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AEC RESEARCH AND DEVELOPMENT REPORT

THE REMOVAL OF IODINE FROM GAS STREAMS BY
REACTION WITH SILVER IN PACKED TOWERS

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THE REMOVAL OF IODINE FROM GAS STREAMS BY
REACTION WITH SILVER IN PACKED TOWERS

by

A. M. Lyon and R. McNabney

ABSTRACT

A process has been developed for the removal of iodine alone in the presence of the various other constituents of pile dissolver off-gases. The principal feature of the process is the use of a column packed with Berl saddles coated with silver nitrate or silver.

Experiments have been run using a column with a packed section 17" long by 2" in diameter through which was passed a stream of air at 2/GPM containing NO_2 , water vapor and iodine. This tower operating on this gas stream is equivalent to a 6-foot plant scale tower operating on Hanford off-gases and described in Appendix A.

Experiments with normal iodine indicated that the usual analytical methods were not sufficiently sensitive at the low concentrations of iodine used (about 0.04 mg./cu. ft. of iodine). Therefore, a series of tracer runs was made using I^{131} .

The following conclusions have been drawn from these experiments:

1. The optimum temperature is about 220°C.
2. The length of the experimental tower was sufficient, and therefore also the 6-foot length of the plant scale unit is probably sufficient.
3. Reduced silver as a coating is slightly less efficient than silver nitrate.
4. Ammonia, present at one stage of the dissolving, has little or no effect on the process.
5. Under the above optimum conditions, removal efficiencies of at least 99.9% are possible.
6. This high efficiency will probably continue until 30 to 40% of the available silver has been reacted. On this basis, the 6-foot plant installation should be good for at least 300 eight-hour shifts and have a capacity of at least 600 g. of iodine.

The experimental results and apparatus are described.

A design for a proposed plant scale unit is given in Appendix A.

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Technical personnel working on this problem were:

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1.0 Introduction. Whenever uranium pile slugs are dissolved for chemical processing, the gases evolved, known as the dissolver off-gases, contain small quantities of radioactive gaseous fission products. The most abundant of these are I-131, Kr-85, and Xe-133, and of these the radioiodine is the most hazardous because it is both the most abundant and the most dangerous physiologically. This report presents what is felt to be a successful method for removing the iodine alone, in the presence of the various other constituents of dissolver off-gases.

The ideal solution to such a decontamination problem would be one with the following characteristics:

1. Highly efficient at very low concentrations of iodine (of the order of .004 mg. per cu. ft. or less).
2. It must not create a difficult decontamination or disposal problem in itself, either by the production of large bulks of radioactive solid material or large volumes of radioactive solutions.
3. The apparatus should be compact and easy to maintain because of its location in very radioactive areas.

Previous to this research, it had been determined at Hanford that a column packed with silver pellets seemed quite efficient in the removal of iodine from the Hanford off-gases. It appeared to this group that such a direct approach deserved further study, and that silver catalysts used in their own operations would be exceedingly effective. Accordingly a sample of a catalyst consisting of silver metal distributed over the surfaces of tabular corundum was sent to Hanford for experimental use. Tests of this material on the actual Hanford off-gas were very promising, but indicated that further study of this process would be impossible on the off-gases at Hanford because of the very high level of radioactivity. Accordingly the research presented in this report has been conducted at the Air Reduction Laboratories.

Studies have been made of a variety of silver bearing packings using normal iodine (Section 2.1) and tracer quantities of iodine-131 (Section 2.2) with the result that a design of a proposed plant scale installation for Hanford has been prepared (Appendix A).

2.0 Results and Conclusions.

2.1 Experiments with Normal Iodine. The laboratory research on the removal of iodine from off-gases was concerned with a process, the principal feature of which was the use of a column packed with silver bearing materials. It was soon established that such a system was promising in that the oxides of nitrogen in the off-gas stream would not interfere as long as the temperature was kept sufficiently high to prevent condensation of nitric acid on the coating.

The first experiments utilized a reduced silver corundum based packing similar to the material which had been tried at Hanford with indications of success.

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Subsequently results seemed to indicate that silver nitrate was as effective as metallic silver in removing iodine from the gas stream. Therefore, in all succeeding experiments including the tracer experiments, the column was coated merely by passing through the packing a concentrated silver nitrate solution and drying. An additional advantage of this procedure seemed to be the ease with which this coating and the silver iodide (soluble in concentrated silver nitrate solution) could be extracted and the packing simultaneously regenerated.

Examination of the interior of used tabular corundum packings showed that only the silver on the outer surfaces was effective. Therefore, the support material adopted was porcelain Berl saddles with their high external surface and desirable absorption characteristics.

The gas stream in most of the cold experiments consisted of air mixed with NO_2 (up to 25%), water vapor and from 0.8 to 1.0 mg. of normal iodine per cubic foot. This iodine concentration was high in comparison with the Hanford average of 0.04 mg. per cubic foot because cold methods of analysis were not sufficiently sensitive to determine efficiencies at such low iodine contents.

The principal limitation on the cold work was the analytical problem. At first a colorimetric method was used depending on the color developed by iodine in carbon tetrachloride, but it proved quite undependable. Subsequently analytical towers, packed with silver nitrate coated base material, were used in series with the main tower. These could be extracted by silver nitrate solution and the amount of iodine determined as silver iodide by reprecipitation from the extracts. This procedure, while the best conceived of at the time, had two disadvantages:

1. The sensitivity of the analysis depended on the solubility of silver iodide in the dilute acid - silver nitrate solution.
2. The efficiency of the analytical absorbers, operating on the low iodine concentrations of the exit gas, was undoubtedly less than that of the main tower.

A rather complete investigation was made of the solubility of silver iodide in acidic silver nitrate solutions. The results (shown in Figure 1), when applied to the analytical procedure, indicated that the method was not sufficiently sensitive to apply to analysis of the exit gas from the tower when operating on an input iodine concentration in the neighborhood of 0.04 mg. per cubic foot (the average Hanford concentration).

In the last and most dependable cold runs, the principal conclusion drawn was that when the iodine content of the incoming gas was in the neighborhood of 1 mg. per cubic foot, the analytical methods were capable of proving removal of efficiencies of about 99% in an 8-inch by 2-inch diameter packed section, up to the time when approximately 40% of the silver nitrate in the tower had reacted.

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2.2 Tracer Experiments. The experience with normal iodine indicated that it would be impossible to study iodine concentrations such as that at Hanford without the use of radioiodine. It was at first thought that the tracer work could best be done on a pilot plant scale on an actual dissolver off-gas at some small pile site. Consultations with pile operating groups indicated that it would be difficult to obtain a satisfactory amount of data under controlled conditions at a pile site. Therefore, a counting laboratory was set up and the absorption apparatus was adapted to tracer techniques.

It was decided at the outset that the maximum radioactive level at any part of the apparatus should be 5 mc. of I-131. This level was felt to be as high as desirable, because at a higher level the necessary precautions would interfere with the conduct of the work. It was necessary to reconcile this low level of activity with the necessity of using it in a relatively large system with gas flows in the neighborhood of two cubic feet per minute. This flow rate was determined by the minimum size of Berl saddles available. The combination of these two factors naturally resulted in a very low specific activity in the exit gas stream, necessitating the accumulation of the activity in the entire exit gas stream from a run in order to obtain the desired precision in counting.

The absorption tower used in the tracer experiments contained a packed bed 17 inches high and 2 inches in diameter packed with one-quarter inch Berl saddles which had been coated with silver nitrate or silver. The gas stream passing through this tower at a velocity of two cubic feet per minute consisted of air, bearing water vapor, nitrogen dioxide, 0.04 mg. of normal iodine per cubic foot and tracer quantities of I-131. This gas stream was designed to approximate the Hanford off-gas. The tower dimensions and flow rate were designed to approximate a plant scale unit six feet in length (described in Appendix A) operating on the 100 cubic feet per minute of dissolver off-gas. The conclusions below were drawn from observations of the performance of the small tower, but should be directly applicable to the plant scale unit.

Runs were made to provide information on (1) the effect of the temperature of the tower on the efficiency, (2) the effect of the length of packed bed on the efficiency, (3) a comparison of silver nitrate and reduced silver coatings, and (4) the effect of the introduction of ammonia, which is present in addition to the constituents mentioned above at certain stages of the dissolving.

The amount of iodine absorbed by the tower was determined by extracting it with silver nitrate solution and counting the radioiodine content of the solution. In order to obtain information on the effect of length of packed tower, the bottom six inches of the main 17-inch tower were extracted separately from the top 11 inches so that efficiency figures were obtained for packed sections of 6 inches and 17 inches. In addition, two towers 10 inches long and 2 inches in diameter were connected on the downstream side of the main 17-inch tower so that data was also obtained on a 37-inch length.

2.21 Summary of Conclusions. Under the above experimental conditions, the efficiency data of Table I were obtained. The following conclusions may be drawn:

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1. Effect of Temperature. The optimum temperature appears to be 220°C.
2. Effect of Length of Packing. An increase in efficiency is observed between the 6-inch and the 17-inch length, but little efficiency is gained in going to the 37-inch length. Therefore, the 17-inch length for the experimental unit and the 6-foot length of the plant scale design are probably sufficient.
3. Comparison of Reduced Silver and Silver Nitrate Coatings. Reduced silver appears to be slightly less efficient than the silver nitrate coating. The silver nitrate coating has the additional advantage that it is far easier to decontaminate the tower by extraction. However, if decontamination is not required, the added handling convenience of the dry reduced silver saddles might offset both the apparent advantages of silver nitrate.
4. The Effect of Introduction of Ammonia. A study was made of the effect of the ammonia which it was understood would be in the lines at some stage of the operations. Tests up to 250°C indicated that the ammonia had no visible effect on silver, silver nitrate or silver iodide and did not appear to affect the iodine removal efficiency of silver or silver nitrate coatings. No explosive substances were formed, and the only apparent effect was the formation of ammonium nitrate with residual nitric acid.
5. Attainable Efficiency. Under the above optimum conditions, removal efficiencies of at least 99.9% are possible.
6. Life Expectancy of Packing. The large quantities of I-131 which would have been required for life tests made it impossible to conduct them on a tracer basis. A fairly reliable estimate would be that the high efficiency would continue until between 30 and 40% of the available silver had been reacted. This had previously been indicated by the normal iodine runs. It would probably be desirable to test this more thoroughly, but these tests should be run on a dissolver off-gas stream. From this estimate, a 6-foot plant installation should be good for at least 300 eight-hour shifts.

2.22 Experimental Results. The iodine removal efficiencies calculated from the counting data of the various runs are summarized in Table I. The actual counting data for the various tracer runs from Run 4 to Run 13 are given in Tables II to IV.

The efficiencies of Table I were calculated from the data of Table II to IV in the following manner: % efficiency = microcuries of I-131 extracted

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from packed sections times 100 divided by the sum of all the I-131 extracted from all towers and analytical absorbers from the main tower through to the last analytical absorber. This method of calculation is obviously based upon the assumption that no significant quantity of iodine had passed through the entire system of absorbers without being caught and measured. At first sight this assumption may not seem to be a safe one, but enough experimental evidence was accumulated to indicate that it is undoubtedly valid. In particular, the following points might be mentioned:

1. It was impossible to base the efficiency calculations on the amount of radioiodine introduced into the apparatus because a variable amount of activity was retained by parts of the system upstream of the main absorber. This material was retained in parts of the system which it had not originally been planned to extract, so that it was difficult to count it for inclusion in an exact material balance for each individual run.
2. The first series of runs through Run 6 included a comparative study of the efficiency of various types of analytical absorbers, in which it is believed that a very efficient absorber was developed. In all of the runs from Run 7 on, three of these were used in series downstream of the silver nitrate absorbers, and in all but one of those runs no activity was detected in the last two of the three.

A diagram of the apparatus is given in Figure 3, with a full description in Section 3.1. A brief description of each run is given in the succeeding paragraphs.

Run 1. This run was designed to test the apparatus, particularly with regard to the tracer injection system and the analytical system. The analytical system for this run consisted of a pair of silver nitrate coated towers connected in series, from which the iodine could be extracted by circulation of silver nitrate solutions over the packing, followed by counting the solution.

The following observations were made:

1. It was observed that substantial quantities of radioiodine were held back in parts of the system upstream of the main tower. Particularly, radioiodine was found unvolatilized in the volatilization chamber and dissolved in the fluorolube in the injection bulb. It was apparent that it would be difficult to maintain a material balance and use the amount introduced into the injector as a basis for the efficiency. It was not possible to extract completely the radioiodine in the fluorolube. Therefore, it seemed probable that a certain amount of the material introduced into the injector for this run might carry over into the next run, since it was not planned to use fresh fluorolube for each run because of the small supply. In

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spite of these difficulties, the injection system operated in a sufficiently satisfactory manner to warrant keeping it with minor modifications, particularly since it was difficult to design a more satisfactory system at this stage of the work.

2. Upon extraction of the silver iodide from the two dry Berl saddle analyzer towers, it was found that almost as much iodine was absorbed by the second analyzer as by the first. This fact indicated that the efficiency of absorption was quite low for the very low iodine content of the exit stream, and that better analytical absorbers would have to be devised.

Run 2. This run was a repetition of Run 1 with certain modifications of the injection system. More radioiodine was extracted from the second analyzer than from the first, confirming the inefficiency of the analyzers.

Run 3. For this run, an analytical wet scrubber had been developed (as shown in Figure 2) which would handle two cubic feet per minute and still be suitable for analytical purposes. This scrubber, used with 1 N silver nitrate solution, was placed between the main tower and the two analytical dry silver absorber towers. The following counts were obtained from the three analytical absorbers:

Liquid Absorber . . .	.24.4 mc.
First Dry Tower . . .	7.8 mc.
Second Dry Tower . . .	1.0 mc.

During the operation of the wet scrubber, it was observed that the solution evaporated to such an extent that its efficiency was seriously impaired during the latter part of the run. This fact probably explains the amount of activity found in the first dry tower. It is obvious from these results that a solution type scrubber was more efficient than the dry coated towers for these low iodine levels; however, it should be mentioned that the NO₂ content of the gas stream was held very low so as not to interfere with the absorption of iodine with the silver nitrate solution. Such a scrubber would not work on an NO₂ concentration such as that at Hanford.

Run 4. In this run, a sodium hydroxide scrubber was introduced upstream of the silver nitrate scrubber to permit raising the NO₂ concentration to its previous level.

In addition, it was discovered that the method in use for calculating the efficiency of the main tower was not going to be satisfactory. It had not been planned originally to extract and count the radioiodine caught by the main tower, but rather to compare the total amount introduced in the gas stream to that in the exit stream. This was to be accomplished by taking one percent of the input stream through a small analyzer during the course of the run, thereby determining the amount introduced, and comparing this analysis with the analysis of the exit stream obtained by the analytical absorbers. However, the small input

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analyzer seemed to be giving spurious results, very much on the low side. It was therefore decided that in this run and subsequent runs, the small input analyzer would no longer be used, but an actual analysis would be made of the material caught in the main tower by extracting it. A further advantage of this procedure was that it eliminated the uncertainty resulting from the amount of radioactivity held back in portions of the system upstream of the main reactor, a quantity which because of the design could be different for the main tower from that for the input analyzer.

Accordingly, the main tower was extracted and the results of the activity counts of the various parts of the system are given in Table II.

Reference to Table I will show that the percentage efficiency for the 17-inch length for both this run and Run 5 is not in agreement with that for Run 6. The calculated efficiencies are apparently on the high side. The reason for this is undoubtedly that not all of the radioactivity in the exit gas from the main tower was being caught by the analytical absorbers, partly because a really efficient analytical absorbing system had not yet been developed and partly because the lower efficiency of the main tower at this temperature allowed a higher concentration of radioiodine to enter this relatively inefficient absorption system. In actuality, the efficiency data of Table I are not completely reliable until Run 7, in which the final analytical absorption system was used. It will be observed in Table II, for example, that in all cases the last analytical absorber in the series was still catching a measurable quantity of radioactivity, confirming the suspicion that an unmeasured quantity of radioactivity was escaping.

Run 5. In this run at 150°C, two modifications of the system were made:

1. The dry analytical towers, which were identical with the main tower except only 10 inches long, were placed directly in series with the main tower and were extracted individually. This change was equivalent to increasing the length of the main tower by increments of 10 inches, and extracting the three dry towers individually made it possible to obtain an estimate of the relationship between the length of tower and iodine removal efficiency.
2. The dry towers were therefore eliminated as analytical absorbers, and were replaced by two silver nitrate solution scrubbers in the analytical system, a type of absorber which was felt to be more efficient than the dry tower for low concentrations. At this point, therefore, the analytical system consisted of a series of three wet scrubbers, the first being an alkaline scrubber and the second two silver nitrate solution scrubbers.

The first data on the effect of length were obtained and are reported in Table I. However, once again the final analytical absorber contained

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quite an appreciable amount of radioactivity indicating again that some activity was escaping and not being counted. This fact is reflected in the high efficiencies obtained for this temperature, which were indicated to be spurious by the results of Run 6.

Run 6. In this run, two further changes were made:

1. The alkalinity of the sodium hydroxide scrubber was greatly increased.
2. In extracting the main tower the first six inches of length were extracted separately from the entire tower to give information on the efficiency of a length shorter than the main tower.

It will be observed in Table II that the sodium hydroxide scrubber efficiency had been greatly increased by the increase in alkalinity. Apparently in both the previous runs, considerable material was passing through the sodium hydroxide scrubber because of insufficient alkalinity. As before, the first silver nitrate solution scrubbers still passed on considerable material to the second, indicating that the silver nitrate solution scrubber was not too efficient on very low concentrations. The detection of an appreciable quantity of radioactivity in the last scrubber still created a doubt as to whether some material had not escaped uncounted. However, the greatly increased efficiency of the alkaline scrubber seemed to indicate that the efficiency calculations for this run were far more valid than in any previous run. It will be observed in Table I that the calculated efficiency for the 17-inch tower dropped thereby from 97% to 86%. This latter figure is acceptable as a reasonable estimate of the efficiency at 150°C.

Two definite conclusions were drawn from this series of three runs at 150°C:

1. Higher temperatures would be required to obtain efficiencies above 90%.
2. A very alkaline sodium hydroxide scrubber is the most efficient type of scrubber. Accordingly, the two silver nitrate solution scrubbers were replaced by sodium hydroxide scrubbers in all subsequent runs. It should be pointed out that, although more efficient for low concentrations an alkaline scrubber could not easily replace the silver absorption tower because of the high concentration of NO_2 in the off-gases.

Runs 7 through 11. With the modification of the absorption system to include three very alkaline sodium hydroxide scrubbers, it was believed that at last it was possible to trap all activity passing through the dry silver nitrate towers. Therefore, from Run 7 on, it is believed that the efficiency calculations are on a valid basis. Further corroboration of this fact can be seen in the fact that with the exception of Run 9, the last two scrubbers in the analytical series

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contained no detectable activity. Using a series of three of the most efficient type of scrubber tested, and detecting no activity in the second two of the series seemed to be the best evidence obtainable for complete removal of iodine by the system. The presence of activity in the third scrubber in Run 9 may be explained by the fact that the first scrubber did not operate properly during the run. The three scrubbers went acid toward the end as the nitrogen dioxide passed through them and, therefore, passed material on to the second and third scrubbers.

In this series of runs, the following two conclusions may be drawn from the data:

1. A temperature of 220°C is most probably the optimum operating temperature. (It was observed that silver nitrate is molten at this temperature).
2. The increase in efficiency between 17 inches and 37 inches is small enough to warrant the conclusion that the 17-inch length is probably sufficient.

Run 12. The original experiments by Hanford and by this group were made using packings coated with reduced silver. All experiments with this type of coating were done by cold methods; therefore, it was felt that a comparison should be made between reduced silver coatings and the more recently employed silver nitrate coatings with the improved analytical precision of tracer methods. The silver nitrate coatings were originally used instead of reduced silver because of ease of extraction. However, since it no longer seemed likely that the towers would be decontaminated in practice, the importance of ease of extraction was no longer very great.

The packing was prepared by coating the tower saddles in place with silver nitrate, as usual, and passing through the tower a reducing atmosphere at elevated temperatures.

Run under the optimum conditions, it will be seen in Table I by comparing the results of Run 12 with those of Run 10 that the efficiency was slightly reduced. With this coating, the main tower proved far more difficult to extract, as anticipated.

Run 13. At one stage of the dissolving operation, a certain amount of ammonia is evolved. There had been some concern that the ammonia might form an explosive complex with the silver salts or might affect the absorption efficiency. Therefore, a run was made in which ammonia was introduced into the system before the run.

Before making this run, a separate test was made to determine whether the ammonia would form an explosive compound with the silver. A small tower was packed with Berl saddles which were coated with a mixture of silver nitrate and silver iodide. Ammonia vapor was passed through this tower at temperatures up to 250°C. No explosions occurred during the operation of the test,

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and no detonating compounds were formed as far as could be determined. In Run 13, itself, the Berl saddles were coated as in Run 12. Ammonia gas was passed through the main tower for about an hour before the run. As may be seen in Table I by comparing the results of Run 13 with those of Run 12 and 10, the ammonia had very little if any effect on the absorption efficiency.

3.0 Apparatus and Procedures.

3.1 Absorption Apparatus (Figure 3). The apparatus as shown in Figure 3 is the system used for Runs 7 through 13, in the tracer series. It therefore shows the final state of the apparatus after a long series of modifications. The apparatus consisted essentially of three major portions:

1. A section for preparing a synthetic mixture of gases approximating the Hanford off-gas.
2. The main absorption tower under study with two additional towers of the same type.
3. A section consisting of analytical absorbers.

Preparation of Input Mixture. The main stream consisting of air entered at 1 controlled by throttle valve 2 and flowmeter 3. A smaller stream of air entered at 4 and was controlled by throttle valve 5 and flowmeter 6. This latter stream was saturated with iodine by passing slowly through saturator 7 containing a bed of resublimed iodine. The saturator was maintained at a constant temperature below room temperature by a thermostat bath 8. The concentration of iodine in the gas stream leaving the saturator was thereby known from the vapor pressure data on iodine. This small stream of air containing a known concentration of iodine was introduced into the main stream in such a proportion as to give the desired concentration of iodine in the final mixture. During the tracer runs the main stream flowed at a rate of 2 cubic feet per minute and the iodine bearing stream was added at a rate to give 0.04 mg. of iodine per cubic foot, the average Hanford concentration. Since the Hanford off-gases were known to contain large volumes of oxides of nitrogen, a continuous stream of NO₂ was added during the runs from tank 9. Up to this point the apparatus was identical for both the cold and the tracer runs with one exception. Since the Hanford off-gases contained water vapor, a humidifying system was incorporated in the cold apparatus. This system was not necessary for the tracer runs since water vapor was introduced by means of the solutions in bulbs 10 and 11.

The I-131 was introduced in the following way into the main gas stream in the tracer runs. Two 50 cc. hypodermic syringes 12 and 13 were attached to two 50 cc. bulbs 10 and 11. The hypodermic syringes contained fluorolube oil. Fifty milliliters of a water solution containing 1 to 2 millicuries of I-131 were introduced into bulb 10 and fifty milliliters of a 50% nitric acid solution into bulb 11. The plungers of the hypodermic syringes were activated by a bar 14 upon which they rested, which was elevated at a constant and predetermined rate by a screw mechanism. The screw mechanism was run by a synchronous motor 15. The mechanism was operated at the rate necessary to introduce both solutions completely

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into the system and fill the bulbs with fluorolube oil during the course of the run. The two injection bulbs were emptied at the rate of about one-third of a milliliter per minute. The iodine bearing solution and the acid solution were slowly dripped into a bed of beads in an evaporator 16 which was heated by an infrared lamp 17. The main stream of air, bearing the normal iodine, was passed through preheater 18 and entered the evaporator in such a way as to draw up a small stream of air with it containing the radioiodine. This final input gas mixture was then passed through preheater 19 maintained at about 50°C above the temperature of the main tower.

The Main Absorption System. The main absorption tower consisted of a tube containing a packed section 17 inches by 2 inches in diameter. The packing was one-quarter inch Berl saddles coated with silver nitrate or with silver. This reactor was enclosed in an oven. In the earlier cold runs, the preheater was depended upon to heat the main reactor, which was simply insulated. This method was not as precise in maintaining temperature. The two towers 21 and 22 were absorption towers with beds packed with silver nitrate Berl saddles, 10 inches long and 2 inches in diameter. Towers similar to these were used as the analytical absorbing system in the cold runs and were extracted for silver iodide analysis. The towers 21 and 22 in the tracer runs were at first used in the analytical absorption system but in the last series of runs were used as shown as extensions of the main absorbing tower.

The main tower characteristics are given in the following table:

Diameter	2"
Height	17"
Packing Area	5.4 sq. ft.
Coating	6.3 g. AgNO ₃ /sq. ft.
Iodine Capacity at 30% of AgNO ₃ Reacted . . .	7.6 g.

The Analytical Absorbers. The final and most successful analytical scrubber system consisted of three gas lift scrubbers 23, 24 and 25 containing a 20% sodium hydroxide solution. Portions of the scrubbers were immersed in water bath 26. To keep the solution in the scrubbers highly alkaline, a bed of sodium hydroxide pellets was placed at the top of the first scrubber over which the solution passed by the action of the airlift, gradually dissolving the caustic to replace that reacted with the NO₂.

Generation of Silver Nitrate Towers. To generate the silver nitrate dry towers such as 20, 21 and 22, a two molar silver nitrate solution was poured through the tower and the tower allowed to drain. The coating was partially dried by a compressed air stream and the drying was completed in place in the tower oven.

Extraction of Components of Systems for Counting. To obtain samples for counting, the towers 20, 21 and 22 were removed from the system after the run and extracted repeatedly with one normal silver nitrate solution until no further count was obtained. The alkaline scrubbers 23, 24 and 25 were removed from the system and drained and were extracted with water. All parts of the system after

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each run were also monitored to determine whether any appreciable quantities of radioactivity were located in parts of the system other than the absorbers. In addition, various parts of the system upstream of the main tower 20 were extracted after each run. The various components of the evaporator were extracted after each run. The various components of the evaporator were extracted, since small amounts of radioactivity were frequently not evaporated from it. In addition, an attempt was made after each run to extract some of the radioiodine dissolved in the fluorolube in bulb 10. The entire system was capable of being disassembled and extracted so that at frequent intervals such parts of the system as the pre-heaters were extracted to determine whether any activity was being lost.

3.2 Analytical Methods.

3.21 Cold Methods. In the runs with normal iodine, the most satisfactory analytical method developed for determining the iodine content of the exit gas was to pass it over a surface covered with silver nitrate at 175°C. The iodine was then removed from the surface by passing small amounts of water through the absorption tube in successive portions. The silver iodide was soluble in silver nitrate solution formed by the residual coating. The iodide was precipitated by dilution to 500 milliliters with 0.1 N nitric acid. The precipitate was filtered, dried, washed and weighed.

In order to determine the effectiveness of the extraction of silver iodide with silver nitrate and to determine the sensitivity of this analytical method, the solubility of silver iodide in 0.1 N nitric acid solution containing various quantities of silver nitrate was found.

To a solution containing silver nitrate and nitric acid, standard potassium iodide (1.000 grams per liter) solution was added from a burette until the precipitate appeared. The precipitate was coagulated by prolonged heating, cooled, filtered, washed, dried and weighed by the methods usually used in halide determinations. The amount of silver iodide in solution was determined by the difference between the iodine added as KI and the amount removed as silver iodide precipitate. Figure 1 shows the relation between silver nitrate content and solubility of silver iodide in the solution.

If a tower is coated with 2.5 g. of silver nitrate and is to be extracted with water and the extract diluted to 500 milliliters, 0.1 mg. of silver iodide will remain in solution. If 100 cubic feet of gas containing 0.001 mg. per cubic feet of iodine were being analyzed, approximately half of the silver iodide would remain in solution. In the initial experiment, where the iodine content of the entering gas was 0.8 mg. per cubic foot or more, the absorption efficiency of 99% could be established. However, when the entering gas contained only 0.04 mg. per cubic foot of iodine, efficiencies higher than 85% could not be established accurately. Another serious limitation of this analytical method was the possibility that the absorption efficiency diminished if the iodine content decreased. For these reasons, it seemed to be necessary to use I-131 as a tracer in counting methods to obtain the necessary sensitivity.

140 015

-17-

3.22 Counting Methods with I-131. Upon initiating tracer experiments at this laboratory, advice was sought of a number of experts in counting methods. It was at first suggested to the group that external end window counters be used to monitor the input and exit gas streams. After investigation this method proved inadvisable, since obtaining the necessary precision in counting a small volume of a gas stream as it passed by the counters would require a total input supply far in excess of the five millicuries restriction imposed on the group. This restriction was imposed from considerations of contamination of the Company's building and of the relatively simple precautionary handling measures required at this level. It seemed that operation at higher levels would require precautions which would impede progress, particularly in view of the fact that none of the group had worked with tracers to any extent previously.

The next proposal was to absorb iodine on silver nitrate coated absorbers constructed as annuli into which a GM tube could be placed. This procedure was discarded because it was questionable that the geometry could be reproduced from sample to sample.

The scheme finally adopted was to analyze the gas streams by absorption on silver reactors, to extract these reactors as in the cold method, and to introduce the radioactive solution into an annulus surrounding a GM tube. The same type of annulus could then be used for solution counting at any stage of the process. This method is described in detail below.

Throughout this work, invaluable assistance has been given the group by Mr. Carl Braestrup of the New York City Department of Hospitals and by members of the staff of the Health and Instrument Section of the New York Office of the Commission.

The procedure of input and analysis for I-131 in the various elements of the series of absorbers was designed for internal comparison, thus precluding the necessity for absolute determination of activity.

The 5 to 10 millicurie sample of I-131 solution, (1 to 3 ml. in volume) as obtained from Oak Ridge was diluted to 100 ml. with distilled water brought to pH 8.5 with NaOH solution. In order to evaluate roughly the activity of this "stock solution" a 5 ml. sample was titrated into a test tube and the activity of this aliquot was determined by comparison with a radium standard by means of an ionization chamber described in Brookhaven Conference Report Radio-iodine, July 28-30, 1948.

On the basis of the ionization chamber results 1 to 2 mc. of I-131 solution was introduced into the system of absorbers.

Dilutions 1/10, 1/100, 1/1000 of the stock solution were prepared, using 1 N AgNO₃ as the diluent. Fifty ml. samples of this series were counted to assure linearity of the I-131 concentration with gamma count per minute in the range of concentration obtained from the adsorption column wash solutions. The iodine held in the various absorbers was washed out with 1 N AgNO₃ solution, aliquot parts of which were counted to determine the total I-131 liberated from these columns.

-18-

In order to compare the amount of gamma radiation from the various solutions analyzed, an immersion type, neon-amylacetate filled GM tube (Mark 1, Model 80, Radiation Counter Laboratory) was surrounded by a 1/8 inch brass tube to cut out the beta activity of I-131, and a glass annular container to hold the 50 ml. sample of the solution to be counted. A cross sectional diagram of the apparatus is shown in Figure 4. Horizontal alignment was by sight, vertical adjustment being measured with a caliper. The scaler used was the standard I. and C. Nuclear instrument. It was found necessary to coat the tips of the GM tubes because of variable light sensitivity.

It was determined empirically that the filling and alignment operations on the various annular containers was reproducible to 3%. Preparing the solutions was calculated to involve an error of less than 1% with the manipulatory devices involved. The statistical probable error of counting, as calculated by the equation $e = .67 \sqrt{n}$ was kept below 1% at all times by counting more than 4300 gamma ionizations. Correction of the activity of samples for decay during the interval over which the various analytical operations were performed was made to the nearest day, which introduces an error of 4.3%. On those few samples which were run at high counting rates (2000 counts per minute or more), corrections for coincidence were made on the basis of a dead time of 3×10^{-4} seconds. The overall probable error of the analyses was:

$$\sqrt{(4.3)^2 + (1)^2 + (1)^2 + (3)^2} = \pm 5\%$$

-19-

TABLE I

Summary of Efficiencies, Tracer Runs 3 through 13

(Calculated from Data of Tables II through IV)

<u>Main Tower Coating</u>	<u>Run No.</u>	<u>Temp. (°C)</u>	<u>6" Length</u>	<u>Efficiency (%)</u>	
				<u>17"* Length</u>	<u>37" Length</u>
AgNO ₃	4	150		96.2	
	5	150		97.4	98.1
	6	150	84.3	85.7	87.1
	7	188	96.0	98.7	99.7
	9	200		99.5	99.6
	11	200	97.3	99.1	99.8
	10	220	98.2	99.9	100.
	8	235	96.3	98.4	99.8
Ag.	12	220		99.6	99.9
	13	220	96.3	99.6**	99.8

* NOTE: The 17" length of the main tower under experimental conditions is estimated to be approximately equal to the six foot tower design submitted to Hanford in ARSC-20 under plant conditions.

** NOTE: Ammonia was passed through the main tower previous to this run.

-20-

TABLE II

Summary of Data, Tracer Runs 4, 5 and 6

(Main Tower Silver Nitrate Coated, Operated at 150°C)

<u>Run 4</u>	<u>Microcuries Caught</u>
Main Silver Nitrate Tower (17" x 2" Diameter)	620.
Analytical Absorbers: NaOH Scrubber	10.2
Silver Nitrate Solution Scrubber	13.4
First Small Berl Saddle Tower (10" x 2" Diameter)	0.8
Second Small Berl Saddle Tower (10" x 2" Diameter)	0.2
<u>Run 5</u>	
Main Silver Nitrate Tower (17" x 2" Diameter)	931.
Small Berl Saddle Towers (10" x 2" Diameter) First Tower	3.0
Second Tower	4.4
Analytical Absorbers: NaOH Scrubber	11.1
First Silver Nitrate Solution Scrubber	5.0
Second Silver Nitrate Solution Scrubber	1.5
<u>Run 6</u>	
Main Silver Nitrate Tower (17" x 2" Diameter): First 6" of Length	315.
Entire 17"	320.
Small Berl Saddle Towers (10" x 2" Diameter) First Tower	3.9
Second Tower	1.5
Analytical Absorbers: NaOH Scrubber	46.1
First Silver Nitrate Solution Scrubber	1.4
Second Silver Nitrate Solution Scrubber	0.7

TABLE III

Summary of Data, Tracer Runs 7 - 11

(Main Tower Silver Nitrate Coated, Operated Various Temperatures)

		Run 7 At 188°C (Microcuries Caught)	Run 8 At 235°C (Microcuries Caught)
Main Berl Saddle Tower (17" x 2" Diameter):	First 6" of Length	1950.	1455.
	Entire 17"	2003.	1487.
Small Berl Saddle Towers (10" x 2" Diameter):	First Small Tower	17.9	4.6
	Second Small Tower	3.0	15.9
Analytical NaOH Scrubbers:	First Scrubber	6.3	3.0
	Second Scrubber	0.0	0.0
	Third Scrubber	0.0	0.0

		Run 9 At 200°C (Microcuries Caught)	Run 10 At 220°C (Microcuries Caught)	Run 11 At 200°C (Microcuries Caught)
Main Berl Saddle Tower (17" x 2" Diameter):	First 6" of Length		1550.	1102.
	Entire 17"	1053.	1578.	1128.
Small Berl Saddle Towers (10" x 2" Diameter):	First Small Tower	0.8	0.4	1.8
	Second Small Tower	0.2	0.1	0.5
Analytical NaOH Scrubbers:	First Scrubber	2.3	0.7	2.5
	Second Scrubber	0.0	0.0	0.0
	Third Scrubber	1.5	0.0	0.0

-22-

TABLE IV

Summary of Tracer Runs 12 and 13

Main Tower Reduced Silver Coated, Operated at 220°C

	Run 12 (Microcuries Caught)	Run 13 ⁽¹⁾ (Microcuries Caught)
Main Berl Saddle Tower (17" x 2" Diameter): First 6" of Length		887.
Entire 17"	384.	917.
Small Berl Saddle Towers (10" x 2" Diameter): First Small Tower	0.7	1.4
Second Small Tower	0.4	0.6
Analytical NaOH Scrubbers: First Scrubber	0.4	2.1
Second Scrubber	0.0	0.0
Third Scrubber	0.0	0.0

(1) NOTE: Ammonia Vapor was passed through the main tower for about an hour previous to beginning Run 13.

220 050

FIG. 2 GAS LIFT SCRUBBER

FIG. 4 COUNTER TUBE ASSEMBLY

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Appendix A: Proposed Design for Full Scale Plant for Hanford. In this Appendix is presented almost verbatim a report to Hanford, ARSC-20, dated April 6, 1949, giving a proposed design for a full scale plant for Hanford. At the time of this proposal, it was believed that the optimum temperature was 175°C. The subsequent tracer runs indicated that the optimum temperature is actually about 220°C. Consequently, both the heating and cooling capacity of the installation would have to be increased over that specified below.

For example, for heating to 220°C, during maximum NO₂ evolution, the estimated power consumption would be 67 Kilowatts. Thus there would be no spare heating unit if only two 36 Kilowatt heating sections were installed as specified below. Instead it would be desirable to use four such sections.

Since this Appendix is introduced solely as an illustration of a typical full scale unit, it was felt unnecessary to redesign to the new operating conditions, especially since the heating and cooling sections are merely auxiliary equipment and would be adapted to the conditions of any given installation.

The design of the absorption tower proper below remains unchanged in the light of present knowledge, and is equivalent under Hanford conditions to the 17" tower of the laboratory experiments. However, it is now advised that $\frac{1}{2}$ " Berl saddles be used rather than the 1" saddles specified below.

Proposed Design, ARSC-20, April 6, 1949, (C. S. Wynn).

1.0 Introduction. In the proposed process, dissolver off-gas is brought to the operating temperature in an electrically heated gas heater. The gas then enters at the base of a tower which is packed with 1" Berl saddles which are coated with a layer of solid silver nitrate. The iodine is removed by reaction with the silver nitrate. The exit gas from the tower is to be cooled to about 30°C in a water cooled exchanger. From this point the gas passes to a filtering system which is being designed by Hanford. The equipment described in this report is designed to handle a maximum flow of 150 standard CFM of dissolver off-gas.

Provision has not been made in the revised design for renewing the silver nitrate surface on the saddles because of the expected large capacity of the tower packing for iodine removal. The initial deposition of silver nitrate on the saddles may be accomplished by soaking the saddles in 4 molar silver nitrate solution, draining off the excess solution and drying. The silver nitrate can also be deposited by pouring the nitrate solution over the saddles a sufficient number of times to ensure wetting of the saddles, and the saddles finally dried. Report No. 18 shows an equipment layout for effecting the renewal of the silver nitrate surface of the saddles, if this operation appears necessary for continued operation.

2.0 Description of Equipment.

2.1 Gas Heater (Figure 5). The gas heater consists of a vertical stainless steel shell, 7'2" high, containing two 36 Kilowatt heating sections for direct heating of the gas. One of the heating sections is intended as a spare in case the other becomes inoperative, since only one heating section is required to bring the dissolver off-gas to a maximum operating temperature of 175°C.

-28-

The heater design is based upon equipment as supplied by the Edwin L. Wiegand Company, 7500 Thomas Boulevard, Pittsburgh, Pennsylvania. Each heating section required four Catalog No. TDH-18AXX Chromalox Tubular Air Duct Heaters, rated at 9 KW, 230 volts, 3 phase, stainless steel construction.

It is recommended that protection against excessive temperature be provided for each TDH heater unit by means of Catalog No. SMMR-6 BG Chromalox Thermal Cutout Control, temperature range 100 to 650°F, with 20' stainless steel capillary and stainless steel threaded fitting. Catalog No. K-3500 A.C. Magnetic Contactors, rated at 230 volts, 60 cycle, 3 pole, 45 amps. per pole, would be required with the cutout switches.

The Chromalox indicating temperature control, No. MR-6 KLSS, is recommended for each heating section. The range of this instrument is 100 to 650°F. The bulb of this instrument should be placed in a well in the inlet line to the tower. The cost of the heating elements and controls would be of the order of \$3000 and delivery could be made in approximately four to six weeks after acceptance of order.

Two additional methods of electric heater construction were considered. In one of these methods, strip heaters are clamped to a suitable length of 4" pipe. Including the spare heater, 72 No. SE240IXX Chromalox strip heater units are required. These units are rated at 230 volts, 1000 watts, curved to an inside radius of $2\frac{1}{4}$ ". Eight No. 5971 Chromalox utility clamps are required for fastening the strip heater units to the pipe. The entire gas heater unit should be protected against excessive temperature by means of eight No. SMMR-6 Chromalox Thermal Cutouts with No. K-3500 A.C. magnetic contactors. Two No. MR-6KLSS Chromalox Temperature Controls would be required for the two sections of the heater. If the piping to which the strip heaters are mounted is horizontal, then it is recommended that the strips be clamped to the lower third of the periphery of the pipe. An air space of $1\frac{1}{2}$ " to 2" should be left between the strips and the insulating material. The cost of electrical materials for a gas heater made up of strip heaters clamped to pipe with controls is of the order of \$1700. Approximately 52 feet of 4" pipe would be required for the 72 strips.

In another method, eight No. GCH-612XX Chromalox Gas Preheaters, rated at 9 KW, 230 volts, 3 phase, are proposed. These units may be obtained in stainless steel construction. Each unit is about 51" in length overall and $8\frac{1}{2}$ " in diameter. The gas connections between units would be piped in series. The units are connected electrically so as to give two heating sections of 36 KW each. Each preheater unit should be protected with a thermal cutout switch and a temperature controller should be provided for each of the two sections. The estimated cost for a 72 KW heater is of the order of \$5200.

The heater design presented in the Airco drawings accompanying this report appears to have some advantage in compactness and piping simplicity over the alternative methods described. However, field conditions may dictate, in part, the type of heater best suited for the job.

-29-

2.2 Tower (Figure 6). The tower for contacting the dissolver off-gas for iodine removal over solid silver nitrate consists of a stainless steel shell 14" in diameter by 7'2" high. A 6-foot packed section of 1" Berl saddles is recommended for the process. The tower and heater are so connected that the tower packing may be flooded with nitrate solution if desired. The tower is provided with gas sampling tubes so that the course of the iodine removal may be followed by suitable analytical procedures.

The tower characteristics are given in the following table:

Packing Area:	1" Saddles	455 Sq. Ft.
	$\frac{1}{2}$ " Saddles	859 Sq. Ft.
Coating	6.3 g. Ag NO ₃ /Sq. Ft.	
Iodine Capacity at 30% of Ag NO ₃ Reacted:	1" Saddles	642 g.
	$\frac{1}{2}$ " Saddles	1211 g.
Life Expectancy (Assuming 2 g. I ₂ Evolved Per 8 Hr. Shift):		
	1" Saddles	Over 300 Shifts
	$\frac{1}{2}$ " Saddles	Over 600 Shifts

2.3 Gas Cooler. The exchanger for cooling the off-gas from the tower is not shown in the layouts since its location can probably be more flexible than the other equipment. A description of a Griscom-Russell Company design for a gas cooler is given. The total heat load for cooling 150 standard CFM of gas from the iodine tower is of the order of 93,500 Btu/hr. with cooling water of 70°F. With 3000 lbs. of water per hour entering at 70° and leaving at 101°F, there would be required for the cooling job either four LXX-124 Twin G-Fin sections or two LXX-248 Twin G-Fin sections connected in series on both the gas and water sides. The pressure drop on the gas side using the four shorter sections would be approximately 0.04 PSI. An estimated cost of four LXX-124 sections in stainless steel construction is of the order of \$3400 and delivery is 16 to 19 weeks.

Because of the long delivery date, it might be necessary to consider double pipe exchangers of comparable capacity.

3.0 Equipment Layouts. A suggested layout is shown in Figure 7. The nature of the equipment lends itself fairly well to a compact arrangement and with minor changes can meet actual field conditions.

AIR REDUCTION NEW YORK, N. Y. APPARATUS RESEARCH DEPARTMENT		UNIT	SIZE	DRAWING NO.	REVISIONS
TOLERANCES UNLESS OTHERWISE SPECIFIED DEC. FRACT. ANGLES		PART	C		
SCALE	FINISH	MATERIAL	ASS'Y. & B. M. NO.		
		FIRST A. R. O. NO.	SUPERSEDES NO.		
			SUPERSEDED BY NO.		
			APPROVED BY

FIG. 3
ABSORPTION APPARATUS

SIZE	DRAWING NO.	REVISIONS
C		

940 024

FIG. 6 TOWER

AIR REDUCTION
NEW YORK, N. Y.
APPARATUS RESEARCH DEPARTMENT

UNIT	TOWER	
PART		
MATERIAL	DRAWN BY	
FIRST A. R. O. NO.	CHECKED BY	
	REVISED BY	

SIZE	DRAWING NO.	REVISIONS
C		
ASSY. & B. M. NO.		
SUPERSEDES NO.		
SUPERSEDED BY NO.		
APPROVED BY		

TOLERANCES UNLESS OTHERWISE SPECIFIED
DEC. FRACT. ANGLES
SCALE FINISH

DETAIL "A"
SCALE: 3" = 1'-0"

NOTE: ALL MAT'L TO BE TYPE 347
STAINLESS STEEL. USE WELDED
GAS TIGHT CONSTRUCTION
THROUGHOUT.

AIR REDUCTION

NEW YORK, N. Y.

APPARATUS RESEARCH DEPARTMENT

UNIT TOWER

PART

SIZE C DRAWING NO. REVISIONS

ASS'Y. & B. M. NO.

SUPERSEDES NO.

SUPERSEDED BY NO.

APPROVED BY

TOLERANCES UNLESS OTHERWISE SPECIFIED

DEC. FRACT. ANGLES

SCALE

FINISH

MATERIAL

FIRST A. R. O. NO.

DRAWN BY

CHECKED BY

REVISED BY

-31-
1/2" MESH WIRE CLOTH
8# GA. (0.1820") WIRE
TACK WELD IN PLACE

NOTCH OUT HOOP TO
RECEIVE BARS

13 7/8" DIA.

DETAIL "A"
SCALE: 3" = 1'-0"

NOTE: MAT'L TO BE TYPE 347
ALL STAINLESS STEEL USE WELDED
GAS TIGHT CONSTRUCTION
THROUGHOUT.

TOWER
SCALE: 1 1/2" = 1'-0"

FIG. 6 TOWER

UNCLASSIFIED

SIZE C DRAWING NO. REVISIONS

C

DRAWING NO.

REVISIONS

40 031

AIR REDUCTION NEW YORK, N. Y. APPARATUS RESEARCH DEPARTMENT		UNIT TOWER AND HEATER UNIT		SIZE C	DRAWING NO.	REVISIONS
TOLERANCES UNLESS OTHERWISE SPECIFIED DEC. FRACT. ANGLES		PART ARRANGEMENT		ASS'Y. & B. M. NO.		
SCALE		MATERIAL		DRAWN BY		SUPERSEDES NO.
FINISH		FIRST A. R. O. NO.		CHECKED BY		SUPERSEDED BY NO.
				REVISED BY		APPROVED BY

PLAN

FRONT ELEVATION

SIDE ELEVATION

REFERENCE DRAWINGS

- Fig. 5 GAS HEATER
- Fig. 6 TOWER

NOTE:

INSULATE EQUIPMENT & INTERCONNECTING PIPING WITH 1/2" 85% MAGNESIA OR EQUIVALENT.

Fig 7. TOWER AND HEATER UNIT ARRANGEMENT

SIZE C	DRAWING NO.	REVISIONS
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NEW YORK, N. Y.
APPARATUS RESEARCH DEPARTMENT

TOLERANCES UNLESS OTHERWISE SPECIFIED

DEC.	FRACT.	ANGLES
------	--------	--------

SCALE	FINISH
-------	--------

UNIT

PART

MATERIAL	QTY	UNIT	PRICE	AMOUNT	TAXES	TOTAL
Cement	100	bags	1.20	120.00	12.00	132.00
Sand	200	cubic yards	0.80	160.00	16.00	176.00
Gravel	150	cubic yards	0.90	135.00	13.50	148.50
Lumber	500	boards	0.30	150.00	15.00	165.00
Bricks	1000	bricks	0.15	150.00	15.00	165.00
Paint	50	gallons	0.40	20.00	2.00	22.00
Nails	100	pounds	0.05	5.00	0.50	5.50
Total				645.00	64.00	709.00

FIRST A. R. O. NO.

DRAWN BY

CHECKED BY

REVISÉD BY

SIZE	PRICE
12	\$12.95
14	\$14.95
16	\$16.95
18	\$18.95
20	\$20.95
22	\$22.95
24	\$24.95
26	\$26.95
28	\$28.95
30	\$30.95

C

DRAWING NO.

ASS'Y. & B. M. NO.

SUPERSEDES NO.

SUPERSEDED BY NO.

APPROVED BY

REVISIONS

[illegible]

NOTES: All Material Stainless Steel Type 347.
Gas Tight All Welded Construction.
Weld Flanges of "Chromolox" Heaters
to Casing & Plug-Weld Any Holes in
Flanges Which are Exposed to Gas Pressure.

FIGURE 5: GAS HEATER

SIZE	PRICE
Small	\$12.95
Medium	\$14.95
Large	\$16.95

C

DRAWING NO.

143-026

REVISIONS

1

AIR REDUCTION NEW YORK, N. Y. APPARATUS RESEARCH DEPARTMENT			UNIT TOWER AND HEATER UNIT		SIZE C	DRAWING NO. 143-024	REVISIONS
TOLERANCES UNLESS OTHERWISE SPECIFIED DEC. FRACT. ANGLES			PART ARRANGEMENT		ASS'Y. & B. M. NO.		
SCALE			MATERIAL		DRAWN BY		SUPERSEDES NO.
FINISH			FIRST A. R. O. NO.		CHECKED BY		SUPERSEDED BY NO.
REVISIONS			REVISED BY		APPROVED BY		REVISIONS

PLAN

FRONT ELEVATION

SIDE ELEVATION

REFERENCE DRAWINGS

Fig. 5 GAS HEATER
 Fig. 6 TOWER

NOTE:

INSULATE EQUIPMENT & INTERCONNECTING
 PIPING WITH 1/2" 85% MAGNESIA OR
 EQUIVALENT.

Fig 7. TOWER AND HEATER UNIT ARRANGEMENT

SIZE C	DRAWING NO. 143-024	REVISIONS
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