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TECHNICAL NOTE

REVIEW OF MACHINE WASHING EFFICIENCY FOR ORIGINAL FILM

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ABSTRACT

@ABS Further silver sulfide stain tests for wash efficiency were conducted with major emphasis on means by which archival keeping quality may be achieved for original mission film.

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1. Fultron processed Apollo Mission film. The processed film from the panoramic and metric cameras aboard Apollo 15 and 16 were found to be suitable for archival keeping. The Fultron machines provide processing to archival quality at the highest speeds of any of the processors investigated.

2. Earth Resources Original Mission Film from Missions 5 through 22. All film types processed through 1965 and 1966 were inspected and found to be free from chemical deterioration. Stain test data indicate a wide variability of keeping quality from archival to less than commercial keeping.

3. Current Earth Resources Original Mission Film. This film is processed at speeds above those recommended by Eastman Kodak for archival keeping. Tests conducted here agree with these recommendations, and the film is not suitable for archival keeping.

4. Improving Wash Efficiency. All processors have flow meters to control addition of wash water and are sufficient for this purpose. The major factor which controls the efficiency of washing is the machine speed. The silver sulfide stain test is suggested as the method to be adopted to determine archival keeping. The value of other tests (hypo clearing agents, etc.) has not been investigated.

SECTION I

INTRODUCTION

Recently a report was issued describing the silver sulfide stain test for measuring wash efficiency (TR 72-7, July 1972). The test is simple, rapid, and reliable, and contains variables which are generally noncritical. From a quite broad and random sampling, it was found that several processing machines produce a wide variability in washing results, and in many cases it appears that processed film contains unusually large amounts of fixing chemicals (hypo). Literature reports indicate that some of these films will produce a brown stain of silver sulfide within 5 to 10 years under normal keeping conditions.

In order to more accurately assess the adequacy of washing of original mission film which is processed in this laboratory the following work was undertaken.

1. Measure the level of retained hypo in panoramic and metric camera film from Apollo 15 and 16. Investigate the washing capabilities of the Fultron machines on which this film was processed.

2. Inspect early original Earth Resources film stored in Building 424. Measure the retained hypo level in these films to assist in the judgment of the necessity to rewash these materials.

3. Measure the retained hypo level of original Earth Resources film which has recently been processed. Check all of the major film types in use and all of the processing machines.

4. Investigate the washing capabilities of all machines which might be expected to handle original mission film. Produce a standard test to measure retained hypo and provide criteria for its assessment.

SECTION II

EXPERIMENTAL PROCEDURES

A. Fultron Processed Apollo Mission Film

Panoramic camera film type 3414, and metric camera film type 3400, from Apollo missions 15 and 16 were processed on the Fultron machines. In addition, 7 of 8 rolls of 70mm film type 3401 from Apollo 16 were put through these processors.

The Panoramic camera film was cut into 18 smaller rolls after processing. Minimum density areas were removed from the first and last rolls of this series. In a similar manner the metric camera film was cut into 5 rolls and the first and last rolls in this series were sampled. No attempt was made to sample 70mm film type 3401.

Each sample was divided into two equal portions identified as "reference" and "test". The test portion was immersed in a solution of silver nitrate and the reference was immersed in a solution that was similar except that it did not contain silver nitrate. After 5 minutes, both portions were immersed in sodium chloride solution followed by immersion in a sodium thiosulfate solution and washing. Each immersion was 5 minutes minimum. The dried samples were cut into 8 pieces and their densities were read through the Status A blue densitometer filter. The procedure was to read progressive thicknesses, one to eight. This may seem somewhat excessive, but where the difference in optical density was small, it was necessary to read multiple thicknesses. Further experience indicates that four thicknesses would be adequate. Also, the graph used to relate optical density to hypo content (TR 72-7) is scaled to four thicknesses. Relatively small fluctuations in sample density that may be manifested as mottle are quite apparent to the eye and can be avoided or allowed for when measuring the density. The results for this series of tests is listed in Table I that follows.

TABLE I

SILVER SULFIDE STAIN TEST FOR WASH EFFICIENCY
PANORAMIC AND METRIC CAMERA FILM ABOARD APOLLO 15 AND 16

Mission	Location of Sample	Fultron Processing Speed (feet/min)	Micrograms of Hypo /cm^2	/in^2
		Panoramic Camera Film Type 3414		
Apollo 15	Head of Roll #1	21	0.93	6
Apollo 15	Sensi. Strip Roll #18	21	1.40	9
Apollo 16	Sensi, Head Roll #1	15	0.62	4
Apollo 16	Sensi, Tail Roll #18	15	0.62	4
		Metric Camera Film Type 3400		
Apollo 15	Head Roll #1	9	$\leq$.16*	$\leq$ 1
Apollo 16	Roll #1	6.5	$\leq$.16	$\leq$ 1
Apollo 16	Sensi, Roll #5	6.5	$\leq$.16	$\leq$ 1

* Limit of test

The panoramic and metric camera films meet the definition of archival keeping quality which is discussed in Section IV of this report. A graphical presentation of machine speed versus retained hypo is given in Figure 1 for three film types processed on the Fultron. A comparison of this data with other data in this report and from TR 72-7 demonstrates that the Fultrons are capable of washing to archival keeping quality at higher speeds than any other machines tested.

The threading diagram for the Fultrons is reproduced in Figure 4 of TR 72-3, Apollo 16 Photographic Standards Documentation, by Paul F. Bourque, June 1972. There are four washes which are enumerated in the following processing sequence. There is first prewetting in a dip of spent developer followed by spray development, a short spray wash (1), and then an immersion fix. Following fixing, there is a single loop spray wash (2), a four loop immersion wash (3), and a final short spray wash (4) followed by a dip in wetting agent and drying.

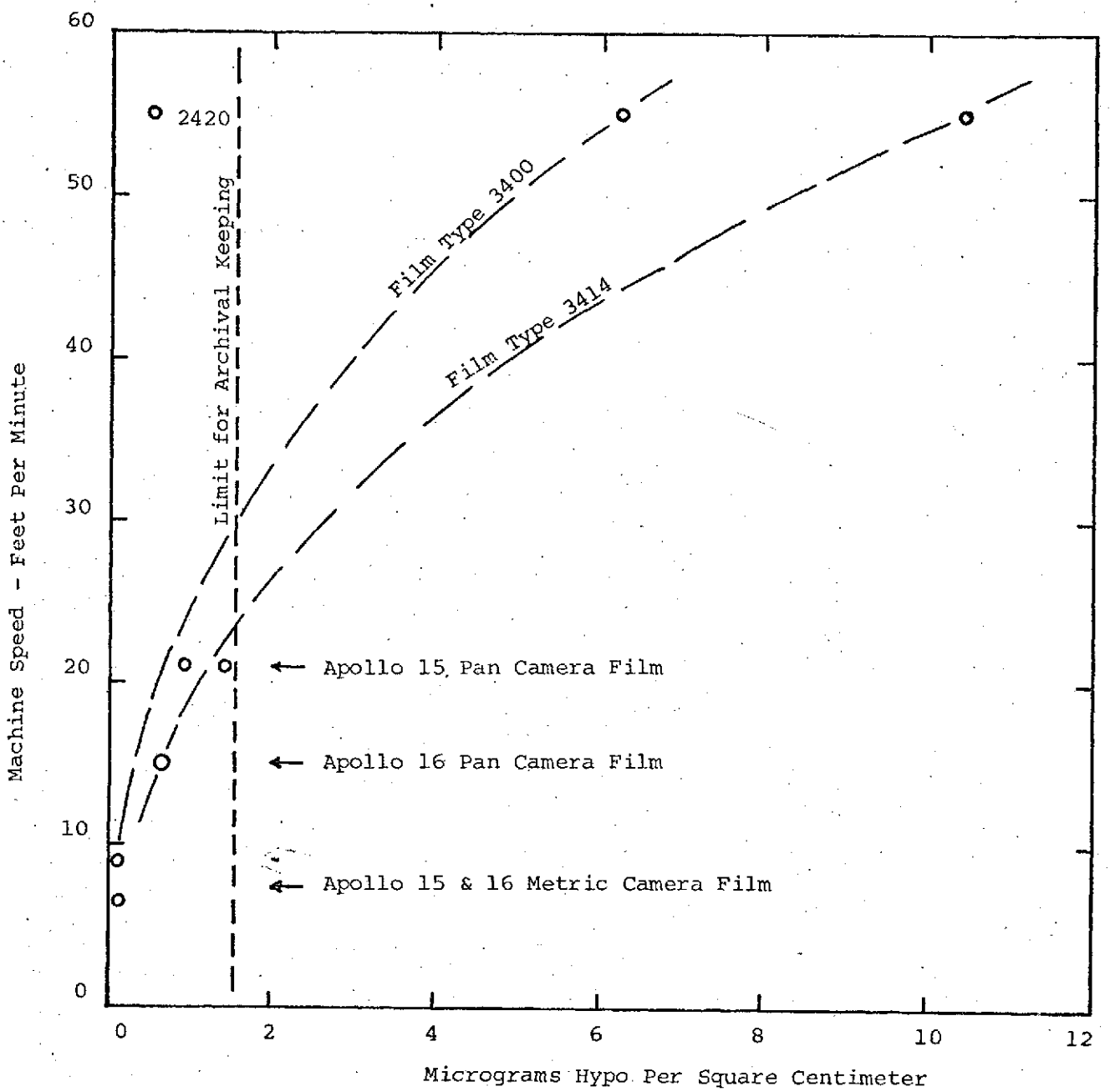
A single water line feeds wash (4) above and by overflow and pumping in a cascade sequence the water proceeds to washes (3), (2), and (1) and is drained. The flowmeter, which monitors the water in, is calibrated from 3 to 7 gallons per minute. Normal operation is at 5 1/4 gallons per minute.

Figure 1 shows that the level of retained hypo is dependent upon both machine speed and film type. Film type 3401 (70mm) from Apollo 16 was processed at 8 1/4 feet per minute. All indications suggest that this film was processed to archival keeping quality on the Fultrons.

B. Early Earth Resources Original Mission Film

Film storage in Building 424 receives all original film after processing and duplication in the laboratory. The Earth Resources film begins

FIGURE 1



WASH EFFICIENCY VERSUS MACHINE SPEED FOR FULTRON PROCESSING OF 3 FILM TYPES

with Mission 5 in February 1965. From Mission 5 to Mission 22 in 1966, a majority of the rolls were totally inspected, and five were put aside so that minimum density areas could be removed to be tested for residual hypo. The condition of the film varied greatly. Folding, tearing, scratches, processing marks (both in the machine and transverse directions) and fogging were abundantly evident. Large brown spots were in evidence on one roll of black and white negative from Mission 7 (Roll 1, frames 145-150) but the source of these stains was not evident. It was not possible to make any tests for image fading since none of the rolls inspected contained sensitometric strips.

Of all the rolls viewed, only five had minimum density areas which could be removed. Residual hypo levels for these five samples were measured in the same manner as described for the panoramic and metric camera films in the previous section. The results varied widely, as shown in Table 2. One sample of black and white negative was suitable for archival keeping while another sample (Tri-X) contained hypo at levels above those recommended by Kodak for commercial products. Fortunately, only small amounts of Tri-X were used. Unfortunately, no processing conditions were recorded for any of the films inspected.

C. Current Earth Resources Original Mission Film

Five Versamat Processors presently process all of the original Earth Resources film at this time. The three color Versamats each process only one type of original film while the two model 11 black and white Versamats process all black and white negative interchangeably. No black and white reversal film is flown at this time.

The model 1411 Versamat processes only (original) film type 2445 (color negative). This film contained the highest levels of residual thiosulfate found in any of the current original which was sampled.

TABLE 2

EARTH RESOURCES ORIGINAL FILM - SILVER SULFIDE STAIN TEST FOR WASH EFFICIENCY

Mission	Roll	Film Type	Micrograms of Hypo Per cm^2	Micrograms of Hypo Per in^2	Remarks
5	1 of 2	B & W Neg.	0.60	4	No sensitometry on roll.
7	1	B & W Neg.	7.60	49	
14	1 of 2	Plus-X	2.80	18	Processing conditions not known. Dates from 1965-66.
14	2 of 2	Tri-X	24.50	158	
21	1 of 2	8442 Color Rev.	2.90	19	
207	6	2445 Color Neg	11.00	71	Processed in this sequence July 24, 1972, day shift, on 1411 Versamat at 6.4 fpm.
207	8		18.00	116	
207	15		11.30	73	
207	19		12.40	80	
207	21		9.50	61	
dated 7/20/72	6	2445 Color Neg	16.60	107	Processed by Forbes AFB. Samples taken from sensitometric strips supplied with the film.
	8		20.20	130	
dated 7/21/72	2AN		14.10	91	
	3AN		20.20	130	

Because of this the five rolls processed on one day shift were tested. The results, presented in Table 2, indicate unusual washing difficulties for this material.

Color positive film type SO-397 is processed on the model 1811 Versamat (#1). It is processed at a higher speed (9 feet per minute) than Film type 2445 (6.4 feet per minute), but contains comparable amounts of residual thiosulfate (see Table 3 and Figure 2).

It is tempting to conclude that color film with its multitude of coatings is impossible to wash well on Versamats. Such might be the case except for film type 2443 (color IR), processed on the model 1811 Versamat (#2) at 5 feet per minute. Of course, this is also the slowest speed used for processing any Earth Resources original film. It is also the only Earth Resources original film (currently processed) which meets the criterion of maximum keeping quality for color film. This is equivalent to archival keeping quality for black and white film which will be discussed in the last section. Table 3 and Figure 2 contain this data.

Various black and white original mission films processed by the two model 11 Versamats at a number of speeds all indicate a consistently high level of retained hypo. Numerical data from the tests is given in Table 3. The hypo level versus machine speed is graphically reproduced in Figure 2. The scatter of data points for the black and white films in Figure 2 is quite random. There seems to be no relationship to film type, film width, or processor. But slower speeds do appear to reduce the level of residual hypo. This is most evident when a single film type is compared. The dashed lines in Figure 2 are drawn to indicate in a general way the direction and magnitude of wash efficiency versus machine speed for Versamat processing of black and white films. These lines appear to converge on archival keeping quality

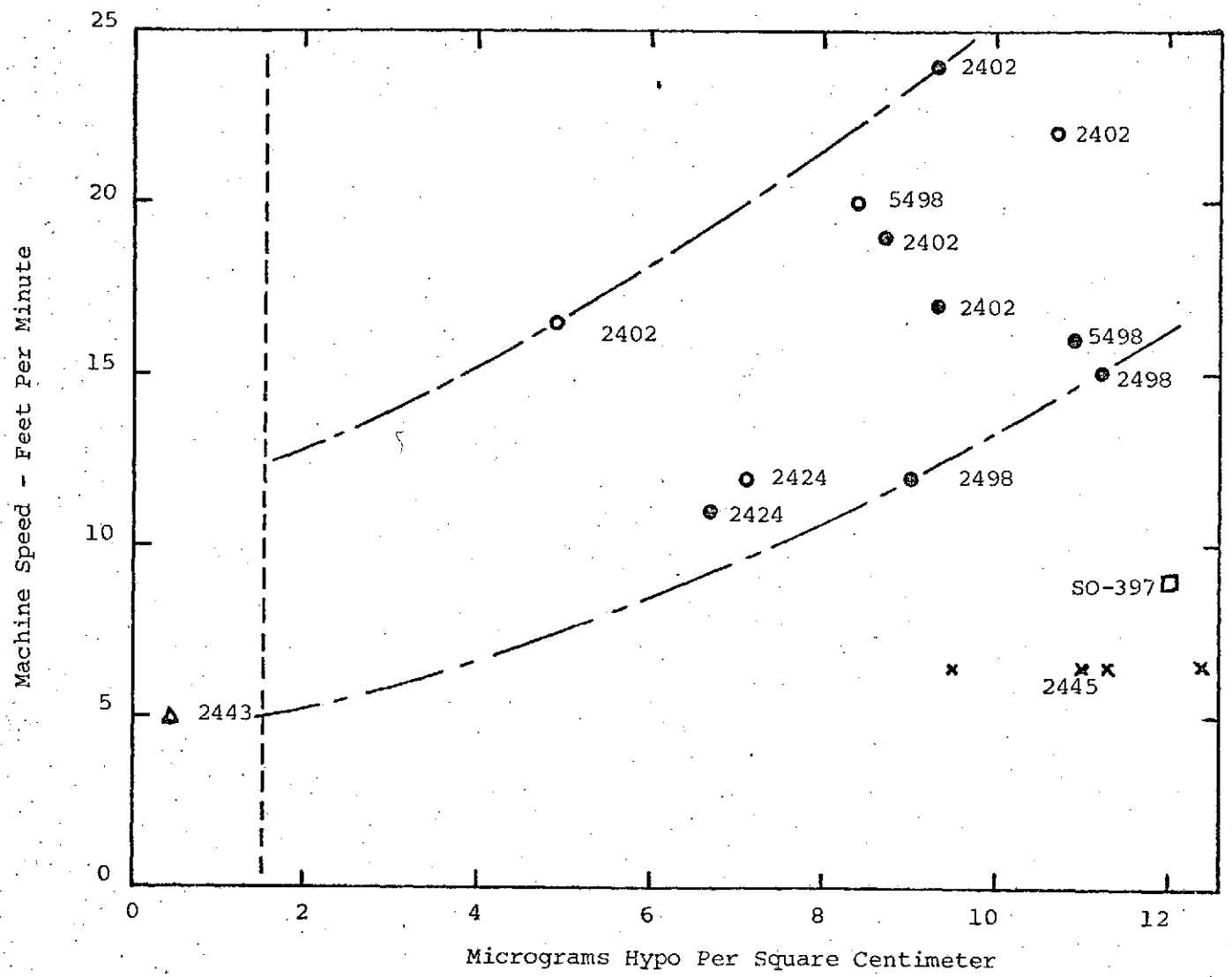
TABLE 3

EARTH RESOURCES ORIGINAL FILM - SILVER SULFIDE STAIN TEST FOR WASH EFFICIENCY

Mission	Roll	Film Type	Micrograms of Hypo Per cm^2	Per in^2	Machine/Speed	Film Width
204	6	SO-397*	12.00	77	1811 VMT #1/9 fpm	5 in.
205	25	5498	8.40	54	VMT 11C-M #1/20 fpm	70mm
205	14	2424	7.10	46	VMT 11C-M #1/12 fpm	70mm
205	31	2402	4.90	32	VMT 11C-M #1/16.5 fpm	70mm
207	4	2402	10.70	69	VMT 11C-M #1/22 fpm	70mm
207	26	2424	6.70	43	VMT 11C-M #2/11 fpm	70mm
207	41	2498	9.00	58	VMT 11C-M #2/12 fpm	70mm
207	48	2443*	0.45	3	1811 VMT #2/5 fpm	9.5 in.
207	50	2402	8.70	56	VMT 11C-M #2/19 fpm	70mm
207	54	5498	10.70	70	VMT 11C-M #2/16 fpm	70mm
209	27	2402	9.30	60	VMT 11C-M #2/17 fpm	9.5 in.
209	32 or 35	2402	9.90	64	VMT 11C-M #1/2.5 or 17fpm	9.5 in.
209	44	2402	9.30	60	VMT 11C-M #2/24 fpm	5 in.
209	48	2498	11.20	72	VMT 11C-M #2/15 fpm	5 in.

* Color

FIGURE 2



WASH EFFICIENCY VERSUS MACHINE SPEED

FOR VERSAMAT PROCESSING

- ○ B&W Versamat #1
- ● B&W Versamat #2
- □ Color Versamat 1811 #1
- ▲ Color Versamat 1811 #2
- × Neg. Color Versamat 1411

Numbers on graph indicate film type.

at machine speeds of 5 to 12 feet per minute. Eastman Kodak has published recommendations for archival processing speeds which have been extracted and assembled in Table 4. Generally, they suggest speeds under 10 feet per minute for archival keeping. Our data from Figure 2 suggest this may be somewhat optimistic.

All of these Versamats have wash water flowmeters which are set to a certain level as part of the start-up procedure. Usually, the water is not run full open, and usually, drainage is not a limiting factor in increasing water flow. The use of hypo clearing aids, such as ion exchange resins, have not been evaluated. The main control for wash quality is machine speed. This is recognized by Kodak as indicated by the data from Table 4.

D. Means to Improve Wash Efficiency

See the end of Parts A and C of the Experiment Procedures Section, and the Discussion Section which follows.

TABLE 4

KODAK DATA FOR AERIAL PHOTOGRAPHY

PUBLICATION NO. M-29, July 1971

Page	Film Type	Versamat Speed w/641 Chemistry Archival Keeping (rpm)	Commercial Keeping (rpm)
15	2402†	≤ 10	≤ 20
54	2424*†	≤ 10	≤ 20
20	2403†	≤ 5	≤ 10
25	2405†	≤ 5	≤ 10
29	3400†	≤ 10	≤ 15
33	3401†	≤ 5	≤ 15
37	3414†	≤ 10	≤ 15
41	8401†	≤ 5	≤ 10
46	2420†† 4427††	≤ 5	≤ 20

* Infrared
† Original Negative
††Duplicating Film

SECTION III

DISCUSSION

Washing quality for the Fultron machines has been discussed at the end of Part A , Experimental Procedures Section. Versamat washing quality has been discussed at the end of Part C, Experimental Procedures Section.

The Motion Picture Laboratory has three machines which have been used for Apollo missions to process original film. In addition to these three, they have three other machines: the Hi-Speed (16mm), the Hi-Speed (35mm), and the Houston Black and White Processors. The variable processing results for retained hypo from these three latter machines are reported in TR 72-7. They are not recommended for processing of original film. The machines which have processed original Apollo mission film are the RAM, Houston color, and Hi-Speed color. Stain test data for the wash efficiency of these machines is given in TR 72-7 and no additional samples were tested. The following discussion is directed at the washing system of each processor. The machine, and the film type processed on them is given in Table 5.

The RAM machine has two final immersion wash tanks and no metering of the water. The last tank before drying contains stabilizer, and this flow is metered. It handles only 16mm color, and because of the narrow width of the film, each tank has many loops. A single datum point indicates reasonably good washing. Since only a small amount of original is processed here the easiest thing to do would be to turn the wash water flow up as high as the drain can accommodate while the original is processed.

The Houston color processor has one wash tank with metered water flow. The meter is set at 4 gallons per minute, which is the maximum point on the scale. As with the RAM machine, there is also one stabilizer

tank with metered flow. The machine has been used to process original Apollo film. The one sample of color flight emulsion which was tested was washed to maximum keeping quality for color film. The machine/film type processing list of Table 5 indicates that this processor will probably not be used for Apollo 17 original footage.

The Hi-Speed color machine is unusual in the sense that it is used to process a variety of emulsions, both color and black and white. With color film a single tank spray wash followed by immersion in stabilizer is used. The 70mm color flight emulsion which was tested was washed reasonably well, but not to maximum keeping quality. The machine also is threaded for 16mm which because of its narrow width has more loops and spends more time in the wash. No 16mm samples were tested.

During black and white processing on the Hi-Speed color processor, the color developer tank is filled with wash water. The film then bypasses the other tanks and goes into the spray wash and stabilizer before drying. This system of washing for black and white film is generally outstanding for all emulsions which were tested. Again for Apollo 17, this machine will be put into use to process a variety of original emulsions as indicated in Table 5.

In considering color processing, it is legitimate to question the meaning and value of the wash efficiency test. No color material using the Fischer dye-coupling reaction for color formation has ever been considered archival. People at Eastman Kodak have done work on dye image stability and report that "dye stability keeping tests (140°F., 70% RH) show that thiosulfate, thiocyanate, thiourea,

TABLE 5

APOLLO ORIGINAL FILM PROCESSING

Lab/Machine	B & W	COLOR	Apollo 16 Film type/width		Apollo 17 Film type/width	
MP/Hi-Speed	X		2485	16mm	2485	16mm
	X		2485	35mm	2485	35mm
	X		2485	70mm	2485	70mm
	X		3401	35mm	3401	35mm
	X		IIaO	70mm	TBD[1]	
	X		NTB-3	35mm		
		X	SO-368	16mm		
		X	SO-368	70mm	SO-368	70mm
MP/Houston	X		SO-164	16mm		
		X	SO-168	35mm		
		X	SO-168	70mm		
MP/RAM		X	SO-168	16mm*	SO-168	16mm*
PPL/Fultron	X		3400	5"	3400	5"
	X		3414	5"	3414	5"
	X		3401	70mm	3401	70mm
PPL/Versamat	X		3401	70mm**		

[1] Lunar Sounder Film

* ASA 500

**1 roll

and sulfite will cause fading of color film".[1] Of these four chemicals, the wash efficiency test measures only thiosulfate. In addition, "it is therefore recommended that the CD-index (Chemical-Densitometric-index) be used by processors of Eastman color films to indicate the adequacy of washing".[2] The CD-index is the silver sulfide stain test for wash efficiency. On this basis, color films are treated in this report in the same manner as black and white films. The route to deterioration for color material is different than for black and white, and since color material is not archival the term "maximum keeping quality" is used.

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[1] Larson, G. W., Habell, D. C., and West, L. E., Journal of SMPTE, 71, 495 (1962). Page 497.

[2] ibid. Page 499

SECTION IV

CONCLUSION AND RECOMMENDATIONS

The silver sulfide densitometric stain test for wash efficiency as described in TR 72-7 and ANSI PH 4.8-1971 should be adopted as a standard laboratory test. The test should be instituted as written and reviewed on a regular basis, such as weekly. As experience is accumulated, the test should be modified to accommodate equipment, time, reliability, or other factors. When it is agreed that the test is in the best form and used to best advantage, it should be adopted and reviews stopped.

From the relationship developed in TR 72-7, it is suggested that a level of 1.55 micrograms of hypo per square centimeter (10μ gm/in^2) be adopted as the maximum limit for archival keeping quality for black and white film. For color products this will be termed maximum keeping quality in recognition that dye instability is the major cause of color film deterioration. All original film should meet these standards.

A level of 15.5 micrograms of hypo per square centimeter (100μ gm/in^2) will be the maximum allowed limit for duplication material. Either black and white or color material which has retained hypo under this value will be termed commercial quality.

Apollo original film should have archival quality certified with processing. For this purpose sensitometric strips processed with the original film should be certified as having met archival keeping standards. If it is necessary to process outside these limits, the film should be rewashed.

For Earth Resources original film several alternatives are available to obtain archival keeping quality:

1. Change machines
2. Alter machines to add extra wash capacity
3. Rewash all film in another machine
4. Decrease processing speeds to achieve archival keeping quality
5. Investigate the possible use of hypo clearing agents as washing accelerators.

A random sampling of recent original Earth Resources films has produced only one roll that has been washed well enough to meet the standards of maximum keeping quality, and none that meet the standards of archival keeping quality.