State of California
Department of Public Works
Division of Highways
Materials and Research Department
April 4, 1958

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Mr. A. H. Brownfield
Supervising Structural Engineer
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Sacramento, California

Dear Sir:

Submitted for your consideration is:

A REPORT ON

THE USE OF X-RAYS TO DETERMINE THE DEPTH

OF REINFORCING STEEL IN A CONCRETE SLAB

Study made by . . . . . Structural Materials Section
Under general direction of . . . . . J. L. Beaton
Work supervised by . . . . . P. G. Jonas
Report prepared by . . . . . P. G. Jonas and C. B. Kendrick

Very truly yours,

58-22

F. N. Hveem
Materials and Research Engineer

PGJ/CBK:mw
cc: AHBrownfield
JWTrask

58-22

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I. SYNOPSIS

Excessive deformations of a reinforced concrete floor slab in the San Jose State College Library initiated an investigation of the size and placement of reinforcing steel in that floor by the Division of Architecture.

The Materials and Research Department was requested to x-ray selected areas of the floor using the "Double Exposure Technique" in order to determine the depth of the bars by triangulation. Technicians of the Materials and Research Department made 64 x-ray exposures and 286 pictures of the floor to locate 369 #6 reinforcing bars.

Following this operation, 5 concrete test cores were removed from the floor and 7 reinforcing bars were uncovered. The result of the coring operation was reported to you by memo dated January 14, 1958. The positions of these bars indicated the bar depths as calculated from the x-rays were accurate to ± 0.3 inch. Allowing for this error, 96 of the 369 bars are positioned outside the construction tolerance.

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II. INTRODUCTION

Problem

The excessive deflection of concrete floor slabs at the San Jose State College Library prompted the Division of Architecture to initiate an investigation as to the cause. Consequently, it was desired to determine non-destructively the size and location of the reinforcing bar within the floor. To this end, engineers from the Division of Architecture studied the feasibility of x-ray inspection of the floor.

History

About October 18, 1957, the Division of Architecture requested a trial use of x-rays to locate by triangulation and determine the size of reinforcing steel in a concrete floor. Appropriate test pieces of concrete were prepared and successfully x-rayed to confirm the technique. Accordingly, the Division of Architecture requested x-ray inspection of the third floor slab of the San Jose State College Library, and on October 24, 1957, the work was initiated. Subsequently about 44½ linear feet of floor were x-rayed on November 10 and 11, 1957, (films 1 through 31).

The bar sizes and positions were calculated from the radiographs in the week afterward. The data showed several bars to be out of position. (This was later attributed to a field error). This material was relayed to the Division of Architecture on November 27, 1957; and, on the basis of the information it contained, they asked the Materials and Research Department to make extensive additional x-rays of the floor and to core the slab as a check against the radiographs.

One hundred sixty-one linear feet of additional x-ray pictures were taken on December 22, 23, and 29, 30, and 31 (films 32 through 129 and 162 through 175) and 5 cores were cut from the floor on January 2 and 3, 1958, exposing 7 bars. (See Exhibit 4.) Other than the error mentioned previously, the observed positions of these bars indicated that the accuracy of the x-ray method of determining the depth of the reinforcing bar in the slab was about ± 0.3 inch.

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III. PROCEDURE

Equipment

The following is a list of the minimum personnel, materials, and equipment necessary to make these x-rays and the calculations therefrom:

1. Two technicians.

2. 13 man-hours of layout time in setting up tube-film positions on floor.

3. 14½ man-hours of x-ray tube operating time at 175 kv and 8 ma (0.5 - 1.0% of probable tube life) using a suitable portable x-ray tube, control, and power source.

4. 29 man-hours of tube handling time (shut down time between exposures is approximately equal to exposure time because of cooling requirements of the tube).

5. 18 man-hours of darkroom time and a portable darkroom (actual handling time was governed by actual tube handling time on this job).

6. 286 sheets of x-ray film (4½" x 17") and 15 gallons of photographic chemical solutions (300 sheets film actually used).

7. 110 man-hours of time in inspecting and interpreting the resulting x-ray film and performing calculations from the data obtained.

8. 0.8 man-hours per linear foot of floor examined. 1.2 man-hours per pair of film.

Travel time has not been accounted for in the figures above. A minimum of 40 man-hours of travel time were necessary for this work.

Technique

The method employed in using radiography to determine the depth of reinforcing bars in the concrete floor involved a simple but tedious system commonly called the "Double Exposure Technique". Similar to Stereo, this method involves making two exposures of exactly the same portion of the floor with the x-ray tube in a different position for each exposure. The image of a given reinforcing bar will be positioned differently on each film. The

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image shift (Z) is measured from the two films. The distance between the tube positions (L) is known, as is the distance from the tube to the film plane (H). The distance from the film plane to the reinforcing bar (h) is calculated from the formula:

$$h = \frac{HZ}{L + Z}$$

This may be further clarified by use of a simple geometry as shown in Exhibit 1.

In order to execute this scheme, the x-ray tube was placed on the second floor and the x-ray beam was projected upward through the third floor. The cassettes were placed on the surface of the third floor.

The x-ray tube traverse was directly underneath the line of film shown in Exhibit 4 with tube positions or stations as shown in Exhibit 5, Sheets 1 through 16.

It was found unnecessary to remove anything in the false ceiling.

At the start of the job, various combinations of tube and film positions were tried in an effort to get maximum coverage in minimum time; hence, the various values for (L) (see Exhibit 5, Sheets 1 through 3). Later the value of 86¼" or 5 cassette lengths was used constantly because this nearly always provided optimum speed and negative readability, and, by standardizing, it reduced the probability of field errors such as described later in the report. (See Exhibit 5, Sheets 4 through 16.)

It was necessary to place some reference marker on the film side of the object being x-rayed in order to determine the shift of the bar image in the film. Initially, the reference markers were taped to the floor randomly about 17 3/8 inches apart along the film line and under one end of the film, and the total length of film was measured. (See Exhibit 5.) This resulted in difficulty of calculation when bar images were between successive sets of pictures. From film set No. 32 on, the markers were placed and taped exactly 17¼ inches apart, and the film was centered over the markers (see Exhibit 5, Sheets 4 through 16). Lead markers were also taped to the floor at principle center-lines to provide tie-ins on the film. Another marker was taped to the underside of the floor, and this was used to check the thickness of the floor (see Exhibit 5, Sheet 3).

Both F and K film were used with calcium tungstate screens and an exposure of 8 minutes for the K film and 15 minutes for the F film. The total time involved in processing one film, from loading in the cassette to the end of the fixing bath, was about 40 minutes; several sets of film were exposed and developed simultaneously. The films were numbered consecutively in the order taken from film set No. 1 to film set No. 129 and from film set No. 162 to film set No. 175.

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The position these films occupy on the floor is shown in Exhibit 1. From film set No. 32 onward the numbers and positions of the film and the positions of the x-ray tube were actually marked on the floor one to two weeks before the films were taken. In tabulating the results, the bars revealed by the x-rays were numbered consecutively in the direction of progression of the film, starting with 1A to 81A on film sets Nos. 1 through 31 and restarting with 1 to 305 on film sets Nos. 32 to 129, and Nos. 162 to 175.

Following the x-ray operation, five concrete cores were cut from the floor. (These have been reported on separately.) Of these five cores, three were made adjacent to, or through, a position where a line of x-ray pictures was taken. Seven reinforcing bars were exposed by this operation, and the observed position of these bars, as compared to the position calculated from x-rays, is tabulated in Exhibits 6 and 7.

The field error was indicated by a complete lack of correlation between the calculated and the observed position of bar No. 55A in the first core. The depth as originally calculated was 3.37 inches, whereas the observed depth was 4.87 inches. This is attributed to an error in recording the x-ray tube placement while making the initial x-rays of the floor. Recalculation after reexamination of the film sets has proven this. More extensive preparation and experience reduced the probability of the recurrence of such errors on the later x-rays.

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IV. DISCUSSION

Treatment of Data

The distance (H) from the plane of the x-ray tube traverse to the plane of the film was determined by subtracting the height of the x-ray tube focal spot above the second floor (with the tube case resting on the floor), from the distance between the second floor to the third floor, as determined from the building plans.

Corrections in (H) because of floor sag and irregular floor spacing were considered unnecessary since an error as great as 2 inches in (H) would result in an error of only 1.4% in the calculated bar depth.

The net distance (H) thus determined was 141 inches for negatives 1 through 31 and 140.75 inches for negatives 32 through 129 and 162 through 175. This small difference in (H) is due to resting the tube in a low cradle to facilitate handling.

In recording the data taken from the film, the distance from the marker image to the bar image was recorded as D_a when measured from the first film taken in the line of progression, and D_b when measured from the second exposure of the same area. When the bar image was ahead of the marker image in the direction of progression, the distance was considered positive, and vice versa when it was behind the marker. In addition, some small compensation had to be made for a shift in the marker image since the marker was the distance of half a cassette thickness (5/32") away from the film. In accordance with formula (p4), this shift was about 1/16 or 0.06 inches for all the ranges of (L) used on this job (see Exhibit 2).

Thus we have:

$$Z = D_a - D_b + 0.06$$

In order to determine the depth of the bar in the slab (d), the calculated distance (h) from the bar to the film plane was corrected to compensate for the distance from the film to the top of the slab. This difference of about 5/16 of an inch corresponded to the thickness of the floor tile and one half the cassette.

Thus:

$$d = h - 0.31'' \text{ (see Exhibit 2)}$$

Taking into account all these factors, the total formula used to calculate bar depth from the top of the slab was as follows:

$$d = \frac{H(D_a - D_b + 0.06'')}{L + D_a - D_b + 0.06''} - 0.31''$$

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This value (d) together with the recorded and observed values for D_a, D_b, L, and H are tabulated in Exhibit 3.

Tabulated figures were carried beyond significance in tables and graphs.

The horizontal location of the bars was determined graphically by scaling a cross-section of the floor with the corresponding tube and film positions (see Exhibit 5). The calculated bar depths also appeared to be confirmed by this graphic check.

Observed vs. Calculated Depth

The observed locations of the seven reinforcing bars which were uncovered during the coring operation are tabulated in Exhibit 6, which shows a comparison between the observed and calculated locations of these bars. These indicate that the average error in the calculated depth of the bar is plus or minus 0.25 of an inch. The standard deviation is plus or minus 0.29 of an inch; the probable error is plus or minus 0.19 of an inch. A simple correction factor of plus or minus 0.12 of an inch may be derived from the data by averaging the difference between the calculated and the observed depths, or these differences may be treated by method of least squares to produce a correction factor which is a function of the calculated bar depth. This factor, as graphed in Exhibit 7, indicates the magnitude and direction of the correction with depth and the probable error of the corrected depth.

The validity of applying any correction factor based on eight observations is questionable. The accuracy of the bar depths, as observed during the coring operation, may not be greater than 0.1 of an inch because of the irregularities of the bar and slab surface.

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V. CONCLUSIONS

A. Use of Radiography

Radiography offers a useful but time consuming method of determining the position of reinforcing bars in concrete floors eight inches thick or thinner. The precision of the determination is largely dependent on the experience of the operators and the amount of time spent in preparation before the x-ray exposures are made.

B. Bar Positions

The depth and horizontal location of 369 No. 6 reinforcing bars were calculated and graphed from the x-ray photographs. Our information indicates that the two outer layers of steel should be 3/4" from the slab surfaces; and the two inner layers are tied to the outer layers. The permitted depth variation, as per verbal information supplied, is $\pm \frac{1}{4}$ inch. Accordingly, the bar centers of the top layers should not be deeper than 1 3/8 inches or 2 1/8 inches, nor can the bar centers of the bottom layers be shallower than 5 5/8 inches or 4 7/8 inches.

After taking into account the correction factor and standard deviation of the calculated bar depths (see Exhibits 6 and 7), 96 bars appear to be positioned outside of these limits. These are tabulated in Exhibit 8.

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VI. BIBLIOGRAPHY

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Eastman Kodak Company
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Rochester 4, New York

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H. R. Clauser
Reinhold Publishing Corporation
New York 36, New York

4. Experimental Physical Chemistry
Daniels, Mathews, Williams, et al
McGraw-Hill Book Company
New York, New York

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VII. ACKNOWLEDGMENTS

Paul Jonas, Charles Kendrick, and Robert Benson worked as Radiographic Technicians in the preparation of the x-ray negatives. They were assisted in the dark room and physical labor by Robert Watkins and Jay Page.

Those procedures peculiar to this application of the "Double Exposure Technique" were outlined by Mr. Kendrick and directed by Mr. Jonas. Final calculations were prepared by Mr. Watkins and Mr. Page and spot checked by Mr. Kendrick and Mr. Rossbo of the Division of Architecture who acted as observer during the preparation of data.

Coring operations were performed by the Concrete Section under the direction of Mr. Bailey Tremper and supervised by Mr. D. Spellman.

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VIII. APPENDIX

Exhibit 1	Double Exposure Technique
2	Application of Correction Factors
3	Tabulated X-Ray Data (Sheets 1 through 23)
4	X-Ray Layout of 3rd Floor
5	Cross Section of 3rd Floor (Sheets 1 through 16)
6	Table of Calculated and Observed Depths of Exposed Bars
7	Graph of Correction Factor Derived from Exposed Bars
8	Table of Bars not within Specified Position Limits (Sheets 1 through 5)

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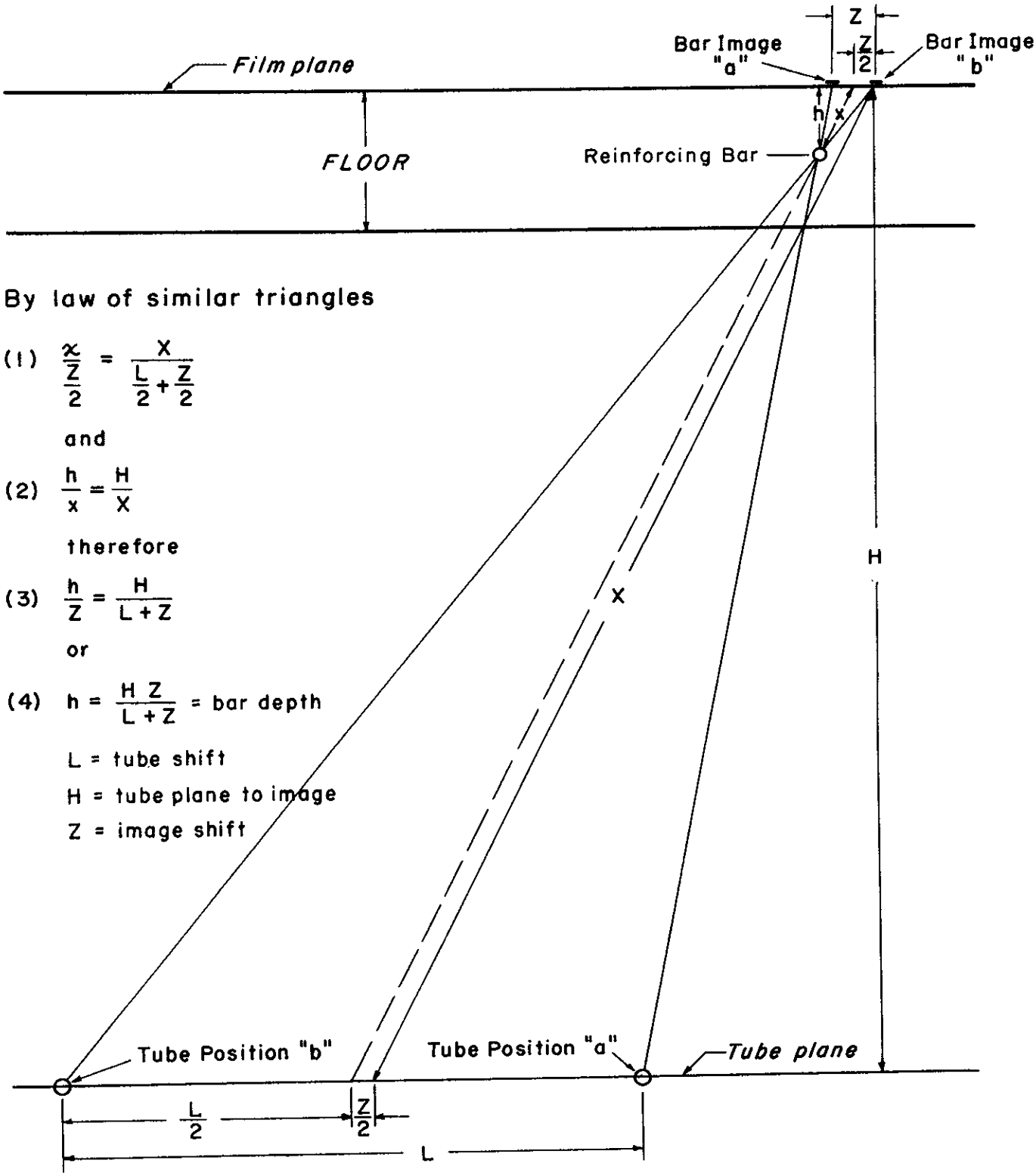
Exhibit 1



By law of similar triangles

(1) $\frac{x}{\frac{Z}{2}} = \frac{X}{\frac{L}{2}+\frac{Z}{2}}$

and

(2) $\frac{h}{x} = \frac{H}{X}$

therefore

(3) $\frac{h}{Z} = \frac{H}{L+Z}$

or

(4) $h = \frac{H\,Z}{L+Z}$ = bar depth

L = tube shift

H = tube plane to image

Z = image shift

DOUBLE EXPOSURE TECHNIQUE

Cross-section illustrating tube, object and image geometry as it was used to determine the depth of the reinforcing bar.

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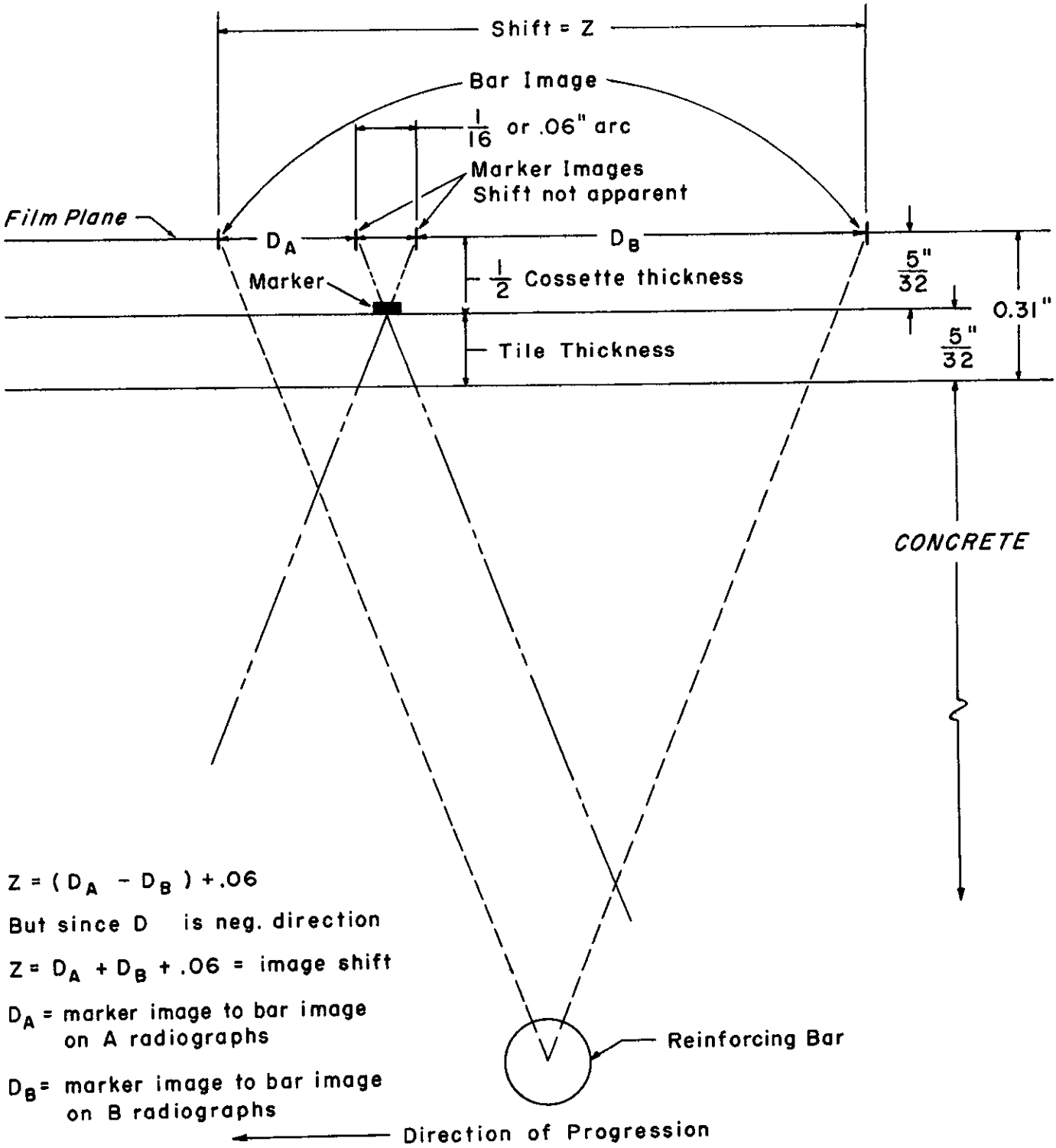
Exhibit 2



$Z = (D_A - D_B) + .06$

But since D is neg. direction

$Z = D_A + D_B + .06$ = image shift

D_A = marker image to bar image on A radiographs

D_B = marker image to bar image on B radiographs

APPLICATION OF CORRECTION FACTORS

This shows graphically the derivation of the correction factors used in calculating the bar depth.

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TABLE OF CONTENTS FOR EXHIBIT 3, SHEETS 1 THROUGH 23

Sheet 1	Bars 1A through 18A - Films 1 through 5			
2	18A'	32A'	6	12
3	33A	51A	13	17
4	52A	56A	17	18
5	57A	65A	19	22
6	66A	81A	23	31
7	1	19	32	40
8	20	38	41	51
9	39	57	51	61
10	58	76	62	69
11	77	95	69	74
12	96	112	74	78
13	113	131	78	84
14	132	150	85	92
15	151	168	92	97
16	169	186	97	101
17	187	205	102	107
18	206	224	108	115
19	225	243	116	120
20	244	262	120	125
21	263	281	125	164
22	282	300	164	173
23	301	305	174	175

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L = 70"
H = 141"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth $d=h-0.31$	Film No.
1A	+1.44	+0.50	0.94	1.00	71.00	1.98	1.67	1
2A	+5.57	+2.43	3.14	3.20	73.20	6.17	5.86	
3A	+10.65	+9.79	0.86	0.92	70.92	1.85	1.54	
4A	?	?	?	?	?	?	?	
5A	2.10	1.24	0.86	0.92	70.92	1.83	1.52	2
6A	9.65	6.55	3.10	3.16	73.16	6.08	5.77	
7A	10.99	10.22	0.77	0.83	70.83	1.65	1.34	
⊥ 8A(1)	+0.30	-2.05	2.35	2.41	72.41	4.69	4.38	3
8A(2)	2.51	-0.50	3.01	3.07	73.07	5.91	5.60	
9A	+2.15	1.25	0.90	0.96	70.96	1.90	1.59	
10A	11.26	10.22	1.04	1.10	71.10	2.06	1.75	
11A	13.49	10.52	2.97	3.03	73.03	5.96	5.59	
12A	2.50	1.72	0.78	0.84	70.84	1.67	1.36	4
13A	8.44	5.04	3.40	3.46	73.46	6.62	6.31	
14A	10.46	9.71	0.75	0.81	70.81	1.61	1.30	
15A	1.60	-1.75	3.35	3.41	73.41	6.53	6.22	5
16A	0.78	-0.08	0.86	0.92	70.92	1.82	1.51	
17A	12.20	8.75	3.45	3.51	73.51	6.72	6.41	
18A	10.53	9.63	0.90	0.96	70.96	1.90	1.59	

Exhibit 3
Sheet 1

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L = 70"
H = 141"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth d=h-0.31	Film No.
18A'	0.93	+0.35	0.58	0.64	70.64	1.27	0.96	6
19A	5.05	1.68	3.37	3.43	73.43	6.57	6.26	
20A	9.60	8.61	0.99	1.05	71.05	2.18	1.87	
21A	?	11.89	?	?	?	?	?	
22A	-0.68	-1.65	0.97	1.03	71.03	2.04	1.73	7
23A	5.68	2.30	3.38	3.44	73.44	6.59	6.28	
24A	8.90	7.84	1.06	1.12	71.12	2.21	1.90	
25A	3.84	0.40	3.44	3.50	73.50	6.70	6.39	8
26A	-1.00	-4.15	3.15	3.21	73.21	6.16	5.85	9
27A	7.33	6.25	1.08	1.14	71.14	2.25	1.94	
28A	13.64	10.32	3.32	3.38	73.38	6.49	6.18	
29A	10.26	6.99	3.27	3.33	73.33	6.39	6.08	10
30A	4.61	3.64	0.97	1.03	71.03	2.04	1.73	11
31A	6.90	3.59	3.31	3.37	73.37	6.47	6.16	
32A	4.86	1.61	3.25	3.31	73.31	6.35	6.04	12
32A	14.68	?	?	?	?	?	?	

Exhibit 3
Sheet 2

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L = 96"
H = 141"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
33A	2.51	0.70	1.81	1.87	97.87	2.70	2.39	13
34A	5.83	2.06	3.77	3.83	99.83	5.41	5.10	
35A	11.26	9.50	1.76	1.82	97.82	2.62	2.31	
36A	-1.35	-5.10	3.75	3.81	99.81	5.38	5.07	14
37A	2.03	0.16	1.87	1.93	97.93	2.80	2.49	
38A	7.53	3.65	3.88	3.94	99.94	5.56	5.25	
39A	11.04	9.15	1.89	1.95	97.95	2.71	2.40	
40A	?	13.11	?	?	?	?	?	15
41A	-3.90	?	?	?	?	?	?	
42A	5.25	1.11	4.14	4.20	100.20	5.90	5.59	
43A	5.25	3.55	1.70	1.76	97.76	2.54	2.23	
44A	-2.53	-6.35	3.82	3.88	99.88	5.48	5.17	16
45A	-2.53	-4.49	1.96	2.02	98.02	2.91	2.60	
46A	3.93	2.25	1.68	1.74	97.74	2.51	2.20	
47A	8.36	4.64	3.72	3.78	99.78	5.34	5.03	
48A	12.30	10.51	1.79	1.85	97.85	2.67	2.36	
49A	-0.21	-3.85	3.64	3.70	99.70	5.23	4.92	
50A	3.92	2.15	1.77	1.83	97.83	2.64	2.33	17
51A	9.21	5.49	3.72	3.78	99.78	5.35	5.04	

Exhibit 3
Sheet 3

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L = 96"
H = 141"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b-0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
52A	11.11	9.31	1.80	1.86	97.86	2.68	2.37	17
53A	0.40	-3.14	3.54	3.60	99.60	5.10	4.79	18
54A	1.67	-0.16	1.83	1.89	97.89	2.72	2.41	
55A	9.76	6.35	3.41	3.47	99.47	4.92	4.61	
56A	10.53	8.65	1.88	1.94	97.94	2.79	2.48	

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L = 73"
H = 141"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
57A	-1.81	?	?	?	?	?	?	19
58A	-0.82	-2.23	1.41	1.47	74.47	2.77	2.46	
59A	+10.26	+7.62	2.64	2.70	75.70	5.03	4.72	
60A	+10.68	+9.31	1.37	1.43	74.43	2.70	2.39	
61A	+6.61	+3.82	2.79	2.85	75.85	5.27	4.96	20
⊥ bar							1.95	
62A	+3.70	+0.92	2.78	2.84	75.84	5.26	4.95	21
63A	+12.15	+10.71	1.44	1.50	74.50	2.82	2.51	
64A	+0.18	-2.54	2.72	2.78	75.78	5.16	4.85	22
65A	13.70	11.14	2.56	2.62	75.62	4.86	4.55	

Exhibit 3
Sheet 5

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L = 86.87"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
66A	6.72	2.63	4.09	4.15	91.02	6.41	6.10	23
67A	5.48	1.43	4.05	4.11	90.98	6.37	6.06	24
68A	6.63	2.79	3.84	3.90	89.77	6.11	5.80	25
69A	5.42	1.50	3.92	3.98	90.85	6.17	5.86	26
Thickness for slab J	2.46	-2.14	4.50	4.56	91.43	7.02	6.71	
70A	3.49	-0.40	3.89	3.96	90.83	6.13	5.82	27
71A	-1.33	-4.49	3.16	3.22	90.09	5.00	4.69	28
72A				THIS IS NOT A BAR				
73A	9.70	6.49	3.21	3.27	90.14	5.10	4.89	
74A	10.20	9.88	0.32	0.38	87.25	0.61	0.30	
75A	3.18	-0.66	3.84	3.90	90.77	6.05	5.74	29
76A	11.94	10.85	1.09	1.16	88.03	1.85	1.54	
77A	-1.62	-5.15	3.53	3.59	90.46	5.59	5.28	
78A	10.01	6.19	3.82	3.88	90.75	6.03	5.72	30
79A	2.34	-1.44	3.78	3.84	90.71	5.97	5.66	31
80A	1.15	-0.02	1.17	1.23	88.10	1.98	1.67	
81A	?	11.10	?	?	?	?	?	

Exhibit 3
Sheet 6

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
1	-3.78	-7.25	3.47	3.53	89.78	5.54	5.23	32
2	+5.03	+1.61	3.42	3.48	89.73	5.46	5.15	
3	-4.97	-6.14	1.17	1.23	87.48	1.98	1.67	33
4	-2.23	-5.56	3.33	3.39	89.64	5.32	5.01	
5	+7.26	+3.91	3.35	3.41	89.66	5.35	5.05	
6	-0.95	-4.27	3.32	3.38	89.63	5.31	5.00	34
7	+7.98	4.76	3.22	3.28	89.53	5.18	4.87	
8	-7.60	-8.98	1.38	1.44	87.69	2.31	2.00	35
9	+0.29	-3.03	3.32	3.38	89.63	5.30	4.99	
10	-7.09	-10.23	3.14	3.20	89.45	5.02	4.71	36
11	+1.76	-1.51	3.27	3.33	89.58	5.24	4.93	
12	?	(SEE PLOT - TWO BARS)		- - - - - - - - -		?	?	37
13	+0.16	-3.20	3.36	3.42	89.67	5.37	5.06	
14	-7.86	-11.11	3.25	3.31	89.56	5.21	4.90	38
15	+1.16	-2.25	3.41	3.47	89.72	5.44	5.13	
16	+3.65	+2.16	1.49	1.55	87.80	2.48	2.17	
17	-7.28	-10.53	3.25	3.31	89.56	5.21	4.90	39
18	+3.24	-0.06	3.30	3.36	89.61	5.28	4.97	
19	-3.68	-6.86	3.18	3.24	89.49	5.10	4.79	40

Exhibit 3
Sheet 7

ClibPDF - www.fastio.com

L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h=\frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
20	+7.93	+4.82	3.11	3.17	89.42	4.98	4.67	40
21	+4.70	+1.52	3.18	3.24	89.49	5.10	4.79	41
22	-3.49	-6.68	3.19	3.25	89.50	5.12	4.81	42
23	-7.14	-10.23	3.09	3.15	89.40	4.91	4.60	43
24	+4.80	+1.66	3.14	3.20	89.45	5.04	4.73	
25	+0.74	-2.45	3.19	3.25	89.50	5.12	4.81	44
26	-3.93	-7.24	3.31	3.37	89.62	5.29	4.98	45
27	+8.49	+5.25	3.24	3.30	89.55	5.19	4.88	
28	+3.19	-0.18	3.37	3.43	89.68	5.38	4.07	46
29	-3.72	-7.10	3.38	3.44	89.69	5.40	5.09	47
30	+8.40	+5.04	3.36	3.42	89.67	5.36	5.05	
31	+0.83	-2.58	3.41	3.47	89.72	5.44	5.13	48
32	+1.84	+0.27	1.57	1.63	87.88	2.61	2.30	
33	-6.15	-9.52	3.37	3.43	89.68	5.38	5.07	49
34	+4.59	+1.15	3.44	3.50	89.75	5.48	5.17	
35	-3.75	-7.27	3.52	3.58	89.83	5.62	5.31	50
36	+2.51	+1.00	1.51	1.57	87.82	2.51	2.21	
37	+6.71	+3.35	3.36	3.42	89.67	5.36	5.05	
38	-0.69	-4.27	3.58	3.64	89.89	5.70	5.39	51

Exhibit 3
Sheet 8

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
39	+8.90	+5.59	3.31	3.37	89.62	5.26	4.95	51
40	-1.69	-5.23	3.54	3.60	89.85	5.64	5.33	52
41	+2.33	+0.50	1.83	1.89	87.14	3.05	2.74	
42	+7.81	+4.25	3.56	3.62	89.87	5.67	5.36	
43	+0.49	-3.05	3.54	3.60	89.85	5.64	5.33	53
44	-5.95	-9.26	3.31	3.37	89.62	5.26	4.95	54
45	-3.85	-6.04	2.19	2.26	87.51	3.63	3.32	
⊥ bar							2.55	
46	+2.35	-1.15	3.50	3.56	89.81	5.58	5.27	
47	-3.12	-6.51	3.39	3.45	89.70	5.41	5.10	55
48	+7.51	+4.12	3.39	3.45	89.70	5.41	5.10	
49	+3.75	+0.35	3.40	3.46	89.71	5.42	5.11	56
50	-5.06	-8.46	3.40	3.46	89.71	5.42	5.11	57
51	+7.61	+4.11	3.50	3.56	89.81	5.58	5.27	
52	+3.61	-0.06	3.55	3.61	89.86	5.66	5.35	58
53	-1.04	-4.64	3.60	3.66	89.91	5.73	5.42	59
54	-4.40	-8.05	3.65	3.71	89.96	5.80	5.49	60
55	+7.95	+4.25	3.70	3.76	90.01	5.88	5.57	
56	+2.60	-0.26	2.86	2.92	89.17	4.61	4.30	61
57	?	?	?	?	?	?	?	

Exhibit 3
Sheet 9

ClibPDF - www.fastio.com

L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
58	+7.86	+4.34	3.52	3.58	89.73	5.61	5.30	62
59	+3.20	-0.41	3.61	3.67	89.92	5.74	5.43	63
60	-4.40	-7.86	3.46	3.52	89.77	5.52	5.21	64
61	+1.06	-0.81	1.97	2.03	88.28	3.24	2.93	
62	+6.69	+3.19	3.50	3.56	89.81	5.58	5.27	
63	-1.65	-5.31	3.66	3.72	89.97	5.82	5.51	65
64	+7.84	+4.21	3.63	3.69	89.94	5.77	5.46	
65	-2.98	-4.88	1.70	1.76	88.01	2.82	2.51	66
66	+0.35	-3.29	3.64	3.70	89.95	5.79	5.48	
67	-10.25	-6.71	3.54	3.60	89.85	5.48	5.17	67
68	+3.12	-0.47	3.59	3.65	89.90	5.72	5.41	
69	-3.82	-5.58	1.76	1.82	88.07	2.91	2.60	68
70	+0.52	-2.92	3.44	3.50	89.75	5.49	5.18	
71	+2.81	+1.04	1.77	1.83	88.08	2.92	2.61	
72	+9.74	+8.12	1.62	1.68	87.93	2.69	2.38	68,69
73	+10.03	+6.52	3.51	3.57	89.82	5.59	5.28	68,69
74	+0.03	-1.39	1.42	1.42	87.67	2.80	2.49	69
75	+1.95	-1.39	3.34	3.40	89.65	5.34	5.03	
76	+7.15	+5.50	1.65	1.71	87.96	2.74	2.43	

Exhibit 3
Sheet 10

ClibPDF - www.fastio.com

L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
77	+11.02	+7.59	3.43	3.49	89.74	5.64	5.33	69, 70
78	-2.99	-4.83	1.84	1.90	88.15	3.03	2.72	70
79	+3.36	+1.56	1.80	1.86	88.11	2.97	2.66	
80	+3.63	-0.12	3.75	3.81	90.06	5.92	5.61	
81	+8.82	+7.14	1.68	1.74	87.99	2.78	2.47	70, 71
82	-3.33	-7.44	4.11	4.17	90.42	6.23	5.92	71
83	+2.84	+0.92	1.92	1.98	88.23	3.15	2.84	
84	+4.79	+0.92	3.87	3.93	90.18	6.02	5.71	
85	+9.82	+7.91	1.91	1.97	88.22	3.14	2.83	71, 72
86	-2.89	-6.51	3.62	3.68	89.93	5.76	5.45	72
87	+0.05	-2.13	2.18	2.24	88.49	3.56	3.25	
88	+6.06	+2.74	3.32	3.38	89.63	5.31	5.00	
89	+7.36	+5.10	2.26	2.32	88.57	3.69	3.38	
90	-5.51	-7.23	1.72	1.78	88.03	2.83	2.52	73
91	-4.95	-7.71	2.76	2.82	89.07	4.46	4.15	
92	2.55	-0.05	2.60	2.66	88.91	4.21	3.90	
93	3.91	+0.58	3.33	3.39	89.64	5.32	5.01	
94	+10.02	+7.48	2.54	2.60	88.85	4.12	3.81	73, 74
95	-4.10	-7.42	3.32	3.38	89.63	5.31	5.00	74

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L = 86.25"
H = 140.75"

	Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
	96	+0.22	-2.41	2.63	2.69	88.94	4.26	3.95	74
	97	+5.38	+2.15	3.23	3.29	89.54	5.17	4.86	
	98	+7.23	+4.65	2.58	2.64	88.89	4.18	3.87	
	99	-5.95	-7.25	1.30	1.36	87.61	2.18	1.87	75
	100	-2.13	-3.90	1.77	1.83	88.08	2.92	2.61	
Alternate	101	+6.10	+4.88	1.22	1.28	87.53	2.06	1.75	
Alternate	101	+6.02	+2.30	3.72	3.78	90.03	5.90	5.59	
	102	+6.50	+2.30	4.20	4.26	90.51	6.63	6.32	
	102	+6.62	+4.89	1.73	1.79	88.04	2.86	2.57	
	103	-1.65	-3.21	1.56	1.62	87.87	2.59	2.28	76
	104	+1.30	-2.54	3.84	3.90	90.15	6.09	5.78	
	105	+7.14	+5.72	1.42	1.48	87.73	2.37	2.06	
	106	-4.09	-7.81	3.72	3.78	90.03	5.90	5.59	77
	107	-2.30	-5.60	3.30	3.36	89.61	5.27	4.96	
	108	-1.55	-2.83	1.28	1.34	87.59	2.15	1.84	
	109	+6.29	+2.46	3.83	3.89	90.14	6.07	5.76	
	110	+7.52	+6.39	1.13	1.19	87.44	1.92	1.61	
	111	-1.53	-2.63	1.10	1.16	87.41	1.87	1.56	78
	112	+2.35	-1.30	3.65	3.72	89.97	5.82	5.51	

Exhibit 3
Sheet 12

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
113	+7.04	+6.00	1.04	1.10	87.35	1.77	1.46	78
114	-2.34	-3.30	0.96	1.02	87.27	1.65	1.34	79
115	-1.76	-5.64	3.88	3.94	90.19	6.15	5.84	
116	+5.63	+4.75	0.88	0.94	87.19	1.52	1.21	
117	+5.79	+5.44	0.35	0.41	86.66	0.67	0.36	
117'	-4.82	-8.17	3.35	3.41	89.66	5.35	5.04	
118	-3.27	-4.40	1.13	1.19	87.44	1.92	1.61	80
119	-0.48	-4.05	3.57	3.63	89.88	5.68	5.37	
120	+5.50	+4.65	0.85	0.91	87.16	1.47	1.16	
121	+10.93	+7.20	3.73	3.79	90.04	5.92	5.61	80, 81
122	-3.31	-4.20	0.89	0.95	87.20	1.53	1.22	81
123	+4.61	+3.44	1.17	1.23	87.48	1.98	1.67	
124	+7.27	+3.84	3.43	3.49	89.74	5.48	5.17	
125	-1.82	-3.43	1.61	1.67	87.92	2.67	2.36	82
126	+5.67	+4.13	1.54	1.60	87.85	2.56	2.25	
127	-2.35	-5.72	3.37	3.43	89.68	5.38	5.07	83
128	-0.13	-1.72	1.59	1.65	87.90	2.64	2.33	84
129	-4.19	-7.59	3.40	3.46	89.71	5.43	5.12	84
130	-2.95	-4.50	1.55	1.61	87.86	2.58	2.27	
131	+5.66	*2.20	3.46	3.52	89.77	5.52	5.21	

Exhibit 3
Sheet 13

ClibPDF - www.fastio.com

L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
132	-5.06	-6.71	1.65	1.71	87.96	2.74	2.43	85
133	+5.04	+1.54	3.50	3.56	89.81	5.58	5.27	
134	-5.86	-7.78	1.92	1.98	88.23	3.16	2.85	86
135	-3.58	-7.04	3.46	3.52	89.77	5.52	5.21	
136	+8.99	+8.22	0.77	0.83	87.08	1.34	1.03	86, 87
137	-4.26	-7.64	3.38	3.44	89.69	5.46	5.15	87
138	+2.12	-1.21	3.33	3.39	88.64	5.38	5.07	
139	+5.79	+3.76	2.03	2.09	88.34	3.34	3.03	
140	+2.36	+0.35	2.01	2.07	88.32	3.30	2.99	88
141	+6.26	+2.95	3.31	3.37	89.62	5.29	4.98	
142	+10.60	+7.30	3.30	3.36	89.61	5.27	4.96	88, 89
143	+2.06	-0.08	2.14	2.20	88.45	3.50	3.19	89
144	-1.33	-2.85	1.52	1.58	87.83	2.53	2.22	90
145	+0.36	-3.41	3.77	3.83	90.08	6.00	5.69	
146	+1.28	-1.98	3.26	3.32	89.57	5.21	4.90	
147	+10.56	+8.67	1.89	1.95	88.20	3.11	2.80	90, 91
148	+1.17	-0.55	1.72	1.78	88.03	3.20	2.89	91
149	?	?	?	?	?	?	?	92
150	-2.11	-3.99	1.88	1.94	88.29	3.09	2.78	

Exhibit 3
Sheet 14

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L = 86.25"
H = 140.75"

	Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
	151	+2.59	-0.52	3.11	3.17	89.42	4.91	4.60	92
	152	+6.09	+4.20	1.89	1.95	88.20	3.11	2.80	
	153	-4.51	-7.78	3.27	3.33	89.58	5.22	4.91	93
	154	-4.84	-6.70	1.86	1.92	88.17	3.06	2.75	
Crack shows	155	+4.37	+2.49	1.88	1.94	88.19	3.09	2.78	
Crack shows	156	+5.09	+1.84	3.25	3.31	89.56	5.20	4.89	
	157	-3.46	-4.76	1.30	1.36	87.61	2.19	1.88	94
	158	-1.56	-5.54	3.98	4.04	90.29	6.30	5.99	
	159	+3.21	+1.26	1.95	2.01	88.26	3.20	2.89	
	160	+8.09	+4.82	3.27	3.33	89.58	5.23	4.92	
	161	-5.70	-7.60	1.90	1.96	88.21	3.13	2.82	95
	162	+3.30	-0.55	3.85	3.91	90.16	6.10	5.79	
	163	+3.41	+1.45	1.96	2.02	88.27	3.22	3.91	
	164	+11.25	+7.94	3.31	3.37	89.62	5.30	4.99	95, 96
	165	-4.88	-6.93	2.05	2.11	88.36	3.36	3.05	96
	166	+3.06	-0.35	3.41	3.47	89.72	5.44	5.13	
	167	+3.89	+1.83	2.06	2.12	88.37	3.38	3.07	
	168	?	?	?	?	?	?	?	97
	168'	?	?	?	?	?	?	?	

L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
169	-0.86	-2.88	2.02	2.08	88.33	3.32	3.01	97
170	+2.95	-0.45	3.40	3.46	89.71	5.42	5.11	
171	+7.56	+5.70	1.86	1.92	88.17	3.06	2.75	
172	-4.93	-8.15	3.22	3.28	89.53	5.15	4.84	98
173	-1.30	-3.00	1.70	1.76	88.01	2.81	2.50	
174	+5.24	+2.05	3.19	3.25	89.50	5.11	4.80	
175	+7.63	+6.13	1.50	1.56	87.81	2.50	2.19	
176	-5.88	-8.60	2.72	2.78	89.03	4.40	4.09	99
177	-0.76	-1.95	1.19	1.25	87.50	2.01	1.70	
178	+6.35	+2.50	3.85	3.91	90.16	6.10	5.79	
179	+7.65	+6.53	1.12	1.18	87.43	1.90	1.59	
180	-2.05	-3.10	1.05	1.11	87.36	1.79	1.48	100
181	+0.57	-3.57	4.07	4.13	90.38	6.45	6.14	
182	+6.61	+5.46	1.15	1.21	87.46	1.94	1.63	
183	+12.00	+7.96	4.04	4.10	90.35	6.40	6.09	100, 101
183A	-2.90	-6.29	3.39	3.45	89.70	5.41	5.10	101
184	-1.92	-3.13	1.21	1.27	87.52	2.04	1.73	
185	+6.89	+2.96	3.93	3.99	90.24	6.23	5.92	
186	+7.31	+6.10	1.21	1.27	87.52	2.04	1.73	

Exhibit 3
Sheet 16

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
187	-1.95	-3.17	1.22	1.28	87.53	2.05	1.74	102
188	+0.83	?	?	?	?	?	?	
189	+6.74	+5.45	1.29	1.35	87.60	2.17	1.86	
190	-3.63	-7.80	4.17	4.23	90.48	6.59	6.28	103
191	-1.10	-2.44	1.34	1.40	87.65	2.24	1.93	
192	+7.76	+3.63	4.13	4.19	90.44	6.53	6.22	
193	?	+7.06	?	?	?	?	?	
* 194	-2.10	-2.86	0.76	0.82	87.07	1.32	1.01	104
* 195	-1.55	-2.86	1.31	1.37	87.62	2.19	1.88	
* 196	+7.62	+5.00	2.62	2.68	88.93	4.24	3.93	
197	-7.41	?	?	?	?	?	?	104, 105
198	-1.84	-3.09	1.25	1.32	87.57	2.12	1.81	105
199	+4.76	+0.50	4.26	4.32	90.57	6.75	6.44	
200	+6.53	+5.25	1.28	1.36	87.61	2.18	1.87	
201	-2.70	-4.64	1.94	2.00	88.25	3.19	2.88	106
202	+5.89	+4.13	1.76	1.82	88.07	2.90	2.59	
203	-1.69	-5.19	3.50	3.56	89.81	5.58	5.27	107
204	-0.49	-2.30	1.81	1.87	88.12	3.00	2.69	
205	+1.01	-2.50	3.51	3.57	89.82	5.59	5.28	

* These values have been discounted because of doubt in reading the negatives.

Exhibit 3
Sheet 17

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
206	-2.65	-4.40	1.75	1.81	88.06	2.89	2.58	108
207	+8.07	+4.70	3.37	3.43	89.68	5.38	5.07	
208	-3.15	-5.33	2.18	2.24	88.49	3.56	3.25	109
209	-1.64	-5.33	3.69	3.73	89.98	5.84	5.53	
210	-5.00	-7.01	2.01	2.07	88.32	3.30	2.99	110
211	-0.26	-3.85	3.59	3.65	89.90	5.72	5.41	
212	+4.67	+1.20	3.47	3.53	89.78	5.54	5.23	
213	?	+6.76	?	?	?	?	?	110, 111
214	+3.85	+0.35	3.50	3.56	89.81	5.58	5.27	111
215	+5.20	+3.36	1.84	1.90	87.15	3.06	2.75	
216	-6.85	-10.15	3.30	3.36	89.61	5.28	4.97	111, 112
217	+3.54	+1.74	1.80	1.86	88.11	2.97	2.66	112
218	-5.70	-9.05	3.35	3.41	89.66	5.35	5.04	112, 113
219	+1.20	-0.44	1.64	1.70	87.95	2.72	2.41	113
220	+4.37	+1.00	3.37	3.43	89.68	5.38	5.07	
221	-0.70	-2.55	1.85	1.91	88.16	3.05	2.74	114
222	+0.35	-3.15	3.50	3.56	89.81	5.58	5.27	
223	-7.82	-9.50	1.68	1.74	87.99	2.78	2.47	114, 115
224	+0.44	-1.39	1.83	1.89	88.14	3.02	2.71	115

L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth d = h-0.31	Film No.
225	-6.23	?	?	?	?	?	?	116
226	-1.79	-3.12	1.33	1.39	87.64	2.23	1.92	
227	+6.51	+2.39	4.12	4.18	90.43	6.50	6.19	
228	+6.90	+5.63	1.27	1.33	87.58	2.14	1.83	
229	-1.96	-3.16	1.20	1.26	87.51	2.03	1.72	117
230	+0.55	-3.45	4.00	4.06	90.31	6.34	6.03	
231	+6.55	+5.45	1.10	1.16	87.41	1.87	1.56	
232	-4.81	?	?	?	?	?	?	118
233	-3.94	-7.40	3.46	3.52	89.77	5.52	5.21	
234	-1.00	-2.16	1.16	1.22	87.47	1.96	1.65	
235	+7.39	+3.69	3.70	3.76	90.01	5.88	5.57	
236	+7.60	+6.21	1.39	1.45	87.70	2.33	2.02	
237	-0.82	-2.07	1.25	1.31	87.56	2.11	1.80	119
238	+2.14	-1.94	4.08	4.14	90.39	6.46	6.15	
239	+6.33	+5.10	1.23	1.29	87.54	2.07	1.76	
240	-6.83	-10.41	3.58	3.64	89.89	5.70	5.39	119, 120
241	-5.02	-8.97	3.95	4.01	90.26	6.22	5.91	119, 120
242	-1.60	-2.93	1.33	1.39	87.64	2.23	1.92	120
243	+6.53	+2.55	3.98	4.04	90.29	6.30	5.99	

Exhibit 3
Sheet 19

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
244	+7.50	+6.28	1.22	1.28	87.53	2.06	1.75	120
245	-3.46	-4.70	1.24	1.30	87.55	2.08	1.77	121
246	-2.10	-6.13	4.03	4.09	90.34	6.37	6.06	
247	+4.66	+3.48	1.18	1.24	87.49	1.99	1.68	
248	+9.28	+5.38	3.90	3.96	90.21	6.18	5.87	121, 122
249	-3.86	-5.11	1.25	1.31	87.56	2.11	1.80	
250	+3.96	-0.07	4.03	4.09	90.34	6.37	6.06	
251	+5.18	+3.94	1.24	1.30	87.55	2.08	1.77	122
252	-7.20	?	?	?	?	?	?	123
253	-2.63	-4.63	2.00	2.06	88.31	3.28	2.97	
254	+3.80	+0.23	3.57	3.63	89.88	5.69	5.38	
255	+5.86	+4.00	1.86	1.92	88.17	3.06	2.75	
256	-4.96	-8.35	3.39	3.45	89.70	5.52	5.21	124
257	-3.15	-5.00	1.85	1.91	88.16	3.05	2.74	
258	+5.39	+1.86	3.53	3.59	89.84	5.63	5.32	
259	+5.00	+3.26	1.74	1.80	88.05	2.87	2.56	
260	-4.36	-6.04	1.68	1.74	87.99	2.78	2.47	125
261	-2.05	-5.75	3.70	3.76	90.01	5.88	5.57	
262	+3.60	+1.87	1.73	1.79	88.04	2.85	2.54	

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Exhibit 3
Sheet 21

L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
263	?	?	?	?	?	?	?	125
264	-6.90	-8.54	1.64	1.70	87.95	2.74	2.43	126
265	+0.75	-2.97	3.72	3.78	90.03	5.91	5.60	
266	+2.80	+1.15	1.65	1.71	87.96	2.74	2.43	
267	+9.70	+6.45	3.25	3.31	89.56	5.20	4.89	127
268	-5.92	-7.72	1.80	1.86	88.11	2.96	2.65	
269	+2.45	+0.69	1.76	1.82	88.07	2.91	2.60	
270	+3.31	-0.26	3.05	3.11	89.36	4.90	4.59	
271	- - - - - - - - - - - - - See Film -							127, 128
272	-0.80	-2.64	1.84	1.90	88.15	3.04	2.73	128
273	+2.60	-0.85	3.45	3.51	89.76	5.51	5.20	
274	+7.34	+5.54	1.80	1.86	88.11	2.97	2.66	
275	+11.31	+7.61	3.70	3.76	90.01	5.88	5.57	128, 129
276	-1.60	-3.45	1.85	1.91	87.16	3.08	2.77	129
277	+4.59	+1.09	3.50	3.56	89.81	5.64	5.33	
278	+5.45	+3.68	1.77	1.83	88.08	2.95	2.64	
279	+4.71	+1.31	3.40	3.46	89.71	5.43	5.12	162
280	+1.48	-1.92	3.40	3.46	89.71	5.43	5.12	163
281	-2.12	-5.55	3.43	3.49	89.74	5.48	5.17	164

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
282	+8.26	+4.92	3.34	3.40	89.65	5.34	5.03	164
283	-5.71	-7.85	2.14	2.20	88.35	3.51	3.20	165
284	+2.57	-0.86	3.43	3.49	89.74	5.48	5.17	
285	-4.30	-7.87	3.57	3.63	89.88	5.69	5.38	166
286	+5.60	+2.04	3.56	3.62	89.87	5.67	5.36	
287	+0.40	-3.02	3.42	3.48	89.73	5.46	5.15	167
288	-4.47	-7.80	3.33	3.39	89.64	5.32	5.01	1.68
289	+4.44	+1.20	3.24	3.30	89.55	5.19	4.88	
290	-3.73	-7.00	3.27	3.33	89.58	5.24	4.93	169
291	-1.12	-2.67	1.55	1.61	87.84	2.58	2.27	
292	+5.97	+2.66	3.31	3.37	89.62	5.29	4.98	
293	-2.24	-5.60	3.36	3.42	89.67	5.37	5.06	170
294	+7.30	+4.03	3.27	3.33	89.58	5.24	4.93	
295	-7.60	?	?	?	?	?	?	171
296	+1.32	-1.79	2.11	2.17	88.42	3.45	3.14	
297	-1.84	-3.52	1.68	1.74	87.99	2.78	2.47	172
298	+0.81	-2.44	3.25	3.31	89.56	5.21	4.90	
299	-7.32	-10.54	3.22	3.28	89.53	5.18	4.77	173
300	+2.15	-1.17	3.32	3.38	89.63	5.31	5.00	

Exhibit 3
Sheet 22

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L = 86.25"
H = 140.75"

Bar No.	D_a	D_b	D_a-D_b	$Z=D_a-D_b+0.06$	L+Z	$h = \frac{HZ}{L+Z}$	X-ray Depth $d = h-0.31$	Film No.
301	-7.88	-9.33	1.45	?	87.92	2.67	2.36	174
302	-5.96	?	?	?	?	?	?	
303	+3.29	±0.00	3.29	3.35	89.60	5.26	4.95	
304	-4.74	-7.99	3.25	3.31	89.56	5.21	4.90	175
305	+7.20	+4.01	3.19	3.25	89.50	5.12	4.81	

Exhibit 3
Sheet 23

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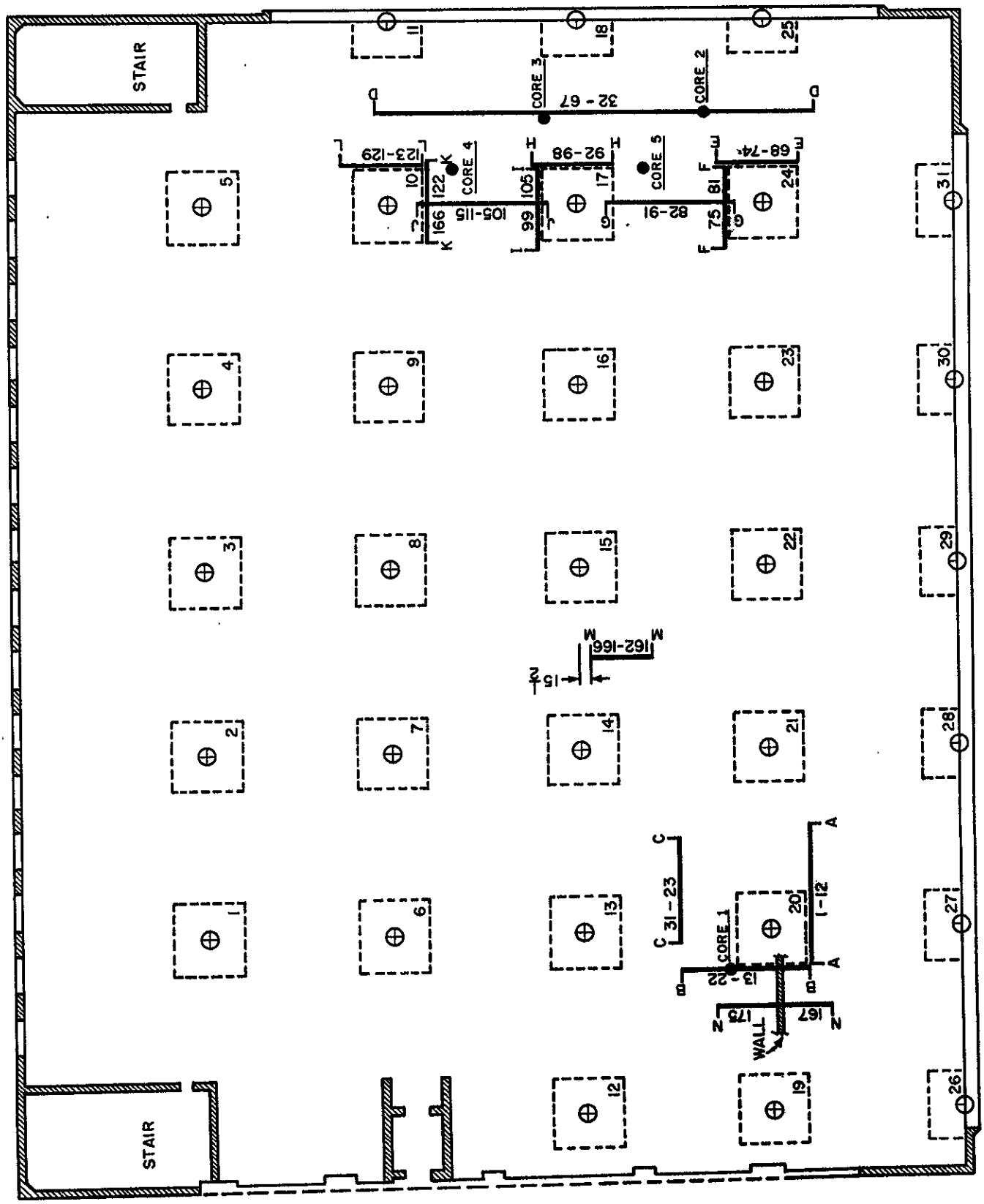

X-RAY LAYOUT OF 3rd FLOOR

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CROSS SECTION OF THIRD FLOOR
ILLUSTRATING VERTICAL X-RAY LAYOUT
AND SHOWING GRAPHED AND CALCULATED BAR POSITIONS

Table of Contents, Exhibit 5, Sheets 1-16

Sheet 1	Section AA	Bars 1A	through 32A'
2	BB	33A	65A
3	CC	66A	80A
4	DD - part 1	1	28
5	2	29	50
6	3	50	68
7	EE	69	98
8	FF	99	124
9	GG	125	148
10	HH	150	175
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12	JJ	201	224
13	KK	225	252
14	LL	252	278
15	MM	279	286
16	NN	287	305

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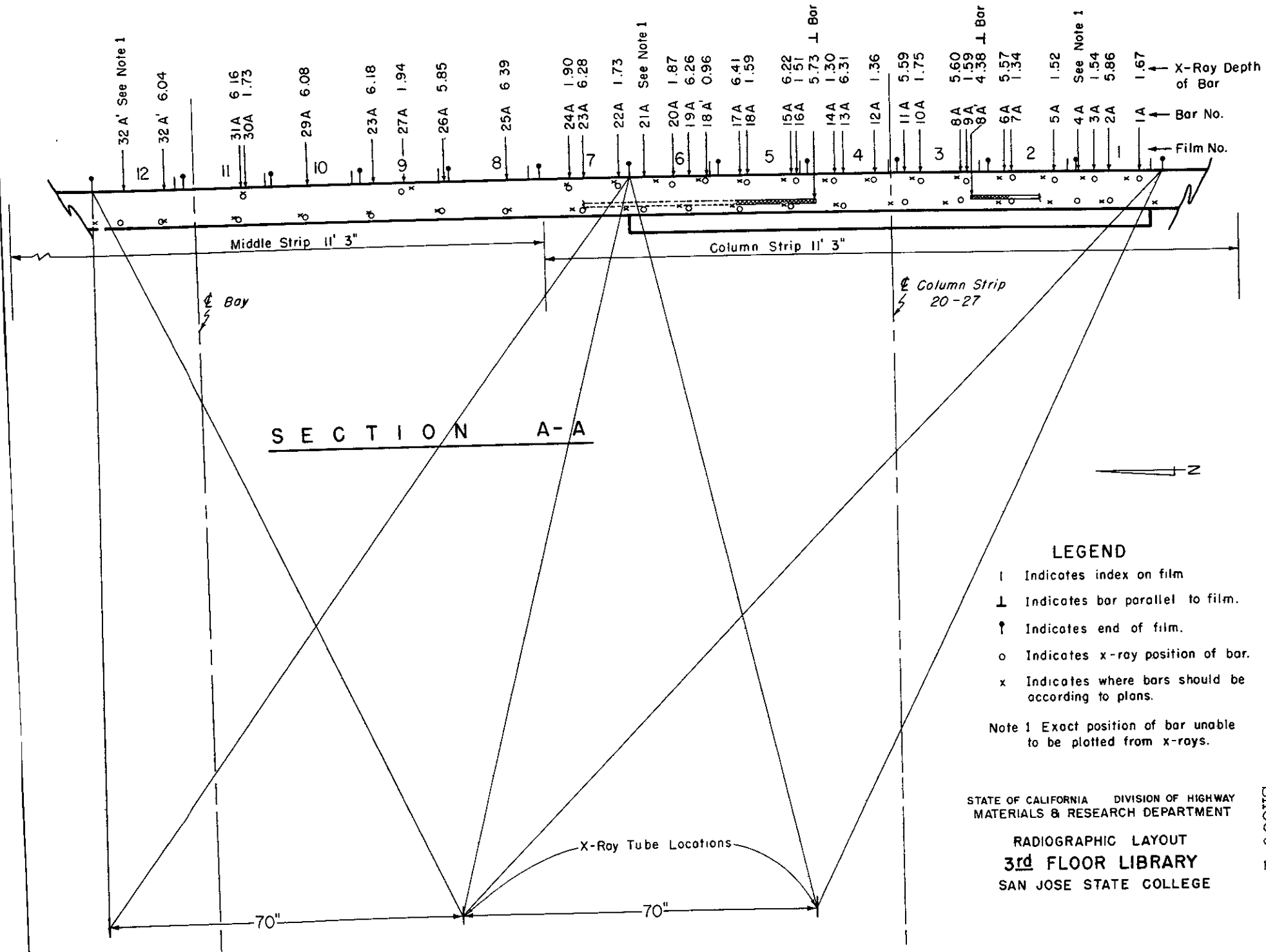

LEGEND

|	Indicates index on film
⊥	Indicates bar parallel to film.
↑	Indicates end of film.
o	Indicates x-ray position of bar.
x	Indicates where bars should be according to plans.

Note 1 Exact position of bar unable to be plotted from x-rays.

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EXHIBIT 5
Sheet 1

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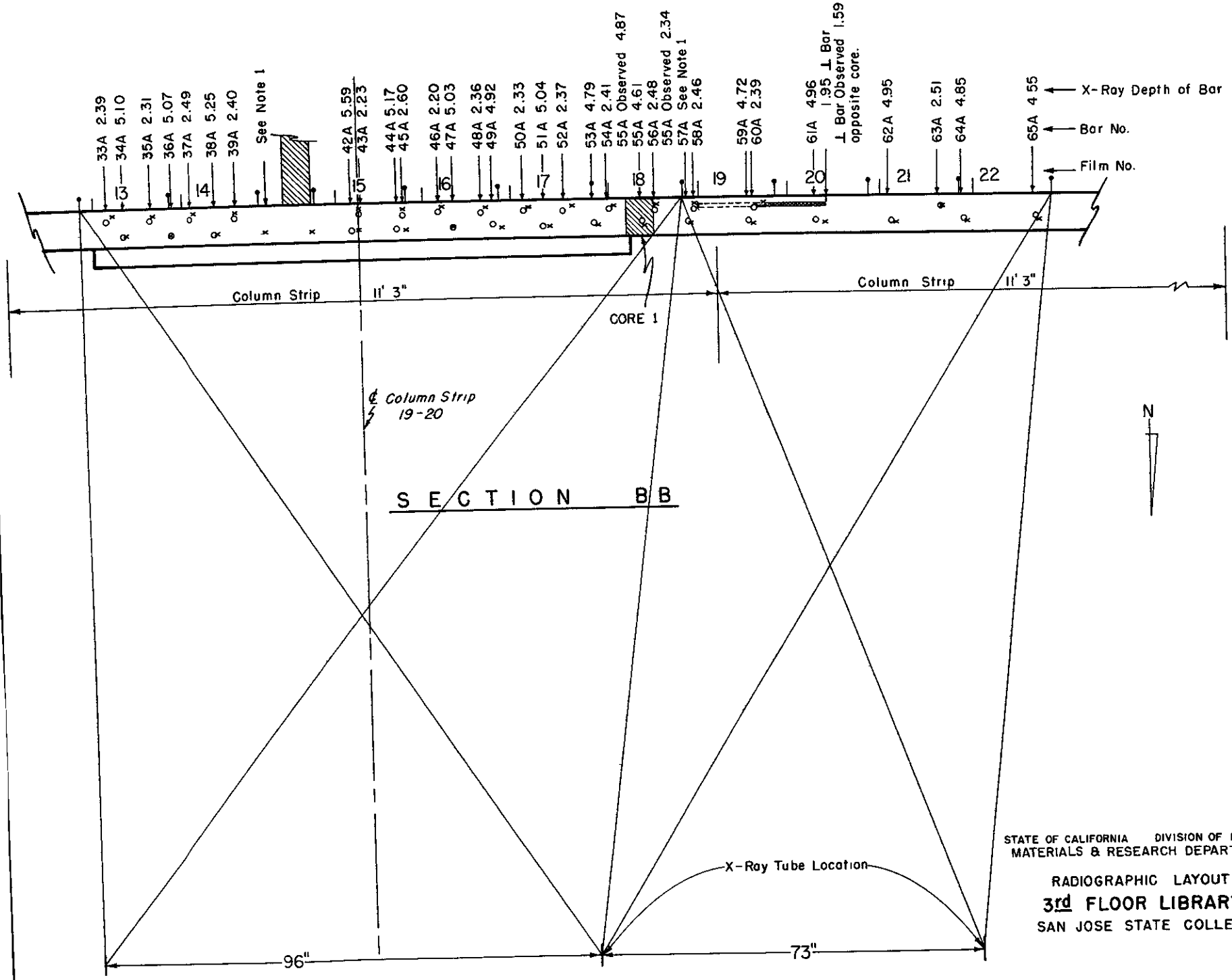

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EXHIBIT 5
Sheet 2

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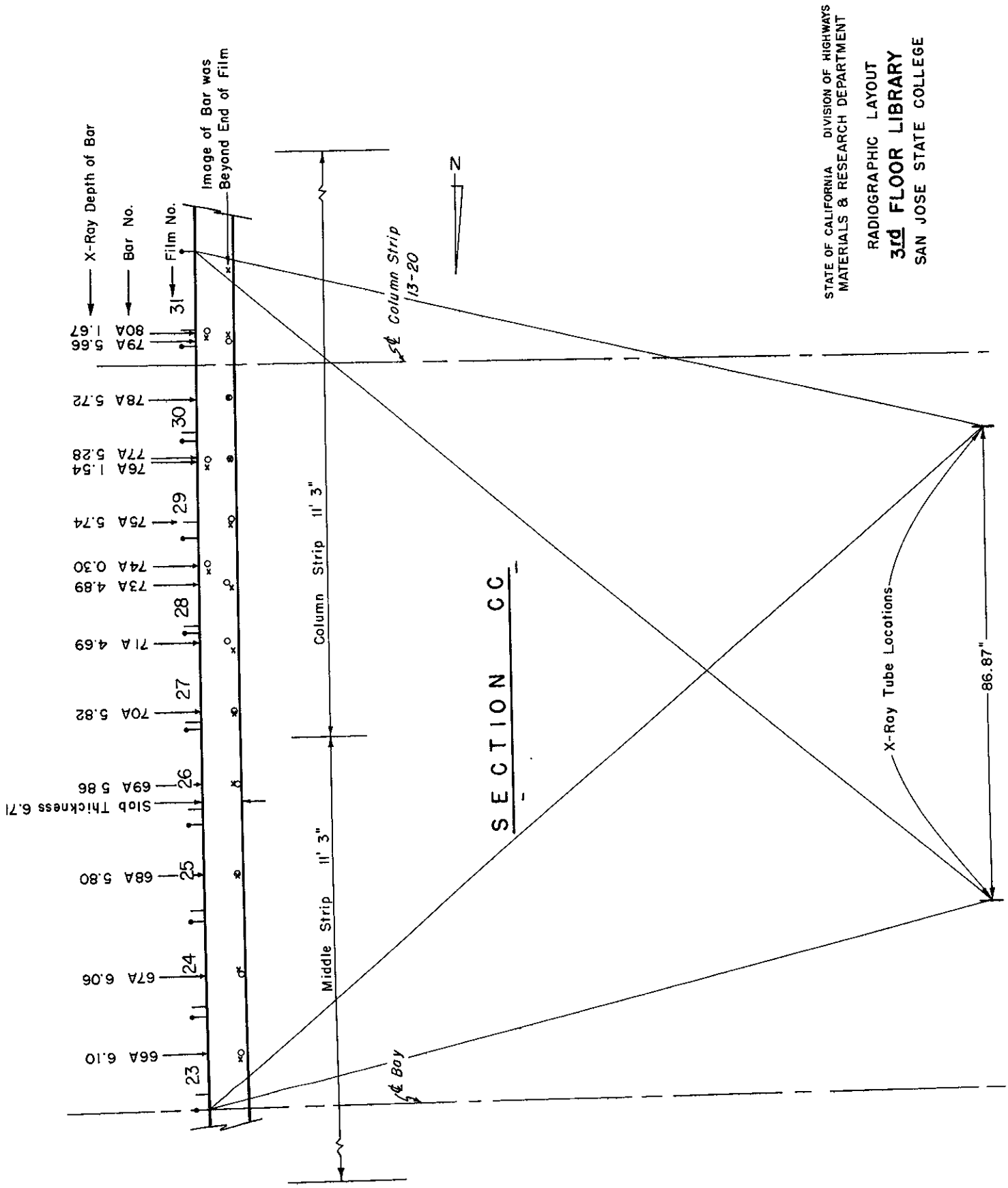
EXHIBIT 5
Sheet 3



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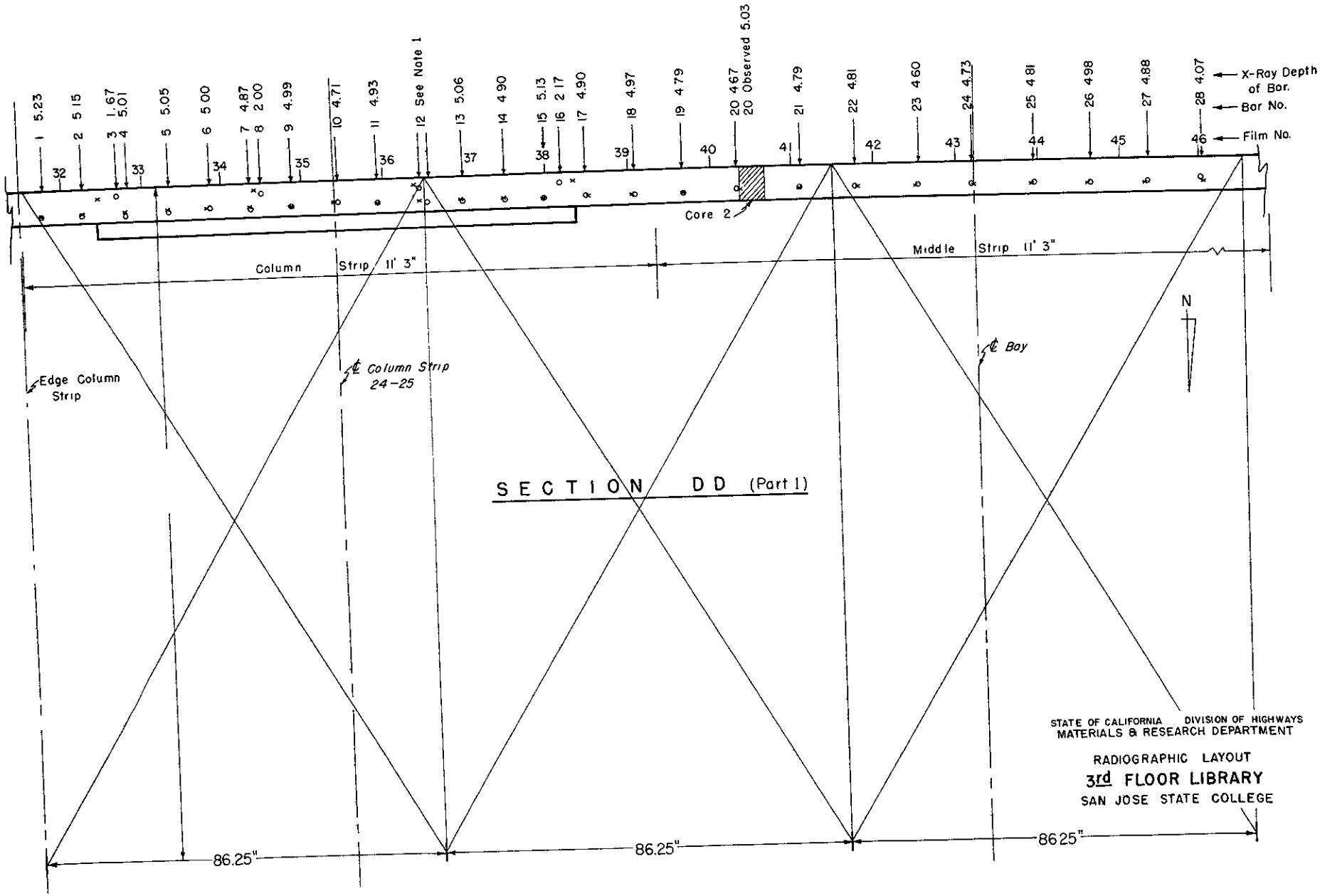

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Sheet 4

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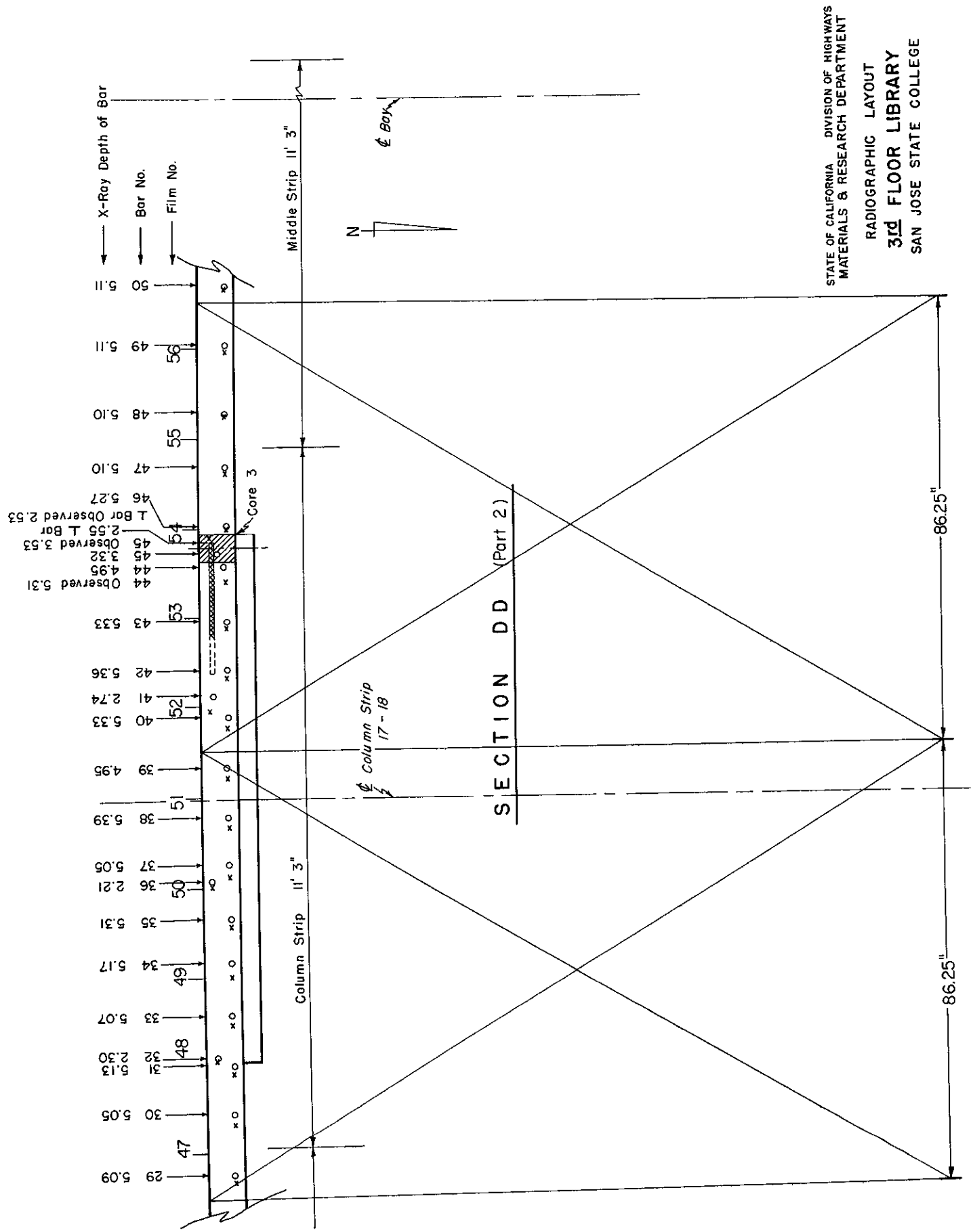

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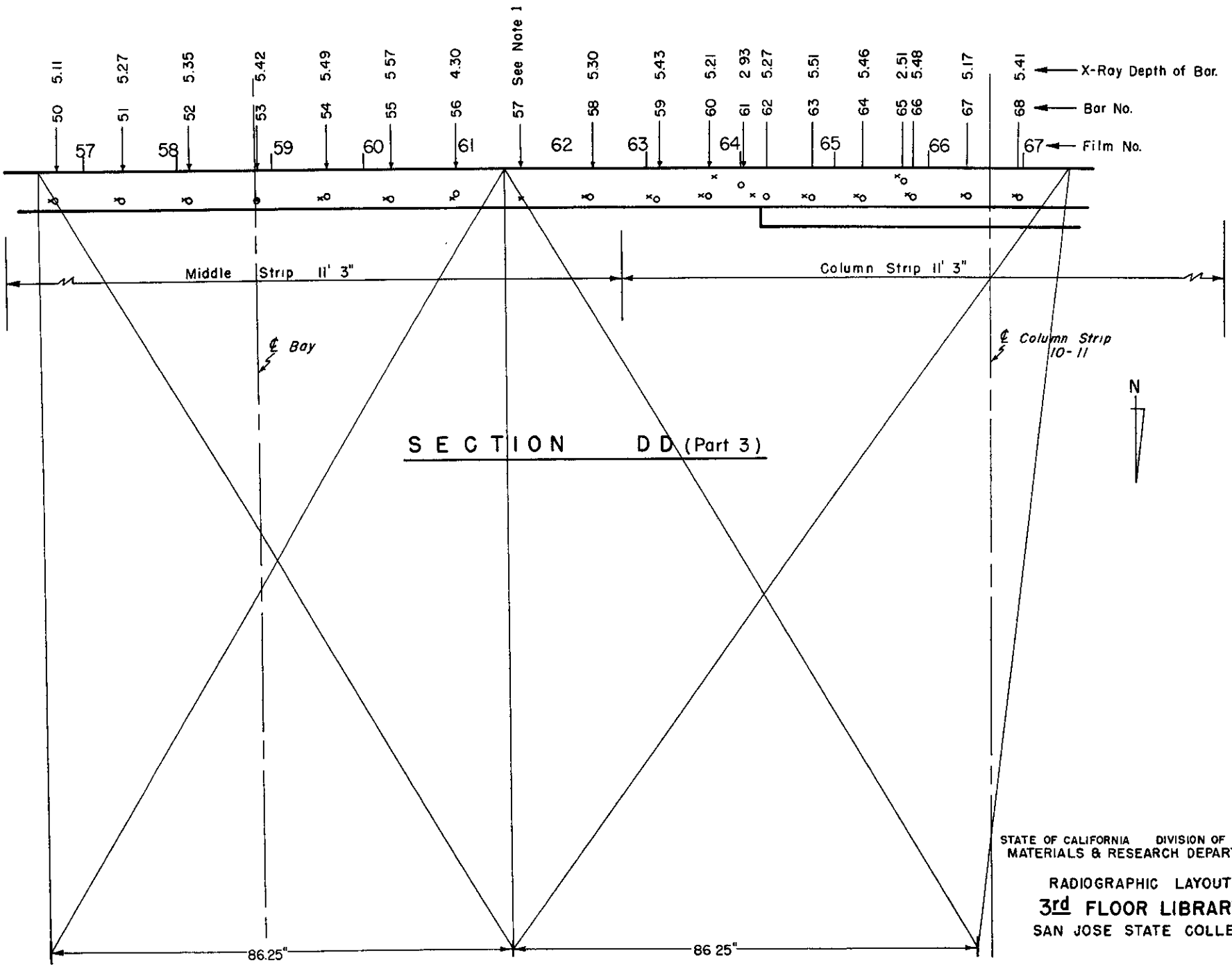

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EXHIBIT 5
Sheet 6

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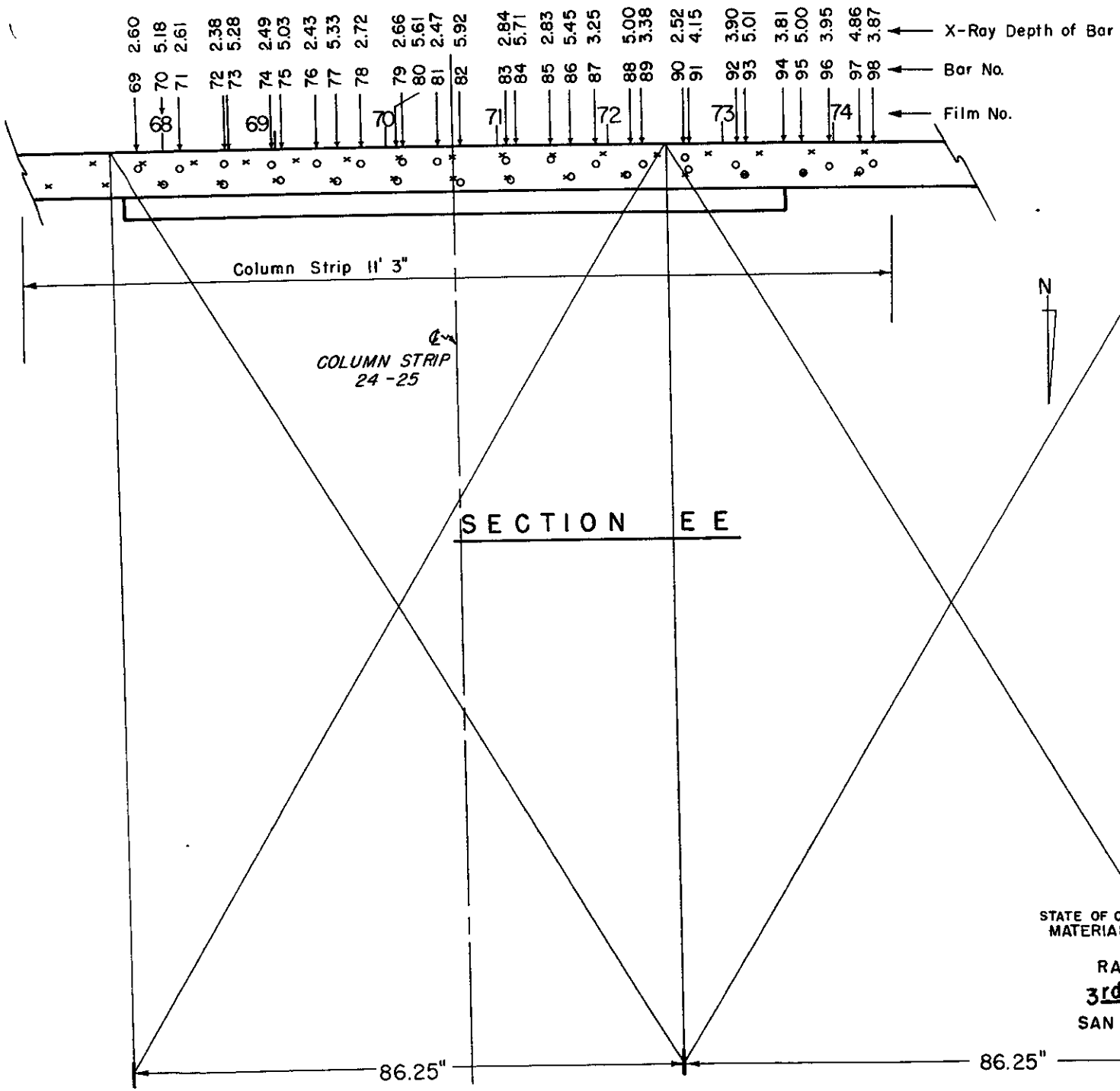

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EXHIBIT 5
Sheet 7

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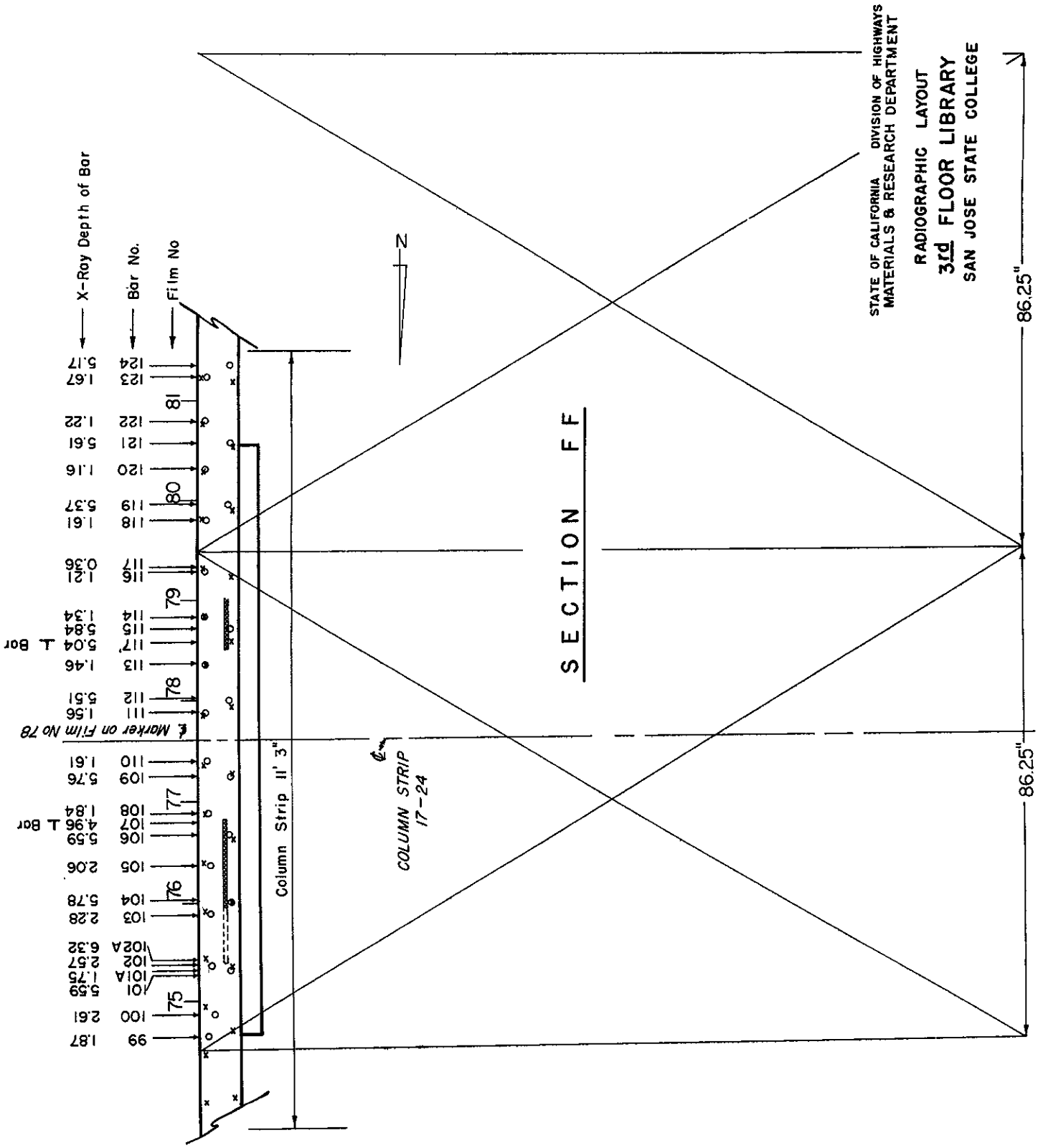

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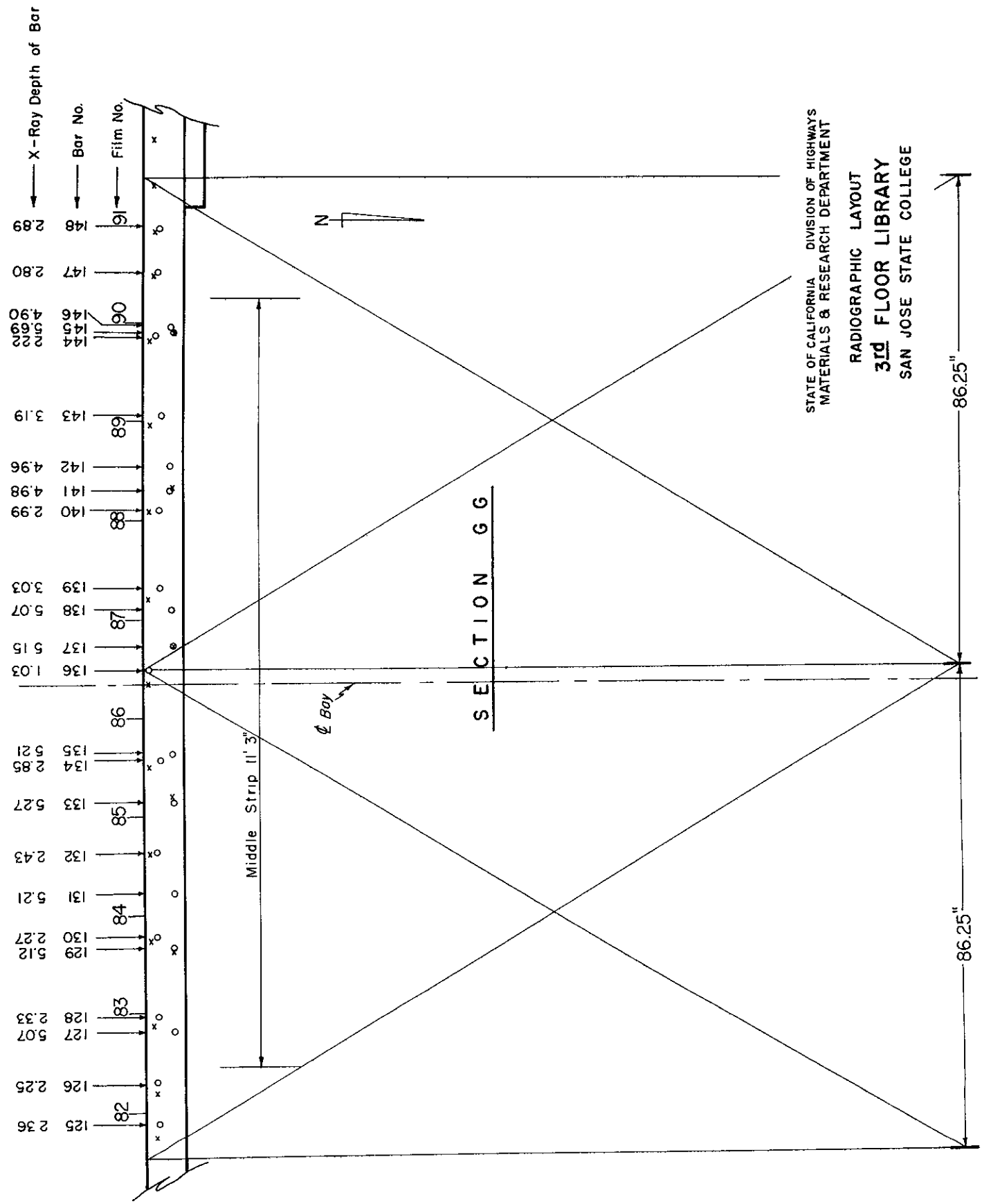

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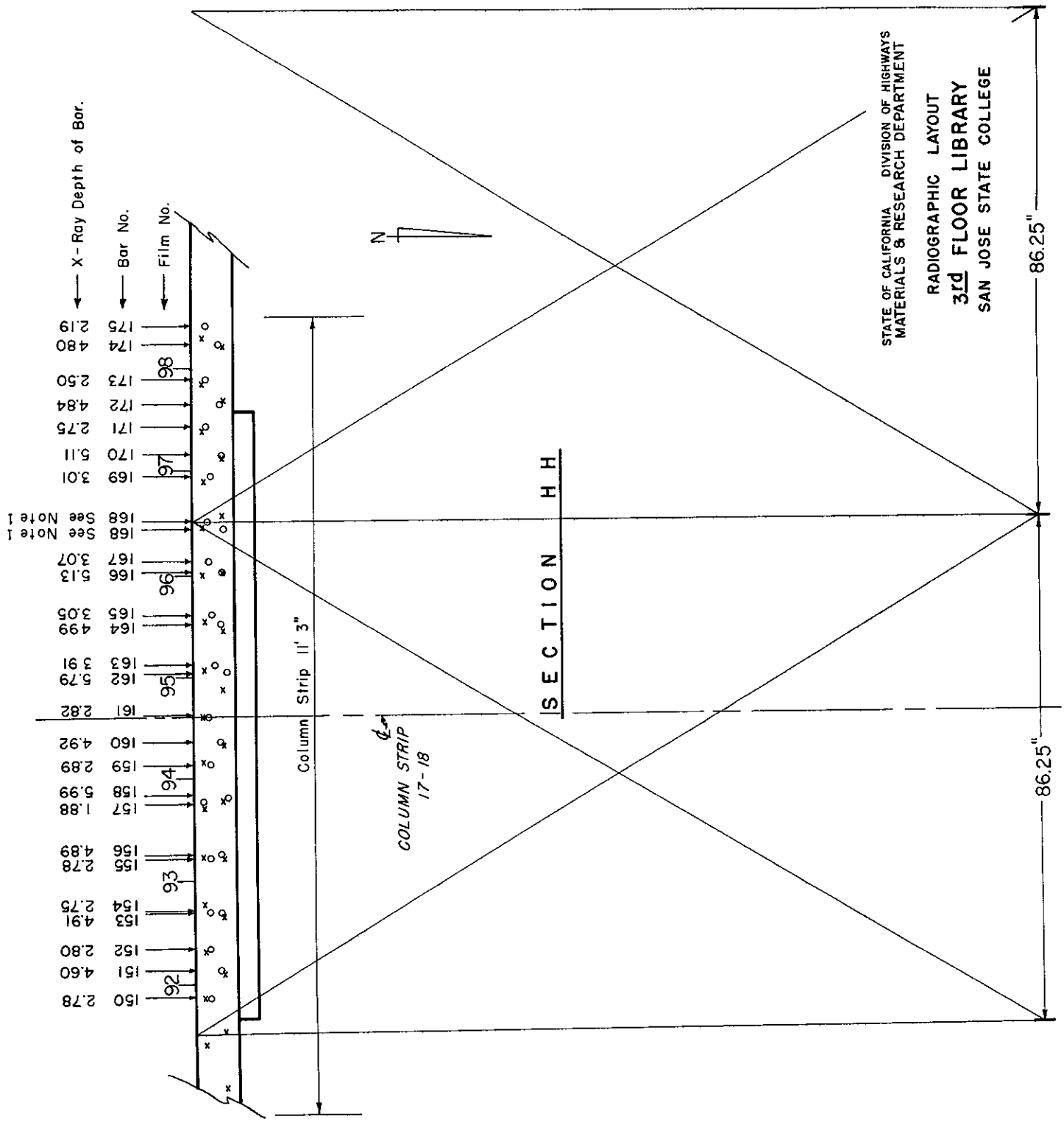

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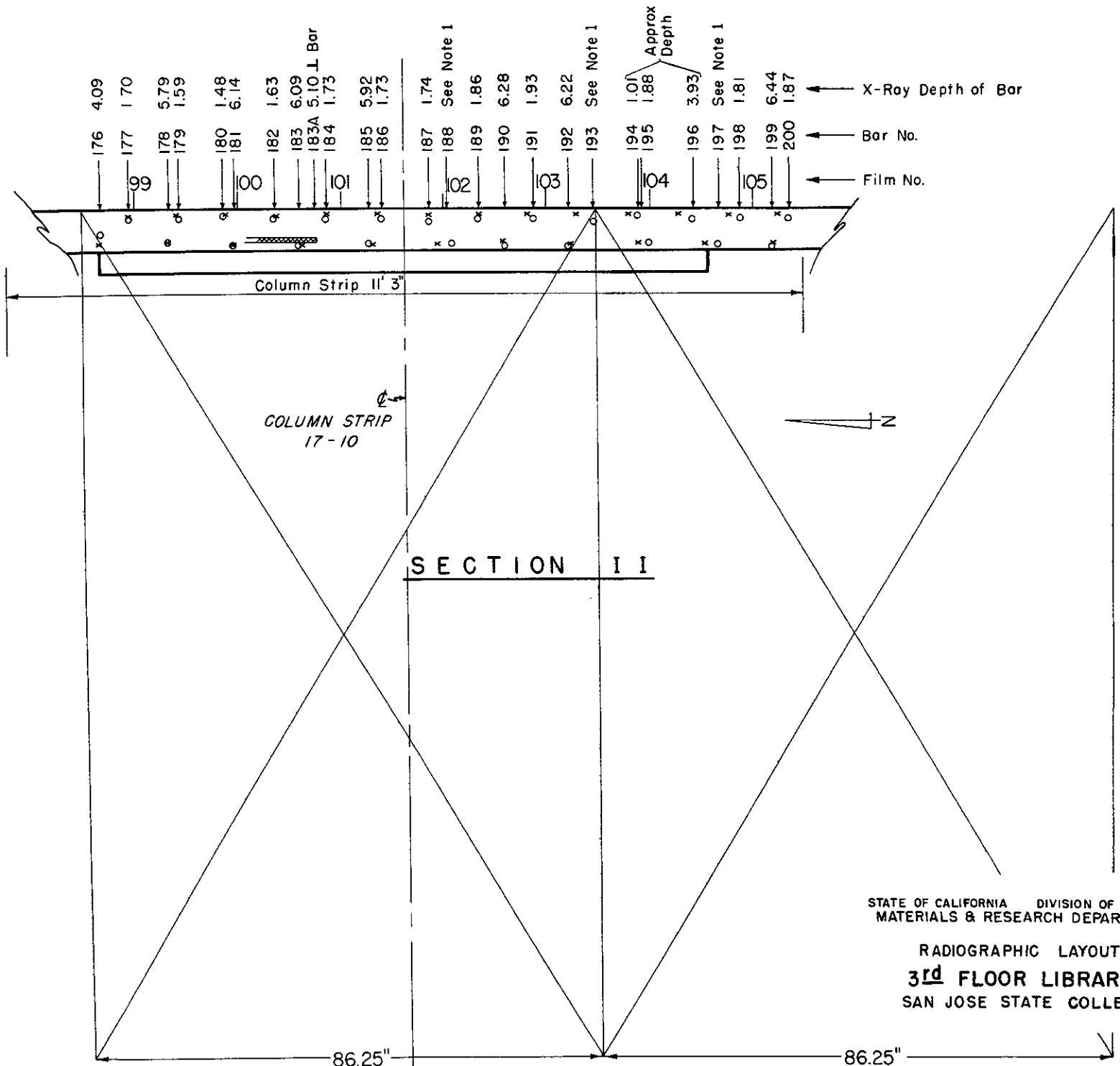

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EXHIBIT 5
Sheet 11

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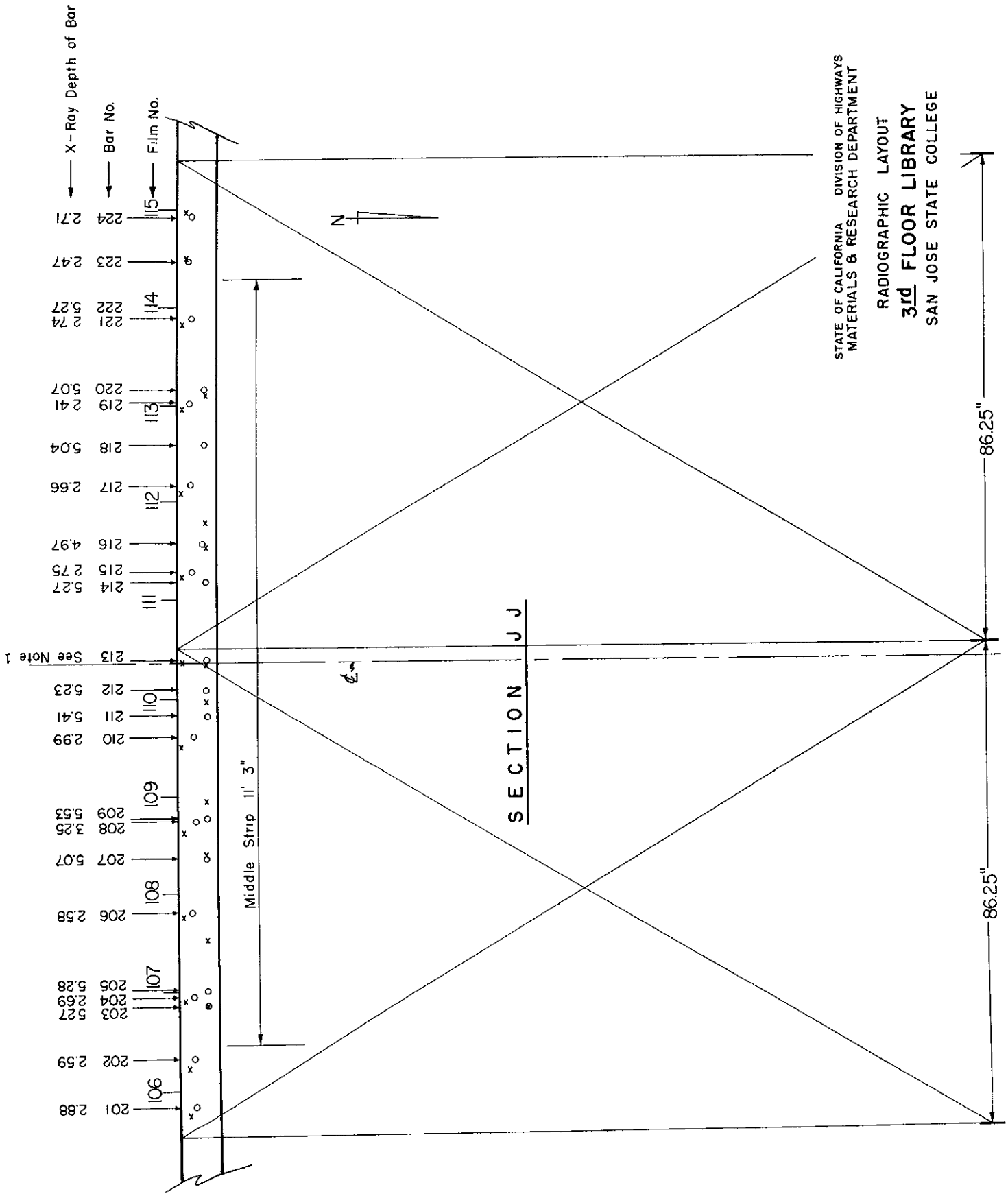
EXHIBIT 5
Sheet 12



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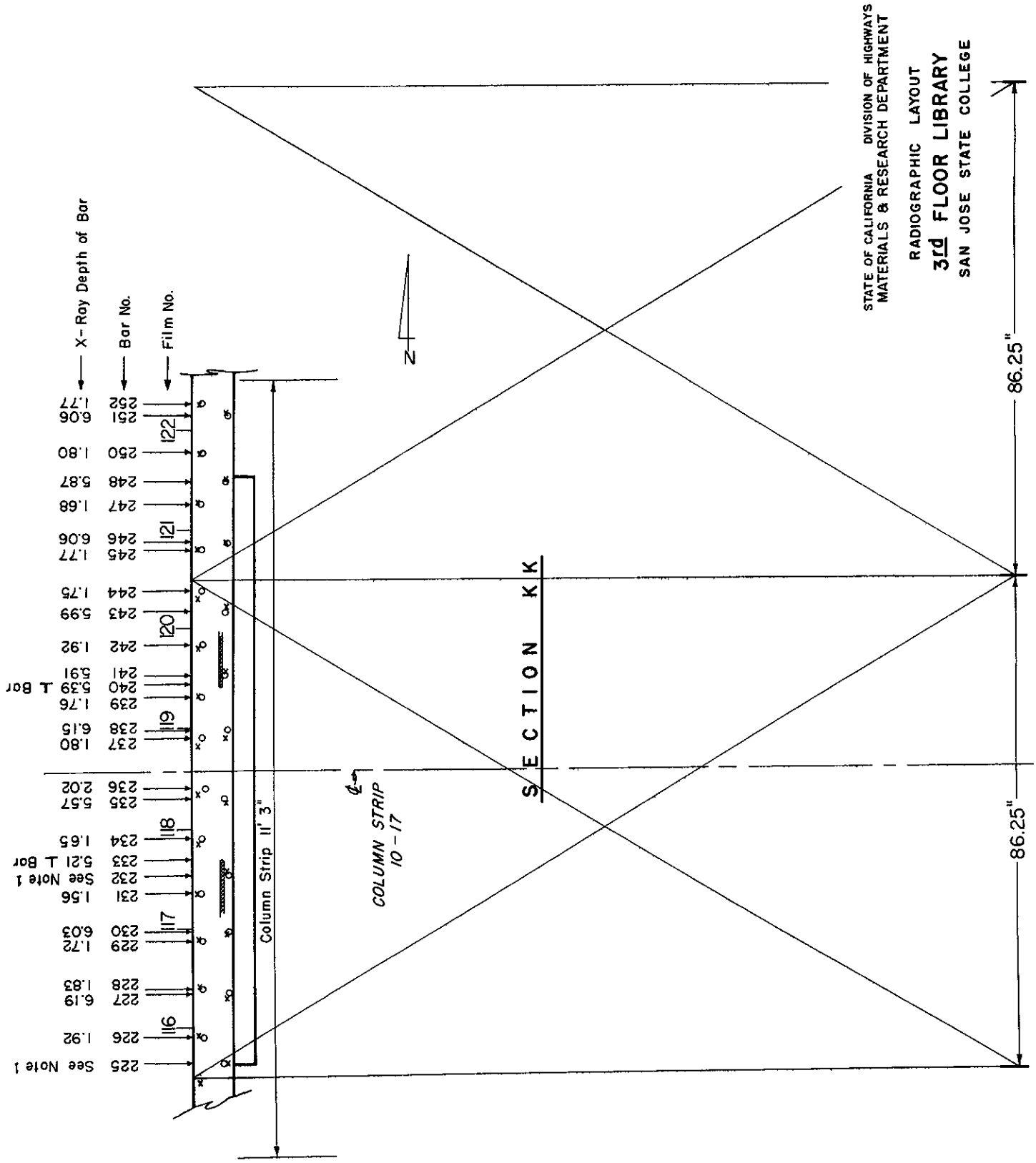

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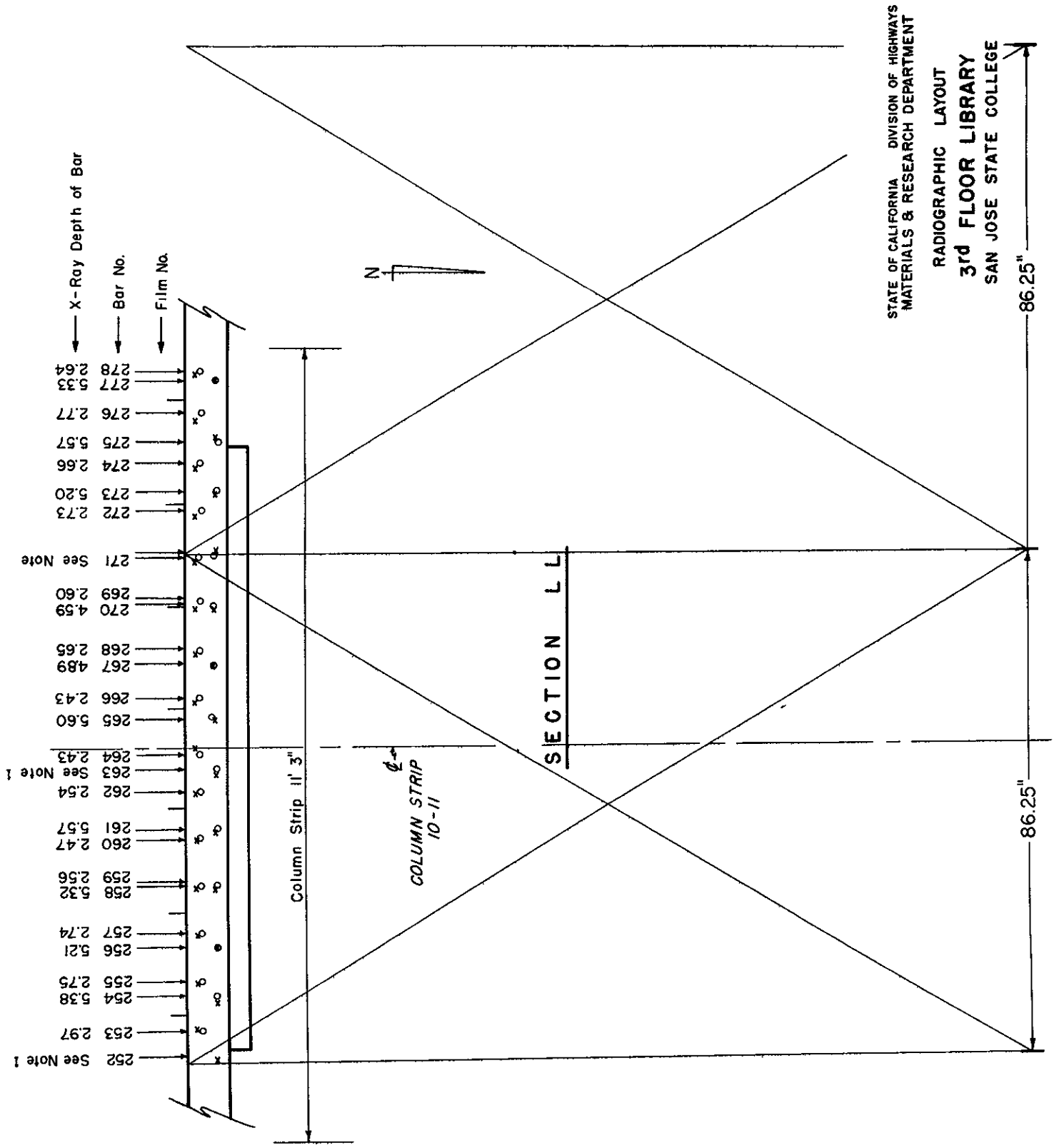

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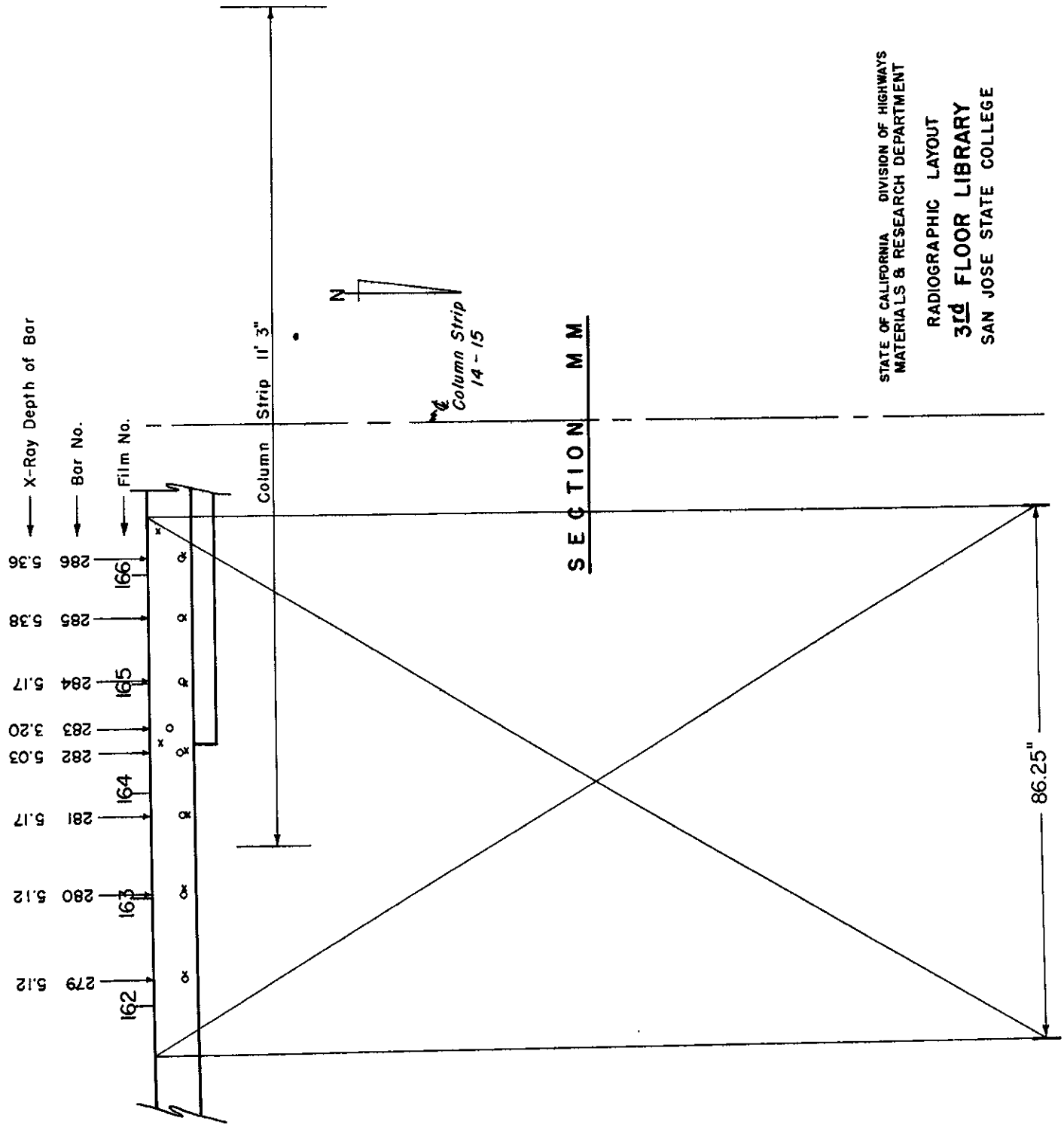

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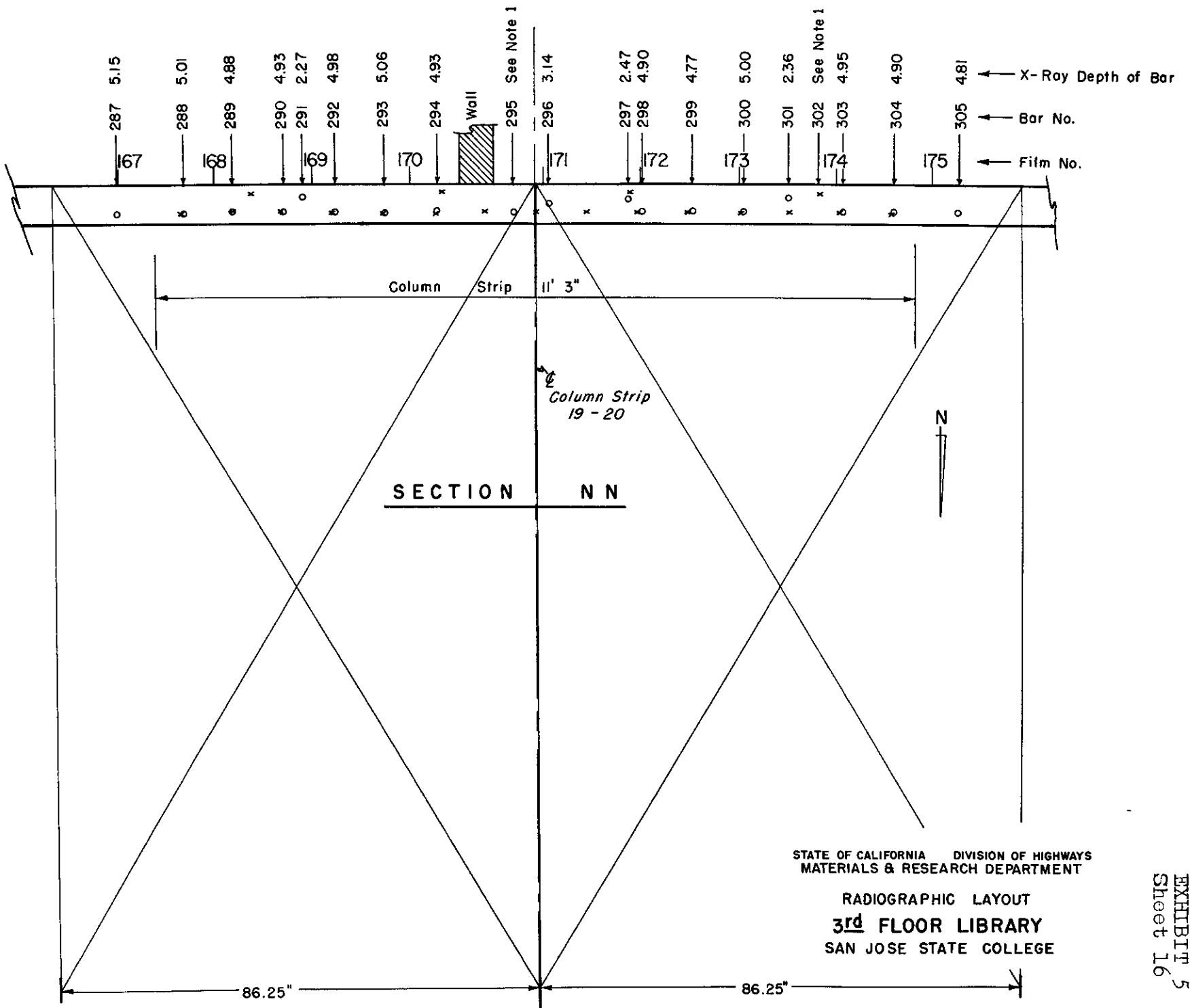

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EXHIBIT 5
Sheet 16

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TABLE OF CALCULATED AND OBSERVED DEPTHS OF EXPOSED BARS

Core No.	Bar No.	Observed Depth	Calculated Depth	(Δd)
a) 1	b) Parallel Bar	1.59	1.95	-0.36
a) 1	56A	2.34	2.48	-0.14
3	b) Parallel Bar	2.53	2.55	-0.02
3	45	3.53	3.32	-0.21
d) 1	55A	4.87	4.61	+0.26
2	20	5.03	4.67	+0.33
3	44	5.31	4.95	+0.36
c) Floor Thickness		d) 6.95	e) 6.67	+0.28

In calculating the correction (Δ d) as a linear function of the calculated depth by means of the least square method, the best line through a graph of these points such as shown in Exhibit 7 is

$$\Delta d = mD + b$$

where

$$m = \frac{(n)\Sigma D \Delta d - \Sigma D \Sigma \Delta d}{(n)\Sigma D^2 - (\Sigma D)^2} = 0.24 \quad \text{(Calculated Values)}$$

and

$$b = \frac{\Sigma D^2 \Sigma \Delta d - \Sigma D \Sigma D \Delta d}{(n)\Sigma D^2 - (\Sigma D)^2} = -0.73 \text{ inches}$$

thus

$$d = 0.24D - 0.73 \text{ inches} \quad \begin{array}{l}(+0.11 \text{ Standard Deviation})\\ (\ 0.08 \text{ Probable Error})\end{array}$$

a) Calculated Depths not certain on bars from #1 core.
b) Bars parallel to film line.
c) This value was discarded in accordance with Chauvenets Criterion.
d) Approximate average length of observed cores.
e) Small correction subtracted for thickness of marker under floor.

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Exhibit 7

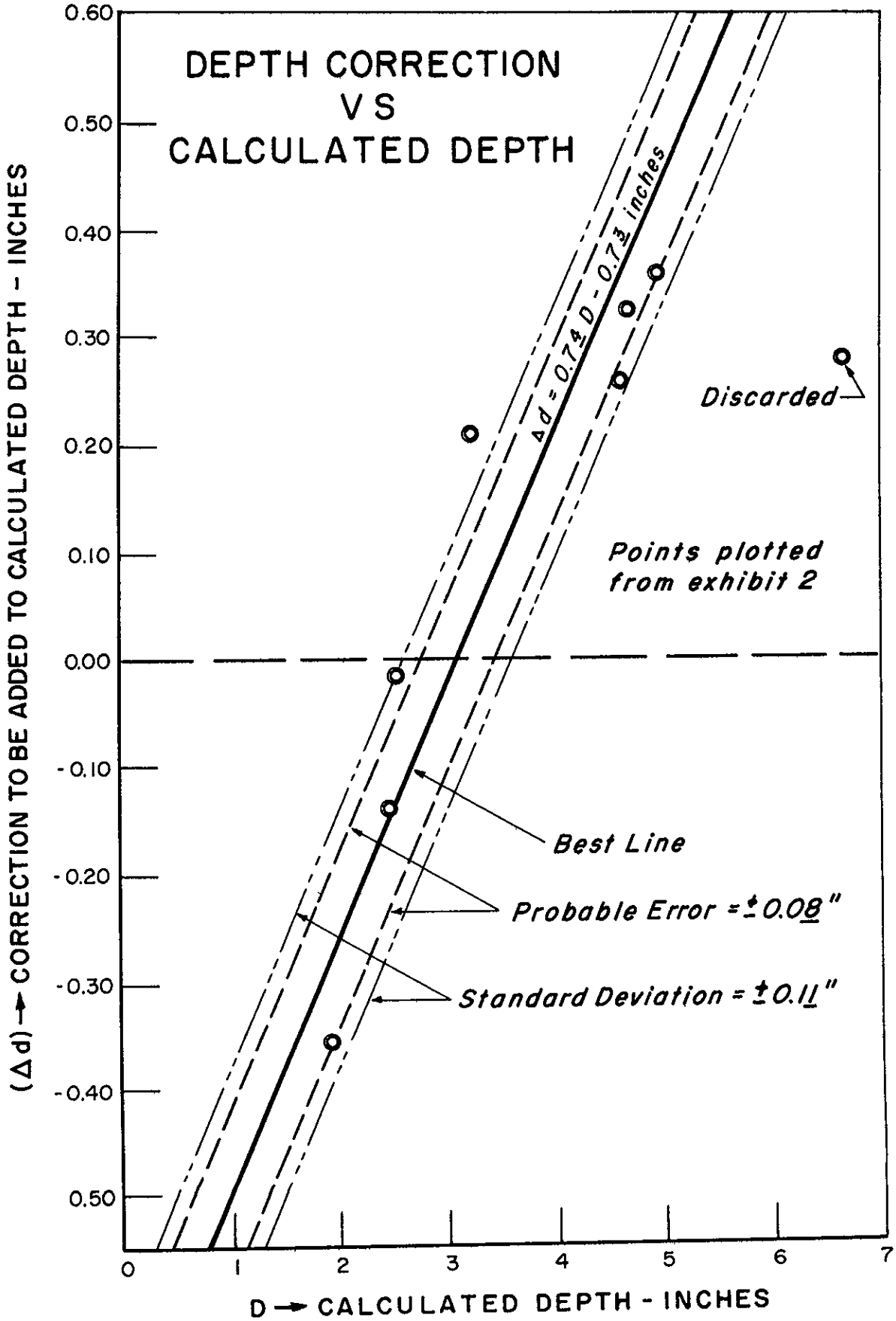

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TABLE OF BARS NOT WITHIN SPECIFIED POSITION LIMITS

Section	Bar #	Calculated Depth	Corrected Depth * Standard Deviation	Limit
AA	8A ⊥	4.38	4.81	> 4.88
	20A	1.87	1.45	< 1.38
	24A	1.90	1.50	< 1.38
	27A	1.94	1.56	< 1.38
BB	37A	2.49	2.23	< 2.13
	45A	2.60	2.36	< 2.13
	56A	2.48	2.21	< 2.13
	Parallel Bar	1.95	1.57	< 1.38
	63A	2.51	2.26	< 2.13
CC	71A	4.69	5.17	> 5.62
	73A	4.89	5.44	> 5.62
DD2	41	2.74	2.54	< 2.13
	45	3.32	3.24	< 2.13
	45 ⊥	2.55	2.30	< 2.13
DD3	56	4.30	4.69	> 4.87
	61	2.93	2.77	< 2.13
	65	2.51	2.26	< 2.13

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TABLE OF BARS NOT WITHIN SPECIFIED POSITION LIMITS

Section	Bar #	Calculated Depth	Corrected Depth + Standard Deviation	Limit
EE	69	2.60	2.36	< 2.13
	71	2.61	2.37	< 2.13
	74	2.49	2.23	< 2.13
	76	2.43	2.15	< 2.13
	78	2.72	2.51	< 2.13
	79	2.66	2.44	< 2.13
	81	2.47	2.20	< 2.13
	83	2.84	2.67	< 2.13
	85	2.83	2.66	< 2.13
	87	3.25	3.18	< 2.13
	89	3.38	3.33	< 2.13
	90	2.52	2.27	< 2.13
	91	4.15	4.47	> 4.87
	92	3.90	3.97	< 2.13
	94	3.81	3.86	< 2.13
	96	3.95	4.04	< 2.13
	98	3.87	3.93	< 2.13

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TABLE OF BARS NOT WITHIN SPECIFIED POSITION LIMITS

Section	Bar #	Calculated Depth	Corrected Depth + Standard Deviation	Limit
FF	99	1.87	1.45	< 1.38
	100	2.61	2.37	< 1.38
	103	2.28	1.98	< 1.38
	105	2.06	1.69	< 1.38
	108	1.84	1.43	< 1.38
GG	132	2.43	2.15	< 2.13
	134	2.85	2.68	< 2.13
	139	3.03	2.88	< 2.13
	140	2.99	2.84	< 2.13
	143	3.19	3.09	< 2.13
	147	2.80	2.61	< 2.13
	148	2.89	2.73	< 2.13
HH	150	2.78	2.58	< 2.13
	152	2.80	2.61	< 2.13
	154	2.75	2.55	< 2.13
	155	2.78	2.58	< 2.13
	159	2.89	2.73	< 2.13
	161	2.82	2.64	< 2.13

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TABLE OF BARS NOT WITHIN SPECIFIED POSITION LIMITS

Section	Bar #	Calculated Depth	Corrected Depth + Standard Deviation	Limit
HH	163	3.91	3.98	< 2.13
	165	3.05	2.91	< 2.13
	167	3.07	2.93	< 2.13
	169	3.01	2.86	< 2.13
	171	2.75	2.55	< 2.13
	173	2.50	2.24	< 2.13
II	176	4.09	4.41	> 5.62
	189	1.86	1.44	< 1.38
	191	1.93	1.55	< 1.38
	198	1.81	1.40	< 1.38
	200	1.87	1.45	< 1.38
JJ	201	2.88	2.71	< 2.13
	202	2.59	2.35	< 2.13
	204	2.69	2.48	< 2.13
	206	2.58	2.34	< 2.13
	208	3.25	3.18	< 2.13
	210	2.99	2.84	< 2.13
	215	2.75	2.55	< 2.13
	217	2.66	2.44	< 2.13
	221	2.74	2.54	< 2.13
	223	2.47	2.20	< 2.13
	224	2.71	2.50	< 2.13

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TABLE OF BARS NOT WITHIN SPECIFIED POSITION LIMITS

Section	Bar #	Calculated Depth	Corrected Depth + Standard Deviation	Limit
KK	226	1.92	1.54	< 1.38
	228	1.83	1.42	< 1.38
	236	2.02	1.64	< 1.38
	237	1.80	1.49	< 1.38
	242	1.92	1.54	< 1.38
LL	253	2.97	2.82	< 2.13
	255	2.75	2.55	< 2.13
	257	2.74	2.54	< 2.13
	259	2.56	2.31	< 2.13
	260	2.47	2.20	< 2.13
	262	2.54	2.29	< 2.13
	264	2.43	2.15	< 2.13
	266	2.43	2.15	< 2.13
	268	2.65	2.42	< 2.13
	269	2.60	2.36	< 2.13
	272	2.73	2.53	< 2.13
	274	2.66	2.44	< 2.13
	276	2.77	2.57	< 2.13
	278	2.64	2.40	< 2.13

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April 4, 1958

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