A.S.M.E ANNUAL MEETING

THIS year's Annual Meeting of the American Society of Mechanical Engineers, with a total registration of nearly 2500 was held at the Hotel Astor, New York, December 2 to 6. The program included forty-five technical sessions of which a substantial number dealt directly or indirectly with the production of power. Among these were papers on silica removal from feedwater, boiler design and circulation, furnaces, boiler casings, stoker fuel beds, fluid temperature of ash, steam piping, condenser tubes, flue dust recovery, turbine lubrication and marine power plants. Digests of some of these papers and their discussions follow:

Methods of Silica Removal

Removal of silica from boiler waters formed the subject of three papers at the Monday evening session on "Boiler Feedwater Studies."

Harold Farmer, Chief Chemist of the Philadelphia Electric Company, in a paper on "Silica in High-Pressure Boiler Waters," observed that, in general, silica had not given serious trouble at steam pressures below 600 lb, or else could be effectively controlled. However, with high steam pressures around 1200 lb, and particularly with high rates of heat input, there have been many tube failures in which silica appears to have played a significant part.

It has been suggested that in some cases high rates of evaporation have disturbed the circulation and resulted in starvation in certain tubes, thus permitting deposition of soluble salts, including silica, on the dry areas. When these areas are again wetted the soluble salts are dissolved, but during the dry period the silica may have undergone a change in structure and ceased to be soluble. With repetition of such cycles the silica deposit will build up and cause overheating of the tube with resulting ultimate failure. Some such failures have been manifested by blistering.

In other cases, instead of a blister, a small hole surrounded by hard silica scale has been noted. Some have attributed this type of failure primarily to starvation with accompanying silica deposits and ultimate failure due to small pieces of this scale breaking away and the exposed metal trying to absorb too much heat.

Even with good condensate feedwater, assuming the total solids to be 1 ppm, the water may contain 0.1 ppm of silica. While this may seem insignificant, many present-day high-pressure boilers evaporate their own volume of water five times in one hour, which represents 12 ppm of silica in the boiler at the end of 24 hr. Many operators set this figure as the limit and resort to blowing down when this figure is approached.

Plants operating with high makeup, not evaporated, have to resort to external chemical treatment for removal of silica. The present effectiveness of such treatment, in the author's opinion, appears to have a limitation of about 2 ppm of silica residual remaining in the water. This may necessitate continuous blowdown in order to maintain the silica in the boiler water under 12 ppm, but frequent blowing down of high-pressure boilers is not looked upon with favor by the operators.

The use of internal chemical treatment for silica has been given some consideration, but as yet has not proved very satisfactory, because of the necessity for very close supervision and control of several variables.

Finally, a knowledge of the combination and form in which silica occurs is most important as it throws light on the physical conditions which play a part in the formation of scale. While chemical analysis of boiler scale will show the total silica present, this may exist in as many as five different forms, all of which have different physical properties. However, the more recent employment of the X-ray diffraction method of analysis of scale has made it possible to identify compounds which from previous knowledge enables one to determine the temperature at which they could have been formed.

An Improved Magnesia Process

"Silica Removal by an Improved Magnesia Process" was the title of the second paper of the session, by **H. L. Tiger**, vice president of The Permutit Company. This process involves the combined use of ionic magnesium and sludges containing undissolved magnesium compounds in which a modified Spaulding Precipitator is employed to afford extended and intimate contact between the water and the sludge. This equipment permits the usual lime-soda reactions to take place at the same time as silica removal and, by the addition of a coagulant, simultaneous turbidity removal can be accomplished. The source of magnesium is low-cost dolomitic lime.

Summarizing the extensive research study of various means of silica removal, as detailed in the paper, the author offered the following conclusions:

(*a*) For any given set of conditions ionic magnesium precipitated as $Mg(OH)_2$ is most efficient, but undissolved magnesium compounds of proper quality (fine particle size, etc.) also give satisfactory results when favorable conditions of sludge concentration and agitation are maintained.

(*b*) The efficiency of removing silica by precipitating ionic magnesium or by undissolved magnesium compounds increases with temperature, but the application of other factors disclosed makes it possible to obtain satisfactory results at low temperatures. Slight pre-warming of the water to about 30 or 40 C (86 to 104 F) reduces the amount of magnesium required to obtain the desired result. Waste heat may be used for this purpose.

(*c*) The efficiency increases with the concentration of the magnesium-containing sludge in contact with the water.

(*d*) Increasing the time of contact with the sludge absorbent in agitated suspension improves the results.

(e) Reducing the silica contamination of the retained concentrated sludge reduces the silica in the effluent. That is, if the magnesium added to the system is increased, the ratio of Mg to SiO_2 in the sludge rises correspondingly and the residual SiO_2 in the effluent decreases.

(f) The presence of phosphate ion interferes with silicon absorption by MgO.

(g) In those cases where additional magnesium is required for the desired silica reduction, it can usually be obtained most economically from dolomite lime [$Ca(OH)_2MgO$]; and where no lime is required in the treatment calcined magnesite (MgO) is used.

(h) Ionic magnesium may be added to the raw water economically without increasing the lime requirement or the total solids content of the effluent by recirculating sludge into a magnesium dissolver compartment, or low pH zone, where the HCO_3^- and CO_2 in the raw water dissolves Mg^{++} from this sludge. If necessary, additional CO_2 may be added by flue-gas carbonation to increase further the amount of Mg^{++} introduced.

In applying this process it may be stated, in general, that if hot-process lime-soda treatment is used to reduce the hardness, superior silica removal is obtained by employing equipment that provides positive agitation and intimate sludge contact, such as the Spaulding Precipitator. If hot-phosphate softening is employed, the silica removal treatment should precede the phosphate treatment. If a cold-process is employed, the silica removal is first applied and advantage may be taken of post-treatment by carbonaceous zeolites which completely eliminate residual hardness. Carbonaceous hydrogen zeolite treatment may also be included to reduce the final alkalinity to any predetermined figure.

Removal by Adsorption

The third paper of the session dealt with "Adsorption Process for Removal of Soluble Silica from Water," by **L. D. Betz, C. A. Noll and J. J. Maguire.** In this process removal of silica from solution is effected, not by chemical reaction, but by adsorption in which a

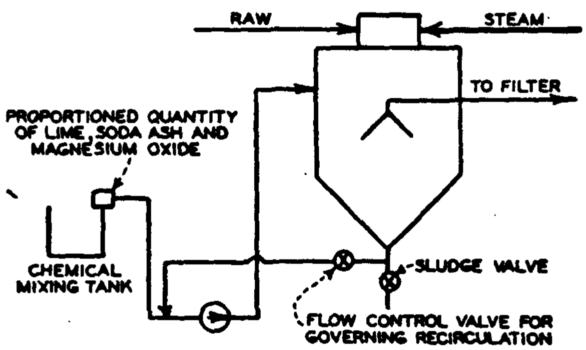


Fig. 1—Diagram showing recirculation of magnesium oxide sludge

specially prepared form of magnesium from sea-water bitterns, identified as "Remosil" is employed. It is well adapted for use in conjunction with hot-process lime-soda softening and requires no increase in the quantities of either lime or soda ash. While the pH range for best operation is not critical, the optimum pH is approximately 10.1

The authors pointed out that although silica is conventionally expressed as SiO_2 in a water analysis, there is a marked distinction between crystalloidal and colloidal

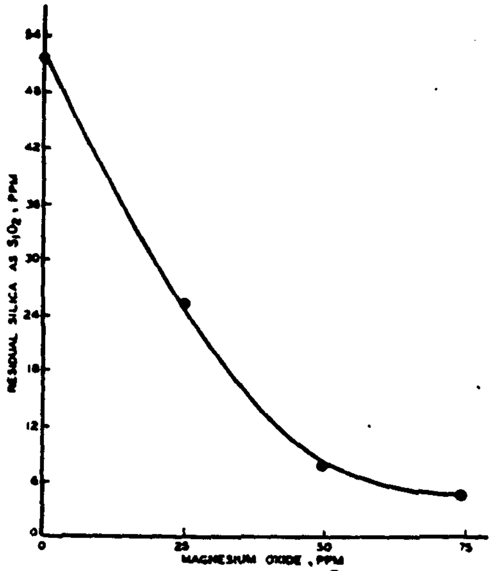


Fig. 2—Field test on silica removal with sludge recirculation

silica. The major portion of the silica found in natural waters is in the crystalloidal state. Silica suspended in water in the form of mud can be readily removed by coagulation and filtration and the major problem in the conditioning of boiler feedwater is the removal of soluble silica from solution. The adsorption process permits a reduction in soluble silica with a decrease in solids content of the treated water, rather than an increase.

An important factor is the temperature at which silica removal is effected by means of magnesium oxide, the efficiency of removal increasing with temperature. The major increase in the percentage of silica removal occurs with an increase in temperature up to 95 C (203 F), the approximate temperature of operation of hot-process softeners. Furthermore, where the silica content of the raw water is to be reduced to 2 to 5 ppm little is to be gained by increasing the time of retention beyond one hour at 95 C. In fact, equilibrium is reached almost completely in about 15 min, in which time the silica removal is about 85 per cent complete, but in the cold a much longer time is required.

A characteristic of the adsorption process is the need for increased quantities of magnesium oxide to effect removal of the last 10 to 20 per cent of the original silica content. This does not mean that the higher the initial silica content, the less that will be removed per part of magnesium oxide; in fact, the reverse is true, but for any definite initial silica content in the raw water, as the amount removed from solution increases with increased quantities of magnesium oxide, the silica removed per part of magnesium decreases. Advantage is taken of this characteristic by employing the partially spent magnesium, through recirculation of the sludge, for partial silica removal and thus lessening the quantity of fresh magnesium oxide to reduce the final percentages of silica [illegible]tion it is actually possible to increase the [illegible] per part of magnesium oxide with in[illegible]al of silica from solution.

[illegible] Fig. 1, illustrates the application of sludge [illegible]ith a lime-and-soda softener and the curve [illegible]ents silica removal accomplished in a hot-[illegible]oda softener with three different rates of [illegible]gnesium oxide, of 25, 50 and 75 ppm. In [illegible] tests the magnesium oxide was added to the [illegible]ixing tank along with the lime and soda ash [illegible]culation of the sludge was effected as shown in [illegible]

Treatment of Makeup at Waterside Stations

At the second Boiler Feedwater Session, Messrs. Arnold, Hanlon and Mindheim of the Consolidated Edison Company of New York, Inc., presented a paper on "Treatment of Makeup Water for the Waterside Topping Installation."

This high-pressure installation at present consists of two 50,000-kw turbine-generators supplied by four 1400-lb boilers and exhausting at 200 lb to the existing low-pressure system. Two more high-pressure turbines and four more high-pressure boilers, capable of supplying 2,460,000 lb of steam per hour are now under construction. The 200-lb system serves the dual purpose of supplying the low-pressure condensing turbines and supplying steam to the heating mains of the New York Steam Company through twelve desuperheaters having a total capacity of about 1,250,000 lb of steam per hour. Although all the low-pressure boilers have been removed from Waterside Station No. 2, the 200-lb system may still be fed by steam from the old low-pressure boilers in Waterside No. 1 which are capable of supplying 1,836,000 lb per hr.

Condensate from the low-pressure turbines and auxiliaries is used for feedwater and at first it was deemed advisable to evaporate makeup for the high-pressure boilers in the low-pressure boilers, but this obviously was not most economical. Consequently, it was decided to treat the makeup which is Croton water from the city mains. On the basis of thermal economy, degasification, treating costs and installation convenience, a cold-water carbonaceous zeolite (Zeo Karb) system was selected as best suited to the hardness characteristics of Croton water. Three sodium and three hydrogen units were installed and special regulating equipment was provided to proportion properly the water treated by these two types of units. Each pair of units is capable of handling 600,000 lb of water per hour and all or any combination of pairs of units may be employed for treating. A degasifier is provided to remove carbon dioxide from the water after the mixing of the effluents from the sodium and hydrogen units.

Although the Zeo Karb system removes most of the hardness from the feedwater, additional chemical treatment is employed. This includes sodium hydroxide fed into the feedwater line at the deaerator outlet in sufficient quantity to maintain a pH of 8.8 in the feedwater passing through the economizers, and disodium phosphate which is fed directly into the boiler drums; this in addition to a continuous blowdown system to maintain the boiler water concentration sufficiently low to prevent carryover.

The following table is indicative of the performance of the water-treating system at Waterside No. 2:

PERFORMANCE OF ZEO KARB UNITS

Chemical Concentration Expressed as ppm	Raw Water Croton Supply	Sodium Zeolite Unit Effluent	Hydrogen Zeolite Unit Effluent	Mixed Effluent of Degasifier Outlet (1)
*Total hardness as $CaCO_3$	45	0	0	0
Calcium hardness as $CaCO_3$	30	0	0	0
Magnesium hardness as $CaCO_3$	15	0	0	0
M.O. alkalinity as $CaCO_3$	34	29	−16**	4
Sodium alkalinity as Na_2CO_3	0	0	0	0
Free carbon dioxide, CO_2	3	3	30	2
Chloride as NaCl	7	7	7	7
Sulphate as Na_2SO_4	18	18	18	18
Silica, SiO_2	6	6	6	6
Total solids	65	60	31	35
pH	7.2	7.0	3.7	6.3

(1) Ratio of hydrogen to sodium effluent 56–44.

* American Public Health Association soap test.
** Free Mineral acidity expressed as minus alkalinity.

It has been found that high hydroxide concentration leads to foaming and to fouling of the turbine blading and the following limits have been prescribed for the high-pressure boiler water composition:

	Ppm Max	Ppm Min
Phosphate Na_3PO_4	25	15
Sodium hydroxide NaOH	30	20
Sodium chloride NaCl	150	
Sodium sulphate Na_2SO_4	250	
Total dissolved solids	450	

Conductivity Determinations

A new degasifying steam condenser for use in conductivity determinations was described by Prof. **F. G. Straub** and **E. E. Nelson**, both of the University of Illinois.

This condenser is designed to furnish a continuous sample of either steam or condensate that is free from dissolved gases but which contains the dissolved solids present in the original sample. The apparatus, which is shown in Fig. 3, makes use of the principle of boiling a sample of the condensed steam from which the gases have been removed to furnish a gas-free steam that, in turn, removes the gases from the condensed steam. In order to obtain efficient removal of the gases, a scrubbing tower or stripping column is employed in connection with a vent condenser, so as to allow venting of the gases after being removed from the condensed steam.

The degasifying condenser may be used for sampling steam or condensate. When used for the former, the steam to be sampled is throttled to allow 60 to 70 lb per hr to flow to the unit. The steam enters through metal tubing *a* to the heating or reboiling coil *b* where the major portion of the available heat is removed. The partially condensed steam then passes to the condensing coil *c* where it is completely condensed and cooled. The condensed and cooled steam sample now passes through valve *d* which is opened wide, while valve *e* is kept closed. The sample passes up and part of it overflows to waste *f*, or to a conductivity cell if the conductivity of the undegasified sample is desired. A portion of the condensed sample flows through an orifice *g* and through a preheating coil *h* where it discharges onto the top of plates *i*. The flow is constant and the sample is representative of the condensed steam, since it has been condensed and cooled prior to passing through the orifice. It contains all the dissolved solids present in the steam along with the dissolved gases.

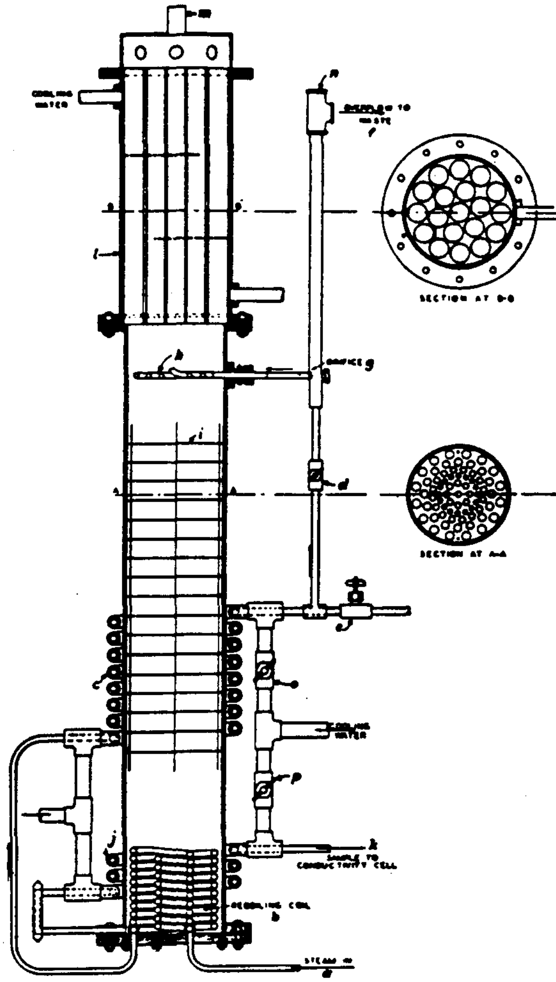


Fig. 3—Degasifying steam condenser

The dissolved gases are removed by passing the sample down through the scrubbing or stripping column which is made up of a series of plates which give very low pressure drop. This gas-free sample then falls to the bottom reservoir or reboiling chamber. The heat from the steam passing through coil *b* boils the gas-free water and thus furnishes gas-free steam which passes up through the column and removes gas from the sample flowing down.

The gas-free sample in the reservoir flows out through a cooling coil *j* and then at the proper temperature is available to flow to a conductivity cell *k*. The conductivity of the sample gives a measure of the dissolved solids directly without correcting for dissolved gases.

Steam, after passing up through the column, is condensed in the top vent-type condenser *l* where the gases pass out the top *m* and the condensed steam drops back on the top plate. The condenser is so operated that no appreciable amount of steam is allowed to be lost through the vent.

Coal-Ash Fusing Temperature

The results of investigations on ash-fusing temperatures were reported in a paper by E. G. Bailey, vice president of Babcock & Wilcox Co. and F. G. Ely of that company. These studies confirmed the earlier work of Fieldner, Nicholls and others in showing that the form of the iron, whether ferrous or ferric, is of increasing importance with increased iron content, but also carried these indications further as applied to the modern high-duty pulverized coal furnace.

Granting that the softening temperature of the ash in a reducing atmosphere, as prescribed by the A.S.T.M. method, is applicable to stoker fuel beds, the authors pointed out that with pulverized-coal firing it is the fluid temperature that is most important. Their studies indicated the iron content of the ash as the determining factor in this respect. In the first part of a slagging-bottom furnace the atmosphere is largely reducing and the iron, which initially is mostly in the pyritic form, first gets rid of its sulphur and then becomes oxidized to FeO, thereby imparting a low fluid temperature to the ash. On the other hand, much of the ash deposited on the upper furnace walls and boiler surfaces is brought there in company with unconsumed coke which burns slowly and in an oxidizing atmosphere. Hence, the iron in the ash at these locations is largely in the Fe_2O_3 state with a fluid temperature some 200 deg higher than that formed in the reducing atmosphere in the first part of the furnace.

This fact seemed to explain why, in certain cases, coals with relatively low ash-fusing temperature have given less trouble from slagging of heating surfaces than had been anticipated; also, why some such coals have been burned satisfactorily in dry-bottom furnaces where ample water-cooled surface was provided to keep the ash below its troublesome temperature.

Measurements, by means of a water-cooled probe, to determine the effect of slag on the rate of heat absorption, showed that a state of equilibrium was reached in about three hours with a slag film $^1/_8$ in. thick and the molten slag dripping off as fast as additional ash collected. Under these conditions the rate of heat absorption decreased to about 50 per cent of the original. It is this state of equilibrium, representing operating conditions, for which a unit must be designed.

It was observed that slag can be tapped more easily when operating with low excess air which produces a more fluid slag because of the ferrous condition of the iron. Pyrites in free pieces when properly pulverized and burned will result in the formation of Fe_2O_3, Fe_3O_4 and FeO, depending upon the degree of oxidizing atmosphere present. But, if the particles are too coarse for partial or complete oxidation, FeS may be formed and this is very troublesome. Furthermore, excess carbon, resulting from coarse unburned coal on slag surfaces, may reduce any form of iron oxide to metallic iron which will settle to the bottom of the molten slag pool and form salamanders which are difficult to remove.

The slag collected in the first part of the furnace is materially higher in iron content than that of the original coal ash, due to the pyrites in the coal being coarser and heavier and thereby falling to the bottom; whereas the ash collected in the boiler-tube bank has about the same iron content as that of the original coal.

In the discussion of the paper, the opinion was advanced that magnesium and lime may have a more important influence on fluid temperature with certain coals than iron; also, that the time element may be a considerable factor in the more complete oxidation of the iron in the slag on the boiler surfaces. While conceding that magnesium and lime content were factors, Mr. Bailey reiterated his opinion that these were secondary to the iron.

An Unique Engine and Boiler Unit

... type of steam engine and forced-circulation ... designed by S. L. G. Knox of Engelwood, N. J., ... tested at Stevens Institute by Professor J. I. Yellott, was the subject of a joint paper by these authors.

The engine is of the high-speed compound uniflow type ...signed to operate at 700 lb pressure 750 F and deliver ...0 hp at 1000 rpm. The inlet valves are of the piston type and the direction of rotation is reversed by changing the direction of flow of the steam through using one set of ports in the valves as steam admission ports when running in one direction and as exhaust ports in the other direction. The main exhaust from all three cylinders is through the uniflow ports with the piston valves handling the auxiliary exhaust necessary to keep compression down to a reasonable amount.

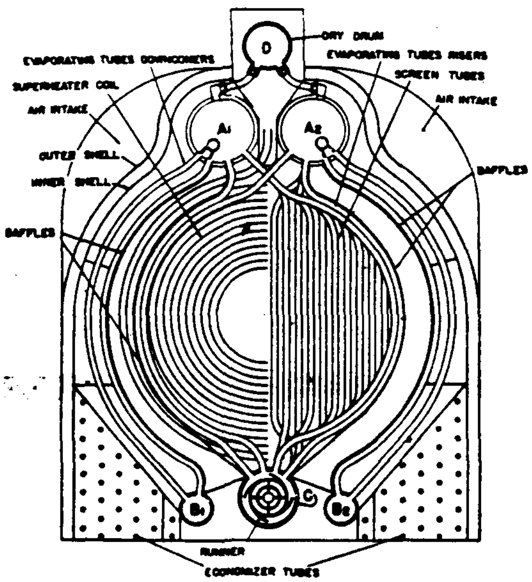


Fig. 4—Sectional elevation of Knox boiler

Although the present engine runs noncondensing it may be arranged to exhaust to a condenser and thus provide additional power. On test a steam consumption of 14.6 lb per bhp-hr (noncondensing) and an engine efficiency of 53.3 per cent was obtained at 75 per cent rated load.

Special interest attaches to the boiler which is light and compact and employs a new principle for obtaining forced circulation by placing an impeller in the lower drum. The present unit has a capacity of 1500 lb of steam per hour at 700 lb pressure 750 F total steam temperature and high combustion rates up to 400,000 Btu per cu ft per hr of furnace volume were obtained on test.

Referring to Fig. 4, which represents a cross-section of the boiler, feedwater enters the two drums A_1 and A_2 after passing through the economizers, two of which are shown in the last pass, the third being located in the duct leading to the stack. The usefulness of this last economizer was demonstrated on test which showed that the flue gas temperature entering the duct was about 590 F at full load, while the gas temperature at the last economizer outlet was 380 F. Leading down from the two upper drums are the downcomers, located in the third ...s and connecting to the two outside lower drums B_1 ...d B_2. The center bottom drum C connects with drums B_1 and B_2 through headers at both ends, and within this center drum is a hollow impeller driven by a shaft which emerges from the header through a stuffing box. When the impeller is rotated, the pumping action creates a pressure that forces the water in drum C to pass upward through the risers which form the walls of the combustion chamber. Inasmuch as the impeller extends the length of the drum, circulation within the risers is quite uniform. The risers consist of four rows of $^1/_2$-in. O. D. stainless-steel tubes staggered on $1^3/_{16}$-in. centers.

As shown in the plan, Fig. 5, firing is by oil burners at one end and the gases have three passes. At the far end of the furnace is located the superheater which consists of a spiral coil of tubing, and steam temperature control is effected by injecting feedwater into the inlet of the superheater. Although the furnace is water-cooled it was found necessary to place refractory over the first few rows of tubes near the burners to provide radiant heat to assist in vaporizing the oil and to obtain smokeless combustion.

Beyond the rear wall is located the forced-draft fan which forces air through the space between the inner and

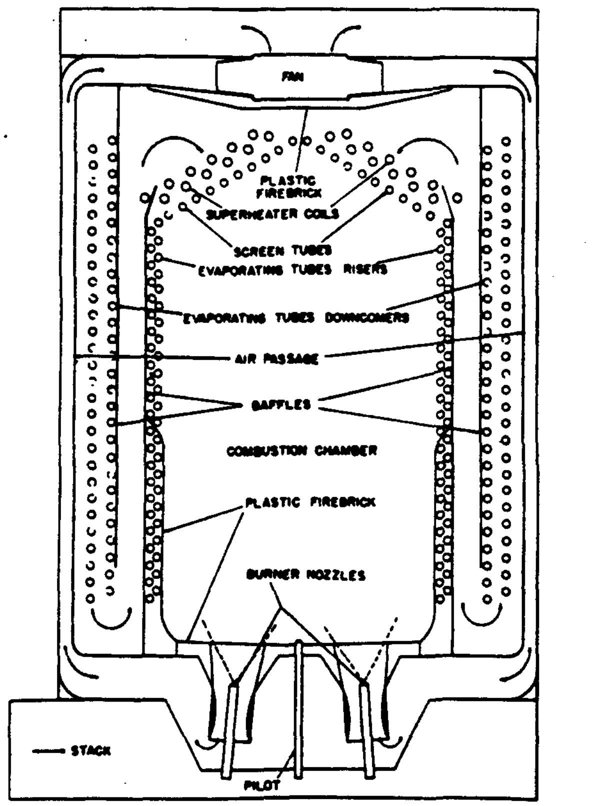


Fig. 5—Plan of Knox boiler

outer shells of the boiler where it is preheated to about 350 F before entering the combustion chamber.

Control of the boiler operation is simplified by the relatively large water capacity of the upper and lower drums, which means that the fuel and water supplies do not have to be instantaneously adjusted. All controls are electrically operated. The pressure control consists of a spring-loaded bellows equipped with contacts connected in series with the solenoid valve in the oil line, and the high- and low-water level controls are of the thermal-expanding type provided with electrical contacts communicating with the fuel supply.

Test Data for Boiler

Duration of test	2 1/2 hr
Rate of steam generation	1180 lb per hr
Evaporation per lb of oil	254 lb
Average steam pressure	515 lb
Average steam temperature	755 F
Temperature of feedwater	71 F
Heating value of oil	19,400 Btu per lb
Average CO_2 in flue gas	12 per cent
Flue gas temperature	380 F
Loss to flue gas	13.6 per cent
Loss due to incomplete combustion and unaccounted for	5.1 per cent
Efficiency (exclusive of auxiliary power)	81.3 per cent

In this test the boiler was started from cold and the steam pressure reached 500 lb and the steam temperature 700 F within 4 min.

Fuel-Bed Observations on Multiple-Retort Stoker

The second Fuels Session comprised two papers, one on "Continuous Heat Balance Control of Boiler Room Operation" by **B. S. Murphy,** and the other on "Flow Processes in Underfeed Stokers," by **Martin A. Mayers,** of the Coal Research Laboratory, Carnegie Institute of Technology.

The first of these papers, dealt with the procedure employed in scheduling boiler operation, loading, coal measurements and testing, and the functioning of the various control devices at the Hudson Avenue Station of the Brooklyn Edison. The author, who is chief engineer of this station, reviewed the many different factors entering into boiler operation and control, and showed how these factors must be synchronized before any comprehensive plan could be formulated.

In the second paper Mr. Mayers dealt primarily with the fuel-bed structure on a multiple-retort underfeed stoker, the flow of air and gas through the fuel bed, the flow of coal and the heat flow, as based on studies and measurements made under operating conditions.

Fig. 6 represents a cross-section through the fuel bed near the middle of such a stoker. The high temperatures generated in the burning lanes above the tuyères cause the formation of shrinkage cracks in the coke walls so that the agitation of the bed breaks off portions of the carbonized walls and the particles fall into the burning lanes, through which the greater portion of the air flows. Sections at different longitudinal positions differ from that shown, only quantitatively but not in kind, the coke walls being thinner at the head of the stoker and thicker at the end.

During the passage of the main primary-air stream through the bed of broken coke its oxygen content usually drops nearly to zero at distances of 3 to 5 in. above the tuyères. If the bed in the lane is much deeper than that, considerable carbon monoxide may appear in the gases leaving the lane. However, if there are places within the lane where the coke bed has not been replenished at the proper rate, unconsumed oxygen may pass through and up into the furnace. In general, the oxygen concentration at any level may vary within wide limits, depending upon the stream velocity, where the sample is taken, and the proximity of the coke surfaces.

A small portion of the air stream passes under the coke wall which defines the burning lane and into the retort where it passes through at low velocity due to the high resistance offered by the densely packed small coal. Part of this air may return to the main stream near the top of the burning lane or directly into the furnace. In either case it carries the tar vapor and gases released by the coal being carbonized.

At the higher levels in the retort, the carbon dioxide and monoxide also increase, while the oxygen decreases, until the skin of the coke at the top of the retort is penetrated, when, in many cases the oxygen concentration again increases while the combustible constituents tend to disappear. This indicates that there may be a layer of comparatively cold stagnant air lying on top of the retorts, which is only slowly aspirated into the main gas stream rising from the burning lanes.

The flow of coal takes place almost entirely in the retorts and in the walls of the burning lanes, there being practically no motion lengthwise or crosswise in the burning lanes. This was shown by the fact that porcelain probes inserted into the burning lanes could remain in position almost indefinitely. Coal which enters the retort near its top rises close to the front wall and is delivered to the burning lane at the head end of the stoker, whereas that which enters at the bottom of the retort passes well down the stoker before being delivered to the burning lane or part may be forced out onto the overfeed section without having reached the burning lanes.

A second function of the retort is to coke the green coal and prepare it for smokeless burning above the tuyère

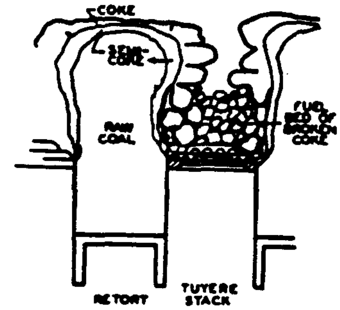


Fig. 6—Cross-section through fuel bed

stacks. This process takes place because the retort produces a transverse component of flow of the coal which has risen above the level of the tuyères, causing it to flow toward and through the coke walls. In this passage the coal is carbonized and is delivered to the burning lane as coke.

Proposed Heavy-Duty Stoker

On the basis of the observations made, Mr. Mayers outlined features that would be desirable in a stoker designed for much higher duty than any now in existence. In the first place, such a stoker would have narrower retorts than those of existing stokers which would make possible the preparation and coking of coal at higher rates. This would permit deeper fuel beds over the tuyères of the same width as now used and thus raise the ratio of active surface to the total area.

It is probably essential that the functions of distribution, coking and delivery, now combined in the retort flow, be separated so that the coke supplied to the tuyères will be as nearly uniform as possible. There should also be sufficient agitation, in this separating function, to [illegible] the possibility that coke walls may expand and [illegible] burning lane.

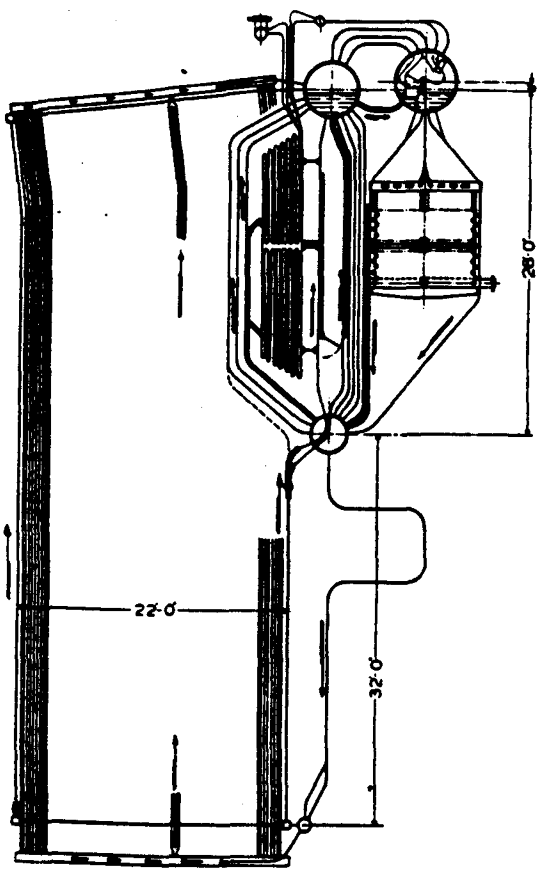
[illegible] it is suggested that such a stoker be sup-[illegible] pulsating air blast the maximum rate of [illegible] be sufficient to produce a condition close [illegible] corresponding to instability of the bed. Under [illegible] conditions the fuel bed would be fluid enough to [illegible] over any incipient blowholes and would allow ash [illegible] by combustion to sink through it to a cool zone at the bottom.

Finally, since it is desirable, by the use of a deep fuel bed, to require the air injected beneath such a stoker to take up as large a weight of the solid fuel, in the form of combustion gases, as it will carry and also, since operation at air-flow rates close to full teeter will cause a portion of the dust to be carried off the bed, it would be necessary to supply a large portion of the combustion air as overfire air.

Circulation in High-Pressure Boilers and Water-Cooled Furnaces

John Van Brunt, vice president of Combustion Engineering Company, analyzed the problem of natural circulation in high-pressure boilers. Starting with a simple U-tube circuit, he traced for various arrangements of circuits the conditions of stabilized circulation in which the head in the downcomers equals that in the risers plus all losses.

Inasmuch as the static head available to overcome all resistances depends upon the density of fluid in the risers and downcomers, any analysis of circulation must begin with determination of the density. This must be based on the correct rate of heat absorption by the exposed surface in the circuit being analyzed. Curves were shown representing the mean density of steam-water mixtures at 1350 lb per sq in., the changes of density along the tube, and the effect of density calculating methods on available static head.



[illegible]. 7—Indicating circulation in typical three-drum steam [illegible]erating unit of 650,000 lb per hr capacity at 1350 lb pressure and 925 F total steam temperature

Selecting a typical three-drum unit of 650,000 lb per hr capacity to operate at 1350 lb pressure and 925 F total steam temperature with feedwater of 470 F, the author traced through the necessary calculations for proportioning the furnace and walls, based on the values given in the curves. The same method was applied in calculating the front bank of boiler tubes.

Conclusions arrived at as a result of the analysis were that circulation in high-pressure units of the type illustrated in Fig. 7 is adequate for maximum load conditions and with a comfortable margin for substantial overloads. If the height of furnace is decreased, the available head and friction losses in the downcomers and risers also decrease, but losses in the horizontal members are unchanged; hence there is a lower limit of height below which the circulation would be progressively less until the top dryness fraction approaches unity. Under these conditions the evaporating tubes would be likely to fail from overheating. Therefore, under certain conditions with high-capacity, high-pressure units of low height, natural circulation may become inadequate.

Discussion

It was pointed out by several discussers that analyses, such as contained in Mr. Van Brunt's paper, are quite necessary in order to avoid difficulties incident to some of the earlier high-pressure installations, providing such analyses are tempered by field data; for average conditions seldom obtain in actual operation. That is, not only does the cleanliness of heat-absorbing surfaces vary but the dryness factor will not be uniform in different tubes because of their locations; also, it is difficult to determine entrance and leaving losses because of turbulence and varying velocities. It was suggested further that if the specific volume of the steam in certain tubes increases faster than that in others a condition of unbalance will be set up.

Some differences of opinion were expressed as to whether the limit was being approached for natural circulation, beyond which forced circulation would be necessary. One view was that there remained much to be learned about natural circulation, which should be studied further before adopting forced circulation for large capacity units for very high pressures and that the high boiler rooms, usually necessary for such natural-circulation units, represent the most economical arrangement in certain localities. Reference was made to the very high heat inputs in Navy boilers employing natural circulation with limited height.

Twin Furnace Boilers

John Blizard and A. C. Foster, both of Foster Wheeler Corp., in a paper on "Some Particulars of Design and

Operation of Twin-Furnace Boilers," described and illustrated three designs falling within this class. These were:

1. A boiler with two furnaces, in only one of which is placed a radiant superheater and, in addition to the radiant superheater, there is a convection superheater over which the gases from both furnaces pass.

2. A boiler with two furnaces in only one of which there is a superheater of the radiant type, and the gases from which pass through the furnace with no superheater. This type is adapted to marine installations and if a separate supply of saturated steam is desired, this may be taken directly from the steam drum.

3. A boiler with two furnaces from both of which the gases pass over a convection superheater, there being no superheater of the radiant type.

With such boilers, it was explained, it is possible to increase the water-wall surface surrounding the furnaces and, by differential firing, to control the steam temperature over a wide range of load without the necessity of providing a large convection superheater. Performance curves of several such boilers were included to show the flat superheat curve attained with differential firing.

In answer to a question from the floor as to what would happen with such a boiler employing a slagging bottom furnace if the load were suddenly lost, Mr. Blizard explained that this design is essentially a dry-bottom unit.

Boiler Settings

The importance of the setting enclosure of a furnace, boiler and heat-recovery equipment was discussed by **Max H. Kuhner**, Chief Engineer of Riley Stoker Corporation in a paper on "Steel Encased Settings for Modern Steam Generating Units."

If a setting becomes leaky after a few starting and stopping cycles, the boiler efficiency suffers, auxiliary power increases, capacity may be reduced, combustion control may be thrown out of adjustment and the boiler-room atmosphere contaminated with dust and gases. The necessity for constant maintenance on sealing joints and openings can occasion a costly expense item as well as large economic loss. After a few months of operation under these conditions, any savings made in the initial investment by the selection of a low-cost setting will have been absorbed many times by the losses chargeable to such a setting.

Experience indicates that a steel-encased setting constructed to withstand an internal pressure of 50 lb per sq ft in the furnace and 75 lb per sq ft in the gas passages between the furnace and the induced-draft fan, without deflection beyond ordinary limits, is remarkably immune to damage from the more common furnace and gas-pass explosions. With settings constructed to withstand furnace puffs and explosions of lesser magnitude, it was the author's opinion that explosion doors serve no practical purpose; for in most cases explosions occur in those locations from which the internal pressure wave created will reach the relief opening after the damage has been done.

In designing a steel-encased setting it is important to consider the movement of pressure parts of the steam generating unit. Expansion and contraction in tubes, drums and headers are considerable in large high-pressure units, hence it is important that the setting enclosure be free and independent.

Among the other minimum requirements for modern boiler settings, the author listed efficient heat insulation for low radiation loss and comfortable outside temperature, permanency not less than the life expectancy of the unit, a structure free from voids and proof against the development of voids in service, reasonable light weight, reasonable cost and pleasing appearance. With reference to the last-mentioned requirement, he observed that an attractive exterior of power plant equipment has a psychological effect on the operating personnel in promoting good housekeeping and pride in maintaining good performance.

Discussion

Much of the discussion of Mr. Kuhner's paper dealt with the employment of explosion doors on units fired with pulverized coal, oil or gas. While the insurance companies appear to insist on their use, with one square foot of explosion door area for each hundred cubic feet of furnace, the general opinion of those present was that their value is uncertain, and that it is very difficult to design such a door combining tightness with minimum inertia. The question was also raised as to why steel casing panels could not be made larger, to reduce the number of joints, and welded instead of employing so many small bolts. To this the author replied that shop facilities, transportation and handling limited the size of the panels and that field welding of such light steel had been tried but without much success.

Turbine Lubrication

C. Dantsizen, Works Chemist of the General Electric Company, in a paper entitled "Lubrication of General Electric Steam Turbines," pointed out that his company issues relatively broad recommendations for turbine oils because the oils may have a variety of physical characteristics and still function well in steam turbines. It is specified that the oil should be a petroleum derivative free from water, sediment, soap and resins or any materials which in service may prove injurious to the oil or to the turbine with its accessory equipment. The other recommendations are contained in Table 1.

TABLE 1—RECOMMENDED LUBRICATING-OIL SPECIFICATIONS FOR TURBINE-GENERATOR SETS

Properties	Land and Marine Direct-Connected Turbine-Generator Sets	Land Gear Sets and Oil-Ring Lubrication, Turbine-Generator Sets	Marine Turbines: Auxiliary, Geared Generator Sets	Marine Turbines: Propulsion, Geared Sets
Saybolt viscosity, sec:				
at 100 F	140–170	280–325	280–325	.....
at 120 F	.....	.....	.....	220–260
at 210 F (approx)	43	49	49	55
Flash point, F (min)	330	350	350	360
Neutralization number	0.05 Max	0.05 Max	0.05 Max	0.05 Max
A.S.T.M. steam-emulsion number	90 Max	90 Max	90 Max	120 Max
Maximum viscosity before starting, sec	800	800	800	800
Minimum oil temperature before starting, F	50	70	70	85
Operating bearing-inlet oil temp, F	110–120	110–120	110–120	110–120
Operating bearing-outlet oil temp, F	140–160	140–160	140–160	140–160
Minimum oil-tank temp, F	130	130	130	130

The value of the organic-acid content of an oil, when expressed as the number of milligrams of caustic potash required to neutralize the acids in one gram of oil, is the neutralization number of the oil. The higher the neutralization number, the greater of course is the acid content of the oil.

These specifications, prepared to include the well-tested oils of many companies, are so broad that they include some poor oils as well as the good ones. The oil selected for use should have a good service record. This need not hinder new developments in the production of turbine oils for most oil companies can test their products in their own turbines before placing them on the market.

It has been noticed lately that new turbines with new turbine oil were the ones which sometimes corroded, while old turbines with used oil never corroded. The company found that many new unused oils will, when agitated with water, allow rust to form on iron, whereas oil which has been in use in the same turbines for several years will inhibit rusting. They also found that the used turbine oil is an effective rust inhibitor when mixed with new oil in proportions as low as 1 part old oil to 99 parts new. It is of interest to note that these used oils have higher neutralization numbers than is specified for new oils. As an oil slowly oxidizes in use, organic acids are gradually formed and the neutralization number rises.

In the Company's laboratory it was found that the rust-inhibiting quality of turbine oil is in some way connected with the formation of hydrophilic groups by oxidation of the oil. Following Dr. Langmuir's procedure with oil films on distilled water, the investigators found that new turbine oils which permitted iron corrosion in the laboratory tests did not spread when dropped on water, whereas a drop of the oil used for several years in the factory turbines spread over the surface of the water very rapidly. Continuing the tests to see what molecular weight organic acids might inhibit rusting and what ones give rise to rusting, it was found that the low molecular-weight acids were rust producers; while complete protection was found with the same percentage of acids whose molecular weight was 116 and above. The results of the tests indicating the relative rusting and rust-inhibiting qualities of 0.25 per cent of various organic acids in white medicinal oil are given in Table 2.

TABLE 2—RESULTS OF CORROSION TESTS ON STEEL SPECIMENS

	Carbon Atoms in Acid	Molecular Weight of Acid	Percentage of Surface Rusted
No acid	..	...	5
Formic acid	1	46	100
Acetic acid	2	60	100
Propionic acid	3	74	50
Butyric acid	4	88	20
Valeric acid	5	88	2
Caproic acid	6	116	0
Caprylic acid	8	144	0
Palmitic acid	16	256	0
Stearic acid	18	284	0

Condenser Tube Corrosion

The second paper at this session, presented by C. W. E. Clarke, United Engineers & Constructors, Inc., A. E. White and C. Upthegrove, University of Michigan, described tests conducted at Narragansett Electric Company.

One of the main difficulties in the development of surface condensers has been corrosion of tubes. Many of the large public utility and industrial power plants are located where the condensing-water supply is contaminated by sewage, industrial waste and gases, all of which make for corrosive water. The increase in temperature and reduction in pressure within condenser tubes releases corrosive gases which are the chief cause of tube deterioration. Various methods have been utilized to attempt to remove these gases before they can act on the cooling surfaces; but for the most part they have been unsatisfactory.

In an attempt to determine the best material for condenser tubes for the extension of the Narragansett Electric Company, it was decided to conduct an extensive test on various materials in a way that would as nearly as possible duplicate the conditions actually existing in a working condenser.

According to available information, Admiralty-metal, aluminum-brass and cupronickel tubes were selected as the ones most likely to give good service. A miniature condenser was used, as shown in Fig. 8, and tubes of each of the three materials, as well as a bronze tube, were installed as indicated in the cross-section. The

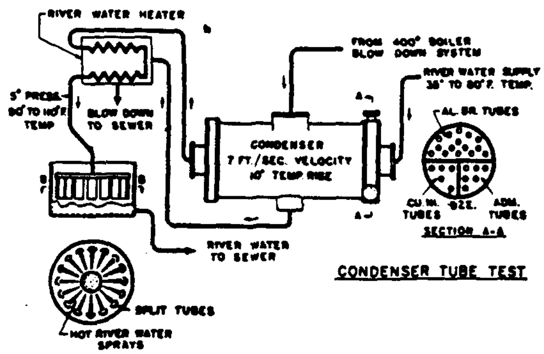


Fig. 8—Arrangement of Test Condenser

inlet water box was fitted with barriers so that the water could not come in contact with more than one type of tube. River water was passed through the tubes at a velocity corresponding to that expected in the actual condenser installation and blowdown water from the 400-lb blowdown system was admitted to the steam space.

At the same time as the condenser test, an impingement test was performed, as shown in plan *B-B* of the figure. The river water from the test condenser was heated to 90–110 F and then sprayed against the inner surface of split-tube samples.

The major emphasis was placed on the results of the above two tests; however supplementing these were mercurous-nitrate, flattening, expansion and tensile tests. No details with regard to the mercurous-nitrate, flattening or expansion tests were included in the paper.

During the condenser-corrosion test the water velocity was 7 ft per sec, and the water temperature ranged from 35 F to 80 F during the 22 months of the test. On completion of the test run the tubes were removed from the condenser and examined for corrosion. The results of this test were plotted graphically for each tube in order of decreasing resistance to corrosion and so scaled as to provide nine classifications.

Following the test, the tube pieces in the impingement apparatus were examined for resistance to impingement attack. Measurements were made of minimum wall thickness at the point of maximum wear for each tube. The ratings were set up on an arbitrary basis in which maximum resistance is indicated by 1, and minimum by 9.

Metallographic examinations of the test tubes indicated that there was little or no definite tie-up between variations in microstructure and corrosion resistance.

In conclusion the authors included among their observations that, on the basis of the particular conditions pertaining to this specific investigation, aluminum-brass is superior in its corrosion resistance to the other metals tested, and microstructure, as such, does not appear to be a controlling factor. A hard-drawn or annealed material may show equally good corrosion resistance qualities. Internal stresses of an order to produce cracking, under the conditions of the standard A.S.T.M. mercurous-nitrate test, do not necessarily decrease the corrosion resistance of the tubes, nor does their absence necessarily increase the corrosion resistance. It should not be inferred from this conclusion, however, that tubes should be furnished under such conditions of internal stress that they will crack in the mercurous-nitrate test. It is realized that expanding tubes in the tube sheets produces local stresses at these points but this is felt to be the lesser of two evils. Proper manufacturing procedure is, beyond any question of a doubt, an important factor in the production of highly corrosion-resistant tubes.

Solving Pipe Problems

At the Wednesday afternoon session on Power-Applied Mechanics, **Fred M. Hill**, Commonwealth and Southern Corporation, explained a mechanical method of solution of pipe problems for cases involving temperature expansion.

With the general acceptance of high pressures and high temperatures in steam-power-plant design, has come the need for accurate, reliable and rapid methods of calculating the stresses and reaction caused by temperature expansion. The mathematical routine of determining these stresses involves much laborious and complex calculation.

The close agreement between the test results and the mathematical calculations appears to justify the adoption of this test method. It consists of small models of piping systems made of solid, die-drawn steel rods suspended in a metal frame, with one end fixed, in such a manner as to simulate the actual proposed installation.

Ball-bearing pulleys are used for load applications, and micrometer heads at various points are used for measuring deflection and rotation. The free end of the model is equipped with an assembly of three moment arms extending in the usual coordinate directions X, Y and Z, and a micrometer head fitted with a carrying ring and four adjustable needle points.

Before the test all needle adjustments are brought into alignment and the graduated micrometer sleeves are set at zero. A scale part of the pipe expansion is now set off in the three coordinate directions on the micrometers at the free end of the model. Forces are applied to each of the moment arms in the proper amount and location, determined by trial, to realign the model in all directions. The free end of the model now assumes the same relative position of the stressed installation.

The formulas for conversion of model reactions are:

For forces

$$\frac{F_p}{F_m} = \frac{E_p}{E_m} \times \frac{I_p}{I_m} \times \frac{\Delta_p}{\Delta_m} \times S^3$$

For moments

$$\frac{M_p}{M_m} = \frac{E_p}{E_m} \times \frac{I_p}{I_m} \times \frac{\Delta_p}{\Delta_m} \times S^2$$

in which

F = Applied load, lb
E = Modulus of elasticity, lb per sq in.
I = Moment of inertia, in.^{4}
Δ = Deflection, in.
S = Ratio of lengths of model to pipe
M = Moment, in.-lb
p = Subscript indicating pipe
m = Subscript indicating model

This method is thought to provide time saving advantages over mathematical methods for complex pipe runs but not for simple pipe runs in one plane having two or three 90-deg bends when only the end reactions are sought.

Effect of Grain Size in Steam Piping

A. E. White, Consulting Engineer, The Detroit Edison Company, Director of Engineering Research, University of Michigan, and **Sabin Crocker**, Senior Engineer, The Detroit Edison Company, presented a paper on the subject, "Effect of Grain Size and Structure on Carbon-Molybdenum Steel Pipe." The paper gives the results of an investigation sponsored by The Detroit Edison Company at the University of Michigan for the purpose of studying these properties in steam pipes for their relation to high-temperature creep properties at 925 F. Pipe specimens were obtained from eight different heats of carbon-molybdenum steel, six being made by the open-hearth and two by the electric-furnace process, and an attempt was made to correlate the respective creep strengths at this temperature with other significant properties obtained through short-time tests. From the tests it is apparent that grain size alone is not a significant factor, but that if the carbide structure is of a Widmanstätten type with grain sizes ranging from 2 to 7, the steel will have good high-temperature creep properties. The steel must be properly killed to obtain the desired structure. A method to determine this is to normalize from around 1700 F.

A discussion following presentation of the paper brought out the following interesting statements. It is to be expected that a change in the structure of the pipe due to heat treatment will bring about a corresponding change in the rupture strength. The steel mills are prepared and ready to supply pipe of the required grain size. Steam pipe having the above-mentioned carbide type and grain size can be expected to show a life of thousands of hours at 925 F. The aluminum content of the test specimens was varied but showed no apparent effect upon the properties of the pipe.

Power in Ships

Under the joint auspices of the A.S.M.E. and the S.N.A. & M.E. a symposium on Thursday evening was devoted to marine power plants, in which short papers were given on boilers by **E. G. Bailey** and by **[illegible] Rakestraw**; on turbines by **E. D. Dickinson** and by

J. A. Davies, and on condensers by Paul Bancel and H. B. Carleton.

The speakers, as well as numerous discussers, all stressed the fundamental similarity of marine and stationary power and the opportunity for marine and stationary engineers to learn from one another; also, the marked advances in marine practice during the last ten years in which marine engineers appear to have broken away from tradition. Discussing this phase of the subject, Mr. Bailey observed that although designers of land power plants have sometimes striven for too high efficiencies and their methods of evaluation usually do not follow fixed standards, they have generally been research minded, in contrast to the usual conservatism of the marine engineer.

Reviewing marine advances in the last decade, Mr. Rakestraw pointed to increases in boiler efficiency from 78 to 88 per cent, to increases in steam pressure to 600 lb and to advances in steam temperatures to 750 and 800 F or even higher in some recent ships; also to the employment of such refinements as combustion control. He showed that the bent-tube boiler was ideally suited to marine service and that excellent performance is being attained in merchant service with small completely water-cooled furnaces employing heat releases of 30,000 to 50,000 Btu per cu ft. Whether comparable results can be attained in naval practice with much higher heat releases remains to be seen. Air heaters are now being installed to supplement economizers where more than three stages of steam extraction are employed.

Details of design for stationary and marine turbines are similar, according to Mr. Davies, although lack of standardization in the marine field has proved a handicap and astern operation makes for some complication. Mr. Dickinson stressed the importance of reliability and efficiency and pointed out the severe mechanical stresses to which a marine turbine may be subjected with movement of the ship and the thermal stresses incurred during maneuvering. The application and development of reduction gears have made possible turbines of smaller dimensions and thus reduced stresses in the shells.

Contrasting marine and stationary problems, Mr. Carleton mentioned that although the power requirements of ships are increasing, the space usually alotted to the power plant is decreasing. Because of limited headroom marine condensers are usually bolted directly to the turbine exhaust, hence the distance between the low-pressure blading and the top condenser tubes is small and often introduces flow distribution problems. While both single- and two-pass condensers are employed, practice favors the latter as the piping arrangement is less complicated. Some vessels with single-pass condensers employ scoops for the circulating water supply, although pumps have to be used when running at low speed or astern. It is common to use about one square foot of condenser surface for each 7 lb of steam condensed, which amounts to about one square foot per horsepower developed.

Mr. Bancel stated that the present practice of his company was to roll the condenser tubes at both ends and provide an expansion joint in the condenser shell. Commenting on condenser tube materials, he cited 21 condensers, aggregating approximately 62,000 sq ft of surface and employing aluminum-brass tubes which had been in service without tube replacement for 9 yr.