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EFFICIENCY OF SILVER RECOVERY FROM AIR FORCE PHOTOGRAPHIC OPERATIONS

DIRECTORATE OF ENVIRONICS
TYNDALL AIR FORCE BASE, FLORIDA 32401

JULY 1975

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AIR FORCE CIVIL ENGINEERING CENTER
(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
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In order to ascertain the efficiency of the silver recovery techniques presently employed at United States Air Force photographic processing facilities, a field sampling program was undertaken to obtain actual performance data. Since silver recovery by metallic replacement utilizing cartridges was found to be the most frequently applied method of recovery, emphasis was placed on this recovery technique. An electrolytic recovery tailing operation was also sampled to determine the efficiency of recovery utilizing this technique.

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Results of this study are reported in terms of cartridge performance with time, volume of fix processed, and average silver loading. Data reflect actual in-the-field efficiencies and indicate that effective silver recovery techniques are available for Air Force application.

PREFACE

This report was prepared by the Air Force Civil Engineering Center (AFCEC), Tyndall Air Force Base, Florida, under Job Order Number 20540306.

This report summarizes work done between August 1974 and June 1975. Lt Brian D. Bennett was project engineer.

The author wishes to thank the personnel assigned to the photographic operations studied during this research effort for their support and timely assistance. The author also acknowledges the timely support of Mr Tom Stauffer, OL-AA, AFCEC, in providing the chemical analysis required to support this project.

This report has been reviewed by the Information Officer (IO) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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TABLE OF CONTENTS

LIST OF FIGURES

SECTION I

INTRODUCTION

The Air Force generates large quantities of silver-bearing waste water from its photographic processing operations. All processes, black and white or color, still, motion picture, and radiographic, generate waste waters containing soluble silver compounds of varying concentrations depending on the particular process. Recovery of the silver generated in these operations has received increased emphasis not only for economic reasons, but also because the permissible effluent discharge levels for this toxic heavy metal are low and may very well be reduced further in the future. The State of Illinois, for example, has adopted a silver concentation of 0.005 milligram/liter as the general standard for water quality (Reference 1). It is anticipated that additional states will adopt standards which are equally as stringent as those of Illinois.

The Environmental Protection Agency's Draft Development Document for Effluent Limitations Guidelines and Standards of Performance, February 1975, addresses silver wastes generated from the photographic processing industry and from medical X-rays. Although these discharge limitations are only proposed at this time, they serve as a good indication of what the final standards are likely to impose. Best practicable control technology currently available and best available technology economically achievable call for a maximum daily discharge of 0.015 pound of silver per 1000 ft^2 of film processed. The average of daily values taken over a 30-consecutive-day period shall not exceed 0.008 pound per 100 ft^2 of film processed.

Silver recovery must be practiced not only to meet these discharge standards, but also to provide treatment of spent photographic solutions in biological treatment plants. Studies performed by the USAF Environmental Health Laboratory, Kelly Air Force Base, have indicated that silver removal is a mandatory requirement for photowaste being introduced into a biological treatment system (Reference 5).

In order to attain these standards and provide for biological treatment of spent photographic solutions, efficient methods of silver recovery must be employed on Air Force photographic processing units. These units currently employ either electrolytic recovery, metallic replacement, or a combination of both in order to recover silver. A field sampling program to determine typical silver recovery efficiencies and operational conditions was performed to insure that the Air Force possesses the capability to meet future environmental constraints without compromising its operational capabilities.

SECTION II

METHODOLOGY

SILVER RECOVERY

Three alternate methods of recovering silver from spent chemical solutions exist. Their applicability will vary greatly depending on the size and type of operation for which they are intended.

a. Chemical Precipitation:

Chemical precipitation of silver from photographic fixer solutions can be accomplished by adding various chemicals to the spent baths. The operation is carried out in batch mode, forming a silver bearing sludge and a supernatant which must be drawn off. The sludge is then filtered, dried, and packaged for shipment to a refinery. This dried sludge contains between 40 to 70 percent silver. Baths delivered using this technique must be discarded since they no longer are suitable for use in photographic processing.

The most common chemical precipitant used is sodium sulfite which is added to the bath after sodium hydroxide has been added to minimize formation of hydrogen sulfide gas. The silver sludge is formed by the reaction:

$$Na_2S + 2\ NaAgS_2O_3 \rightarrow Ag_2S \downarrow + 2Na_2S_2O_3 \qquad \text{(Reference 2)}$$

The overall efficiency of this reaction is high, usually 100 percent, due to the relatively low solubility of silver sulfide.

Chemical precipitation offers an economical nonelectric method of silver recovery, requiring a minimum of skilled operation. However, the settling times are usually prohibitive, with a large area needed to process the spent solutions. This method of recovery is not widely used in Air Force operations.

b. Metallic Replacement:

"Metallic replacement occurs when a metal such as iron comes in contact with a solution containing dissolved ions of a less active metal such as silver," (Reference 3). Silver will displace several metals in a solution, including iron, zinc and copper, and drive these elements into solution. Eastman Kodak® is the primary producer of the metallic replacement system, which finds extensive use in the Air Force inventory. The system consists of an all-plastic, 5-gallon drum which is filled with a spun-iron filler, and has a PVC plastic circulating unit attached to the top of the container as a means of introducing and circulating the fixer solution in the container (Figure 1), (Reference 4). The lid is

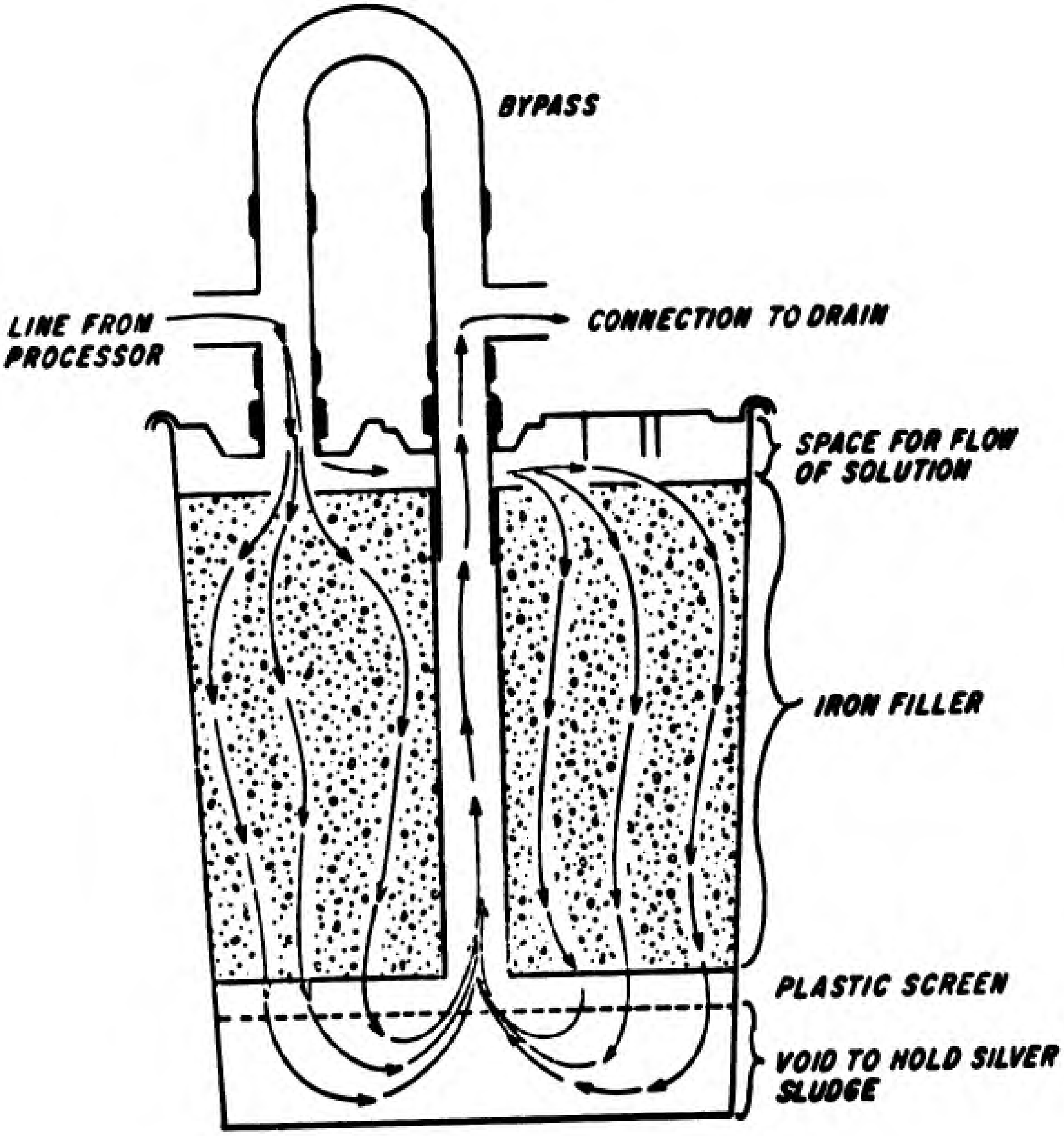

Figure 1. Cutaway of Kodak® Cartridge

sealed in place to maintain cartridge integrity for shipping to a refinery. Cartridges are theoretically designed so that "one atom of iron will be exchanged for two atoms of silver" (Reference 2). On a weight basis, almost four pounds of silver would be produced for every pound of iron consumed.

The effective life of metallic replacement cartridges is determined by a number of factors. First, the rate of fixer flow through the cartridge must be slow enough to allow complete reaction to take place. A maximum continuous flow of 300 millimeters per minute is generally recommended. Second is the quantity of silver in solution processed by the cartridge. This will vary according to the material processed, the amount of silver exposed, and other factors. The acidity of the solution processed will also affect cartridge exhaustion rate and performance. A solution that is too acidic will result in premature exhaustion of the steel wool. Highly alkaline solutions will inhibit the replacement reaction. The optimum acidity is in the range of 4 to 6 pH, which is normally within the range used for photoprocessing.

Metallic replacement offers several advantages over other silver recovery techniques. The system requires no electrical connections or addition of chemicals and offers high efficiency with minimum maintenance. However, the fix must be discarded after desilvering because of the high iron concentration resulting from the replacement reaction.

Use of metallic replacement cartridges finds wide Air Force application and is especially advantageous at installations handling smaller volumes of spent fix.

c. Electrolytic Methods:

The electrolytic method of silver recovery employs a controlled, direct current between an anode and a cathode hung in the fixing solution to remove the silver. The silver is deposited on the cathode in the form of a nearly pure plate, typically 95 percent (Reference 4).

Electrolytic systems have been installed two ways. The first is to desilver the fix overflow from a processing machine as it is discharged to the sewer. This method can be either a continuous or a batch operation depending on the volumes to be processed. The second method is to desilver the fix continuously at the same rate that it is added during processing and to recirculate the desilvered fix. This minimizes the silver lost by dragout by maintaining a low silver concentration in the fixer. It has been found that the silver concentration of the recirculating fix can be maintained as low as 0.5 gram/liter with proper operation and control of the electrolyte process.

The main problem encountered in the electrolytic recovery operation is a reaction known as sulfiding. During electrolysis, competing reactions occur at the cathode. The greater the electric current utilized, the faster will be the reactions. A limit exists when the current gets so high that silver ions cannot migrate to the cathode fast enough. This results in decomposition of the thiosulfate in the fixer and the formation of sulfide. Sulfiding cannot be tolerated in fix recirculating systems, and the current density must be closely monitored to insure that this contaminant is not produced. Formation of sulfide not only destroys the fix but also reduces the current efficiency and the quality of the silver plate.

Several factors influence the plating process. Agitation of the solution undergoing electrolysis is probably the single most important consideration in obtaining efficient plating without decomposing the fixer bath. Depending on the type of fixer used, different currents may be utilized. Ammonium thiosulfate will tolerate higher currents than sodium thiosulfate and, as such, the silver is plated more efficiently. Silver in an acid fix is plated more efficiently, with the optimum being in the range of 4.5. The addition of sulfate to the fixer during electrolysis will inhibit the formation of sulfide and increase the quality of the plate.

The major advantage of the electrolytic process is that the fixer can be reused. This is an economic advantage to those installations processing large amounts of spent fix. The silver plate is of a high purity, 95 percent, and can easily be handled in the form of a solid.

SECTION III

FIELD SAMPLING PROGRAM

1. USAF HOSPITAL, TYNDALL AIR FORCE BASE

The Radiology Department, USAF Hospital, Tyndall Air Force Base, processes medical diagnostic X-rays using a Kodak® PR X-omat Model M6A-N automatic processor (Figure 2). Developer and fix solutions are fed to the processor automatically upon injection of the films to be processed. A continuous water rinse flows through the processor to the drain. The developer and fix which overflow during the processing operation are processed through a Kodak® cartridge prior to discharge to the sewer. A schematic of the system is shown in Figure 3.

The initial sampling program was established utilizing two Sigmamotor automatic samplers: one to sample the rinse water stream and the other to sample the desilvered effluent from the cartridge. Twenty-four hourly samples were collected and composited daily for each stream. The results indicated effective silver removal by the cartridge with no silver being detected in the rinse water during the sampling period. All analyses were performed using atomic absorption spectroscopy. After only 12 days of operation, the sampling program was suspended due to a malfunction in one of the samplers.

Although the results were encouraging, a longer sampling period was required to adequately address the capability of the cartridge. An extended sampling period was outlined to determine the removal efficiency and the silver recovery capacity of the cartridge.

A survey to determine the amount of spent fix generated daily was undertaken along with a re-evaluation of the sampling methods employed. The amount of waste fixer generated was sufficiently small, about 4 to 5 gallons per day, to permit collection of the entire daily discharge. This was the basis for the revised sampling technique employed and the elimination of the inaccuracies caused by compositing of samples. Not only could a more representative sample of the total daily waste be obtained, but the inaccuracies caused by slack periods or period of no processing were eliminated. A daily film and fix inventory was maintained to define the operating parameters and estimate the silver being input to the processor. Figure 4 shows the silver concentration in the effluent from the cartridge versus time. It was readily seen that the cartridge was an excellent silver recovery technique during the early stages of operation. The efficiency deteriorated with time and a distinct breakpoint was evident, at which time the cartridge was no longer efficient and large amounts of silver passed through the drain.

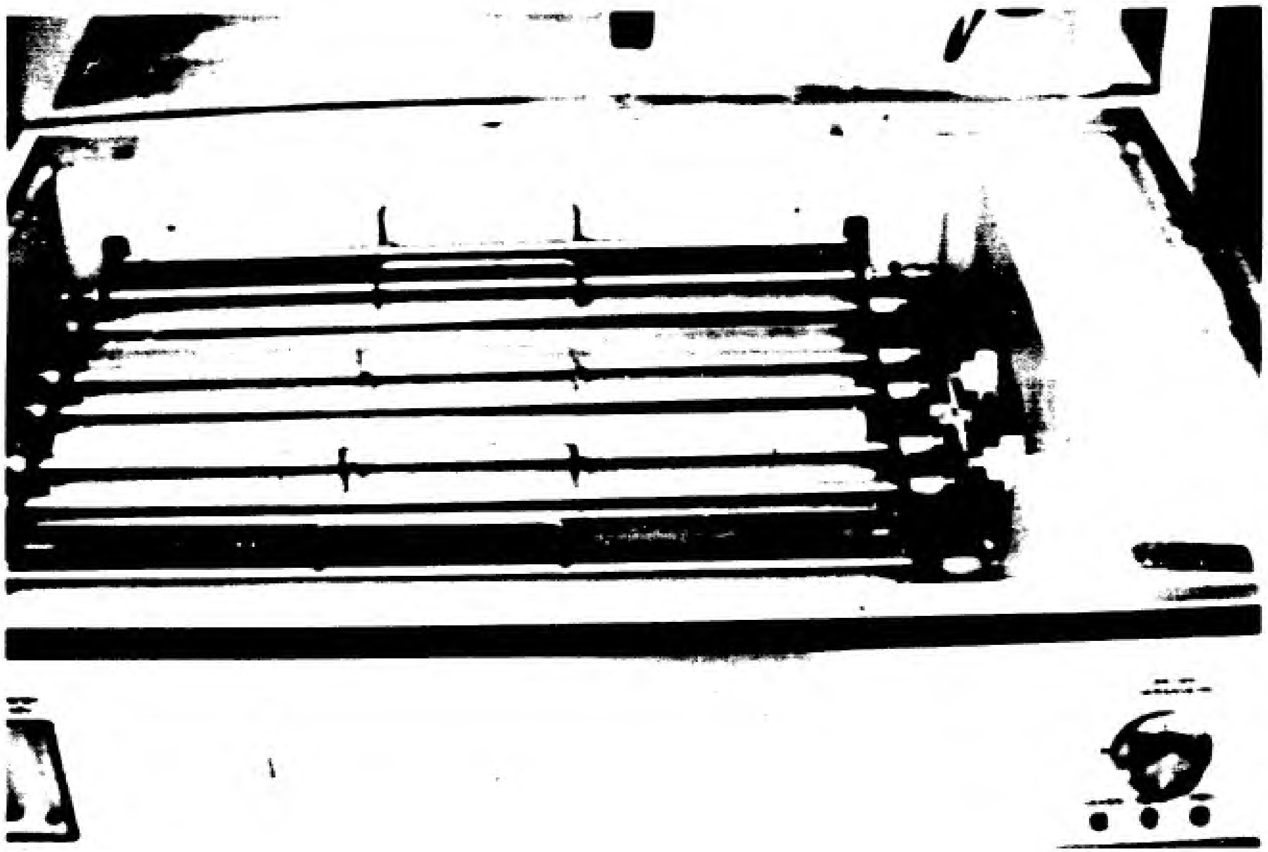

Figure 2. Automatic Processor - USAF Hospital, Tyndall Air Force Base

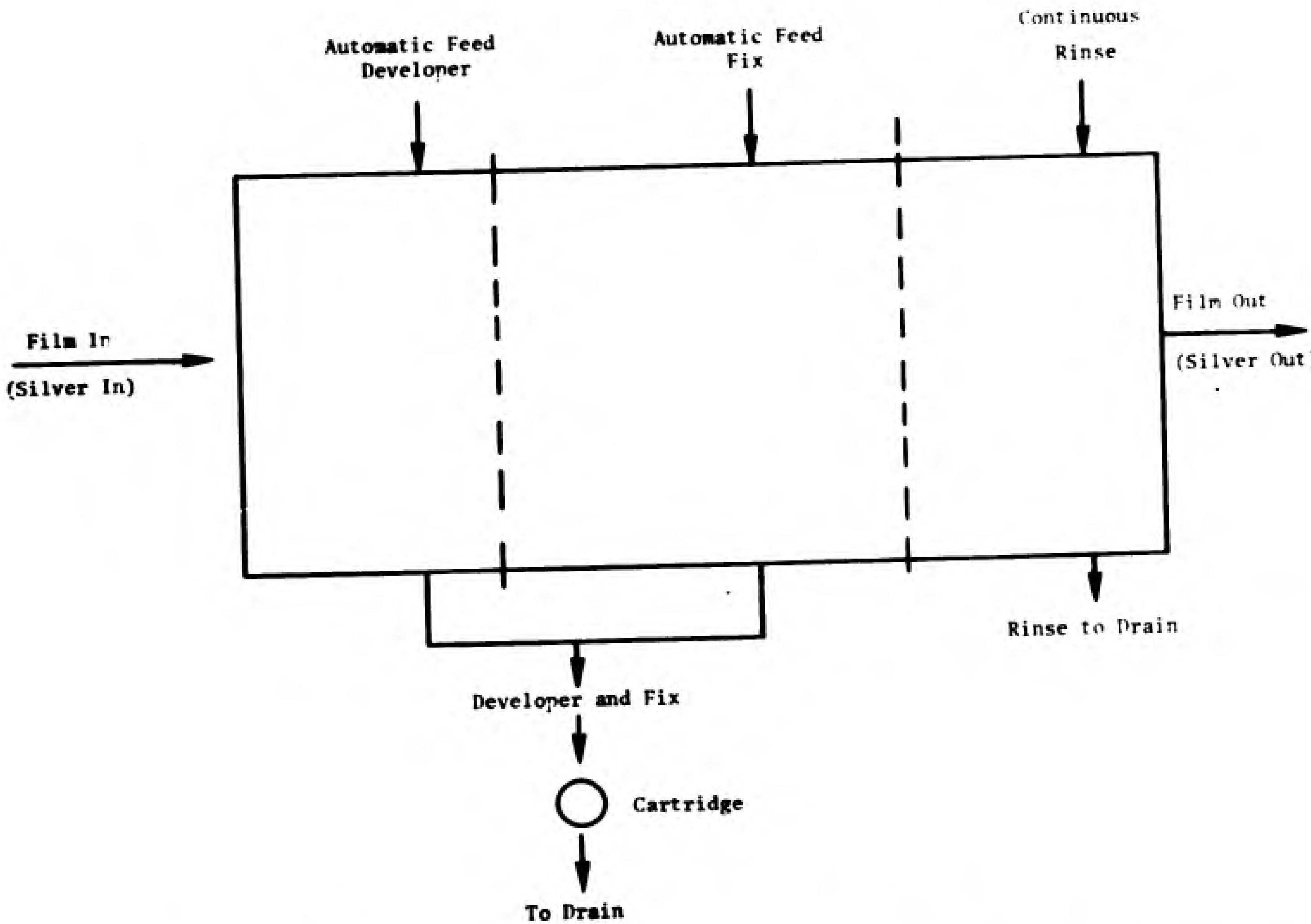

Figure 3. Flow Schematic - X-Ray Processor, USAF Hospital, Tyndall Air Force Base

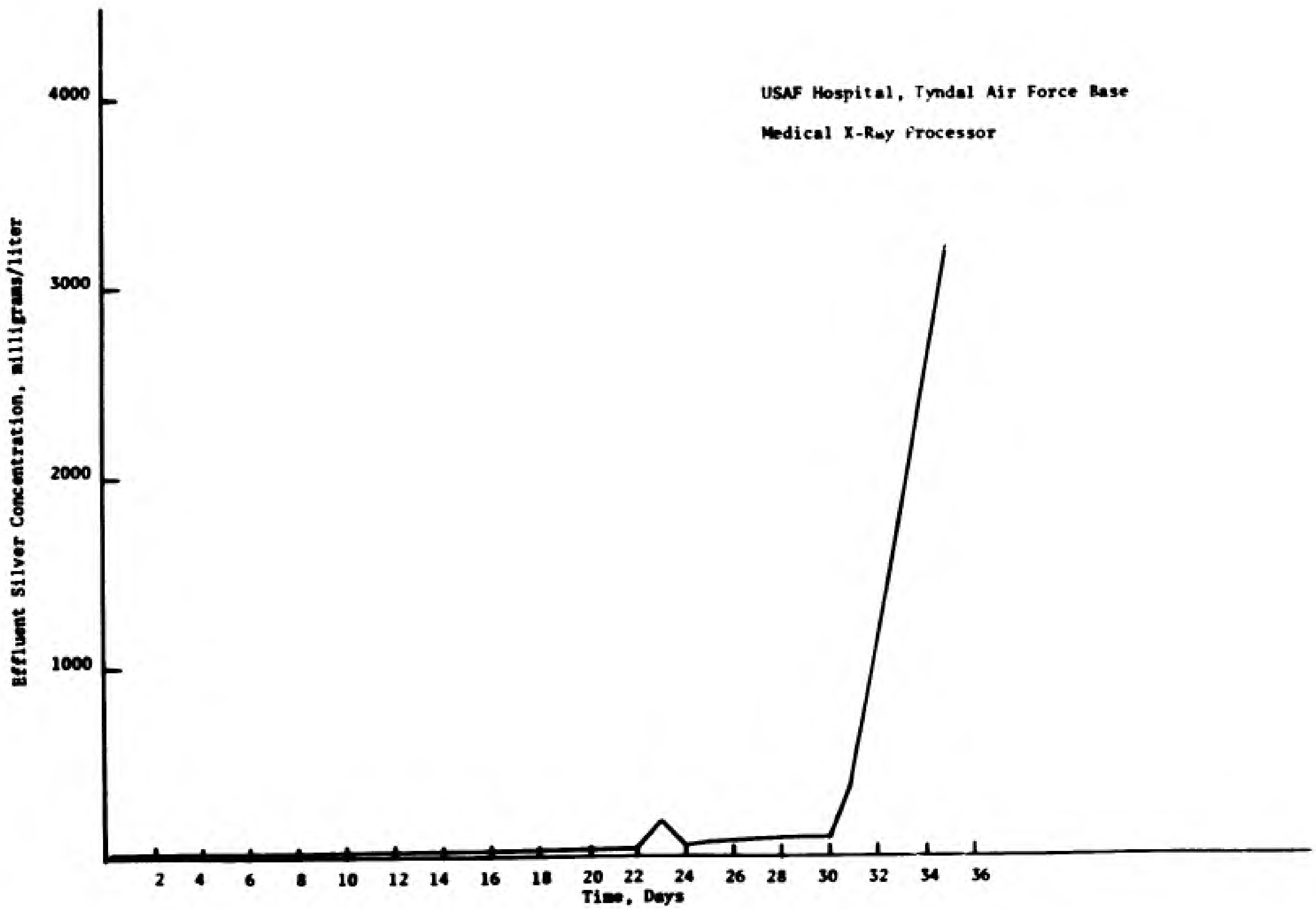

Figure 4. Medical X-Ray Processor - Effluent Silver Concentration Versus Time

Figure 5 shows the effluent silver concentrations from the cartridge as a function of the amount of fix processed. Once again, the removal was excellent and quite uniform, regardless of the amount of fix processed per day during the early stages of operation. The breakpoint was experienced in the region of 160 gallons of fix processed which is the manufacturer's recommended capacity for this particular system, based on a one gram/liter allowable silver concentration in the effluent.

From the film inventory, average values of silver input to the processor were estimated based on size and number of films processed in a 24-hour period and on the silver potentially available for recovery (Reference 3). The results indicate that the silver in the effluent was independent of the amount of silver fed to the cartridge until the cartridge neared depletion. Figure 6 shows the silver concentration in the discharge from the cartridge versus the average silver load input.

Since cartridge performance depends on flow rate through the metallic media, an attempt was made to determine flow conditions. The system, as installed, contained no flow control devices and handled all of the flow as produced by the processor. The flow rate from the processor is highly variable, depending on the size and number of films processed per run. The manufacturer's literature suggests a fixer flow of 100 milliliters per 14- by 17-inch film processed for the processing loading being handled at this location. Attempts to sample the discharge for flow determination were inconclusive due to high variability.

A comparison of analytical laboratory analysis was made versus those results obtained using the Kodak® test strips. Results indicate that the test strip serves only as an approximation to the true silver concentration. Readings of between 0.5 to 0.8 gram/liter and 2.5 to 3.0 gram/liter silver were obtained on separate effluent samples using the test strips. Corresponding values of silver concentration were 1.71 grams/liter and 3.22 grams/liter, respectively.

The average silver concentration fed to the cartridge as sampled during this investigation was 10.3 grams/liter or 0.33 troy ounce per liter. Based on data accumulated during the study, a yearly volume of 1,070 gallons of spent fix can be produced. This amounts to approximately 1,340 troy ounces of recoverable silver generated per year.

2. PHOTOGRAPHIC LABORATORY, TYNDALL AIR FORCE BASE

The Base Photographic Laboratory, Tyndall Air Force Base, processes spent rapid-fix solutions for recovery of silver in a batch mode utilizing a metallic replacement cartridge (Figure 7). Most of the spent fix, 15 to 20 gallons per week, is generated as a result of developing black and white prints. Spent photographic fixer solutions from the Avionics Maintenance Squadron are also processed through the Base Photographic Laboratory's silver recovery cartridge. The quantity is again small,

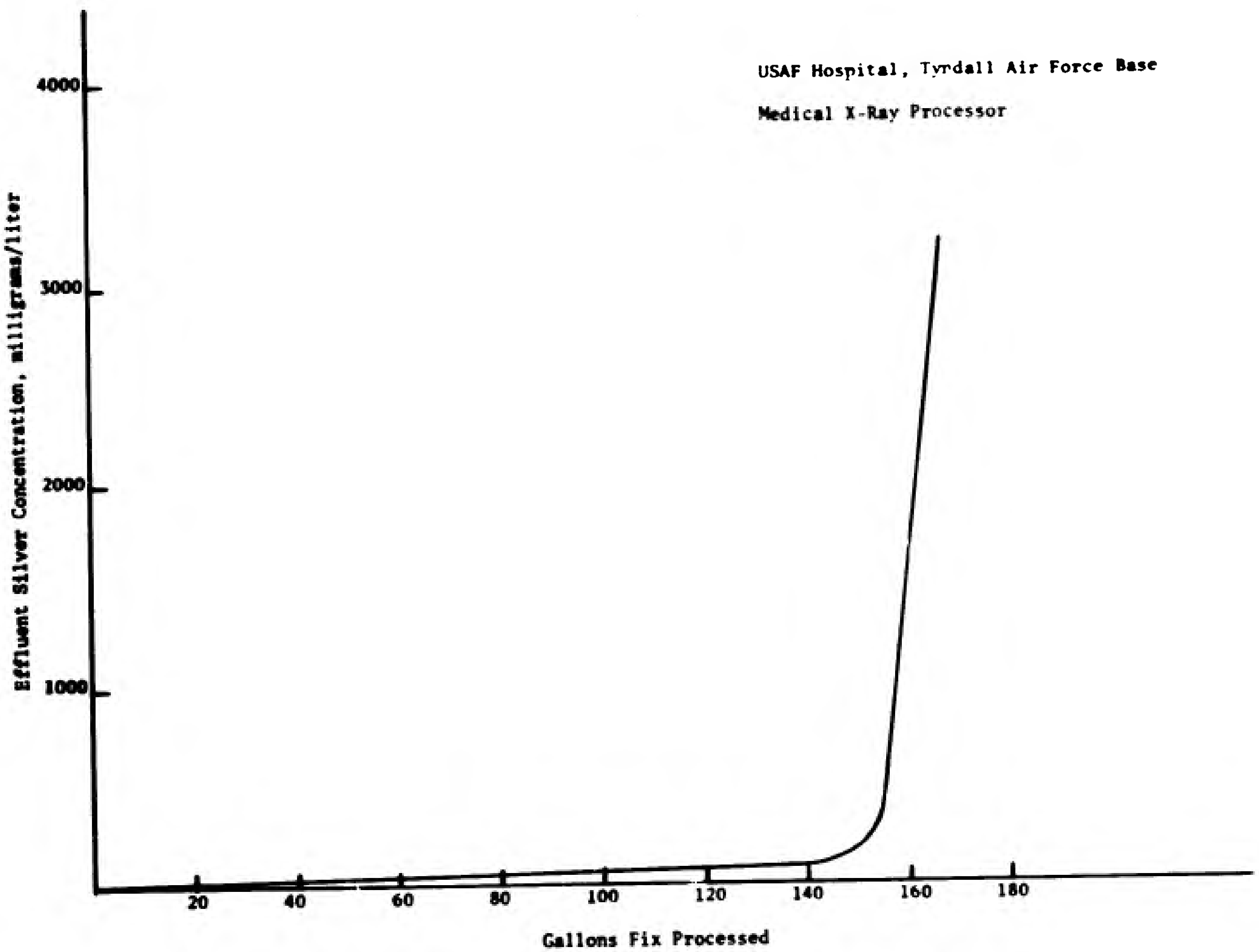

Figure 5. Medical X-Ray Processor - Effluent Silver Concentration Versus Volume of Fix Processed

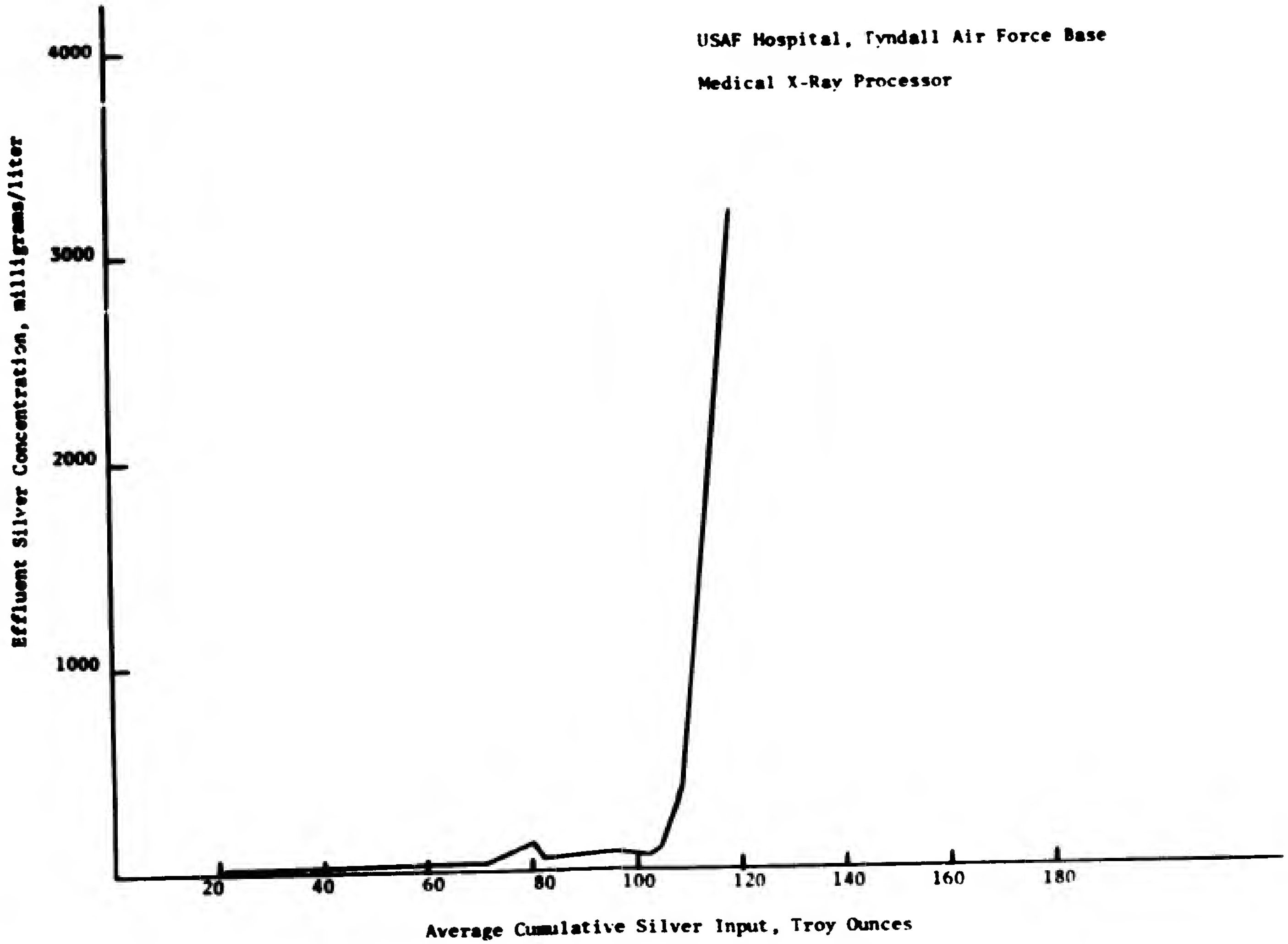

Figure 6. Medical X-Ray Processor - Effluent Silver Concentration Versus Average Silver Input

Figure 7. Batch Processing - Photographic Laboratory, Tyndall Air Force Base

usually about 5 gallons per month. Although a low volume source, this operation may be considered typical of many base operations in the CONUS.

A sampling program was initiated to determine the efficiency of the Kodak® cartridge utilized at this facility. All spent fixer solutions were containerized and held for periodic disposal, generally performed twice a week depending on the volume collected. Each time a batch was to be desilvered, a sample was taken from the storage tank to determine the influent silver concentration. The fix was then permitted to run through the cartridge by gravity at a controlled flow rate of 110 milliliters per minute. A sample was taken of the effluent from the cartridge after a sufficient volume had passed through the cartridge (5 gallons) to displace the fixer already in the cartridge and insure measurement of the solution being disposed. The quantity of fixer processed through the cartridge was recorded in order to determine the useful capacity of the cartridge. All samples were analyzed using the atomic absorption technique.

The cartridge provided excellent silver removal during the early phases of testing. Recovery efficiencies exceeded 99 percent during this time, as seen from Figure 8. This level of performance continued until over 300 gallons of fix had been processed, at which point a distinct breakpoint was evident where the efficiency was reduced drastically down to a level less than 10 percent. This dramatic break in efficiency emphasizes the need to monitor the discharge from the cartridges frequently once the manufacturer's recommended capacity is within reach.

The manufacturer's specifications for cartridge performance on this system call for a capacity of 220 gallons at a maximum flow rate of 300 milliliters/minute. The operational flow rate of 110 milliliters/minute contributed significantly to the high level of efficiency obtained. The fact that relatively low levels (0.5 to 1.0 gram/liter) of silver concentration were being disposed of from the black and white printing operation contributed to the increased cartridge capacity.

The metallic replacement technique also exhibited the ability to maintain a constant high percentage of recovery regardless of the influent concentration of silver being processed. As seen from Figure 9, the influent concentration varied by a factor of 10 with no significant decrease in recovery performance. No maintenance or operational adjustments were necessary to handle this variability.

Test strips were used in conjunction with the laboratory analysis to determine the accuracies obtainable using the estimating paper. Results indicate that lower silver concentrations are obtained using the test strips as compared with laboratory analysis.

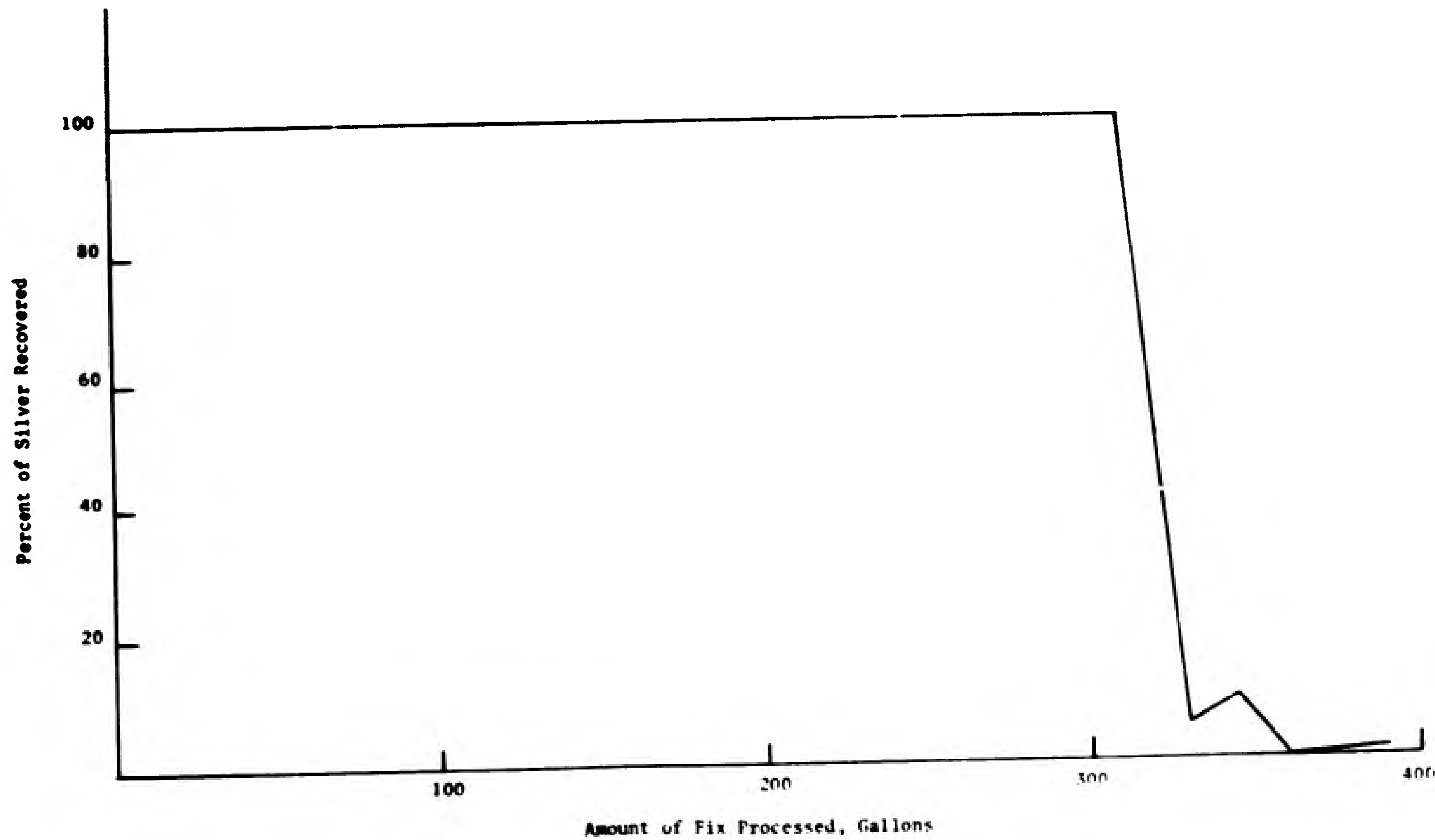

Figure 8. Silver Recovery Efficiency Versus Volume of Fix Processed

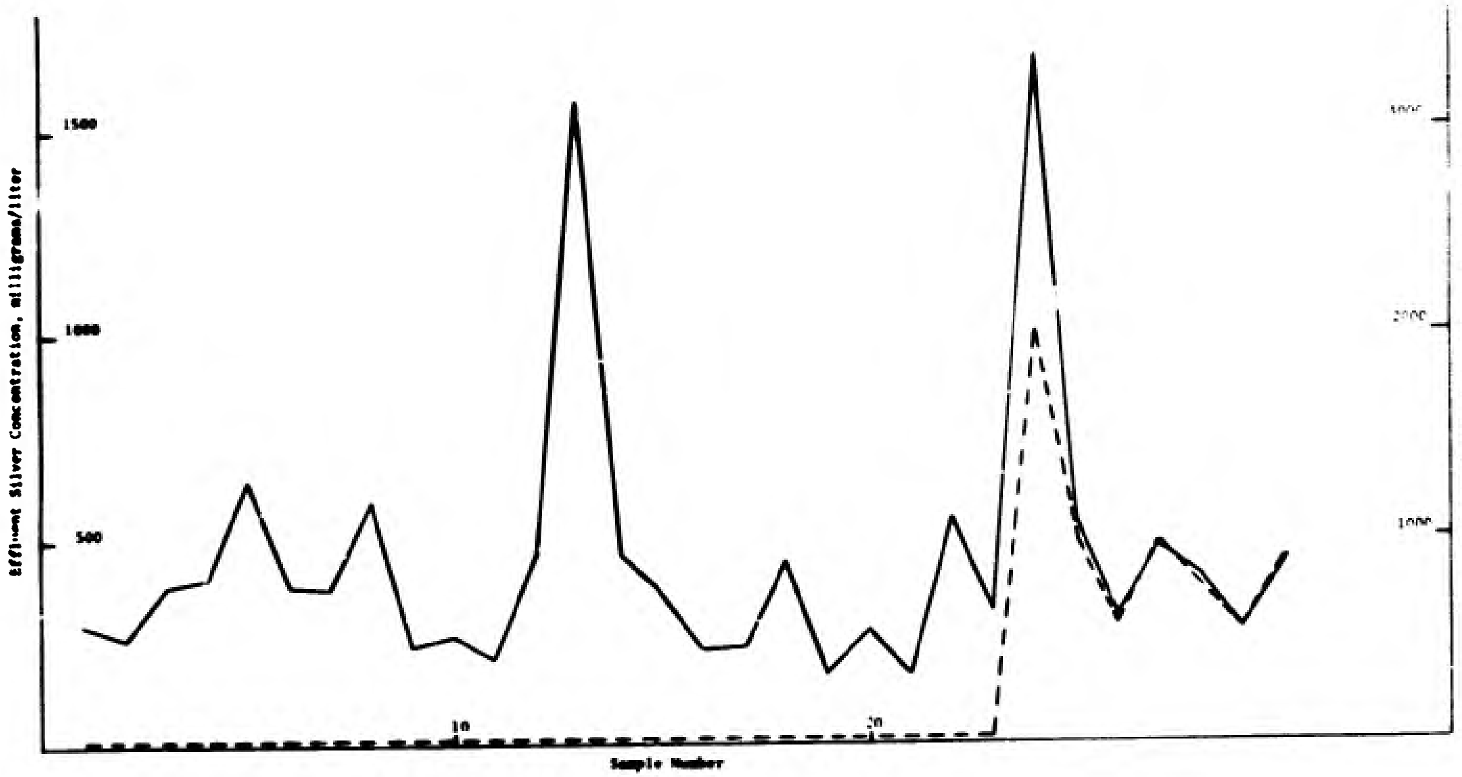

Figure 9. Photographic Laboratory - Silver Concentration of Influent and Effluent Waste Streams

3. AEROSPACE AUDIO VISUAL SERVICE, NORTON AIR FORCE BASE

The Aerospace Audio Visual Service (AAVS) operates a large film processing facility at Norton Air Force Base, California. The liquid wastes generated from various processing units contain large amounts of silver. One study has estimated that 110,500 grams of silver enter the rinses and solutions during a 3-month period (Reference 8).

Electrolytic units are utilized to recover the silver from the spent photographic fixers at this facility. Two Rotex units are used in series providing a cascade removal effect and a concentration of approximately 500 milligrams/liter silver for fix recirculation. This recirculated fix is fed to holding tanks and then to a mix tank where it is combined with fresh makeup chemistry and used again in photoprocessing.

The excess partially desilvered fix from all fixer recirculation processes and dichromate-contaminated second fix from the Eastman Color® print process are collected for additional silver recovery. These solutions are processed through an electrolytic rotating dual cathode tailing unit using the maximum available current settings of 20 amperes. No attempt is made to recycle the fix from the tailings unit. The volume of waste fixer generated is approximately 15 gallons per hour from the color print operation and 25 gallons per hour from the black and white processes. Both sodium and ammonium thiosulfate fixers were in use at AAVS during this study and, as a result, the fixer being desilvered in the tailing unit is some mixture of the two.

In order to determine the removal efficiency of the tailing operation, a field sampling program was conducted during the period from 17 March 1975 to 10 April 1975. Samples were taken during normal operation of both the influent silver bearing fix and of the desilvered effluent from the recovery unit. Laboratory analysis using atomic absorption procedures was performed on all samples to determine the efficiency of silver recovery.

The results are shown in Figure 10. Both influent and effluent silver concentrations showed a wide range of fluctuation. The influent concentration varied by a factor greater than 6 ranging from about 300 milligrams/liter to about 2000 milligrams/liter silver. The effluent from the tailing unit contained appreciable amounts of silver ranging from 100 milligrams/liter to about 350 milligrams/liter.

The reasons for the large range in silver concentrations in the influent are due to the number of units connected to this silver recovery unit and the variable workload. The percent removal averaged 74 percent during the sampling period.

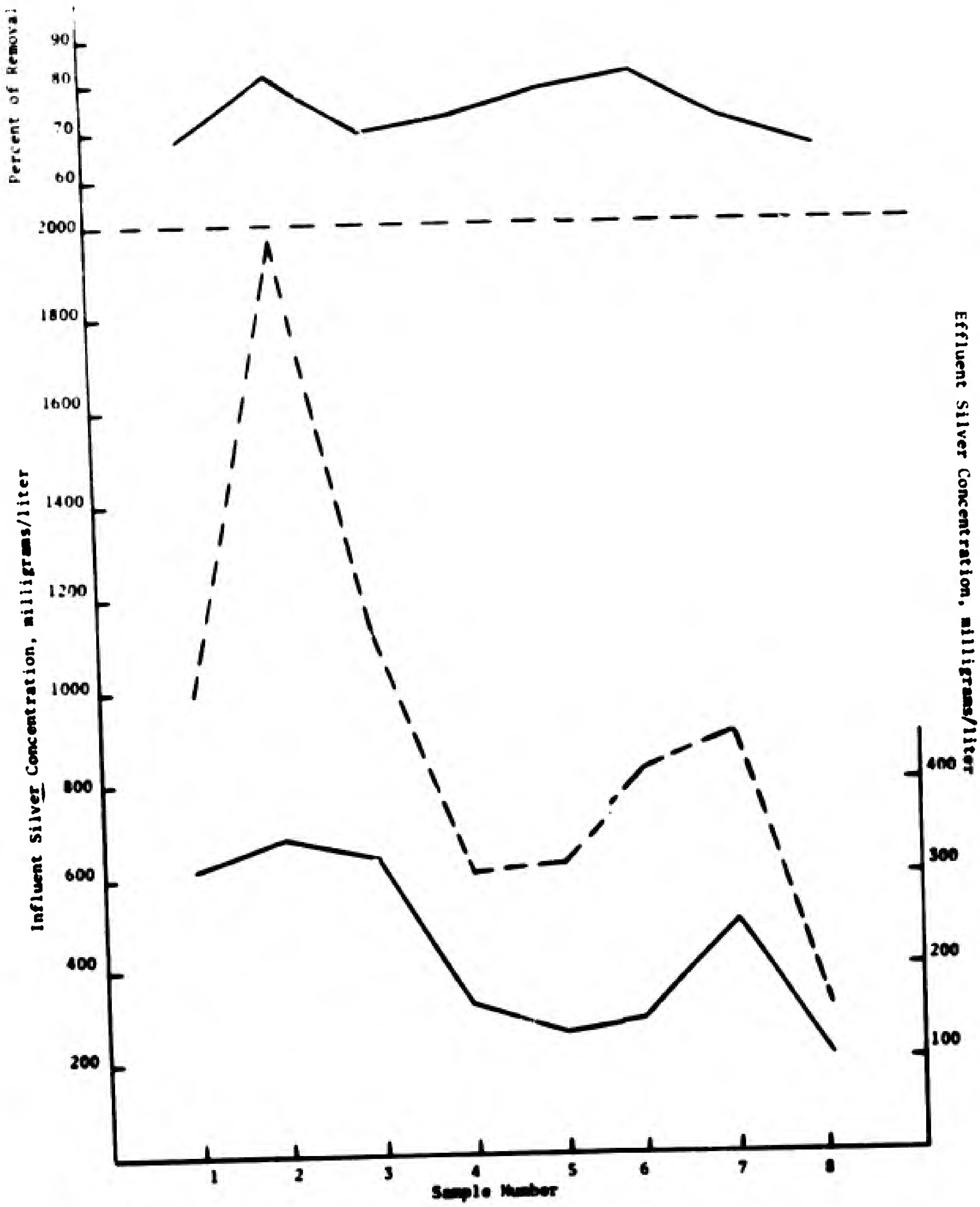

Figure 10. Electrolytic Recovery brformance Data

These results indicate inefficient overall silver recovery from the tailings operation. The reasons for this performance were traced to electrical problems with the connections to one of the rotating cathodes. Visual inspection of the cathodes indicated that one cathode had accumulated a lesser quantity of the silver than the other. Also, subsequent to obtaining the results of the silver analysis, it was discovered that the flow rate through the tailings unit had been set at an excessive rate of 350 milliliters/24 seconds. The flow rate was readjusted to 350 milliliters/52 seconds, and analysis was performed by AAVS personnel using an Argentometer. Results of these analyses indicated silver concentrations less than 0.1 gram/liter are being obtained.

SECTION IV

CONCLUSIONS

The results of this study indicate that efficient methods of silver recovery are being employed by the Air Force on various photoprocessing operations. Silver recovery using the metallic replacement technique was seen to be extremely efficient during the initial stages of operation on all processes investigated regardless of the influent silver concentration. The cartridges recovered 99 percent of the influent silver generated from black and white printing operations limiting the effluent silver concentration to less than 1 milligram/liter. Silver recovery from medical X-ray processing was also efficient, limiting the silver discharge to less than 10 milligrams/liter during initial use. The gradual increase in silver discharged up to 350 milligrams/liter prior to breakpoint would warrant the use of two silver recovery cartridges in series on this effluent. Rotation of the cartridges would then be performed when the number 1 cartridge is exhausted. The cartridges exhibited a distinct breakpoint on both processes, at which time the efficiency was reduced to unacceptable levels, allowing most of the silver to pass through the cartridge.

Although this study indicated that the metallic replacement cartridge was an effective means of silver recovery, proper usage and monitoring of the desilvered effluent is imperative. A comparison of results obtained from laboratory analysis versus the test strips indicate that the strips are only an approximation of the silver being discharged which, in most cases, were less than the results obtained from the laboratory analysis. It is essential that an inventory of the amount of fix being processed be maintained in order to determine the approximate breakpoint. The capacities suggested by the manufacturer were seen to be a good indication of the useful cartridge life. The success of a silver recovery program rests on accurate and timely analyses of the effluents from silver recovery operations. A simple, more accurate test is needed to provide operators with the capability of determining low levels of silver and early detection of the exhaustion point of the metallic replacement cartridges. Specific ion electrodes may offer a possible solution.

The use of the metallic replacement cartridge results in the undesirable emission of zinc or iron when the silver is recovered. Its use, therefore, is not generally considered acceptable from an environmental standpoint (Reference 7). The Air Force should investigate alternate methods of silver recovery in order to insure compliance with future environmental constraints.

Silver recovery using electrolysis was seen to be less efficient than the metallic replacement technique during this study. This was probably due to a malfunctioning cathode during the test period -- an indication of the problems that can be experienced with this type system and the need for close process control and maintenance.

Silver recovery has been shown to offer significant cost benefits. As an example, based on data accumulated during this study, approximately 1,340 troy ounces of recoverable silver are generated at a typical medical X-ray processor per year. Based on a 95 percent recovery rate and a cost of $4.50 per ounce of silver, a savings of $5,700 could be realized, less the cost of the cartridges estimated at $150 per year and refining of the recoverable silver. Projecting this estimate Air Force-wide would result in substantial dollar savings.

The overall results of this study indicate that adequate and efficient silver recovery systems are in use or available for use at Air Force installations. Emphasis should be placed on the operation and maintenance aspects of these systems to insure maximum efficiency is attained.

REFERENCES

1. "State Standards for Mercury and Heavy Metals," Environmental Reporter, August 1972, pp 621:0401 to 621:0410.

2. M. L. Schreiber, "Present Status of Silver Recovery in Motion Picture Laboratories," Journal of SMPTE, Vol 74, pp 505 to 513.

3. Recovering Silver from Photographic Materials, Publication No. J-10, Eastman Kodak, December 1969.

4. Silver Recovery with the Kodak Chemical Recovery Cartridge, Publication No. J-9, Eastman Kodak, April 1969.

5. LeFebvre and Callahan, Toxic Effects of Color Photographic Processing Wastes on Biological Systems, USAF Report EHL(K) 70-0, August 1970.

6. Richard E. Lotz, Chemical Wastes Generated by Air Force Photographic Operations, USAF Report AFWL DE-TN-72-002, February 1972.

7. Draft Development Document for Effluent Limitations Guidelines and Standards of Performance Miscellaneous Chemical Industry, February 1975.

8. Dean D. Nelson, Recovery and Recycle of Photo Chemicals at the Aerospace Audio Visual Service Facility, Norton AFB, California, USAF Report AFWL DE-TN-71-014, June 1971.

APPENDIX A

SILVER RECOVERY DATA: USAF HOSPITAL, TYNDALL AIR FORCE BASE

Date	Effluent Silver Concentration (milligrams/liter)	Gallons Fix Used
10 Jan 75	3.1	9
13 Jan 75	2.0	
14 Jan 75	2.8	
15 Jan 75	3.8	
16 Jan 75	4.0	18
17 Jan 75	3.8	
18 Jan 75	6.3	
20 Jan 75	3.7	
21 Jan 75	5.2	
22 Jan 75	7.1	20
23 Jan 75	6.4	
24 Jan 75	6.0	
27 Jan 75	5.8	
28 Jan 75	6.4	
29 Jan 75	5.7	
30 Jan 75	6.5	
31 Jan 75	9.0	
3 Feb 75	16.3	
4 Feb 75	19.4	17
5 Feb 75	25.5	
6 Feb 75	34.0	
7 Feb 75	38.3	
9 Feb 75	13.5	19
10 Feb 75	58.4	
11 Feb 75	53.0	
12 Feb 75	60.4	20
13 Feb 75	66.4	
14 Feb 75	98	19
21 Feb 75	--	20
27 Feb 75	69.2	
28 Feb 75	95.0	
3 Mar 75	35.3	
4 Mar 75	--	20
5 Mar 75	1710	
6 Mar 75	2440	6
7 Mar 75	3220	

APPENDIX B

SILVER RECOVERY DATA: PHOTOGRAPHIC LABORATORY, TYNDALL AIR FORCE BASE

Sample Number	Influent Silver Concentration (milligrams/liter)	Effluent Silver Concentration (milligrams/liter)
1	580	L.5
2	510	LL.5
3	780	L.5
4	820	L.5
5	1300	.9
7	761	L.5
8	1190	2.3
9	460	.26
10	520	.10
11	400	.10
12	940	.47
13	3160	.18
14	930	.24
15	740	.10
16	450	.30
17	460	.10
18	900	.5
19	320	.1
20	550	.1
21	329	.2
22	1100	.4
23	644	.1
24	3360	2040
25	1080	1020
26	637	577
27	975	985
28	815	795
29	565	555
30	880	905
31	975	695

APPENDIX C

SILVER RECOVERY DATA: AEROSPACE AUDIO VISUAL SERVICE, NORTON AIR FORCE BASE

Date	Influent Silver Concentration (milligrams/liter)	Effluent Silver Concentration (milligrams/liter)	Percent Removal
17 Mar 75	990	314	68.28
20 Mar 75	1970	340	82.74
24 Mar 75	1100	320	70.90
28 Mar 75	610	160	73.77
31 Mar 75	620	130	79.03
3 Apr 75	830	145	82.53
7 Apr 75	912	250	72.47
10 Apr 75	314	107	65.92

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