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Increased image resolution and film efficiency via vacuum platens and other mechanical devices

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INCREASED IMAGE RESOLUTION AND FILM EFFICIENCY VIA VACUUM PLATENS AND OTHER MECHANICAL DEVICES

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Bachelor of Science in the School of
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ABSTRACT

With an appropriate lens, focusing arrangement, film and processing, motor driven 35mm cameras will attain resolutions of hundreds of line pairs per millimeter. The combination of a narrow depth of focus, unusually thin films, a relatively large film gate and rapidly advancing films can produce imagery with less than optimum resolution across or within individual frames.

A vacuum platen and an additional styrene pressure plate were fitted to a motorized 35mm camera in an effort to insure the film lies flat. Continuous vacuum pulling mechanisms, suction and induction, were evaluated. Each system's simplicity, portability and statistically analyzed imagery were assessed.

Test imagery indicated a ten percent increase of in focus image area for the vacuum platen and a fifty-five percent increase for the styrene pressure plate. Several suitable vacuum pulling mechanisms were found. Overall, the inexpensive, simply constructed and easily installed styrene pressure plate is recommended for any high resolution, small format camera system.

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INTRODUCTION

With an appropriate lens, focusing arrangement, film, and processing, motor driven 35mm cameras will attain resolutions of hundreds of line pairs per millimeter (lp/mm). The combination of a narrow depth of focus (less than 0.005 inches), unusually thin films (less than 0.005 inches), a relatively large film gate (more than 0.010 inches), and rapidly advancing film (up to five frames per second) can produce imagery with less than optimum resolution across or within individual frames. Present practice insures high resolution by exposing, processing, and evaluating dozens of images per scene, adding bulk, expense, and time to the operation. Mechanical devices to hold the film within the depth of focus and without imparting smear to the image have been theorized and constructed in efforts to increase the efficiency and resolution of the camera system. Besides the lack of data as to their success, a simple and portable device suitable for field use has not been designed and tested.[1]

Two devices, a vacuum platen and an additional styrene pressure plate, were fitted to a motor driven 35mm camera. Continuous vacuum pulling mechanisms, suction and induction, were evaluated as to feasibility and resolution affect. Each modification's simplicity, portability and statisically analyzed imagery were assessed.

Overall, mechanical devices to increase camera system film efficiency and resolution were designed, tested, and evaluated to formulate recommendation's for their implementation.

EXPERIMENTAL WORK

CALCULATIONS

After procuring a Minolta XG-1 body equipped with a Minolta 50mm f/1.7 lens and a Minolta two frames per second Auto Winder G, the magnification and resolution of the system at its minimum object distance (for an easily reproducible and compact working distance) was determined. Minolta's reported focal length and the measured object to image plane distance:

$$f = 50.0\text{mm}$$

$$s' - s = 490.0\text{mm}$$

inserted in the paraxial equation:

$$s' = f\,s \,/\, (f + s)$$

$$490 + s = 50\,s \,/\, (50 + s)$$

yielded object and image distances of:

$$s = -433.5\text{mm}$$

$$s' = 56.5\text{mm}$$

and a magnification of:

$$m = s' \,/\, s = -0.13.$$

Kodak Kodalith 6556 type 3 exposed under conditions described later produced imagery with a resolution of 50 lp/mm or 0.02 mm/lp from an RIT alphanumeric test object.

Rayleigh's criterion, employed in the transition from resolution to depth of focus, relates the cutoff period, 0.02 mm/lp, to one-half of the airy disc or blur circle diameter, 0.04mm (Figure 1).[2]

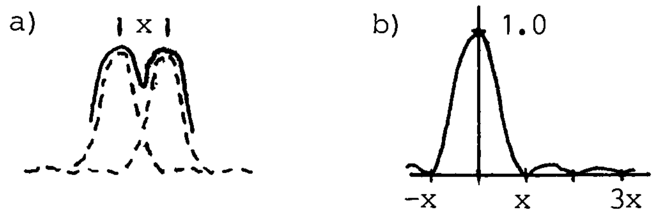

Figure 1: Rayleigh's criterion a) minimum observable period and b) airy disc diameter

The blur circle, a', is the image outlined by the axial rays at the film plane as the film drifts fore and aft of the image plane (Figure 2). The depth of focus, 2s", is the distance from the fore to aft film plane when the largest acceptable blur circle, 0.04mm, is imaged at each. To find the depth of focus, an equation may be derived from Figure 2 using similiar triangles:

$$s'' / s' = s' / D,$$

$$s'' = a' s' / D.$$

As $D = f / N$,

$$s'' = a' s' N / f,$$

and as $s' / f \approx 1$,

$$s'' \approx a' N.$$ [3]

Once the blur circle diameter has been determined, the depth of focus is solely dependent on the lens' f-number and therefore, a fast, wide-open lens is required to minimize the depth of focus. With the Minolta equipment employed:

$$s'' = 0.04\text{mm} \cdot 1.7$$

$$= 0.07\text{mm}.$$

The total depth of focus is twice s", 0.14mm or 0.005 in.

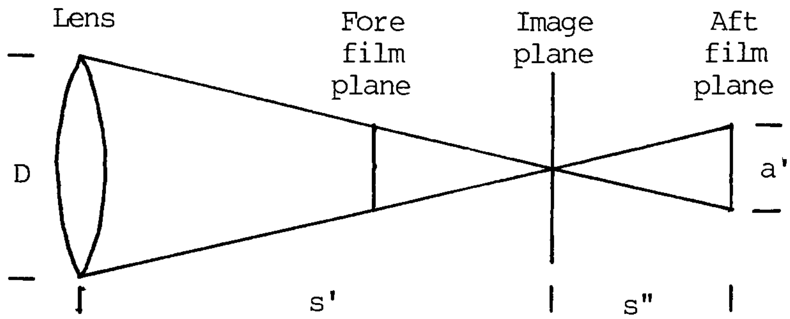

Figure 2: Depth of focus geometry

As early test imagery indicated no significant difference between the stock camera and proposed modifications, it was necessary to simulate a higher resolution system. With the 50 lp/mm system, the film gate depth of 0.012in was 2.4 times the depth of focus, 0.005in. A 150 lp/mm system's depth of focus would be one-third of the 50 lp/mm's and the film gate to depth of focus ratio would be increased to 7.2. To simulate the 150 lp/mm system, the film gate depth was increased to 0.036in, the depth of focus unchanged, and the desired ratio, 7.2, obtained.

To increase the film gate depth, 0.025in styrene shims were added between the platen edges and camera front rails. Subsequently, the image distance increased to 57.2mm, the object distance decreased to 399.4mm, and the object to image plane distance became 456.6mm. The last distance had to be set each time exposures were to be made.

CAMERA MODIFICATIONS

An array of holes, Figure 3, was drilled in Minolta's stock platen. The 102 0.024in diameter holes combined for an area of 0.045in^2 (arbitrary and perhaps not optimum values). They were arranged to grasp the film at its edges and as it entered the image area. Due to the natural curve of the film, Figure 4, the holes expand from the center to the edge of the platen so that the film is grabbed where it is already in contact with the platen and gradually pulled flat where it is not.

A 3/16in hole to accept the tubing from the vacuum pulling mechanisms was drilled in the camera back. It was centered behind the platen so that the suction was evenly spread among the array of holes.

An airtight seal was made between the camera back and platen to contain the vacuum. It consisted of a 1/16in thick sheet of rubber attached to the rear of the platen with contact cement. The sheet rubber was fitted around the array of platen holes, within the camera back and around the platen mounting lugs on the camera back (Figure 5). With the camera back closed, the platen, rubber sheet and camera back are compressed and the seal made.

The spring steel form attached to the rear of the platen had to be removed and modified to clear the platen holes and sheet rubber. A jeweler's file removed the obtrusive material (Figure 6) and the spring steel was remounted with 00-90 screws. The material left in the center of the form was purposefully kept to deflect and diffuse the suction from the camera back hole directly behind it. The platen holes the center section covers were deemed unimportant as the film should already be flat in that area due to the other holes and its natural curve.

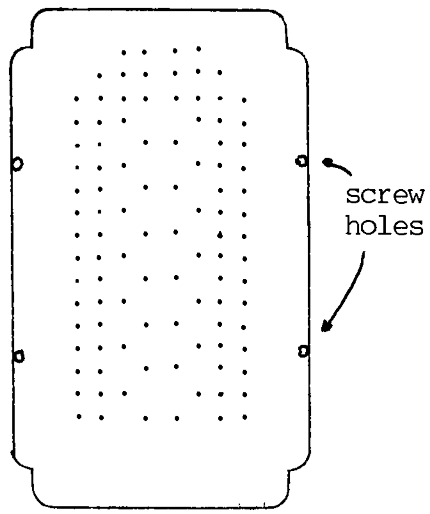

Figure 3: Platen hole array

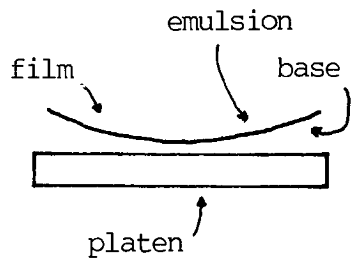

Figure 4: Natural curve of film

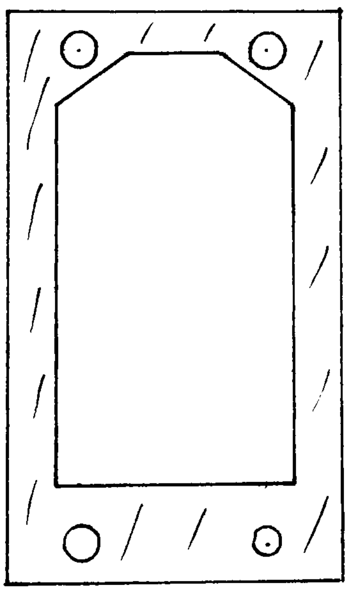

Figure 5: Sheet rubber design

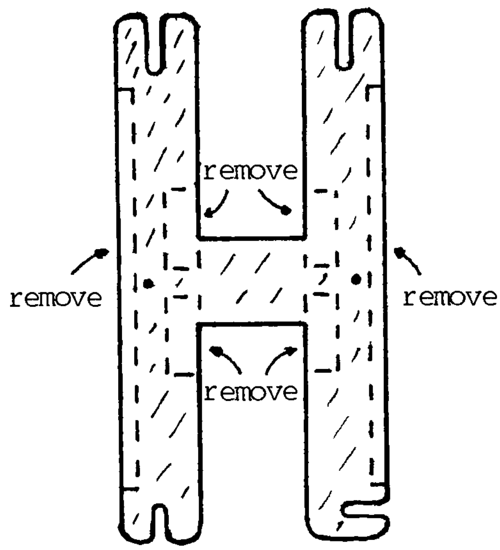

Figure 6: Spring steel modification

STYRENE PRESSURE PLATE

The additional pressure plate was constructed of styrene, a sheet of plastic available in most hobby stores. The main sheet of styrene extends to the edges of the platen with an open area just large enough for the image, Figure 7. The surface that will contact the film must be smooth so as not to scratch the film. On the side that faces the platen, spacers as thick as the film to be used were placed at the edges. On the other side, styrene was added to match the inside contours of the camera. Together, the two sides will hold the film flat with constant and even pressure while exposures are made.

The styrene pressure plate (like the shims described earlier) attaches with 00-90 screws. As both the plate and shims are 0.025in thick at the platen edges, the object and image distances listed for the shims (p.4) hold for the styrene plate. When loading film with the plate attached, the film is threaded thru the plate/platen opening, the film is attached to the take-up spool, and the camera back closed as the film cartridge is positioned.

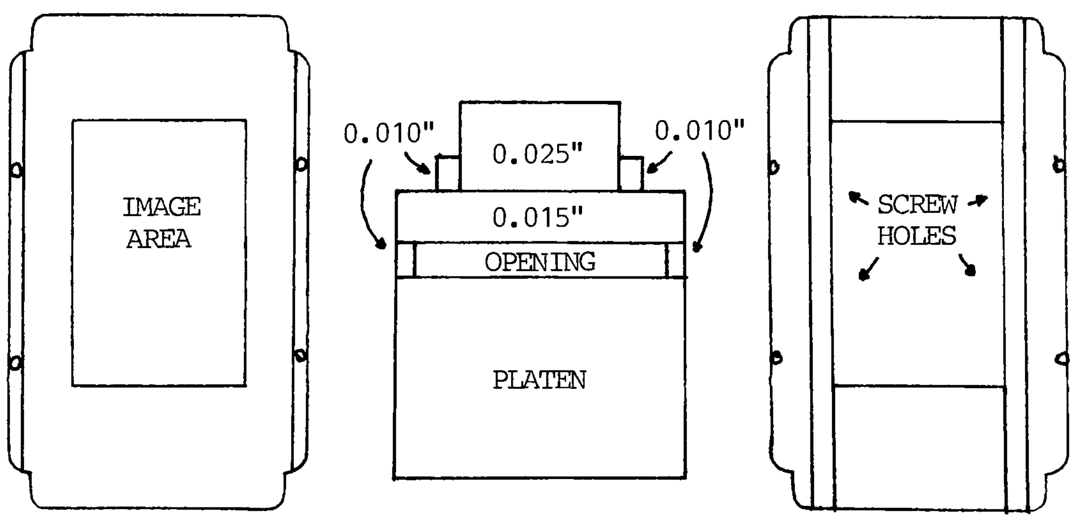

Figure 7: Styrene pressure plate

VACUUM MECHANISMS

Two methods of vacuum assembly, suction and induction (Figure 8), where necessitated by the variety of vacuum mechanisms. The "T" connection at the induction junction was an aquarium accessory. A "T" with a narrow inside diameter seemed to work best. For maximum suction via the induction method, the appropriate branch of the "T" should be inserted in the camera back and the exit branch unencumbered. Vinyl tubing ran between the camera and mechanisms. The camera/tubing and mechanism/tubing (if necessary) joints were made with 3/16in outside diameter brass tubing.

The initial list of vacuum mechanisms was trimmed via a visual inspection of their capabilities. The lenless camera and each vacuum mechanism were assembled and with the shutter open, film movement was watched for as the vacuum was initiated. If no movement of the film towards the platen was noted, the mechanism was eliminated from further consideration. Those excluded were a 75cc syringe (too small a volume to generate suction for more that one frame), a ballon (not enough velocity to create suction during induction) and an electric air pump (vibrated the film during suction and induction).

Six mechanisms passed the visual inspection: canned compressed air and a regulated air compressor (to eliminate vibrations) as induction sources and the human mouth, a vacuum bottle, a battery powered hand held vacuum cleaner and an electric household vacuum cleaner as suction sources. The vacuum bottle was actually an evacuated and stoppered thermos bottle. Although the air compressor and electric vacuum cleaner are not portable, they were included due to their strong showing in the visual inspection. All together, eight systems (the vacuum mechanisms, the styrene pressure plate, and an unmodified camera as control) were to be evaluated.

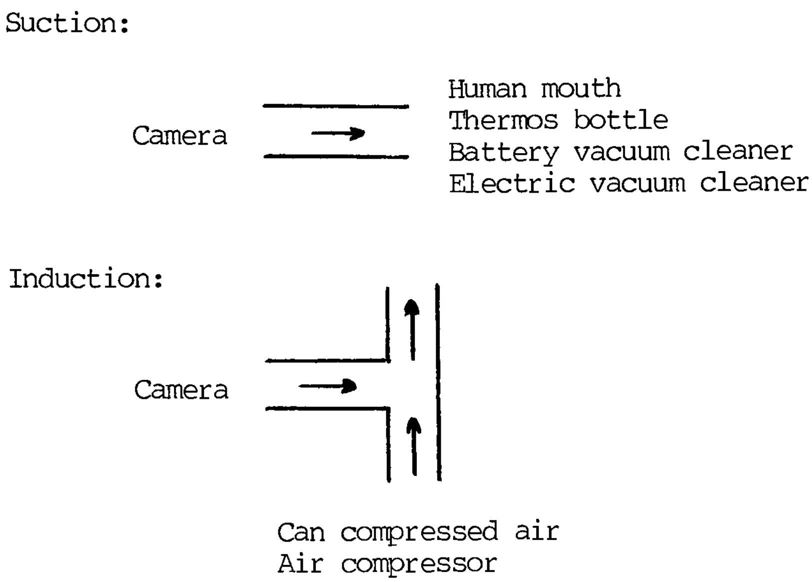

Figure 8: Vacuum assembly methods

TESTING CONDITIONS

The test object was a four by six array of typed asterisks that filled a nine by six inch page. Asterisks were chosen as those imaged in and out of focus were easily discernable with an 8x lupe. To keep it planer and perpendicular to the camera, the page was held against a glass plate with rubber bands and the whole object secured to a wall.

When lighting the object, the light falloff at the image plane due to the wide open lens had to be compensated for. A reasonably uniform result was obtained with four 18 inch, 15 watt fluorescent lamps held in a square, nine inches from the object.

With Kodalith 6556 under the prescribed lighting conditions and the lens set at f/1.7, the camera's meter indicated a shutter speed of 1/60 of a second. The processing schedule for a 35mm tank is outlined in Table 1.

Five exposures per trial were made of each of the eight systems. Three trials per system were randomly distributed over four rolls of film. The exposures were made in one evening and the processing done the next morning.

Table 1: Processing schedule

Step	Time	Agitation
Developer (D-19)	5min	Continuous
Water rinse	½min	Continuous
Fixer	3min	First 30sec
Water wash	5min	First 60sec

ANALYSIS

After deciding for himself what constituted an in or out of focus asterisk, each observer summed the number of out of focus asterisks across the five images of each trial of each system. The five image film strips were punched with the appropriate number of holes for the trial number and colored labels randomly added within trials to identify the system. A master key unscrambled the encoding after judging.

Table A1 of the Appendix presents the scoring in its original form with the exception of observer five. Twenty was added to each score of observer five so that his mean was comparable with the others without changing his standard deviation. Table 2 summarizes the scoring in preparation for the analysis.

Statistically, the control mean was compared with the other means and the overall mean of the vacuum systems.[4] As Table 3 indicates, the styrene pressure plate, two vacuum systems, and the vacuum systems mean were significantly lower than the control mean.

Overall, the sum column of Table 2 shows a 55% decrease of out of focus asterisks for a 55% increase of in focus image area for the styrene pressure plate when compared with the unmodified camera. The vacuum systems averaged a 10% difference.

Table 2: Scoring summary

System	Trail # 1	2	3	Sum	Mean	St dev
Control	243	292	252	787	37.5	6.2
Styrene plate	84	184	98	366	17.4	10.3
Human mouth	252	240	247	739	35.2	4.2
Thermos bottle	262	230	215	707	33.7	6.7
Elec vac clean	259	254	224	737	35.1	5.5
Bat vac clean	249	240	213	702	33.4	3.9
Compressed air	242	244	253	739	35.2	6.5
Air compressor	228	241	226	695	33.1	6.0
Vacuum systems	249	242	230	720	34.3	5.6
Overall	227	241	216	684	32.6	8.6

Table 3: Statistical analysis

Control versus	Test statistic* Calculated	Critical value	$U_1 \stackrel{?}{=} U_2$
Styrene plate	7.66	2.02	No
Human mouth	1.41	2.02	Yes
Thermos bottle	1.91	2.02	Yes
Elec vac clean	1.33	2.02	Yes
Bat vac clean	2.57	2.02	No
Compressed air	1.17	2.02	Yes
Air compressor	2.34	2.02	No
Vacuum systems	2.39	1.98+	No

*40 degrees of freedom, alpha = 0.025, one-tail

+145 degrees of freedom, alpha = 0.025, one-tail

CONCLUSION

The test imagery and statistical analysis indicated a ten percent increase of in focus image area for the vacuum platen and a fifty-five percent increase for the styrene pressure plate.

Several suitable vacuum mechanisms were found. The most promising as to workability and portability was a battery powered, hand held vacuum cleaner.

Overall, the inexpensive, simply constructed and easily installed styrene pressure plate is recommended for any high resolution, small format camera system.

FOOTNOTES

[1]Classified Documents at the Central Intelligence Agency.

[2]Warren J. Smith, Modern Optical Engineering (New York: McGraw-Hill Book Company, 1966), pp. 139-40.

[3]John F. Carson, Lecture Notes - Introduction to Photographic Optics (Rochester, New York: Rochester Institute of Technology, 1976), pp. 5.10-11.

[4]Albert D. Rickmers and Hollis N. Todd, Statistics (New York: McGraw-Hill Book Company, 1967), pp. 85-6.

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Smith, Warren J. Modern Optical Engineering. New York: McGraw-Hill Book Company, 1966.

APPENDIX

Table A1: Scoring by observers

APPENDIX KEY:

	TRIAL #			SUM

	OBSERVER 1			
	1	2	3	Σ
CONTROL	33	35	38	106
STYRENE PLATE	29	34	29	92
HUMAN MOUTH	35	33	38	106
THERMOS BOTTLE	27	34	36	97
ELEC VAC CLEANER	36	34	31	101
BAT VAC CLEANER	35	34	34	103
COMPRESSED AIR	37	30	32	99
AIR COMPRESSER	33	36	28	97
MEAN / STAN DEV / MEAN SUM	33.4	3.0	100	

	OBSERVER 2			
	1	2	3	Σ
CONTROL	32	50	38	120
STYRENE PLATE	7	32	13	52
HUMAN MOUTH	39	35	27	101
THERMOS BOTTLE	47	25	30	102
ELEC VAC CLEANER	42	37	31	110
BAT VAC CLEANER	40	32	26	98
COMPRESSED AIR	46	47	42	135
AIR COMPRESSER	32	38	39	109
MEAN / STAN DEV / MEAN SUM	34.5	10.2	103	

	OBSERVER 3			
	1	2	3	Σ
CONTROL	37	36	37	110
STYRENE PLATE	12	28	22	62
HUMAN MOUTH	37	36	42	115
THERMOS BOTTLE	38	30	29	97
ELEC VAC CLEANER	42	35	35	112
BAT VAC CLEANER	34	33	35	102
COMPRESSED AIR	31	33	44	108
AIR COMPRESSER	30	38	40	108
MEAN / STAN DEV / MEAN SUM	33.9	6.8	102	

	OBSERVER 4			
	1	2	3	Σ
CONTROL	35	34	25	94
STYRENE PLATE	4	21	0	25
HUMAN MOUTH	39	40	27	106
THERMOS BOTTLE	32	33	31	96
ELEC VAC CLEANER	38	34	27	99
BAT VAC CLEANER	33	38	26	97
COMPRESSED AIR	36	36	30	102
AIR COMPRESSER	26	26	34	86
MEAN / STAN DEV / MEAN SUM	29.4	9.8	88	

	OBSERVER 5			
	1	2	3	Σ
CONTROL	34	41	37	112
STYRENE PLATE	20	23	20	63
HUMAN MOUTH	31	30	36	97
THERMOS BOTTLE	39	34	26	99
ELEC VAC CLEANER	31	40	34	105
BAT VAC CLEANER	32	32	26	90
COMPRESSED AIR	37	38	28	103
AIR COMPRESSER	27	35	27	89
MEAN / STAN DEV / MEAN SUM	31.6	6.0	95	

	OBSERVER 6			
	1	2	3	Σ
CONTROL	40	49	45	134
STYRENE PLATE	6	23	7	36
HUMAN MOUTH	34	36	37	107
THERMOS BOTTLE	35	25	34	94
ELEC VAC CLEANER	39	43	22	104
BAT VAC CLEANER	36	33	34	103
COMPRESSED AIR	20	32	40	92
AIR COMPRESSER	44	25	34	103
MEAN / STAN DEV / MEAN SUM	32.2	10.8	97	

	OBSERVER 7			
	1	2	3	Σ
CONTROL	32	47	32	111
STYRENE PLATE	6	23	7	36
HUMAN MOUTH	37	30	40	107
THERMOS BOTTLE	44	49	29	122
ELEC VAC CLEANER	31	31	44	106
BAT VAC CLEANER	39	38	32	109
COMPRESSED AIR	35	28	37	100
AIR COMPRESSER	36	43	24	103
MEAN / STAN DEV / MEAN SUM	33.1	10.6	99	