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*Construction and Operation of
Larsan-Lane Steam Purity
and Condensate Analyzers*

by

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CONSTRUCTION AND OPERATION OF LARSON-LANE STEAM PURITY AND CONDENSATE ANALYZERS

BY A. B. SISSON,¹ F. G. STRAUB,² AND R. W. LANE³

Conductivity measurement (1, 2)⁴ to determine steam or condensate purity has been used extensively for many years in steam-electric generating stations and has been an excellent guide in many cases. However, with varying amounts of ammonia present in the steam-water cycle, evaluation has been difficult, particularly in steam of very low dissolved solids content.

In the past, the calorimetric measurement of steam quality has provided important information; however in the modern plant, the calorimeter is not considered sufficiently sensitive, particularly at elevated pressures. Steam quality, as determined calorimetrically refers to the moisture content as H₂O, whereas steam purity refers to ingredients other than H₂O which may be present.

Steam Purity:

From an academic standpoint, any divergence of conductivity from 0.054 micromho per cm at 25 C should be an indication of the presence of impurities, whether they be gaseous or mineral. This is probably not a practical way of looking at steam purity from the standpoint of trouble-free operation, since the limits of impurities of various types have been neither completely identified nor quan-

titatively defined for various operating conditions. Pure steam or condensate or water meeting the above definition is not necessary and may not be desirable. The object of all steam purity testing for the purpose of indicating mineral carry-over is to observe or record deviations from a uniform or satisfactory level of conductivity. Elimination of interference from volatile components is essential in such a measurement.

Steam impurities may be of the volatile class which includes silica, carbon dioxide, sulfur dioxide, ammonia, the volatile and filming amines, and oil, or of the nonvolatile class which includes mineral ingredients obtained from mist, spray, prime, or other causes.

The presence of volatile impurities in steam and condensate is subject to the laws of chemical equilibria and is dependent primarily on rating, pressure, and boiler water concentrations. The design of boiler drum internals may also influence the resultant concentration of volatile compounds, particularly sulfur dioxide and silica, in steam to a greater or lesser degree. Also, steady state conditions in the boiler are proportionally upset by increasingly rapid changes in load. Sampling and testing procedures for the volatile components are usually of more specific interest at the particular points of potential harm.

The presence of nonvolatile impurities is not governed by chemical equilibria, and may or may not be expected to be quantitatively dependent on rating, pressure, or boiler water concentration but to a large extent is dependent on design

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⁴ The boldface numbers in parentheses refer to the list of references appended to this paper, see p. 47.

and water treatment. It is the deviation from a uniform conductivity which is important to plant operating personnel, since this indicates an abnormal condition which must be corrected. Appropriate sampling and testing procedures for the

and since it could be used to test condensate as well as steam, it was suitable for detection of boiler water carry-over as well as condenser leakage.

During the condensing of steam samples or the cooling of boiler water samples

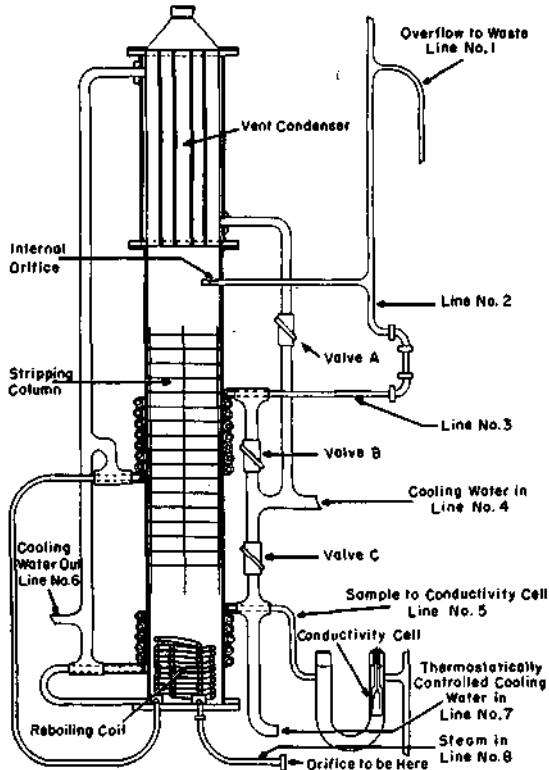


FIG. 1.—Straub Degassing Condenser.

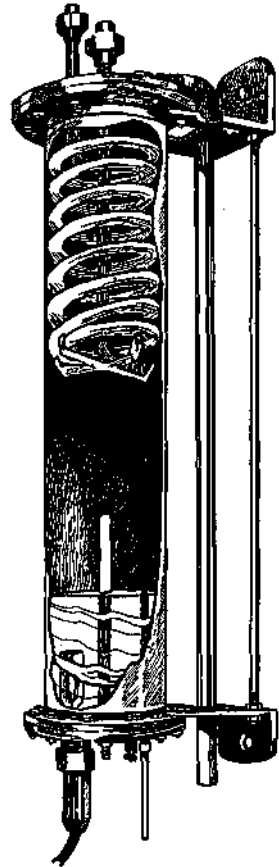


FIG. 2.—Constant Temperature Unit.

abnormal presence of nonvolatile impurities (carry-over) are of primary importance.

Straub Degassing Condenser:

Development of the Straub degassing condenser provided a more accurate means of testing steam purity (3) (Fig. 1). This degasser reduced the ammonia and carbon dioxide to extremely low values,

for conductivity determinations, much difficulty had been experienced due to the effect of temperature variation on the conductivity. In an attempt to eliminate this variation, a unit was developed to determine the conductivity at a constant temperature. The steam or hot water was flashed into a container with a cooling coil in the steam space which was vented to the atmosphere. With suf-

ficient cooling to prevent steam venting, the liquid remained at the atmospheric boiling point. A conductivity cell was placed in the liquid, and the conductivity determined at the constant temperature of the atmospheric boiling point. The constant temperature unit is shown in Fig. 2. This unit reduced the carbon dioxide effect but did not materially reduce that of the ammonia. In plants having a

higher steam pressures, attempts have been made to check for extremely small amounts of condenser leakage. In these cases the variation of a few tenths of a micromho in conductivity account for a measurable amount of condenser leakage. In many of these plants ammonia and morpholine may be present in varying amounts (4), making accurate measurement practically impossible.

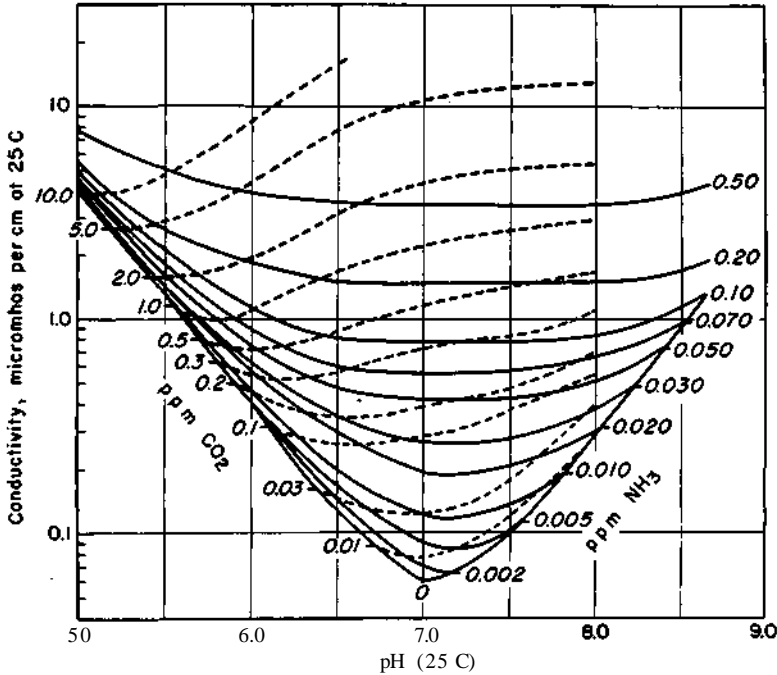


FIG. 3.—Carbon Dioxide, Ammonia, pH, and Conductivity Relationships.

fairly constant ammonia content, this unit served to indicate any variation in the steam purity.

Corrections for ammonia and carbon dioxide were made by reference to the relationships shown in Fig. 3, which was prepared from the latest equilibrium constant data. This method proved to be tedious and inexact for evaluating the purity of steam containing varying gas contents.

CONDENSATE ANALYZER

In recent years, in the large steam-electric generating stations operating at

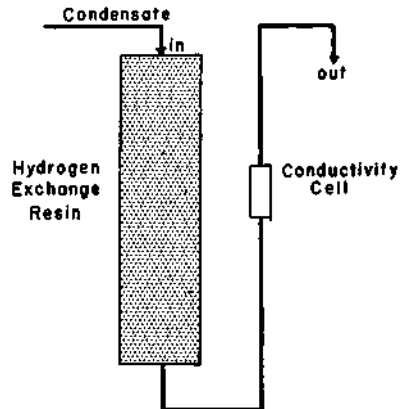


FIG. 4.—Condensate Analyzer.

Introduction of the idea of incorporating a small hydrogen exchange unit for eliminating the effect of these alkaline compounds on the conductivity measurement was tried successfully in several

ied so little from a low and average value in a long run from a large 1800-psi unit that comparison with a condensed steam sample (to provide a control or zero value) was no longer required.

TABLE I.—REACTIONS OF MINERAL SALTS IN PASSAGE THROUGH HYDROGEN ION EXCHANGER.

2 NaCl	+	H ₂ Ex ^a	→	2 HCl	+	Na ₂ Ex ^a
Na ₂ SO ₄	+	H ₂ Ex	→	H ₂ SO ₄	+	Na ₂ Ex
2 Na ₃ PO ₄	+	3 H ₂ Ex	→	2 H ₃ PO ₄	+	3 Na ₂ Ex
2 NaOH	+	H ₂ Ex	→	2 H ₂ O	+	Na ₂ Ex
CaCO ₃	+	H ₂ Ex	→	H ₂ CO ₃	+	Ca Ex
Ca(HCO ₃) ₂	+	H ₂ Ex	→	2 H ₂ CO ₃	+	Ca Ex

^a Ex = exchanger.

power plants. The condensate when passed through the analyzer (Fig. 4) at approximately 30 to 40 lb per hr, had all the ammonia⁵ and morpholine⁶ removed, thus the conductivity indicated the dissolved solids independent of the ammonia and morpholine present. Carbon dioxide was not removed by this process, but in the plants where these units were used, the carbon dioxide content was very low. The action of the hydrogen exchanger in removal of ammonia and in the conversion of raw water mineral salts to the corresponding acids is illustrated in the equations given in Table I. While the conductivity due to hydroxide alkalinity was lost by ion exchange, the increased conductivity of the hydrochloric, sulfuric, and other acids formed, increased the sensitivity of measurement of mineral dissolved solids (Table II).

This increased sensitivity permitted the accurate determination of condenser leakage of the order of 0.01 per cent or 60 to 100 lb of cooling water (150 ppm dissolved solids) per hr into the condensate of a 100,000-kw turbine condenser. The conductivity of the condensate var-

The only maintenance which has been required is regeneration, which is necessary very infrequently. When using an exchange column containing 0.028 cu ft of resin, employing a flow rate of 20 lb per hr and testing condensate containing 4 ppm of morpholine, regeneration is required every three to four months. The need for regeneration is easily recognized by the steady increase in conductance of the effluent water from its normal value.

No particular construction or corrosion problems were encountered in fabricating this instrument, since it was built of plastic and stainless steel and is operated below a temperature of 120 F (Fig. 5). High-capacity sulfonated sty-

TABLE II.—RELATION BETWEEN THE CONDUCTANCE OF THE MINERAL SALT AND CORRESPONDING ACID.

Constituent	Conductance, micromhos per ppm, at 25 deg C	Conductance after Passage Through Cation Resin, micromhos per ppm of original constituent	Ratio or Multiplying Factor
NaCl	2.16	7.28	3.37
Na ₂ SO ₄	1.83	6.04	3.30
Na ₂ S ₂ O ₃	1.53	6.27	4.10
Na ₃ PO ₄	2.23	7.71	3.46
NaOH	6.07	0.0	0.0
CaCO ₃	2.53	8.39 ^b	3.25
Ca(HCO ₃) ₂	1.60	20.65 ^b	12.91

^a Handbook of Chemistry and Physics, 37th Edition (1955).

^b Assuming complete ionization of the H₂CO₃.

⁵ Reduction of ammonia to 0.01 ppm (as N) or lower is indicated, however the accuracy of the method of analysis is somewhat questionable below 0.05 ppm.

⁶ Reduction of morpholine to 0.4 ppm or lower is indicated, however the accuracy of the method of analysis is somewhat questionable below 1.0 ppm.

rene divinylbenzene resin in the hydrogen form has been employed as the hydrogen

is removed from the system. Prolonged immersion of the conductivity cell in strong acid is not recommended.

Since a flowmeter is included in this instrument, flow adjustment is quite

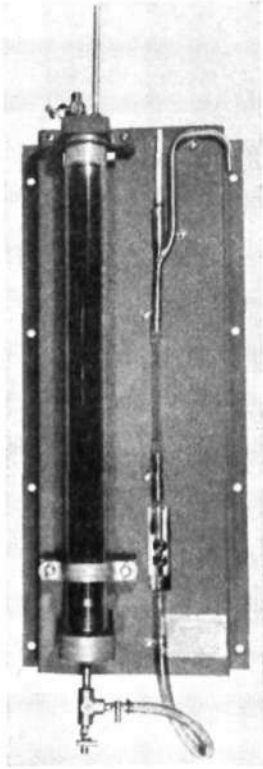


FIG. 5.—Condensate Analyzer.

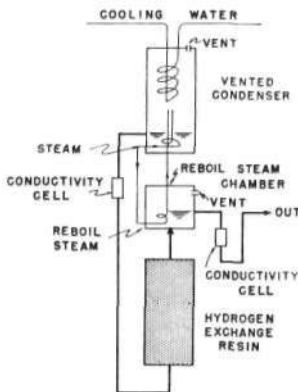


FIG. 6.—Steam Purity Analyzer.

exchanger. Regeneration with 5 per cent HCl in the unit may be performed satisfactorily provided the conductivity cell

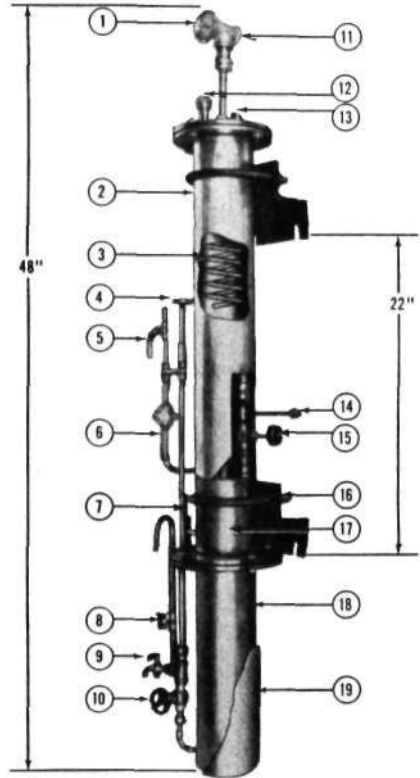


FIG. 7.—Steam Purity Analyzer.

1. Thermometer
2. Condensing chamber
3. Condensing coil
4. Thermometer
5. Overflow
6. Placement for second conductivity cell
7. Alternate thermometer location and reboil outlet
8. Conductivity cell
9. Drain
10. Throttling valve
11. 1/2 in. NPT cold water outlet
12. 1/2 in. NPT cold water inlet
13. Steam vent
14. Steam inlet
15. Steam throttling valve
16. Reboil vent
17. Reboil chamber
18. Resin chamber
19. 1 in. Insulation throughout

simple. With relatively constant condensate temperatures, temperature adjustment is not required.

STEAM PURITY ANALYZER

The steam purity analyzer was developed to eliminate the inaccuracies resulting from the presence of carbon dioxide, ammonia, or volatile amines in the conductivity measurement of condensed steam for purity. This has been accomplished by employing the constant temperature unit (Fig. 2) to condense the steam, then passing the condensed steam through a hydrogen ion exchanger

water dissolved solids before decrease in conductivity will result).

This procedure proved to be successful in eliminating the inaccuracies resulting from gas contaminants, as disclosed in Figs. 8 and 9, (5, 6, 7, 8). In Table III, morpholine is shown to be reduced to a minimum by passage through the hydrogen exchange resin. Also 1 ppm morpholine is shown to provide approximately 0.8 micromhos conductivity. Approxi-

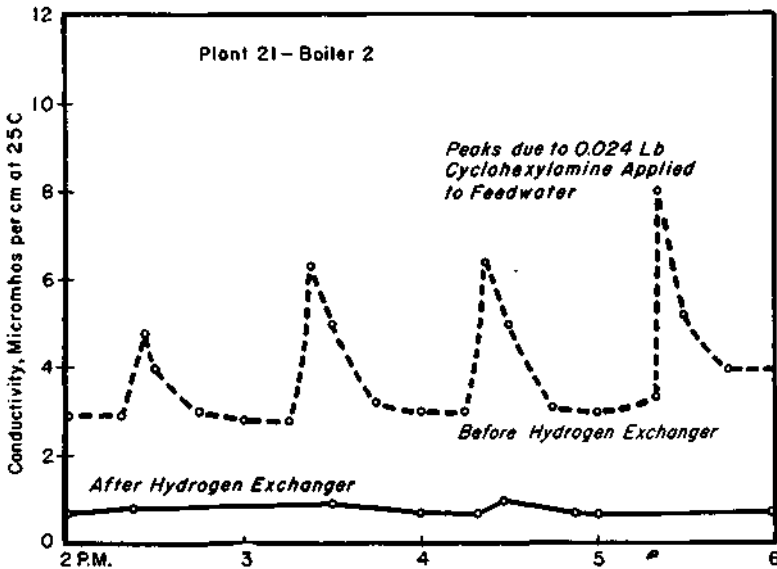


FIG. 8.—Conductivity Measurements of Cyclohexylamine Treated Condensate Before and After Hydrogen Exchange Treatment.

and finally through a reboil process to eliminate the remaining carbon dioxide. This instrument is therefore different from the condensate analyzer in that (1) a constant boiling water temperature is maintained and measurements made at this temperature, and (2) carbon dioxide is removed (Figs. 6 and 7). While the carry-over conductivity due to hydroxide and carbonate was known to be lost by the ion exchange and reboiling processes, the increased conductivity provided by the acid form was shown to increase the sensitivity of the method for detecting carry-over (hydroxide and carbonate content must exceed 50 per cent of boiler

mately the same value has been obtained by Straub in other experiments.

Construction:

The Straub degassing condenser originally was constructed of stainless steel, but later, due to war time restrictions, stainless steel was used only in the sample lines, the reboiling coil, and the vent condenser tubes, with the rest of the metal in contact with steam or water being copper or brass. Since no measurable changes in conductivity were detected when these changes were made and since no corrosion problems had been experienced in employing brass,

copper, and stainless steel tubing in the constant-temperature unit, these same materials of construction were used in construction of the condensing portion of the analyzer.

Originally, the resin chamber and re-

On the basis of these tests, stainless steel construction has been specified for the resin chamber and all parts contacted by the resin effluent.

No other corrosion problems have been encountered.

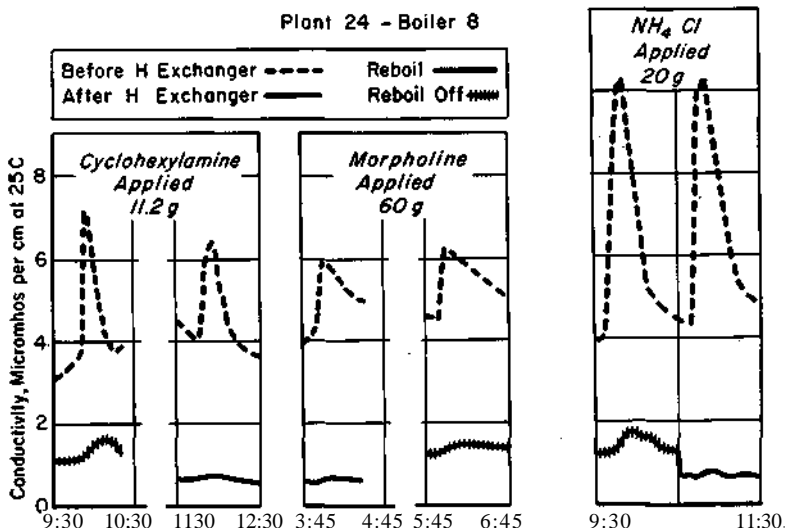


FIG. 9.—Hydrogen Exchange Treatment Plus Reboil Eliminates Conductivity Effects of Cyclohexylamine, Morpholine, and Ammonium Chloride on Steam Purity Measurement.

boil chamber were constructed of monel metal. After two months of use, the monel metal screen at the bottom of the resin column was found to have corroded severely. Also, pits (estimated 1/64 to 1/32 in. in depth and diameter) were observed in the interior walls of the monel metal resin chamber, where the resin is in contact with the metal walls.

Another instrument, constructed of AISI type 304 stainless steel, which had been in use for a two-year period, was examined closely and was found to be free of these corrosion problems.

While the stainless steel screen was observed to be bright in color, indicating possible attack, weight loss measurements indicated negligible corrosion. Further tests have indicated that Inconel screen is slightly superior in coirrosion resistance.

Resin Performance and Selection:

Since a difference in effluent conductivity was observed when using various resins, investigation of the commercial sulfonated styrene-divinylbenzene, 8 per cent cross linked resins supplied by several manufacturers and investigation of

TABLE III.—REMOVAL OF MORPHOLINE BY HYDROGEN EXCHANGE RESIN IN STEAM ANALYZER.

	Conductivity Corrected to 25 deg C, (micromho per cm)	Morpholine, ppm
After condensing chamber	3.55	3.6
After H resin and reboil	0.65	<1.0 ^a

^a Accuracy of the method of analysis is somewhat questionable below 1.0 ppm.

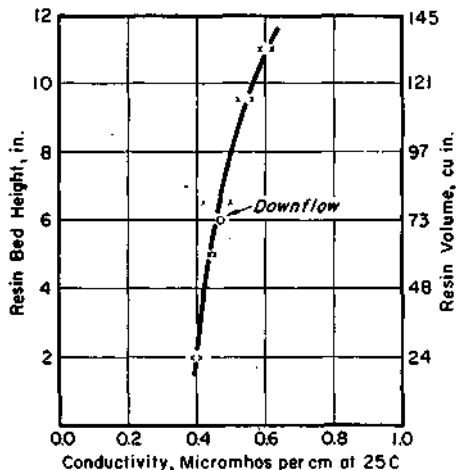


FIG. 10.—Effect of Quantity of Resin on Effluent Conductivity From Steam Purity Analyzer.

linked styrene resin (more porous), a 9-in. resin bed provided an effluent conductivity of 0.42 micromhos while a 2 in. depth provided a conductivity of 0.39 micromhos, indicating that this resin was superior to the other resins in providing minimum contamination.

This constant leakage or contamination was identified as sulfuric acid, which apparently is derived from the original sulfonation process, since hydrochloric acid regeneration does not reduce it appreciably. Gravimetric sulfate, microacidity and pH results at 100 C have indicated the presence of approximately 0.01 to 0.03 ppm acid, as H_2SO_4 .

The results in Table IV also indicate that the resin with 4 per cent cross link

TABLE IV.—MINIMUM EFFLUENT CONDUCTIVITY EMPLOYING SULFONATED STYRENE-DIVINYLBENZENE RESINS SUPPLIED BY DIFFERENT MANUFACTURERS.

40 to 50 lb per hr of high-purity steam were condensed in steam purity analyzer, passed upflow through 9 in. depth (109 cu in.) hydrogen exchange bed and through reboil process.

Resin Characteristics (Cross Linkage), per cent	Manufacturer	Regeneration	Minimum Conductivity Corrected to 25 deg C (micromho per cm)
8 High capacity	A	Na form, 20 lb H_2SO_4 per cu ft	0.75
8 High capacity	B	Na form, 20 lb H_2SO_4 per cu ft	0.75
8 High capacity	C	H form, never regenerated	0.57
4 Medium capacity	C	H form, never regenerated	0.42

a resin with 4 per cent cross linkage of different composition and physical properties were made. Factors which affected the effluent conductivity, were the quantity of resin used, the method of regeneration applied, and the number of times that the resin had been regenerated.

The effect of quantity (or bed depth) of an 8 per cent cross linked styrene resin (regenerated several times) on effluent conductivity revealed in Fig. 10 that increased resin quantity produced a higher effluent conductivity (for example, a 9-in. bed provided an effluent conductivity of 0.53 micromhos and a 2 in. bed, 0.4 micromhos). In the case of the 4 per cent cross

age is superior to the other resins in providing minimum contamination to the effluent.

There was some indication that hydrochloric acid regeneration of 8 per cent cross linked styrene resins provided a lower effluent conductivity than sulfuric acid regeneration. In the case of the resin with 4 per cent cross linkage, the same minimum conductivity was obtained with both regenerants.

Gasket Contamination:

In original tests conducted on the steam purity analyzer, abnormally high effluent conductivity was found to be

the result of contamination contributed by commercial asbestos type gaskets employed at the top of the resin chamber. Lead gaskets were then used, but these also were found to contribute contamination. Block tin proved to be satisfactory except for a slight leakage problem. Teflon, as well, proved satisfactory from the standpoint of contamination but became deformed after repeated use. The most satisfactory gasket has been found

to save heat and water losses in one plant, zeolite softened cooling water and condensate from the analyzer are discharged into the condensate holding tank.

Installation of a needle type gage valve (1/2 in.) of stainless steel stem and disk construction is recommended for throttling the cooling water. Minimum adjustment of this valve and the reboil steam valve are required; often readjust-

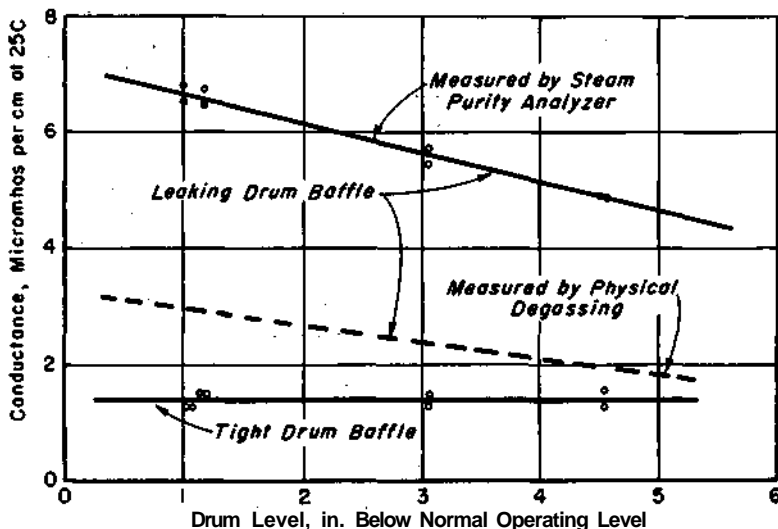


FIG. 11.—Comparison of Steam Purity Testing Methods in Detecting Leakage of Drum Baffles at Several Water Levels.

to be a Teflon filled stainless steel spiral wound gasket.

Operating Variables:

Cooling water effluent temperature is normally maintained at 120 to 140 F. Higher temperatures have been maintained successfully; however adjustment is a little more critical and scaling problems are greater at the higher temperature if hard water is used for cooling. Assuming 55 F cooling water and 50 lb per hr 250 psig saturated steam flow, approximately 2300 gal of cooling water are required for 24 hr operation. In order

ments are not required for weeks. In plants employing higher dosages of neutralizing amines (3 to 5 ppm), it has been observed that increased reboil steam is required to remove the higher carbon dioxide content. In this case, only an adjustment of the reboil steam valve is required to vent a more definite plume of steam.

A steam flow rate of 40 to 60 lb per hr is specified. Lower flows than 40 lb per hr may accentuate temperature control and resin contamination problems. The instrument is not designed to handle flows above 70 lb per hr.

Some difficulty has been experienced in obtaining continuous accurate results from the conductivity cells, particularly at the condensing chamber effluent. Cleaning electrodes with hydrochloric acid (1:1) or replatinization has been required about every two to three months. This has largely been due to the coating of the cell surfaces with oil, rust, pipe dope, etc. after continued service in plants employing black iron pipe sampling lines. This experience is a further indication that clean stainless steel sampling lines are to be preferred.

Operating Experiences (Institutional Power Plants):

For the past several years, this equipment has been employed to test the purity of steam from 33 boilers in 14 Illinois State Institutional power plants (5). As a result of these studies, improvements in steam purity have been accomplished by adjusting operating procedures and chemical treatment. Factors that have been found important in improving steam purity are:

1. Operation at proper and uniform water level (proper feedwater regulator adjustment).
2. Scheduling ash pull and soot blow during periods of minimum load or minimum fluctuating load.
3. Avoidance of extreme load changes (for example, proper pressure reducing valve operation).
4. Employment of make-up water of minimum hardness content.
5. Accurate and proper feedwater treatment and blowdown control.

Following adjustment of these factors, improvement in steam purity was obtained in nine of these boilers. As a result, all but three of the 33 boilers produce steam of consistent high-purity (below 2.0 micromhos). Two of these three are to be replaced since the equipment is

old and worn out; the third is having extensive changes made in the interior of the drum to improve steam purity.

Recently, justification for installation of one of these instruments in a state plant (Plant 31) was derived following calculation of the savings in fuel, water and chemical treatment. These calculations revealed that annual savings of fuel, water, and treatment amounting to \$3400 would be obtained by raising the dissolved solids limits from 3400 ppm to 6000 ppm. Without having a continuous record of the steam purity, such an increase would not have been considered a safe procedure, since evidences of carry-over had been observed at boiler dissolved solids tests of 7000 ppm. With this continuous record and with close attention to other analytical tests, economical and efficient operation has been proceeding for a six months' period. The anticipated savings are being obtained.

The analyzer has gained the name of "Lie Detector" at this plant. In starting up a boiler, an operating engineer failed to open valves draining a centrifugal steam purifier to a trap outside the boiler. Within a few hours, steam purity results of 5 to 20 micromhos were indicated. The operator then realized what he had failed to do, opened the valves and the steam purity results returned to normal.

In one plant, it has been observed that the differences between the continuous recording of the condensing chamber and resin chamber effluents provides an approximation of the neutralizing amine concentration (Table III). This information should be of particular interest to manufacturing plants concerned with possible contamination of the product by excessive concentration of neutralizing amines in process steam. An additional advantage of recording the condensing chamber effluent is that an indication of the exhaustion of the resin is provided, since at this time, the resin

effluent conductivity approaches the condensing chamber conductivity.

In another plant, abnormally high readings of the condensing chamber effluent and normal readings of the resin chamber effluent indicated that the plant softening and dealkalizing system was not operating properly. Channeling was found to be occurring in the plant softening bed.

Operating Experiences (Central Stations):

The function of the steam purity analyzer is well illustrated by its use in the determination of carryover from a boiler drum having faulty interior. Repeated inspections of the drum interior had failed to reveal the reasons for numerous superheater tube failures in a rather narrow zone of four to six tube width.

Steam was sampled from various locations along the length of the drum above the steam purifiers and scrubbers during operation at constant load at several water levels. The conductivity results by physical degassing were not entirely conclusive although a trend was indicated. Positive location of carry-over was pro-

vided by use of the steam purity analyzer.

The results from both tests at the point of leakage in the drum are shown in Fig. 11. At all three water levels tested, the difference in conductivity between a tight drum baffle and the faulty point in the baffle was highly accentuated by the steam purity analyzer.

Reinspection of the drum internals using feeler gages showed that minute openings (of the order of 0.015 in.) were present at the position in the drum where the high conductance was indicated. After removal, repair and reinstallation of these internals, the difficulty was corrected and steam was determined to be of high purity. Most important, of course, was the cessation of tube failures.

In summary, the importance of the measurement of steam or condensate purity warrants that the greatest attention be given to reliability both in sensitivity and accuracy. This discussion has shown the use of both of these devices in central station plants greatly to improve the value of the conductivity measurement as an indicator of purity.

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DISCUSSION

MR. R. O. PARKER.¹—There are two comments I should like to make:

The chemical amplification effected by replacing low-conductance cations with the high-conductance hydrogen ion is certainly intriguing.

In personal correspondence, Mr. Lane advanced the idea that conductivity be measured and reported at 100 C. With dissolved gases present, interpretation might be difficult because of the absence of published data on the dissociation constants at elevated temperatures, particularly the first and second dissociation constants for carbonic acid. Work is being done at Battelle Memorial Inst. on this subject.²

MR. H. M. RIVERS.³ (*presented in written form*).—The equipment described clearly represents an important advance in our search for better means of measuring and controlling steam purity. It provides a simple and straightforward way to eliminate all or most of the conductivity effects of volatile alkaline amines which are extremely difficult to remove by physical degassing of steam condensate.

As the authors point out, sodium hydroxide is completely removed in the cation exchanger. Carbonates and bicarbonates should be lost as well in the

reboil chamber. Ordinarily, this loss may not be important if sulfates, chlorides, and other inorganic salts comprise a substantial percentage of the entrained solids. But there are some indications that sodium hydroxide may be selectively carried over so that the ratio of caustic to other solids in the steam is substantially higher than it is in the boiler water. Furthermore, in many high-pressure plants sodium hydroxide may be the major constituent of the boiler water. When we remember that sodium hydroxide itself has a conductivity considerably higher than that of the neutral salts, I wonder whether the utility of the test data will always be improved by substituting mineral acids for the original salts and sodium alkalies.

Our experience with a variety of steam sampling and degassing devices indicates that the volume of liquid retained in the apparatus can have an extremely important effect on the meaning of the test data. Many carry-over problems are characterized by contamination that occurs in spurts of relatively short duration. All but the largest of these peaks may be blurred or eradicated almost entirely if the water storage capacity of the degasser is not held at the lowest possible minimum. The diluting effect of the rather considerable volume of water retained in the condenser, exchange column, and reboil chamber cannot be ignored in this connection. Nevertheless, where steam contamination is fairly steady or where knowledge of the instantaneous steam

¹ Manager, Research Test Dept., the Griscom-Russell Co., Massillon, Ohio.

² This work is being done by Mr. J. J. Ward at the Battelle Memorial Institute and will soon be made available.

³ Director, Engineering Service, Hall Labs., Inc., Pittsburgh, Pa.

purity is not particularly important, the Lane-Larson apparatus should prove quite satisfactory.

MR. LOUIS C. THAYER.⁴—What effects do the filming amines have on the operation of the analyzer?

MR. R. W. LANE (*author*).—I appreciate Mr. Parker's offer of cooperation.

Replying to Mr. Rivers, when the boiler water alkalinity is above 50 per cent of the dissolved solids, there will be a decrease in conductivity coming from the analyzer. It would be expected that this would be an unusual situation, since the boiler water alkalinity is maintained much below this in most boilers.

We agree that keeping a minimum volume of liquid in the equipment is an important feature. The analyzer was designed with this in mind; however, sufficient volume of resin had to be included

in order to obtain complete ion exchange and also to reduce the frequency of regeneration. The time required for passage of steam through the analyzer is approximately 4 min.

In reply to Mr. Thayer's question on the effect of filming amine on the operation of the analyzer, we can report that operation of the analyzer for a 3-week period on steam containing 2 to 3 ppm of filming amine showed no effect on the steam purity results or on the resin. Conductivity results following the condensing chamber before hydrogen exchange, indicated that little if any conductivity was provided by the filming amine. This would be expected since filming amine is known to have a very low conductivity. While no difficulty has been experienced due to filming amine contamination of the resin, isopropyl alcohol could be used to remove the amine from the resin during the regeneration.

⁴ Director of Research, Arnold O. Beckman, Inc., Pasadena, Calif.