energy Research Establishment at Harwell are discharged into the Thames River following treatment consisting of chemical coagulation. Treatment must be such that the quantities of radioactive materials discharged not exceed 20 curies per month or 5 curies in any one day as determined by the formula:

$$\text{Ra (curies)} \times 2500 + \text{Other Alpha (curies)} \times 420 + (Ca^{++} + Sr^{++}) \text{ (curies)} \times 50 + \text{Remaining Beta (curies)} \leqslant 20 \text{ (curies) per month.}$$

This formula was arrived at by applying a factor of 1/100 to the maximum permissible concentration recommended by the International Commission on Radiological Protection (16).*

Burns (17) reports that a small plant has been in operation at

*The British selected a factor of 1/100 because of the large numbers of people located downstream on the Thames River below the Harwell Establishment. This factor may be compared with a value of 1/10 used in this country when recommending levels for the general population.

Harwell for some considerable time treating mixed fission product solution in water of a low solids content. By treating this waste with phosphate and iron salts followed by a sulfide treatment and passing the liquid through columns of Vermiculite, decontamination factors of the order of 1000 have been obtained. If necessary, the water could be treated further by an electric deionization process which is expected to increase the decontamination factor to 100,000. If this is achieved it should be possible to reuse the water for many purposes and thus effect an economy.

Other formulas were developed for use in connection with the discharge of radioactive materials from the operations at Windscale, near Sellafield, England. Here the limiting levels for discharge into the Irish Sea were determined by the accumulation of activity in fish, in an edible sea weed, and on the beach sands. The formulas are:

$$\frac{\text{Total Alpha (curies)}}{200} + \frac{\text{Ru (curies)}}{5000} + \frac{\text{Total Beta (curies)}}{20000} \leqslant 1 \text{ (curie) per month}$$

$$\frac{\text{Sr (curies)}}{2500} + \frac{\text{Total Alpha (curies)}}{300} \leqslant 1 \text{ (curie) per month}$$

The most common method of disposal, particularly by users of radioactive isotopes following application in medicine, research, or industry, is to discharge these materials into the sewer. Although this practice does not appear to be objectionable at present levels of activity, it may become necessary for public health authorities to maintain vigilance over the quantities of radioactive materials discharged as the use of radioisotopes increases.

Considerable information has been published on the effectiveness of water treatment methods for the removal of low level radioactive contamination. It will not be reviewed here, but the principles involved may be applied successfully to the treatment of low level wastes. Methods that may be used include coagulation (18) (19), softening (18) (19), ion exchange (18) (19) (20), permselective membranes (21) (22), clays (19) (23), powdered metals (24), etc.

Intermediate Level Wastes

In the past, storage was used for the retention of all liquid radioactive wastes containing appreciable quantities of radioactive materials. More recently, consideration has been given to the release of radioactive materials into the ground and into the oceans. If this can be accomplished without hazard to the environment, the cost of waste treatment and disposal may be materially reduced.

Ground Disposal. This method has been practiced at the Hanford site for approximately 10 years. Under the rather unique geologic, hydrologic, and meteorologic conditions at this site approximately 10^9 liters of active waste containing several hundred thousand curies of fission products have been released into the ground for storage (25). At the Oak Ridge National Laboratory, four waste pits have been scooped out in the weathered Conasauga shale overburden and have received the quantities of waste reported in Table I (26). Experience indicates that the nitrate moves through the soil most rapidly followed by the anionic ruthenium present.

It is reported that about 130,000 gallons of waste are discharged daily into the soil at the Savannah Project (27).

In the use of the ground, as will be defined more specifically under high level wastes, one must always be certain that the amount of radioactive material transmitted to the ground water will be at a sufficiently low level that the maximum permissible concentration levels will not be exceeded in its use as a source of water supply. Furthermore, it must be remembered that once radioactive materials are introduced into the ground, control of them has been lost.

Ocean Disposal. Except for the reference made to the Windscale operations in England little if any radioactive materials are discharged directly into the oceans. Some materials are discharged but these are in packaged form. The radioactive materials, in the form of evaporator concentrates, precipitated and dewatered sludges, etc., are mixed with concrete directly or placed in previously prepared concrete shielded cylinders, and then shipped out to sea for disposal. It has been reported (28) that approximately 20 to 30 tons of waste are disposed of annually on the East Coast as compared to 4 to 5 tons on the West Coast. Disposal must take place beyond the 1000 fathom level (29) in this country, and the British disposals are carried out in water more than 2000 fathoms deep, several hundred miles from

TABLE I—WASTE PIT CHARACTERISTICS
(as of October 31, 1955)

Waste Pit Number:	1	2*	3
1. Design capacity—gal	180,000	1,000,000	1,000,000
2. Dimensions of pit— length, width, depth—ft	100x20x15	210x100x15	210x100x15
3. Period of use	8/1/51-10/5/51	6/20/52-10/31/55	1/24/55-10/31/55
4. Raw waste added—gal	123,000	1,331,760	1,434,600
5. Waste from Pit 3—gal		398,200[a]	—398,200
6. Total volume waste—gal	123,000	1,729,960	1,036,400
7. Beta activity added—curies	389	15,975	18,911
8. Beta activity taken from Pit 3—curies		3,449[a]	—3,449
9. Total beta activity—curies	389	19,424	15,462
10. Radioisotopes present Per cent of total			
Cs^{137}-Ba^{137}	60	60*	77
Ru^{106}-Rh^{106}	40	40*	12
Sr^{90}-Y^{90}			11
11. pH of waste added	~12.5	~12.5	~10-11
12. Approximate construction cost—dollars/million gal	$14,500	$14,500	$14,500
13. Approximate cost/gal waste capacity—cents	1.45	1.45	1.45
14. Approximate cost—gal waste discharge to pit—cents	2.12	< 0.84[b]	< 1.40[b]

*Decanted liquid from Pit No. 3 and added the material to Pit No. 2 after 1/24/55.
[a]Volume of waste and activity decanted from Pit No. 3 and added to Pit No. 2. Activity estimated from activity added just before decanting.
[b]Based on total gal waste volume in pit. Equal to line 13 values divided by line 6/1,000,000 values.

the British Coast, and in areas approved by the Minister of Agriculture, Fisheries and Food (30). The need was pointed out (28) for special reinforcing of the concrete in the containers to provide strength to meet the impact when the container strikes the hard ocean floor and the high hydrostatic pressures in 500 or 1000 fathoms of water.

In describing Brookhaven experience with ocean disposal, Ginnell (31) reports that about 660 drums of waste totalling 600 curies were dumped at a cost of $20 per drum exclusive of overhead. North American Aviation (32) ships its stored wastes to sea at a cost of approximately 71 cents per gallon based upon 100, 55-gallon drums per dumping 60 miles off the coast of Southern California at a depth greater than 800 fathoms.

High Level Wastes

These originate principally from the chemical processing of spent fuel for the recovery of the fissionable material. Associated with the irradiated fuel is the entire spectrum of fission products which occurs when the uranium atoms are split. The fission products must be separated from the fuel to permit further processing or reuse of the fuel in the reactor. Following removal from the reactor, the irradiated fuels are generally stored under water for periods of from 90 to 120 days to permit decay of the short-lived fission products. The problems of handling and disposing of the product are intensified when shortened storage periods are employed.

After decay, the fuel material is processed. The processing varies depending on whether the fuels came from a heterogeneous or a homogeneous fuel reactor and on the materials used in the construction of the fuel element. The separations processes that are being utilized or are under study include precipitation, ion exchange, fractional distillation, solvent extraction, high temperature processing (volatility), and pyroprocessing.

The characteristics of a typical reactor-fuel-processing waste as reported by Wolman and Gorman (28) are given in Table II. The wastes contain the fission products, some unrecovered fissionable material, and the various acids and salts required for dissolution of the material. These wastes, which are highly acid, may be stored in stainless steel tanks or they may be neutralized and stored in mild steel lined concrete tanks. Tank storage is the method presently employed at all atomic energy plants. Thus far we have had little over a decade of experience with such tanks without any serious results. However, the storage facilities have been located in relatively isolated or remote areas of the country. With the impetus being given to the use of nuclear energy for power development, it is reasonable to expect that nuclear power reactors will be located, and they are being located, close to large centers of population.

TABLE II—CHARACTERISTICS OF TYPICAL REACTOR FUEL PROCESSING WASTES
(High-Level Waste)

Gross Beta activity, 1.6×10^6-2.2×10^{10} cpm/ml
Alpha activity, 6.0×10^3-6.0×10^5 cpm/ml
Radioactivity, 1 to 4×10^2 curies per gallon (neutralized)
Effective life, about 600 years
Heat generation, 1 to 3 BTU/hr/gallon
Power equivalent, 1 gm U^{235}-24,000 kwh (100% efficiency)
Fission product wastes, 1 gm U^{235} forms 1 gm fission products
Wastes from processing 0.5 to 5.0 gal waste solution/gm U^{235} consumed

Waste chemistry:

Ions	Concentration in moles per liter
Al	0.5-2.5
NO_3	2.0-8.0
H	0.5-3.0
N_a	0.1-0.2
F	2.0-3.0
Zr	0.3-0.6
SO_4	0.3-0.6

Specific gravity, 1.1 to 1.4

In the reactor types under consideration at present, particularly those employing solid fuels, chemical processing of the fuel was to take place at one of the AEC sites having such facilities. However, on January 5, 1956, the AEC advanced a policy aimed at having commercial chemical plants ready to process spent fuel elements from the first privately owned power reactors (33). In addition, the Commission would supply the plants with an initial base load of spent fuel from one or more of perhaps 20 reactors. Since these facilities will probably be near proposed reactor stations or at least near transportation facilities, it is probable that they too will be near centers of population.

In the case of homogeneous reactor stations, the chemical processing plant, at least for the partial treatment of the fuel, will have to be located adjacent to the reactor. Under these conditions, the location of facilities for the storage of the large quantities of waste resulting from an expanding nuclear power economy presents a more difficult problem. Accordingly, considerable thought and energy is being given to the development of more satisfactory and permanent methods of disposal. Some of the proposed methods have been studied on a laboratory scale and are now being investigated in pilot plant facilities. Others are only in the thinking stage. The methods that have been demonstrated or suggested will be discussed in somewhat greater detail in the sections which follow.

Storage. Storage itself is not being abandoned even though the cost on a per gallon basis seems rather high. Prices quoted range from about 30 cents to $2.00 per gallon of tank capacity. However, when calculated on a kilowatt hour basis the cost is not high. Because power reactor wastes will have higher activity levels, it is necessary to provide facilities for cooling the waste solution. In conventional terms, the energy release in separations plant waste is small, up to 1 watt per liter of solution, but its management is complicated by the large volumes involved and nonuniform distribution promoted by the tendency to form precipitates in wastes normally made alkaline to minimize corrosion (34).

Grandquist and Tomlinson (35) point out that with a special type of fuel recovery process and mechanical dejacketing of the fuel elements about 20,000 gallons of highly active waste would be produced by irradiation of natural or slightly enriched uranium to about 2500 megawatt-days per ton. The waste volume would be expected to self-boil perhaps for 50 years. At Hanford nonboiling wastes in 500,000 to 1,000,000 gallon tanks can be stored in reinforced concrete tanks with mild steel liners at a cost of 20 to 25 cents per gallon and self-concentrating wastes may be stored at a cost of 40 to 50 cents per gallon of tank space. Since this cost amounts to but 0.01 to 0.05 mils per kilowatt of electrical power produced, there is no pressing economic need to develop a better system of waste handling (35).

Separation and Storage. Glueckauf (36) suggests that the quantitative removal of Sr^{90} and Cs^{137} from the wastes and separate storage from the bulk of radioactivity will permit consideration of relatively short-time storage (about 20 years) for the residual activity. By such separation and storage it may be possible to recover the more usable radioisotopes and to release the residual activity under suitable conditions into either the ground or the oceans. A similar scheme is under investigation at the Oak Ridge National Laboratory where the removal of specific radionuclides (strontium, cesium, zirconium, niobium, yttrium, ruthenium, and cerium) from simulated wastes by precipitation (37) and solvent extraction (38) has been evaluated. The separation of the waste into such components with separate storage of the more hazardous fraction has advantages in that less storage space will have to be provided, less elaborate storage may be provided for the bulk of the wastes, self-boiling of the wastes will not take place, and there will be no need to provide special tank cooling facilities.

Jonke (39) has described a process for converting aqueous nuclear wastes to solid form by injection into a fluidized bed of heated solids, where evaporation and calcination of the waste to oxides is effected. Another calcining operation has been described by Hatch, Regan, Manowitz, and Hittman (40) in which simulated high activity waste streams containing 30 wt % salt were converted to anhydrous free-flowing melts.

Specific studies for decontaminating aluminum waste solutions were described by Blanco, Higgins, and Kibbey (41). They utilized a scavenging precipitation and an Al-resin ion exchange tecnhique. Gross beta-gamma decontamination factors of 10^3 (influent over effluent activity) were obtained with 97 to 99 per cent of the aluminum appearing in the eluate. The Cs and Sr decontamination factors were 10^3 to 10^4, respectively. A further development was reported by Higgins and Wymer (42) who decontaminated an $Al(NO_3)_3$– nitric acid radioactive waste. Ninety per cent of the niobium and 95 per cent of the ruthenium and zirconium were removed by a ferric hydroxide-manganese dioxide scavenging precipitation. The aluminum nitrate was converted to a dibasic aluminum nitrate by destructive distillation and dissolved by 12-hour digestion at 160°C. The strontium, cesium, and rare earths were removed by cation exchange in a continuous contactor. The decontaminated waste can be volume-reduced to about 6*M* aluminum before disposal and then stored cheaply. The fission products can be eluted from the column, concentrated to a small volume of highly radioactive waste, and stored with all necessary precautions.

At Los Alamos (43), a radioactive waste containing Ba^{140}, La^{140}, Sr^{90}, and Y^{90} was passed through a cation exchange resin column. Storage in the column results in the decay of short-lived Ba and La isotopes. Within reasonable limits of raw waste quality, the ion exchanger reduces the Sr^{90} concentration to permissible levels for discharge. The resin column was regenerated on exhaustion and spent regenerant treated by chemical precipitation and vacuum filtration.

Another scheme, reported by Glueckauf and Healy (44), for the separation of cesium and strontium involves the following: The fission products are taken to dryness to remove all nitric acid and water; then the dry material is roasted for about an hour at 300°C., whereby all the nitrates except those of alkali and alkaline earth metals are decomposed into oxides. The solid is then leached with warm water which dissolves the cesium and strontium nitrates, leaving behind all the water insoluble oxides. Usually about 95 per cent of the cesium and 85 per cent of the strontium can be extracted. The roasting temperature is critical to ± 10°C., otherwise the leached material either contains too many impurities (at $<$290°C.), or retains too much cesium and strontium with the oxides (at $>$310°C.). The strontium and cesium recovered in this way may be further concentrated for separate storage and the residual fission products may be stored for a shorter time in separate facilities.

Fixation of Wastes and Firing. Ginell (45) and Hatch *et al.* (46) (47) (48) have conducted experiments dealing with the fixation of radioactive contaminants on montmorillonite clays. In their process, the fission products were passed through a column containing extruded clay (spaghetti) and the clay was fired at temperatures up to 1000°C. Subsequent leaching showed that the amount of material leached was a function of the initial firing temperature. At temperatures approaching 1000°C. the amount of leaching was small and stabilized quickly. More recent investigations by the Brookhaven group have extended this method of disposal to high level wastes. Because of the large amounts of nitric acid or aluminum nitrate in the waste solutions, and because these quickly saturated the montmorillonite clay, it was necessary to pretreat the wastes to remove these high concentrations of stable materials. This was done originally through the use of permselective membranes. More recently, the pretreatment has been modified and now includes kiln-drying of the aluminum nitrate-fission products waste to form aluminum oxide. The aluminum oxide plus fission products is leached; the leachate containing a fraction of the fission products is then passed through montmorillonite clay; the clay columns are fired; and the activity fixed permanently.

The approach used by the Health Physics Division, Oak Ridge National Laboratory, was somewhat different in two respects. One, adsorption on the indigenous Conasauga shale was investigated, and two, fixation following mixing of the Conasauga shale and acid aluminum nitrate waste with specific quantities of limestone and sodium carbonate was evaluated. It was found that sintering at temperatures above approximately 500°C. could fix much of the activity. Subsequent leaching with water showed little release of activity with the exception of cesium. The next approach investigated the possibility of utilizing the heat of decay to fix the activity directly to the soil without the need of any external heat. The amounts of heat available have been reported by Perring (49) and could be sufficient, with enough concentrated activity, to permit self-fixation of the waste.

From studies reported by Johnson *et al.* (50) at ORNL it was concluded that liquid containing between 100 and 1000 curies per gallon may be disposed in insulated concrete lined earth pits and will self-heat to temperatures adequate to become fixed in clay-flux mixtures. The mixtures used in these experiments were developed by McVay, Hamner, and Haydon (51). They combined Conasauga shale, soda ash, and limestone with a simulated aluminum nitrate-nitric acid waste solution to form a ceramic mass at a temperature as low as 1050°F.

The Oak Ridge studies led to the development of the so-called pilot plant hot-pot experiment which employed clay and outside sources of heat. Fixation of fission products from acid aluminum nitrate waste was effected and studies are now being planned in which high level wastes will be employed directly to determine the self-heating and self-fixing characteristics of such mixtures.

Studies at Los Alamos (52) showed that alpha activity in filter cake (4000 c/m/g) and raffinate wastes (126,000 c/m/ml) were fixed for safe disposal when fired with clay. Beta-gamma wastes at the 400 millicurie level have not been satisfactorily fixed by this method. Additional studies are underway to determine the influence of such factors as clay mixtures, controlled firing, fluxes and glazes, and leaching solutions. Patrick (53) has proposed a method of synthesizing aluminum silicates which eventually metamorphose to feldspatic structures with alkali or alkaline earth oxides. He is applying this method to the removal of strontium and cesium from high level wastes.

Mawson (54) refers to pilot plant studies made at Chalk River, Canada in which a $2.5N$ nitric acid waste of high activity is mixed with nephaline syenite, and fused at a temperature slightly below 1000°C. forming an opal glass. Tests have shown that a very small amount of activity is leached initially, but after a short time very little activity comes off.

Amphlett (55) (56) has investigated this problem in England and reports (56):

"The use of natural silicate materials or soils as bases for formation of unleachable products, by mixing with the waste and firing to high temperatures, offers promise. Higher loadings can be achieved than by means of ion exchange, and inactive ions and acid do not appear to affect the adsorption of activity. This method may enable absorption of bulk wastes in one operation, and because of the shorter-lived nuclides are included there is a possibility of self-fixation on a reasonable scale. No preparation of the material is required, and the process may be applicable to slurry and solid wastes as well as to solutions. If possible, the process should be aimed at melting the mixture to form a glass, in order to achieve the maximum density and hence the maximum concentration factor. This requirement is of course subject to leaching properties, loss of activity by volatilization during firing, and the possibility of lowering the melting point by the use of suitable additives. It is clear that much further work is required.

Ground Disposal. Before burial of radioactive materials the geology and hydrology of the particular disposal site must be well understood. The hydrological and geological factors affecting ground disposal at Hanford, Brookhaven, Oak Ridge, Idaho Falls and Savannah were discussed by Brown *et al.* (57) de Laguna (58), and Theis (59). Theis (60) also described the general types of formations useful for ground disposal. These include 1) sandy, relatively permeable formations; 2) permeable cavernous formation; 3) jointed or otherwise fractured rocks; 4) relatively impermeable shales; or 5) deposits of salines—rock salt or gypsum. Thurston (61) points out that many geological principles and methods used in the petroleum industry are applicable to radioactive waste disposal. The preparation of artificial cavities in salt and shale for the storage of hydrocarbons may be adaptable to the shallow underground disposal of a comparable volume of radioactive wastes. Furthermore, the natural porosity of many sedimentary rocks may be suitable as reservoirs for the safe disposal of wastes at great depths.

The factors which must be evaluated in considering the feasibility of disposal of high level radioactive wastes into the ground include: 1) the chemical and radiochemical content of the waste; 2) the effectiveness of retention of the radioisotopes in the available soil column above the ground water table; 3) the degree of permanence of such retention, as influenced by subsequent diffusion, leaching by natural forces, and additional disposal; 4) the natural rate and direction of movement of the ground water from the disposal site to public waterways, and possible changes in the characteristics from the over-all liquid disposal practices; 5) feasibility of control of access to ground water in the affected region; 6) additional retention, if any, on sands and gravels in the expected ground water travel pattern; 7) dilution of the ground water upon entering public waters; 8) maximum permissible concentrations in those public waters of the radioelements concerned; 9) the temperature and pressure effects resulting from the heat of decay; and 10) the effect of waste discharges on present or potential mineral wealth of the region. High level wastes are not discharged into the ground in any location at the present time.

The reactions of radioisotope solutions with Hanford soils were described by McHenry, Rhodes and Rowe (62) with respect to the effects of concentration, pH, total ion concentration, and the type of soil. A significant increase in Sr adsorption in the presence of phosphate ion is shown to counteract the adverse effect of high salt concentrations. Experimental evidence and theoretical considerations illustrate the very low diffusion rate of strontium. Preliminary investigations were carried out by Kaufman *et al.* (63) on the feasibility of high level radioactive waste disposal by injection into isolated geological formations. Density effects and exchange reactions between the simulated Sr wastes and columns of clay or oil sand were studied. They observed that exchange reactions may retard the advance of radiostrontium concentration fronts to as much as 1/40 that of the liquid front.

Ocean Disposal. As reported earlier, the only direct discharge of radioactive waste materials into the ocean is at Sellafield, England, where the wastes from the Windscale plant are discharged into the Irish Sea. In other instances, packaged materials are dumped in specified disposal areas, but in all cases these are of low- or intermediate-level wastes. There has been no discharge of high-level radioactive materials. Some of the problems facing the oceanographer in determining the feasibility of such a disposal scheme have been reported by the British in describing their studies prior to the Irish Sea discharges (64) (65) (66). It is obvious that mixing, either desired or undesired, will play a major role in defining suitable disposal areas, if such exist.

With respect to ocean disposal of radioactive materials, the National Academy of Sciences (67) states:

"Sea disposal of radioactive waste materials, if carried out in a limited, experimental, controlled fashion, can provide some of the information required to evaluate the possibilities of, and limitations on, this method of disposal. Very careful regulation and evaluation of such operations will, however, be required. We, therefore, recommend that a national agency, with adequate authority, financial support, and technical staff, regulate and maintain records of such disposal, and that continuing scientific and engineering studies be made of the resulting effects in the sea."

Cost. Zentlin (68) has estimated the allowable cost of waste disposal to be $4 per gallon in the case where the reactor burnup is 5000 megawatt-days (heat) per ton, the processing volume 1200 gallons per ton, and the allocated cost for waste disposal 2 per cent (or 0.16 mills/$kwhr_e$).

Non-Radioactive Wastes

Not all wastes produced by the nuclear energy industry are radioactive. Where acid dissolution of partially spent fuel materials is practiced, large quantities of nitrate wastes will result. Christenson *et al.* (69) have developed an activated sludge process without diffused air which has a maximum rate of nitrate reduction in the order of 70 ppm per hour. Their feed, based upon a 6-liter feed volume, is 600 ppm methanol, 250 ppm nitrate nitrogen and 10 ppm PO_4. This mixture is reduced in the 8-hour contact time to no nitrogen and about 40 ppm oxygen consumed.

Liquid wastes from the production of hafnium-free zirconium contain 1.8 pounds of ammonia per pound of zirconium produced along with trace amounts of cyanides, thiocyanates, sulfates and chlorides. McDermott (70) indicates that the process wastes, most objectionable from the pollution standpoint, amount to 10 gallons of concentrated ammoniacal waste per pound of zirconium produced. The waste is held in basins before trucking to a large river for disposal by dilution.

In the uranium and thorium refining and reduction operations large quantities of fluoride containing wastes are produced by dumping in a pit at a cost of $0.54 per cubic foot (71). Liquid wastes are released in such a manner that fluoride content of the stream does not exceed 1.2 ppm (background fluoride level of stream is 0.4 ppm).

Summary

The Yankee Atomic Power Reactor installation, planned for Rowe, Massachusetts, has been described. Since little information has been made available relative to provision for waste disposal facilities, the disposal facilities associated with the power reactor installation at Shippingsport, Pennsylvania, a similar type reactor, have been listed and the types of wastes produced noted.

The techniques in use or under study for the handling, storage, and/or disposal of solid, gaseous or airborne, and liquid wastes have been discussed. Burial, incineration, or disposal at sea have been suggested for handling solid wastes; collection, concentration, and dilution for gaseous or airborne wastes; and storage, separation, fixation on clays and other materials, ground disposal, and ocean disposal for liquid wastes. Examples are also given of non-radioactive wastes that pose potential pollution problems.

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A FORWARD LOOK IN TRANSPORTATION

By Ernest A. Herzog,* *Member*

(Presented at a meeting of the Transportation Section, B.S.C.E., held on September 18, 1957.)

Of all of the municipal problems facing American cities today, none is as great as that of the crisis proportion rapid transit problem—

A sober look at the reason and a shift in concept scale thinking is required to bring this horribly distorted picture back into focus so that a workable answer can be determined. The problem, of course, is to transport thousands of people, comfortably and rapidly and at a profit, into city centers from suburban living areas—and back again. All mass transportation forms, intercity and local public carriers have been fighting rising operating and maintenance costs while their percentage of persons carried of the total moved has dropped; reflecting a drop in their total percentage take of the transportation dollar. The drop in passengers carried has gone so far that the number needed for profit is no longer being reached, indeed the percentage needed to break even is not being reached. The result of operating at a sustained loss, of course, is bankruptcy.

What are the causes, major and contributing, of this situation?

The automobile, the resulting sprawling suburbs, and the ultra-conservative maintenance thinking on the part of the rapid transit systems are the major causes. As the transportation lines lose their income, the purchase of new equipment is stopped and the maintenance cost of the old equipment becomes staggering. Popular feeling will not accept the dingy, crowded, outmoded equipment and the rate of shift to automobiles increases. New and modern buses are on the roads but because of the bus bulk it is particularly subject to traffic snarls and the speed of bus transportation is reduced to a mere sixty percent of that possible by private automobiles.

What about the private automobile? Is it an answer to rapid transit? Are large and modern highways that not only by-pass but funnel thousands of cars into our cities the answer? Are multi-tiered, multi-laned, multi-million dollar elevated highways the answer? Can

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the auto traffic stifled cities accommodate themselves to onslaught after onslaught of cars? Can the cities lose taxable property to the parking lot—can they build garages—can the mercantile establishments stand the delivery difficulties—the answers are, of course, no.

What is the solution?

New and modern elevated lines, silent, on rubber wheels, with automatic controls are fast carriers of passengers but expensive—costing eight or nine million dollars a mile. Moving sidewalks are practical for city short hauls. These are all solutions and are all workable to varying degrees of success. The problem, as mentioned, is of crisis proportion and calls for a major revision in our thinking. It is my firm belief that only two solutions are possible. Subsidize the railroads so they can modernize—an expensive solution, economically and politically; or resort to a "modern" concept in transportation—the monorail.

The monorail is an adaptable, fast, economical rapid transit system, riding on a single rail above and relieving congestion, adjusting to almost any passenger capacity requirements. Monorail cabs in trains of five or six, traveling silently on pneumatic tires, sway free, gyroscopically balanced, riding above grade crossings, free from collisions, can carry thirty thousand passengers an hour on a single rail. The construction costs are less than any other form of rapid transit. A fifteen minute monorail ride instead of a fifty minute automobile ride.

This, admittedly, is a radical solution, but think of our problem, and remember other radical solutions to other crisis proportion problems—the elevator—the subway—the transcontinental railroad.

We must supply a twentieth century answer to a twentieth century problem. The usual resistance to a shift in thinking must be overcome. Reasons of why it can't be done will be offered and they will include—

1 — No history
2 — People won't like riding in the air
3 — It looks too radical
4 — People don't like being a part of an experiment.

A pilot monorail system would have to be engineered, and built to find and correct the operational bugs and misconceptions.

The organization of the project must be a management, engineering, construction, financial, legal, public relations, and a political one —ending in a solution that includes profit.

The engineering problem first. What would a monorail look like, how large would the cabs be, the rail, the towers? How about sway, uplift, power? How much space is required, how much land, how high above the ground—and how much money?

We require a rail or beam, supports for the rail and a cab. The cab could ride on top of or below the rail. We need a propulsion unit, wheels, controls and brakes.

The cab would be lightweight—all aluminum, an airplane body without wings. Physical dimensions could be 60′0″ long, 9′0″ wide, 7′9″ high. This would provide for 60 seats, room for 50 standees, 1.9 passengers per foot of car, 4 square feet per passenger. Car weight would be about 30,000 pounds, loaded weight about 52,000 pounds, with propulsion unit about one kip per running foot of beam. The design of a beam spanning, say, 100′0″ is not an unusual structural problem. If we supported the rail off of one side of columns spaced 100′0″ on center moments of the magnitude of eight hundred foot kips. are roughly what can be expected, including wind, impact, and centrifugal loading. We encounter far larger moments in transmission tower work, some buildings and many bridges—structurally we are not dealing with designs beyond the scope of our experience.

The motive power, wheel carriages, controls and brakes would be part of a separate unit riding atop the rail in the underslung version, or incorporated with the cab body on the rail straddling design. The propulsion unit could be gasoline, diesel or electric powered. The wheels—pneumatic rubber tires, steel or a combination of both.

The beam and columns or towers could be reinforced concrete, prestressed concrete, rolled steel sections or steel shell sections. Utilities and power lines would be carried on, under or in the beam. There is nothing new or radical in concept here. Safety devices would incorporate all the latest innovations developed by the automatic control people and would not be nearly as extensive in concept as those presently being employed and being considered by the railroads.

Wherever a lamp post can go we can also put a monorail tower.

1 — Center lane of highways
2 — River beds and river banks
3 — Sides of downtown city streets
4 — Railroad rights of way.

How high in the air would the top of the beam have to be for transit above the traffic—

The cab	8′0″ high
Beam, say,	4′0″
Space	1′0″
	13′0″

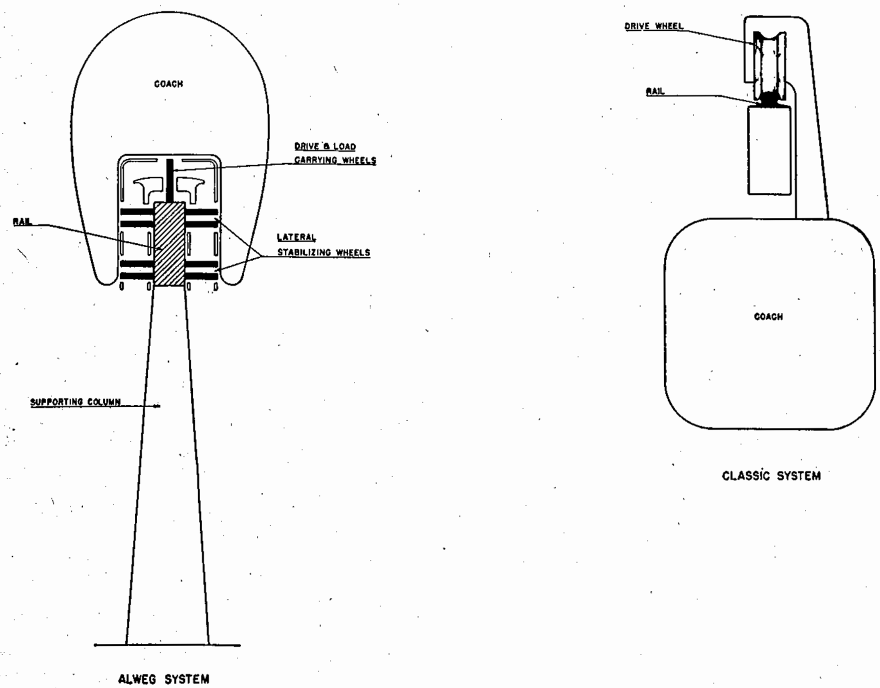
For a feeling of safe clearance, we would need about 15′0″ for a total of 28′0″ from grade to top of beam. The cab certainly could climb grades and with pneumatic tires the grades could be of 5% magnitude. Suburban stations could have ground level platforms—intown stations would unload in the air. People ride and have ridden in elevated transit lines in New York, Philadelphia and Boston for over a half century.

The control of side sway and uplift is certainly possible by many methods, the most obvious one being the use of guide wheels.

If we can design cabs to carry 100 people, if we can have trains of up to five cabs, if we can transport these people at 60 mph, then, we can handle high density traffic.

Costs—The primary controlling factor in most ventures, is extremely favorable. A modern elevated highway costs about 6 million dollars a mile, the depressed highway about 8 million dollars and a subway up to 20 million and not much less than 15 million dollars a mile. The monorail can be constructed and equipped for high density areas for less than a million dollars a mile. When one perceives the scope of this comparison the thought is staggering. Carried to an extreme ultimate condition this means that a single track monorail system can provide the same transit capacity as a twenty-four lane highway. The speed of construction is very great. The difficulty of terrain, a great problem in all other transit systems, provides relatively minor problems here. The alignment is maintained by merely varying the tower height in much the same manner as a transmission line is installed.

Organization of financing, construction and operation would be peculiar to a specific community. We can do many things on paper but can they work—how practical is a monorail—have any full size systems been constructed. The idea is not new. Monorails were built in this country. In 1878 a steam driven, rail straddling, monorail system was successful in hauling passengers from Bradford to Gilmore, Pennsylvania, a distance of 4 miles, at 30 mph. Five men were killed when a boiler exploded—the result was financial ruin. A model was built in Cambridge, Mass. in 1886. An electric car attained speed of 55 mph in 1892 in New York. These projects failed because of lack of financial interest and the lack of need. In 1901 in Wuppertal,

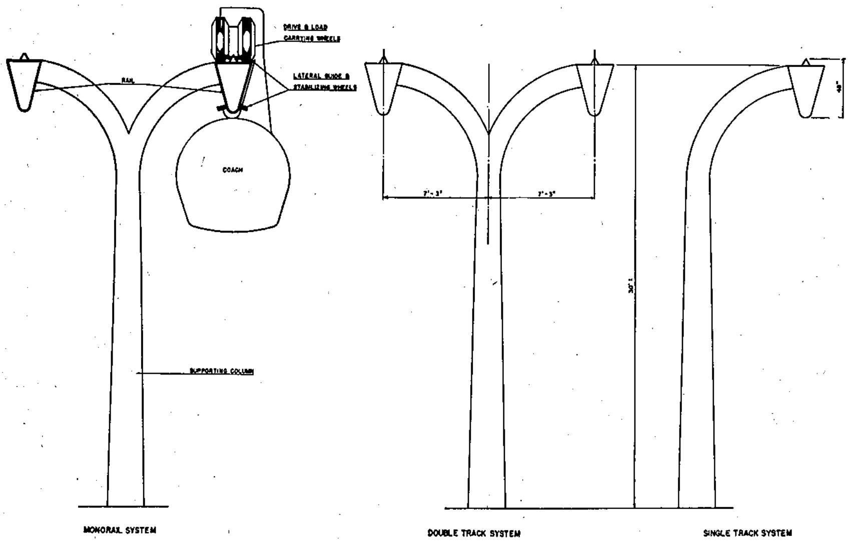


MONORAIL TYPES.

Germany a monorail system went into operation and has successfully carried roughly 900,000,000 passengers, without a fatality in 56 years. This line is 9½ miles long.

Another system is being built near Köln, Germany. A 1¼ mile full scale section has been completed, and test runs have produced speeds of 50 mph. I believe that prior to this full scale operation which was described in the August 29, 1957 issue of *Engineering News-Record,* a two-thirds scale model had to be built for test purposes. This is a rail straddling concept given the name ALWEG system developed by Alweg-Forschung, Inc.

We have a successfully operated monorail installation in this country. At Houston, Texas a Pilot Line with a full size cab was built and later was moved to Dallas, Texas where it has been in successful operation for a year. This system was installed by "Monorail, Inc." This firm has designed, tested, set up specifications, through experimentation has overcome many bugs, has operated a full scale system for over a year and because they have proved the claims it is reputed that they have financial backing amounting to over $100,-000,000.



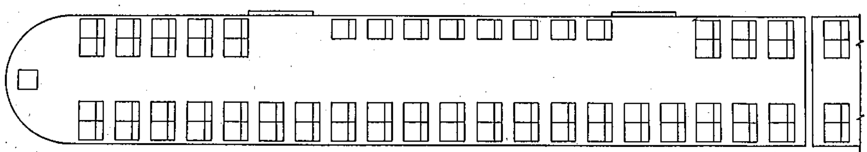
TOWER DESIGNS.

I would like to review their system and some of their claims.

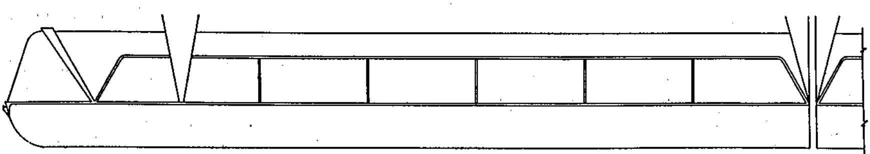
In general, they have modified the classic monorail system. Towers support beams which act as the rail. The cabs are hung from a propulsion unit, the wheels are pneumatic rubber tires. The tower designs are architecturally pleasing, and are made of steel all welded box sections, the towers taper from the ground to cantilever arm. Towers have been developed for single and double tracks. The use of a double track system is economical in that construction costs are very nearly as much for a single track as for a double track. The height of the towers has been designed to allow clearance of the coach bottom from zero to 50 feet above grade.

The rail as designed and used by Monorail is a welded steel box girder. The rail is 30″ wide, 42″ deep with a guide fin on top. It is designed to span 100′0″ and rails have been developed that span 150′0″. Expansion joints have been designed and made. The services for an all electric system are carried inside the beam.

The cab designed along the lines of and employing the aircraft designs is a very lightweight structurally and aerodynamically correct body. The coach body is embossed aluminum with green tinted solex type windows. The floor is vinyl plastic tile, wall panels below the window levels are scratch and wear resistant, rigidized metal, the ceil-



COACH SEATING PLAN



COACH SIDE VIEW

COACH DESIGN.

ing is light-reflective fiberglass reinforced plastic. The windows comprise 25% of the total surface area of the coach body. There are three basic coach designs for individual and train operation. The head-end coach is the power and prime control coach for all train make-up, squared off at the trailing end. There is a train make-up coach squared at both ends, powered or unpowered, and there is a trailing end coach powered and equipped with limited control equipment. The basic coach, as designed, is 52′ long 7′9″ high, 8′9″ wide with a seating capacity for 64 persons and room for 50 more standing which breaks down to 2.2 passengers per foot of car length. Present designs are for two 48″ divided doors at approximately ¼ points. All controls are designed for maximum safety and the use of fully automatic control and operation devices is possible. Cars can be separated or intercommunicating. The car weight is 26,700 pounds.

The power Nacelle consists of propulsion equipment, truck assemblies, wheels and accessory equipment. It is completely detachable from the coach body and interchangeable with other coaches of same control design. The coaches are powered with 4-600 VDC-100 horsepower traction motors and dynamic braking. Braking is by standard drum type air brakes on each load wheel. The brakes and door operator controls are interlocked for maximum safety.

Speeds of over 100 mph can be obtained and on a curve with a radius of 1800′ maximum speeds are possible. The system can operate on curves that can turn on ordinary city street corner at speeds of 20 mph.

Actual land requirements are about 6 square feet every 100′0″ and the aerial right of way. The claims that the system can be constructed and equipped for $850,000 per mile for a double track system sounds low and most of us would want to see a firm agreement in miles and dollars. There was recorded such an agreement in the August 29 issue of the *New York Herald-Tribune*. A petition to construct 7½ miles of monorail system from Upper Darby to Media, Pennsylvania has been filed by the Red Arrow Lines with the Public Utility Commission. Service is proposed to start by spring of 1959 and the total cost is to be $4,500,000.

I think that we have enough proof that the monorail system can work and has worked. I would even go so far as to say that I believe it is going to be one of the major solutions to the increasing problems of transportation from suburbs to city centers.

In Boston as in all American cities the most fantastic problem facing us today is our totally bankrupt transport system. Turning to the automobile for solution only begets more trouble in the form of more automobiles, more extremely expensive elevated or depressed highways, more traffic jams with their resulting staggering loss of productive time. The glutting of city streets with private automobiles brings about the strangulation of the mercantile operation and finally the construction of parking facilities on valuable downtown properties completes the suicidal pyramid. The way to economic Renaissance for Boston does not lie through the automobile. What is necessary is the reconstruction of our mass rapid transit. Fantastic is the cry! If they can't do with what they have how can we build new systems. A solution is not a matter of choice. Our present problem is a crisis and now while private capital can still be interested in new transit systems is the time to make a start. With imaginative planning, with energetic non-restrictive thinking and with less money than we are now spending, we can go far in curing our transportation ills. Railroad technology has advanced to a point that allows us to drop operating costs to an extremely low level. Whatever plan is adopted it will first have to have an administration that would extend beyond Boston to all of the suburbs.

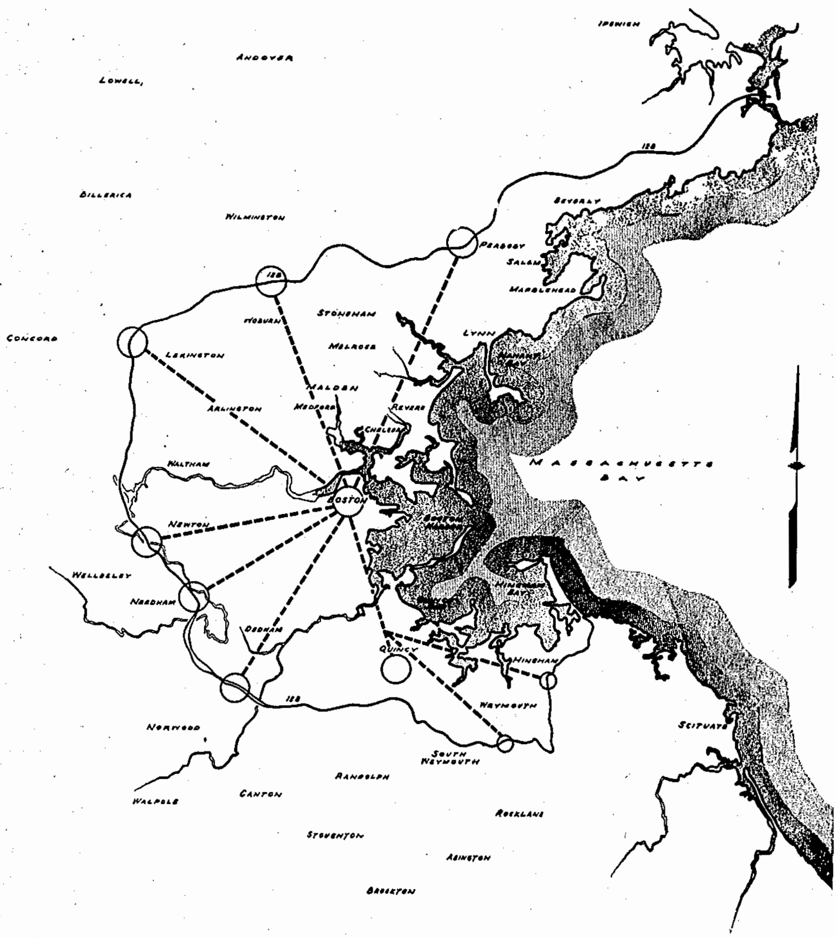
Two immediate problems are now making the newspaper columns. One is the problem of the South Shores battle with the Old Colony and the latter's threat to abandon the line entirely. With the existing right of way it is possible to establish a monorail system to Weymouth from Boston for less than last year's deficit chalked up by the M.T.A. —eight million dollars.

Transportation to Newton—another sore point. Rather than expensive M.T.A. extension why not a monorail system along the same right of way, or along the Charles River—express to Watertown? Or along the center strip of the proposed toll road. These are not fanciful dreams but highly practical solutions that should be considered. To discuss an ultimate solution, let us look at Boston and its suburbs.

Route 128 forms a ring around Boston through its major suburbs. The ultimate desirable would be radial transit lines extending from Boston to 128. At these junctions would be huge parking facilities plus the system's maintenance shops. Veins or suburban feeder lines would connect this main system—busses or surface cars running on transit only roads. The total number of miles for this main system with links to Lynn, Woburn, Lexington, Waltham, Wellesley, Dedham, Weymouth and Hingham, following roughly routes 107, 28, 2, 20, 9, 1, 3 and 3a would be 78 miles. Total initial installation cost would be in the neighborhood of 70 million dollars. The arteries would be any modern rapid transit method that could be most economically installed. The above figure was based on the monorail over most of the lines. The communities involved would contribute the right of way and land franchise in which case I believe enough private capital would be interested to accept the construction and operating risk.

In downtown Boston there could be an inner monorail loop, following Atlantic Avenue from South Station to North Station, Park Square area, down Stuart Street to South Station, with a chord line running down Washington Street from Stuart through Scollay Square to North Station. This last would be a local with two stops along

Washington Street. Stations at downtown points would be above street level and could enter at second floor levels of several stores with a lobby area and escalators or direct entrance to stores. The platform would be a canopy over the sidewalk. The termini at the 128 end of all the major lines would be made available, landwise, by the towns involved. The termini would be basically parking areas, parking to



MASTER PLAN
RAPID TRANSIT SYSTEM
ALONZO B. REED INCORPORATED
ARCHITECTS-ENGINEERS

be in concentric circles. A concentration of people of this magnitude would naturally be of interest to certain types of mercantile establishments which in turn would stimulate real estate interest in the form of build and lease shopping areas. As I picture it, these buildings could be circular, housing maintenance shop, storage of coaches could be on two track levels, platforms at grade rising 30′ to travel level.

More consideration must be given to the Boston area in the form of city planning. The concept I have in mind is peculiarly practical for Boston because of the mercantile and financial concentration in a small area.

First, we must prohibit any private automobile traffic in an area of downtown Boston bounded roughly by Park Square, Scollay Square, Tremont Street and Devonshire Street.

Second, convert Washington Street from Stuart to Scollay Square to a sidewalk plaza.

Third, the preparation of a master plan for the rehabilitation of Boston to be accomplished by Boston architectural and engineering firms, each firm designing for a different area. This would keep the designs in the hands of vitally interested parties and also provide the intelligence of design that comes with living with the problem. Further, by decentralizing the master plan, variety and a mild sense of competition would guarantee the choice of ideas of a great number of the thinking men in our country as they are represented by our many Boston firms. Property owners would be made aware of what was in store for their holdings in the future. Some would react immediately by complying with the plan, some would be forced into a move by their neighbors, some would sell to new forming real estate syndicates and some property would have to be taken by eminent domain. Revisions to the city would have to include dock area planning and the energetic pursuit of steamship and airline franchises of foreign countries. Delivery to the mercantile houses would be underground and by ramps, roughly approximating the side streets we now have, Temple Place, Winter Street, etc. Time schedules for each area are necessary so that a record can be kept of progress. Responsibility for this program will have to be multiple. The major control of the scheme should be by the private enterprises most affected. It should have approval by the state, the interested enthusiasm of city officialdom, and energetic promotion by the Chamber of Commerce.

Any city master plan would have to be coordinated and integrated with a highway master plan and a transportation master plan and note I do not consider the latter two plans as being anything like synonymous.

That is an overall ultimate. I would now like to suggest a South Shore rapid transit system that would encompass the territory roughly once served by the Old Colony as an immediate solution.

I think that a triple line could be run to Quincy with a spur entering Quincy, a double line continuing to Hingham with a spur turning at Braintree for future expansion. I believe that a minor terminal could be constructed at Hingham with a major terminal planned for Plymouth in the future and with a major terminal for Quincy now. A group containing town and city representatives from Boston, Quincy, Braintree, Weymouth, Hingham, interested real estate and Railroad representatives should go to Texas, see what this existing line looks like, talk to the operator, ride the cars. If, in the opinion of these interested parties, the monorail is indeed a possible answer to our transit problem, then, we can make a survey of the proposed line. The cities and town can conduct surveys to determine possible popular use, real estate and banking and railroad people can determine platform sizes and mercantile possibilities. Monorail, Inc. can be invited to make their construction proposal in terms of money and miles. If, then, we can put in the above system as described, including rolling stock to amply handle transportation of people during the rush hours, plus several other coaches during the day, plus light freight and mail, if a ride from Hingham can be made in 23 minutes, if the cost for travel can be held to 3 cents a mile, then, I think this is a sound solution.

One can make all the suppositions one wants, all the drawings, and all the claims, but there is nothing like a firm contract in terms of money and performance. I believe that the above described system can be installed, making extensive use of the very great technical advances in automatic controls that the railroads have made in recent years, complete with rolling stock, exclusive of land rights and stations, for $12,000,000. If this is so, then serious consideration should be given to this first possible link in Boston's required forward look.

Technical Information Sources

1. "Wuppertaler Schwebebahn" das Vereines Deutscher Ingenieure Bd. 93 (1951) Nr. 75,153 — 169.
2. Monorail, Inc., Houston, Texas.

TALL TELEVISION TOWERS

By J. Roger Hayden*

(Presented at a meeting of the Structural Section, B.S.C.E., held on October 9, 1957.)

Tall television towers, in heights of 1000 feet or over, were almost non-existent just a few years ago. As television began to come of age the need for broader coverage patterns in some of the larger markets became apparent and the trend toward taller towers began. Video signals travel in a line-of-sight path hence the higher the antenna, the farther the signal goes. The first tall television tower was 1057 feet in height and was constructed for TV Station WSB in Atlanta, Georgia. Today about 10 per cent of the country's TV stations are equipped with towers in the 1000 foot to 1600 foot range.

Boston's new WBZ-TV tower which has been recently completed and the new WHDH-TV tower are typical television towers of this type.

The new television tower recently completed for WBZ in Needham near Boston, Massachusetts, has a number of future uses which are not apparent to the casual eye. These future uses added a number of different loading conditions to the design of the tower.

The present height of the structure is 1,199 feet above ground with the ground elevation being 150 feet above mean sea level. This places the overall height of the structure at 1,349 feet above mean sea level. At the present time, this height is the maximum permitted by existing air traffic considerations.

Air traffic will change from time to time and future considerations might permit an increase in height. Due to this possibility the design of the structure will permit the height being extended to 1,499 feet above ground or a height of 1,649 feet above sea level.

The present limitation on the height of the structure is 1,300 feet above mean sea level to a tolerance of plus 50 feet. This explains the rather odd dimension of 1,349 feet above mean sea level which is one foot short of the allowable limit of 1,350 feet.

*Dresser-Ideco Co., Columbus, Ohio.

Considerations of the future indicate that an overall height of 1,649 feet above mean sea level would be a reasonable top height, hence the reason for settling on an extension of 300 feet for the future.

The main tower body is triangular with each side of the triangle being 12′-0″ center to center of the corner members. The top 230 foot portion of the structure is restricted to a dimension of 5′-3″ center to center of the corner members. This portion of the tower is designed to permit installing two different television transmitting antennas mounted around the structure. Electrical considerations limit the size of this portion of the tower to a maximum dimension of a triangle 5′-3″ on a side.

The main tower body size is determined by the structural design and is the most economical size for this height tower. The lower 40 foot portion tapers to a flexure point or a pivot. This pivot assembly is made of circular plates welded to form an inverted "Wedding Cake" appearance. The diameter of the bearing plate is 8 inches and the entire weight of the structure rests upon this pivot point. The weight is then distributed to a concrete foundation through a similar "Wedding Cake" assembly which tapers from 8″ in diameter to a base plate which is 60 inches in diameter and is 4 inches thick. The pivot point base was used to eliminate any bending from the base foundation and to eliminate any need for considering secondary loads due to bending in the lower part of the tower.

Many television towers today have rigid foundation bases where the tower structure does not pivot and any loads existing at the base are handled in bending. This type structure is extremely desirable to permit simple connections to the various electrical lines feeding the television antennas. However, the ground at the WBZ tower is extremely hilly and the transmitter building is placed in a location that requires all electrical connections leaving the tower 50 feet above the base. This feature permits the use of the pivoted base with the simpler design work attached to it.

The structure is supported by a number of sets of guys with each set consisting of six guys. The six guys extend in three equally spaced directions and are arranged in pairs of parallel guys which are attached to concrete anchorages. The present tower uses 4 sets of guys with two sets extending to three anchors 400 feet from the base of the tower. The two upper sets extend to anchors 890 feet from the tower. If the tower is extended in the future a fifth set of guys will be used which will attach to the outer ring of anchors.

The guys are bridge strand and vary in size from 1 7/16 inches in diameter to 2 1/16 inches in diameter. The guys are pre-stressed to give an elasticity modulus of 28,000,000. The attachment of the guys to the tower and to the foundations is made by using bridge sockets with zinced-in connections. All connections are tested to a loading fifty per cent greater than the maximum expected design load.

The equipment supported on the tower at present is to be used entirely by WBZ on Channel 4. The top 82′-9″ of the structure is a transmitting antenna consisting of 6 sets of radiating elements named "Bat-Wings," a name coined from their shape. The main structural support is a steel pole 99′-2″ long which extends into the main tower structure. The dead weight of the antenna is 18,250 pounds. This antenna is fed by four transmission lines, 3⅛″ in diameter each, which extend from the antenna down through the tower and into the building to the transmitter.

A reflector, 8′ x 12′, is mounted on the side of the tower at a height of 540 feet. Signals are sent by micro-wave through the air from the studios of WBZ and are reflected to the ground at Needham where a receiving metal parabola picks them up and sends them into the transmitter building where they are used to send a signal into the transmitter.

The structure is constructed so that two additional television channels may be served by equipment mounted on the tower. Channel 5 may use a 14 bay antenna mounted around the tower near the top of the tower. This antenna may also be fed by two lines with each line being 6⅛″ in diameter. Channel 4 may also use an antenna consisting of a number of elements attached to the corners of the tower near the top. This antenna would be fed by two lines which would be 6⅛″ in diameter each. Another future use of the tower is space for 3 FM antennas which may be mounted below the television antennas and which would be fed by 3⅛″ diameter transmission lines.

The combination of a future height increase plus the addition of two future antennas required that the tower design be checked for any combination of one antenna, two antennas, three antennas on a tower of either of two heights. This combination required six different analyses of the structure.

The horizontal loads which must be carried by the stuctures and its supporting guys may be stated as follows:

Antenna Load	— 231,000#
Transmission Live Load	— 212,000#
Tower Structure Load	— 253,000#

The loads to be carried are divided almost equally between the antennas, lines and towers.

The design wind load adopted for the WBZ tower was graduated from a loading at the base of 60 pounds per square foot to a top loading of 80 pounds per square foot. These figures are the loads applied to a flat rectangular surface using the formula $P = .0042\ V$. Appropriate corrections are made for the use of cylindrical surfaces. No other corrections are made for different shaped surfaces or flat surfaces inclined to the wind.

The only shielding effect considered in calculating the loading on the tower is the bracing on the back sides of the structure. These faces are considered to be equivalent to ½ that of the front exposed face. The full projected area of all other parts of the structure is used as a basis for calculating the area exposed to the wind.

The graduated loading is divided into three parts consisting of a basic 60 pound loading on the lower third, 70 pounds on the middle third and 80 pounds on the upper third.

Since the air loading characteristics of a shape vary so extremely with different size material, shapes and relation of shapes to each other, good engineering judgment dictates that the loading be kept in terms of pounds per square foot rather than being translated into miles per hour velocity. The cost of making innumerable wind tunnel tests on various tower sections plus the rather dubious value of using a perfectly controlled smooth flow of air as a basis for rating a structure in miles per hour makes a rating in pounds per square foot with a definitely stated method of design a far more sensible way of stating the structure. However, the lay mind does not understand a design loading in pounds per square foot and does understand miles per hour. Hence we could say that the load used on this tower varies between 120 miles per hour to a load of 140 miles per hour, approximately, and we emphasize these are approximate. These are working loads and do not represent the ultimate strength of the tower.

The design of the tower follows the general practice used in all structural work today where working loads are selected, stresses in members are calculated and sizes are selected with the final unit stresses being within code limitations. These final unit stresses allow a safety factor based upon the yield point of the material. The working load multiplied by the safety factor would come close to representing the true ultimate strength of the structure. I would like to see structural design practice changed so that the strength of any structure could be stated in true terms.

A number of different types of steel was selected for various applications in the tower. The use of these materials may be of interest to the structural engineer. The leg members are made of U. S. Carilloy Steel having a guaranteed yield point of 90,000 pounds per square inch. This material is a rather complex alloy which is heat treated and has the very desirable characteristic of permitting welding operations without losing any of the physical properties of the material. Special welding rods and techniques must be used with this material. These leg members are round, solid and are machine straightened at the mill. This material is somewhat expensive but the cost is justified by using rather high unit stresses which in turn permits keeping the size to a minimum and keeps the area exposed to the wind to a minimum. This in turn imposes less load on the tower.

The bracing in the tower is made of standard hot-rolled structural steel to an A7-ASTM specification with a yield point of 33,000 pounds per square inch. Connections of the bracing to the leg members is made by the use of structural rib-bolts with a self-locking nut. These rib bolts are heat treated and are a high-strength bolt with ribs that require power equipment to drive into place. The bolts fill the holes completely and the entire structure tends to become a single piece with no possibility of slippage at any connection.

The guy cables are made of wire strands spun into bridge cable and are a typical high-strength steel wire assembly which has been galvanized prior to the final spinning.

The elevator rails are solid rods which are made of cold rolled steel. The reason for selecting round members is to keep the wind load to an absolute minimum.

As you can see this structure represents the use of steel in many different forms and compositions. The present style construction has been a gradual development through constructing a number of tall towers. For example: The leg members used at WSB in Atlanta on the first 1000′ tower were made of 14 inch diameter pipe. This proved to be too big and too costly. The next use was that of solid round members of Hot-Rolled steel to a 33,000 pound per square inch yield point. This proved to be a good solution until towers began to require bigger sizes than were rolled. A 1,572 foot tower, an even 100 feet taller than the Empire State Building in New York City, at Oklahoma City for KWTV was built using 14 inch wide flange beams for legs. Once again this was too big and too costly.

The next step was a 1,521 foot tower for Dallas, Texas, operated by KRLD-TV and WRAA-TV. We used forgings, 10½ inches in diameter, solid, and with a yield point of 45,000 pounds per square inch. Here the sizes are big and the wind load high.

The latest step is the use of 90,000 pound per square inch material for WBZ. This material permitted using 7½″ diameter solid rounds instead of 10½″ diameter forgings.

One other item of interest in the tower is the maintenance elevator which will be used to keep the various pieces of broadcasting equipment operating properly. This elevator consists of a small but extremely heavy cab running on round rails with plastic rollers to hold the cab in place in the tower. The cab has dual cables and all the safety devices necessary to insure the safety of the maintenance men working on the equipment. Since the transmission lines extend the full height of the tower, work may be necessary at any point throughout the height of the tower. Therefore, a ladder is mounted in front of the elevator cab and a workman may step from the cab to the ladder at any point. In effect we might say that the elevator has landings every 15 inches which is the ladder rung spacing. The elevator engine is powered by a standard electric motor and drives the cab up or down.

The tower for WHDH in Boston is now under construction and is quite similar in style with the exception that this tower does not have provision for extra antennas for other TV stations. The height of the WHDH structure will be 1,240 feet above ground and 1,649 feet above mean sea-level. This tower will have an elevator and will be equipped with all of the necessary ladders and work platforms.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING
Boston Society of Civil Engineers

SEPTEMBER 25, 1957.—A regular meeting of the Boston Society of Civil Engineers was held this date at the United Community Service Building, 14 Somerset Street, Boston, Mass., and was called to order by President Arthur Casagrande, at 7:05 P.M.

President Casagrande stated that the minutes of the previous meeting May 15, 1957 would be published in a forthcoming issue of the JOURNAL and that the reading of those minutes would be waived unless there was objection.

President Casagrande announced the death of the following members:—

James M. McNulty, who was elected a member September 16, 1908, and who died May 11, 1956.

Horace L. Clark, who was elected a member November 16, 1927, and who died March 3, 1957.

Robert W. Pond, who was elected a member June 18, 1902, and who died February 17, 1957.

Thomas F. Sullivan, who was elected a member March 16, 1921, and who died August 27, 1957.

Parker Holbrook, who was elected a member January 26, 1921, and who died July 3, 1957.

Henry L. Kennedy, who was elected a member December 10, 1951, and who died September 10, 1957.

George N. Watson, who was elected a member September 24, 1930, and who died September 14, 1957.

The Secretary announced the names of applicants for Membership in the BSCE.

President Casagrande then introduced the speaker of the evening, Mr. J. O. Ackerman, Chief, Engr. Div. Omaha Dist., Corps of Engineers, Omaha, Nebraska, who gave a most interesting paper on "Oahe Dam on the Missouri River—The Engineering Problems of a Shale Foundation".

A brief discussion followed after which a collation was served.

Seventy six members and guests attended the meeting.

The meeting adjourned at 8:55 P.M.

ROBERT W. MUIR, *Secretary*

OCTOBER 23, 1957.—A Joint Meeting of the Boston Society of Civil Engineers with the Massachusetts Section of the American Society of Civil Engineers was held this evening at Northeastern University, Boston, Mass. The Student Chapters of the New England Colleges were especially urged to attend.

A dinner was held in University Commons Hall, Northeastern University, from 6:30 to 7:45 P.M. Student delegations were present from Northeastern University, Harvard, Tufts University, Massachusetts Institute of Technology, Brown University, University of Rhode Island, Dartmouth College, Yale University, University of Massachusetts and Worcester Polytechnic Institute.

The meeting was held in the Alumni

Auditorium and was called to order at 8:10 P.M., by President Arthur Casagrande.

President Casagrande stated that this was the 47th Student Night meeting, the first having been held on April 5, 1911. This meeting originated with the Boston Society of Civil Engineers and in its early years included only the civil engineering students at Harvard, Tufts and Massachusetts Institute of Technology. It is now held as a Joint activity of the BSCE and the Mass. Section, ASCE with student chapters of the BSCE and ASCE of the New England Colleges invited.

President Casagrande 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. He also thanked Miss Jean Langmaid who entertained with organ selections.

President Casagrande called upon the Secretary to announce names of applications for membership in the BSCE.

The Secretary also announced that the speaker for the November 20th meeting of the Society would be Dr. Philip C. Rutledge, member of the firm of Moran, Proctor, Mueser & Rutledge. Meeting to be held at United Community Services Building, 14 Somerset Street, Boston, Mass.

President Casagrande introduced A. Russell Barnes, Jr., President of Massachusetts Section, ASCE and asked him to conduct any necessary business of ASCE at this time.

President Casagrande then introduced the speaker of the evening, Dr. Karl Terzaghi, Professor Emeritus, Practice of Civil Engineering, Harvard University, who gave a most interesting illustrated talk on "Use and Abuse of Consultants in Foundation and Earthwork Engineering".

Three hundred sixty nine members and guests attended the dinner and four hundred thirty six attended the meeting.

The meeting adjourned at 9:25 P.M.

ROBERT W. MUIR, *Secretary*

SANITARY SECTION

OCTOBER 2, 1957.—The meeting was called to order by Chairman John F. Flaherty at 7:15 P.M., at the Society Rooms following an informal dinner at Patten's Restaurant. Twenty-eight members and guests attended the meeting and fifteen members were at the dinner.

The speaker of the evening, Werner Stumm, Asst. Professor of Sanitary Engineering at Harvard University was introduced by Chairman Flaherty. Professor Stumm's presentation of the subject "Ozone as a Disinfectant for Water and Sewage", was most interesting and instructive. His discussion of the bactericidal and chemical properties of ozone and economical aspects of ozonization of water and sewage was based on studies conducted by the speaker in Switzerland.

The meeting adjourned at 8:45 P.M.

JOSEPH C. KNOX, *Clerk*

STRUCTURAL SECTION

OCTOBER 9, 1957.—The meeting was called to order at 7:08 P.M. in the Society Rooms in the Tremont Temple Building.

The minutes of the previous meeting were read.

Chairman Biggs said that the next meeting would be held in the new Rooms.

Mr. Biggs then introduced J. Roger Hayden of the Dresser-Ideco Company, who spoke on the design and construction of the new television broadcasting tower erected for WBZ in Needham. The height of the television mast, 1199 feet above ground (as determined by air traffic considerations), places it among the highest such structures in the United States. With a 12 foot triangular section, the main tower weighs approximately 231,000 pounds and rests on an 8-inch pivot bearing to eliminate movement from the base. Four sets of guys are used to brace the mast. Near the top, a triangular platform 80 feet on a side is capable of supporting three individual antennas. The mast was designed for a lateral pressure of 60 psf at the base and 80 psf at the top, pressures being reduced for cylindrical shapes of the main members. The design was specified as to pressure and code. The use of pressure instead of wind velocity eliminated wind tunnel tests with dubious results. The main legs of the mast are U. S. Carilloy steel with a yield point of 90,000 psi. Bracing is of A-7 steel and is fastened with structural rib bolts. An elevator with all safety equipment can stop at any height for maintenance purposes. Mr. Hayden then showed a movie illustrating the erection of a television tower in Dallas, construction of which was similar to that of the WBZ tower.

After an extended question period, the meeting was adjourned at 8:30 P.M.

Attendance was 34.

William A. Henderson, *Clerk*

CONSTRUCTION SECTION

October 30, 1957.—Meeting was opened at 8:00 P.M., at the Society Rooms, 715 Tremont Temple. Chairman Robert J. Hanson introduced the speaker, Professor Albert G. H. Dietz, who is Professor of Building Engineering at Massachusetts Institute of Technology.

Professor Dietz spoke on "The Increasing Use of Component Construction". The talk was illustrated with slides. Professor Dietz discussed component construction in wood and plastic construction. The construction industry has long realized the importance of component construction using wood. Component construction with plastics is a comparatively new phase. Professor Dietz has recently taken part in the development of a plastic house which was sponsored by the Monsanto Chemical Company. The talk was most interesting both in presentation and context.

There were sixteen members and guests attending the meeting.

Albert A. Adelman, *Clerk*

ADDITIONS

Members

Royal C. Flanders, 56 Lexington Road, Concord, Mass.
Robert S. Larson, Cross Street, Norwell, Mass.
Anthony P. LaRosa, 117 Oliver Street, Malden 48, Mass.
Leonard J. Peterson, 14 Hillside Road, Reading, Mass.
Alexander Sibbald, 14 Mandalay Road, South Weymouth, Mass.
John W. Towers, 372 Winter Street, Weston, Mass.
Frederick T. Webb, Schuyler Clapp Co., 373 Washington St., Braintree, Mass.
Donald H. Hastie, 48 Neale Gate St., P.O. Box 194, Greenbush, Mass.
Ermonian Krikor, 76 Cleveland Street, Arlington, Mass.
Andrew C. Paton, 137 Freeman Street, Brookline, Mass.

Juniors

John J. Chisholm, 108 Winthrop Street, Boston 19, Mass.
Nicholas R. D'Allessandro, 29 Churchill Street, Newtonville, Mass.
Nicholas H. Fitzgerald, 250 Washington Street, Winchester, Mass.
Richard L. Foster, 97 Plain Dr., E. Hartford 8, Conn.
Arthur R. Giangrande, 93 Central Street, Somerville, Mass.
Richard D. Howard, 5 Florence Street, Cambridge, Mass.

John P. Hickey, Jr., 115 Wolcott Road, Brookline, Mass.

William Moy, 401 Norfolk Street, Dorchester, Mass.

George H. Power, 78 Main Street, Concord, Mass.

Wallace G. Sanborn, 545 Cohannet Street, Taunton, Mass.

Peter P. Saunders, 10 Park Street, Box 314, Norwood, Mass.

Maurice Vezina, 9 Sunset Avenue, Montreal 8, Canada.

DEATHS

Arthur E. Harding, Oct. 4, 1957
Parker Holbrook, July 3, 1957
Robert Gillespie, Oct. 5, 1957
Henry L. Kennedy, Sept. 10, 1957
Edward F. Kelley, Oct. 28, 1957
Chester A. Moore, Sept. 18, 1957
Thomas F. Sullivan, Aug. 27, 1957
George N. Watson, Sept. 14, 1957
Louis A. Chase, Nov. 3, 1957
Arthur A. Shurcliff, Nov. 12, 1957

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