

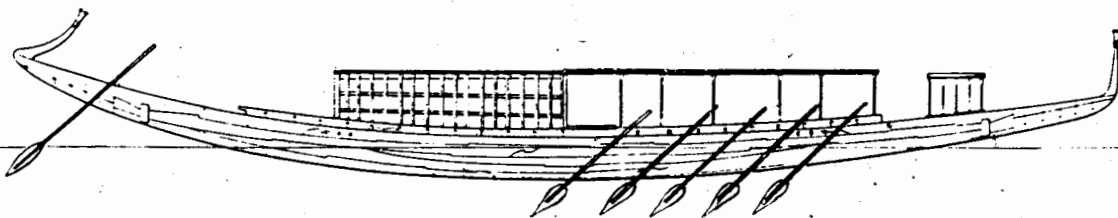


KUNGL.
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Institutionen för fotogrammetri
Department of Photogrammetry

Photogrammetric Documentation of the Royal Ship of KHUFU

Report of field operations carried out in June-July 1982



ROYAL INSTITUTE OF TECHNOLOGY
DEPARTMENT OF PHOTOGRAMMETRY
STOCKHOLM SWEDEN NOVEMBER 1982

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THE TASK

The Egyptian Antiquities Organisation (EAO), the Egyptian Ministry of Culture, has through its chairman Dr Ahmed Kadry, given the Department of Photogrammetry at the Royal Institute of Technology, Stockholm, Sweden, the task of making the photogrammetric documentation and measurement of the Royal Ship of Khufu, which is now in the museum beside the Khufu's Pyramid in El Giza, south-west of Cairo.

The head of the Department of Photogrammetry in Stockholm, Professor Dr Kennert Torlegård, commissioned photogrammetric engineer Carl-Olov Jonason, with Waldemar Rosborg as assistant, to carry out the field operations during the summer of 1982. This work began on May 29 and was completed on July 3.

The aim of this field work was to make a photogrammetric documentation which would serve as a basis for plane drawings in all three projections. The three-dimensional co-ordinate system is defined in Figure 1.

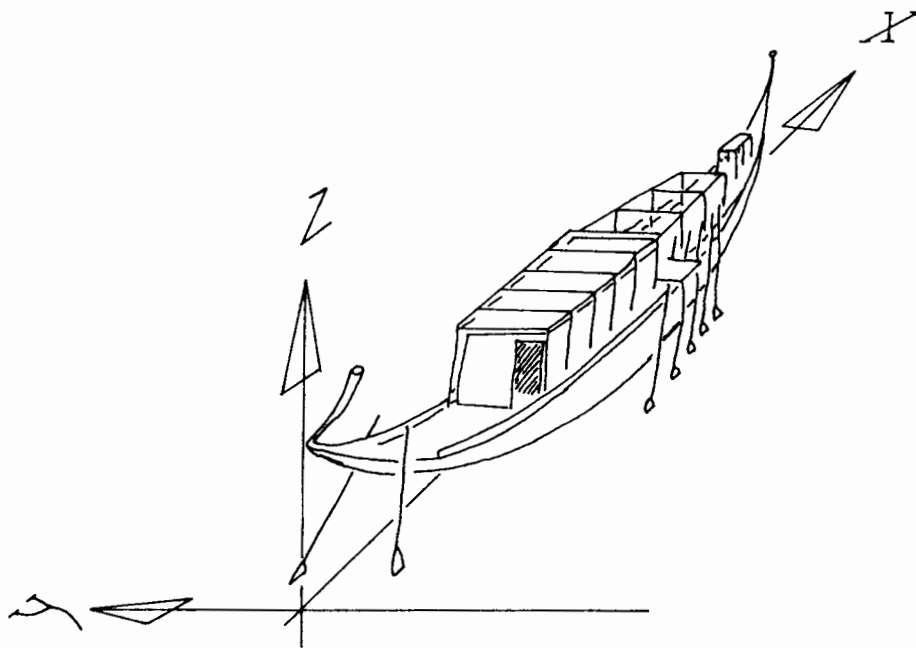


Figure 1

It is intended that the final drawings will consist of transverse and longitudinal vertical cross sections as well as horizontal cross sections.

EQUIPMENT

To carry out the actual photogrammetric field work a Zeiss Oberkochen stereometric camera, SMK 40 no. 28131 with special accessories constructed at the Department of Photogrammetry, was used. The SMK 40 camera has a base of 400 mm. The left camera, A, has a camera constant of 61.81 mm and the right camera, B, a camera constant of 61.78 mm (Figure 2).

Figure 2

Another photogrammetric camera, a Swiss Wild P 32 no. 53218, has a camera constant of 63.86 mm and was used together with a Wild theodolite T 16 no. 250748 (Figure 3).

The photographic material used for SMK 40 was Agfa-Gevaert glass plates, Aviophot Pan of size 9 x 12 cm and having a thickness of about 1.7 mm. The photographic material used for the P 32 was also glass plates, Agfa-Gevaert Gevapan 30, of size 6 x 9 cm and having a thickness of about 1.5 mm.

Some other measuring aids, such as special plumb-lines, marked lengths of string etc were also used.

Figure 3

PHOTOGRAMMETRIC CONTROL

In order to obtain photogrammetric control, a large number of pre-targeted points were established. The targets used to identify the control points were specially designed at the Department of Photogrammetry, both for ease and accuracy in identification. This target is shown in Figure 4. The target has a diameter of 40 mm.

Figure 4

The boat rests on a platform 39.5 m x 2.06 m. On each side of the platform, both port and starboard, pairs of targets with the distance of 2 m between them, were placed. On the platform itself 15 targeted points, which could be identified from both sides, were established. On the port side the museum has two balconies at different heights for visitors and spectators. On the glass fence of the upper balcony, 11 targeted points with a distance of 4 m between them, were established. On the starboard side the museum has only one balcony. On the glass fence of this balcony another 11 targeted points were established. Below this balcony, at the height of the platform, 20 targets were placed directly on the wall.

A measuring tape, with each 1 m clearly marked on the tape, was stretched along each of the port and starboard side of the platform, yielding a further 40 control points on each side.

Thus there are 123 photogrammetric targets and 80 measuring tape points which form the basis for control. In addition, to define vertical planes, plumb lines with several marked points were set up on each side of the platform. On the port side the vertical plane was about 1.1 m from the platform. On the starboard side the vertical plane was about 0.9 m from the platform at one end and about 0.5 m from the platform at the other end. On the port side the plumb lines were mounted individually and lined in with a T 16 theodolite. On the starboard side, plumb lines were hung at 1 m intervals from a line, stretched the whole length of the boat. This gave a total of 49 plumb line points on the port side and 100 plumb line points on the starboard side.

Totally 354 numbered control points were established. Table 1 and Drawing 1 indicate how these control points were numbered and their locations in the museum and in relation to the boat itself. Further, included in Appendix 1, 11 enlarged photos show the locations of all 354 points in detail. The photogrammetric and measuring tape targeted points are marked with red circles and red letters. The plumb-line points are marked with blue rectangles and blue letters.

PHOTOGRAPHY

After all the photogrammetric pre-targeted control points had been set out and identified, the next step was the photography itself.

On the port side 12 camera stations were established on the upper balcony and 24 camera stations on the lower balcony. On the starboard side, 24 camera stations were established on the balcony (see Drawing 2).

To carry out the photography on the starboard side special arrangements had to be made to have the camera at the desired height. Two ladders were used. At the top of one of these ladders a platform to hold the body of the camera was constructed by the carpenter of the museum. The photographer stood near the top of the other ladder (Figure 5). To change camera stations with good security a rope was used to lift and lower the camera from the starboard balcony. The ladder with the platform was moved in the same way.

The stereoscopic pairs of photographs taken with the SMK 40 are identified with an A for the left camera and a B for the right camera. The P 32 camera was used to take photographs from 5 stations in front of the boat. Each photograph has its unique identification as shown in Table 2.

The pictures were developed and controlled stereoscopically as the work progressed to ensure that each pair was acceptable for later use in stereoscopic measuring. The equipment for developing the glass-plates and producing the diapositives was brought from the department. Two pans, one for developing and the other for fixing the photographs were used. They were formed for a special glass-plate holder for a dozen glass-plates. To process the film, we needed a dark room with running water. The bathroom of my hotel room served this purpose excellently (Figure 6).

Figure 6

The developer used was Agfa Refinal and the fix, Kodak F-24. A special lamp-box was used as a light table for stereoscopical control viewing. Diapositive copies on film were made to be on the safe side in case anything happened to the original glass-plates. In such a case the later photogrammetric

work would be done using the diapositives. The diapositive film used was Agfa Gevaert Graphic, Gevatone N 33 P, medium gradation. For making the diapositives the lamp-box was used. In the box were both a red light and a white light, so the diapositive film could be put on the glass-plate and then exposed with white light. The exposure time was about 1/2 - 1 sek.

In Table 3 a complete record of all photographic work is given.

ACKNOWLEDGEMENT

We would finally like to express our sincere gratefulness to the staff of EAO for their help and cooperation.

Table 1

System of numbering of control points. Numbers increase from stern to bow

Identification of points	Point numbers	Number of points
<u>Targets</u>		
Port side of the platform. Interval of 2 m	1100 - 1120	21
Middle of the platform. Interval of 2 m	1200 - 1214	15
Cross marked on supporting pillars:		
- port side, odd numbers	1217 - 1239	12
- starboard side, even numbers	1218 - 1240	12
Starboard side of the platform. Interval of 2 m	1300 - 1390	21
Port side. Upper balcony. Interval of 4 m	1400 - 1410	11
Starboard side. Window wall. Interval of 2 m	1500 - 1519	20
Starboard balcony. Interval of 4 m	1600 - 1610	11
<u>Plumbines</u>		
Port side	1700 - 1748	49
Starboard side	1800 - 1899	100
<u>Measuring tape (each 1 m)</u>		
Port side	1900 - 1940	41
Starboard side	2000 - 2040	41
Total number of marked points		354

Table 2

Numbering of photographs

Port side		Starboard side	
upper balcony	lower balcony	ladder platform	balcony
100 A along B the boat	200 A + 15 gon B	300 A B	400 A along B the boat
101 A + 15 gon B	201 A B	301 A + 10 gon B	401 A B
102 A B	202 A + 15 gon B	302 A + 10 gon B	402 A B
103 A B	203 A B	303 A + 10 gon B	403 A B
104 A B	204 A B	304 A + 10 gon B	404 A B
105 A B	205 A B	305 A + 10 gon B	405 A - 15 gon B
106 A B	206 A B	306 A + 10 gon B	406 A - 15 gon B
107 A B	207 A B	307 A B	407 A - 15 gon B
108 A B	208 A B	308 A + 15 gon B	408 A - 15 gon B
109 A B	209 A B	309 A B	409 A - 15 gon B
110 A B	210 A B	310 A + 10 gon B	410 A - 15 gon B
111 A B	211 A B	311 A B	411 A - 15 gon B
112 A along B the boat	212 A B	312 A + 15 gon B	412 A - 15 gon B
	213 A B	313 A + 15 gon B	413 A - 15 gon B
	214 A B	314 A B	414 A - 15 gon B
	215 A B	315 A B	415 A - 15 gon B
	216 A B	316 A B	416 A - 15 gon B
	217 A B	317 A B	417 A - 15 gon B
	218 A B	318 A B	418 A - 15 gon B

Table 2 (cont.)

Numbering of photographs

Port side		Starboard side	
upper balcony	lower balcony	ladder platform	balcony
	219 A + 15 gon B	319 A B	419 A - 15 gon B
	220 A B	320 A + 10 gon B	420 A B
	221 A B	321 A + 10 gon B	421 A along B the boat
	222 A B	322 A + 10 gon B	422 A from the middle B toward the bow
	223 A + 15 gon B	323 A + 10 gon B	423 A from the middle B toward the bow

P 32 In front of the boat

500
501
502
503
504
505

On board the boat

600 A from cabin against bow
B
601 A from bow against cabin
B
602 A from cabin against stern
B

The model of the boat

701 A starboard, stern part
B
702 A starboard, middle part
B
703 A starboard, bow part
B
704 A from the front side against the boat
B
705 A port side, bow part
B
706 A port side, stern part
B
707 A from the back side against the boat
B
708 A from above
B

Table 3 (a)

Photographic data

Model number	Exposure time sek	Photography date 82-06-	Photogrammetric inspection date 82-06-	Production of diapositives date 83-06-
Port side, upper balcony				
100	1/5	28	29	30
101	1/12	28	29	30
102	1/12	7	20	27
103	1/12	7	20	20
104	1/15	7	20	20
105	1/8	6	20	20
106	1/8	6	20	20
107	1/10	10	20	20
108	1/10	10	20	20
109	1/8	10	20	20
110	1/10	10	19	19
111	1/10	10	19	19
112	1/10	10	19	19

Table 3 (b)

Photographic data

Model number	Exposure time sek	Photography date 82-06-	Photogrammetric inspection date 82-06-	Production of diapositives date 82-06-
Port side, lower balcony				
200	1/12	9	14	20
201	1/12	9	14	20
202	1/12	9	14	20
203	1/12	9	14	20
204	1/12	9	14	20
205	1/12	9	14	20
206	1/12	9	14	20
207	1/12	9	14	20
208	1/12	9	14	20
209	1/12	9	14	20
210	1/15	6	19	20
211	1/10	6	19	20
212	1/8	6	19	20
213	1/8	6	19	20
214	1/6	9	19	20
215	1/10	10	19	20
216	1/10	10	19	20
217	1/10	10	19	20
218	1/8	10	19	20
219	1/10	10	19	20
220	1/10	10	19	20
221	1/10	10	20	20
222	1/10	10	19	20
223	1/10	10	19	20

Table 3 (c)

Photographic data

Model number	Exposure time sek	Photography date 82-06-	Photogrammetric inspection date 82-06-	Production of diapositives date 82-06-
Starboard, ladder platform				
300	1/10	21	22	22
301	1/10	21	22	22
302	1/10	21	22	22
303	1/10	21	22	22
304	1/10	21	22	22
305	1/10	21	22	22
306	1/10	21	22	22
307	1/8	21	22	22
308	1/8	21	22	22
309	1/8	21	22	22
310	1/8	21	22	22
311	1/8	21	22	22
312	1/8	21	22	22
313	1/8	21	22	22
314	1/8	21	22	22
315	1/8	22	22	22
316	1/8	22	22	22
317	1/8	22	22	22
318	1/8	23	25	25
319	1/8	23	25	25
320	1/8	23	25	25
321	1/8	23	25	25
322	1/8	23	25	25
323	1/8	23	25	25

Table 3 (d)

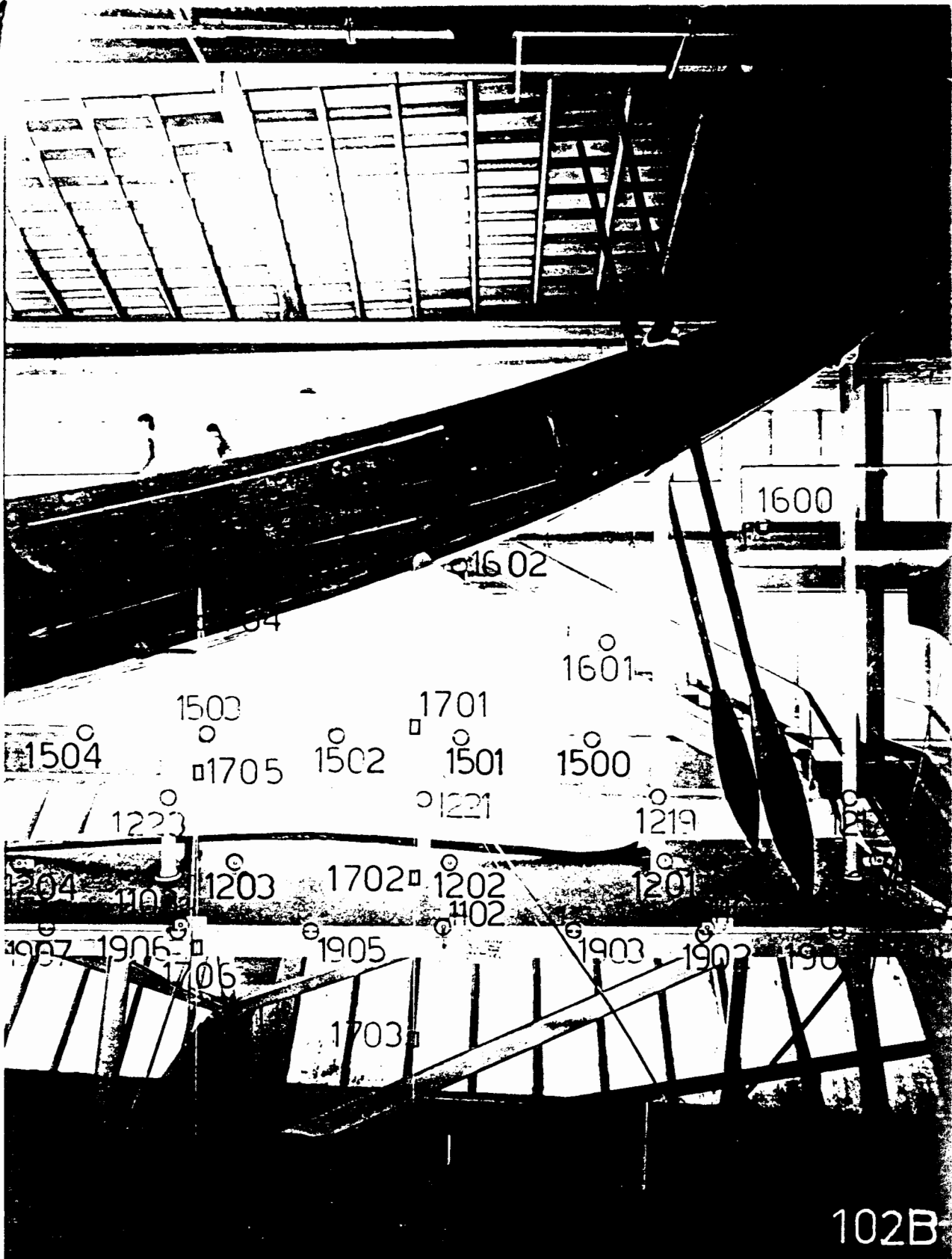
Photographic data

Model number	Exposure time sek	Photography date 82-06-	Photogrammetric inspection date 82-06-	Production of diapositives date 82-06
Balcony				
400	1/5	28	29	29
401	1/5	17	20	20
402	1/5	17	20	20
403	1/5	17	20	20
404	1/5	23	25	25
405	1/5	23	25	25
406	1/5	23	25	25
407	1/5	23	25	25
408	1/5	23	25	25
409	1/5	23	25	25
410	1/5	23	25	25
411	1/5	23	25	25
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417	1/5	24	25	25
418	1/5	24	25	25
419	1/5	24	25	25
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421	1/5	24	25	25
422	1/5	24	25	25
423	1/5	24	25	25

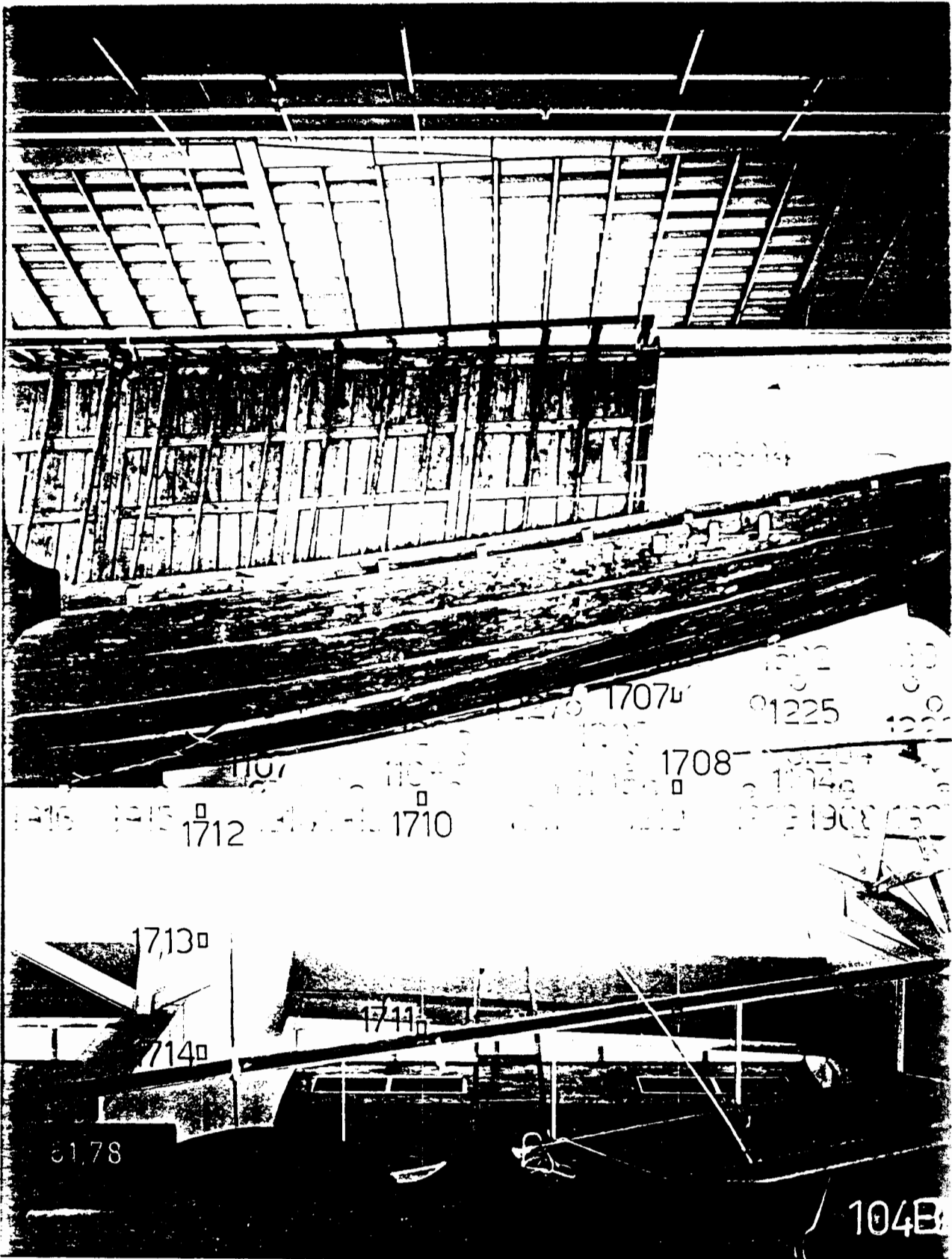
Table 3 (e)

Photographic data

Photograph number	Exposure time sek	Scatter	Photography date 82-06-	Photogrammetric inspection date 82-06-	Production of diapositives date 82-06-
From in front of the boat					
500	1/4	22	23	27	30
501	1/4	22	23	27	30
502	1/8	22	23	27	30
503	1/4	22	23	27	30
504	1/4	22	23	27	30
505	1/4	22	23	27	30
On board					
600	1/3		24	25	25
601	1/3		24	25	25
602	1/3		24	25	25
Model boat					
701	1/1		28	29	30
702	1/1		28	29	30
703	1/1		28	29	30
704	1/4		16	20	30
705	1/1		28	29	30
706	1/1		28	29	30
707	1/4		16	20	30
708	1/3		23	25	25



102B



1707 1707 1708 1708
1712 1710 1710 1710
1712 1710 1710 1710

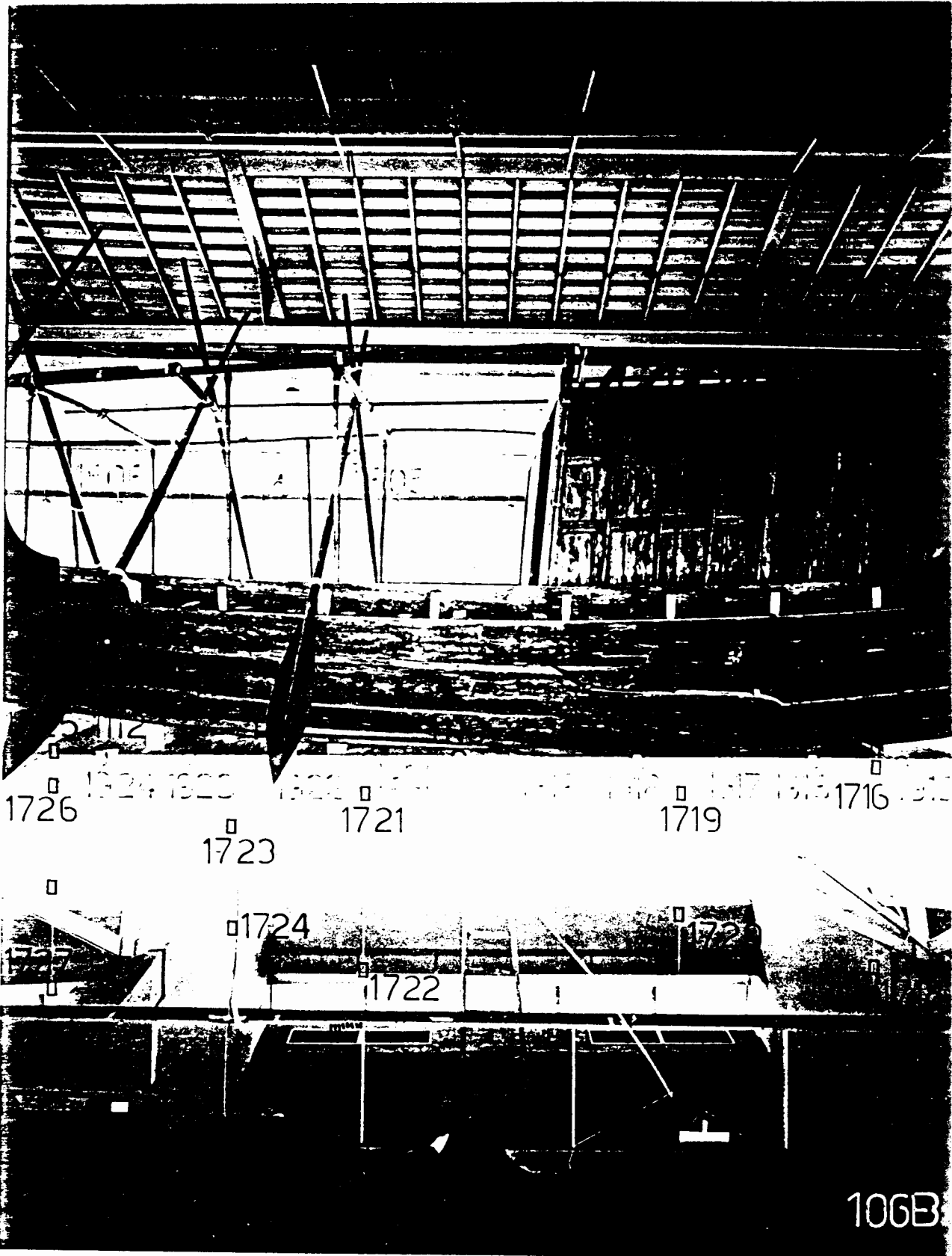
1713

1711

1714

1718

104B



1726

1724 1723

1723

1721

1719

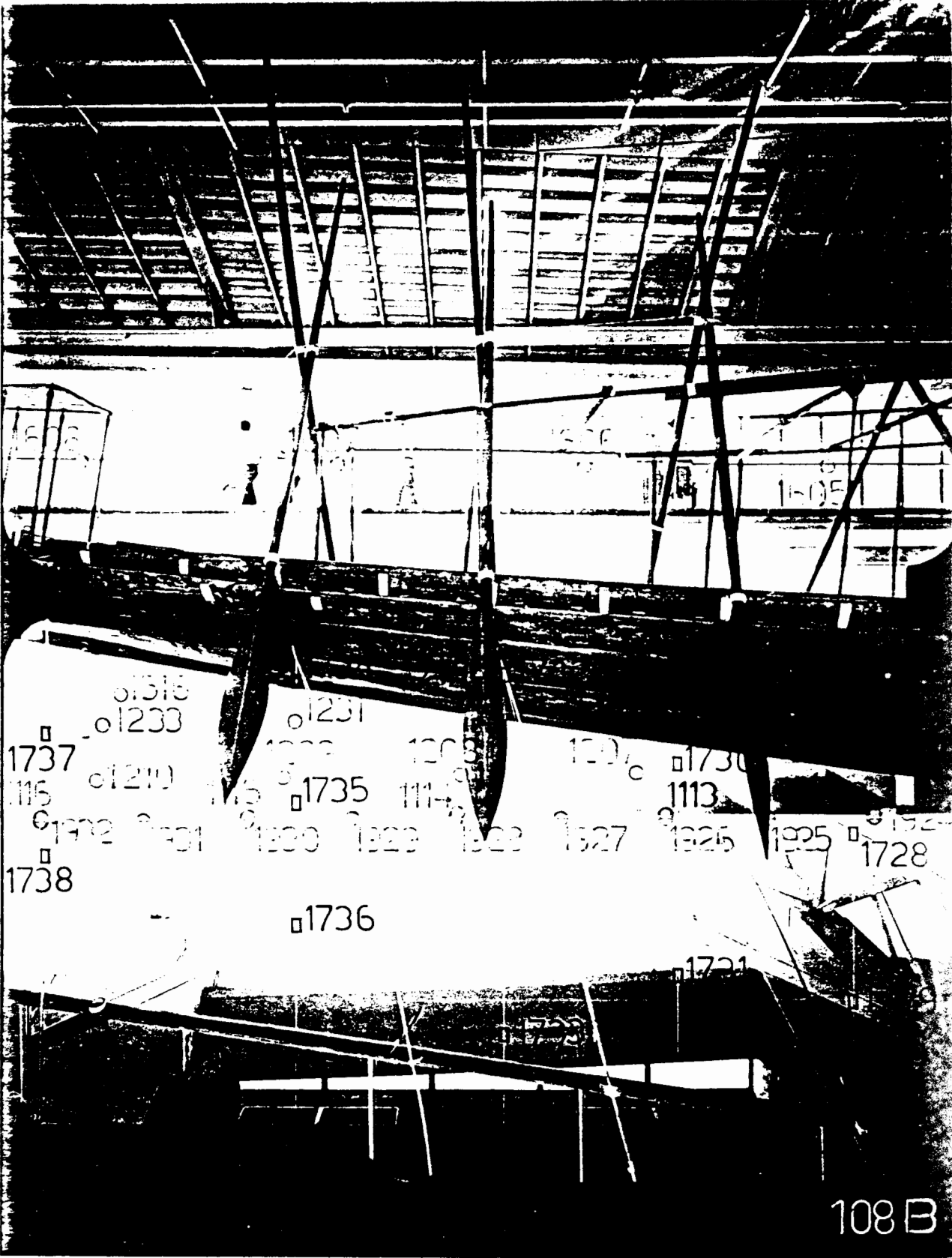
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1724

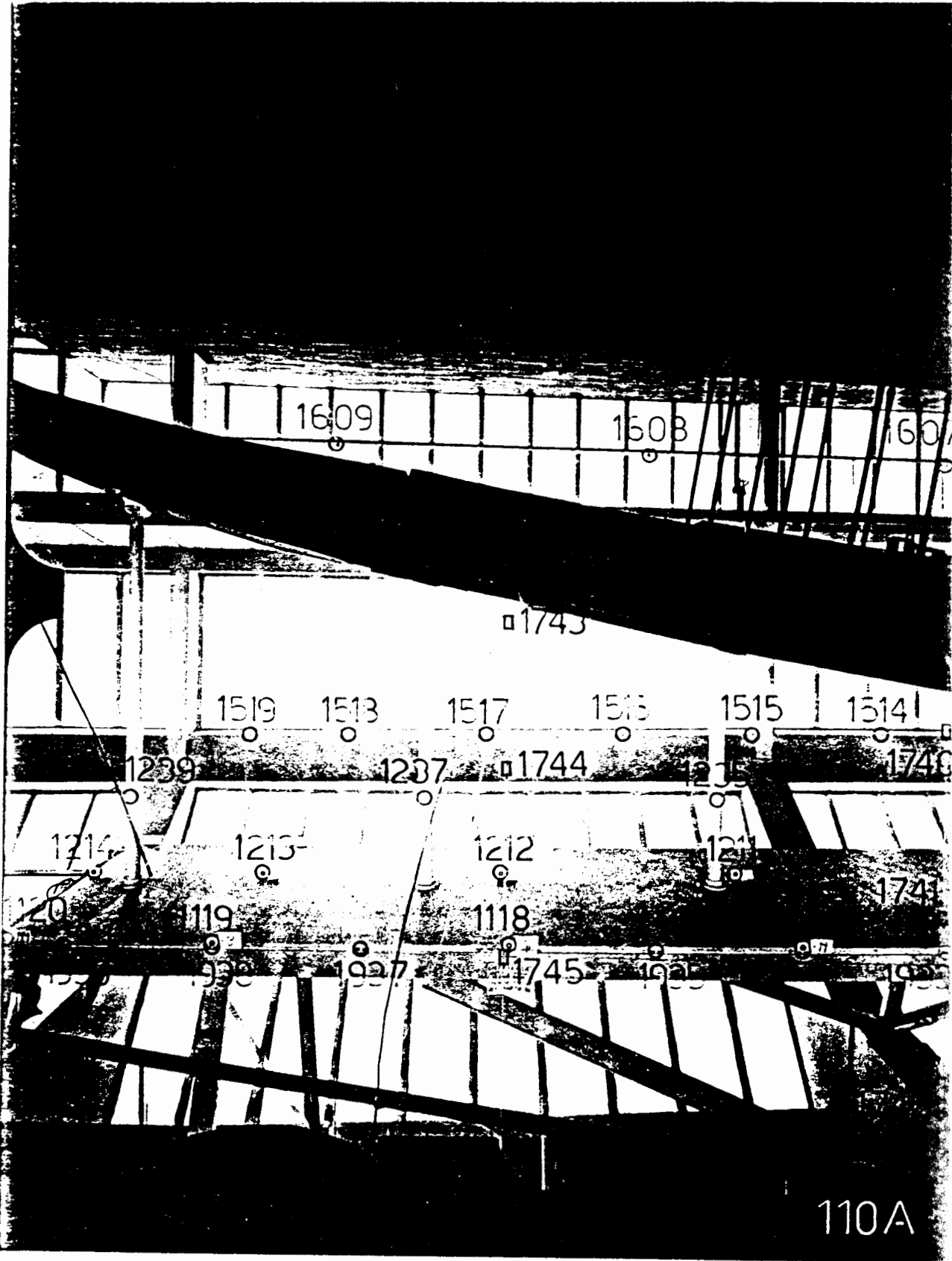
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1722

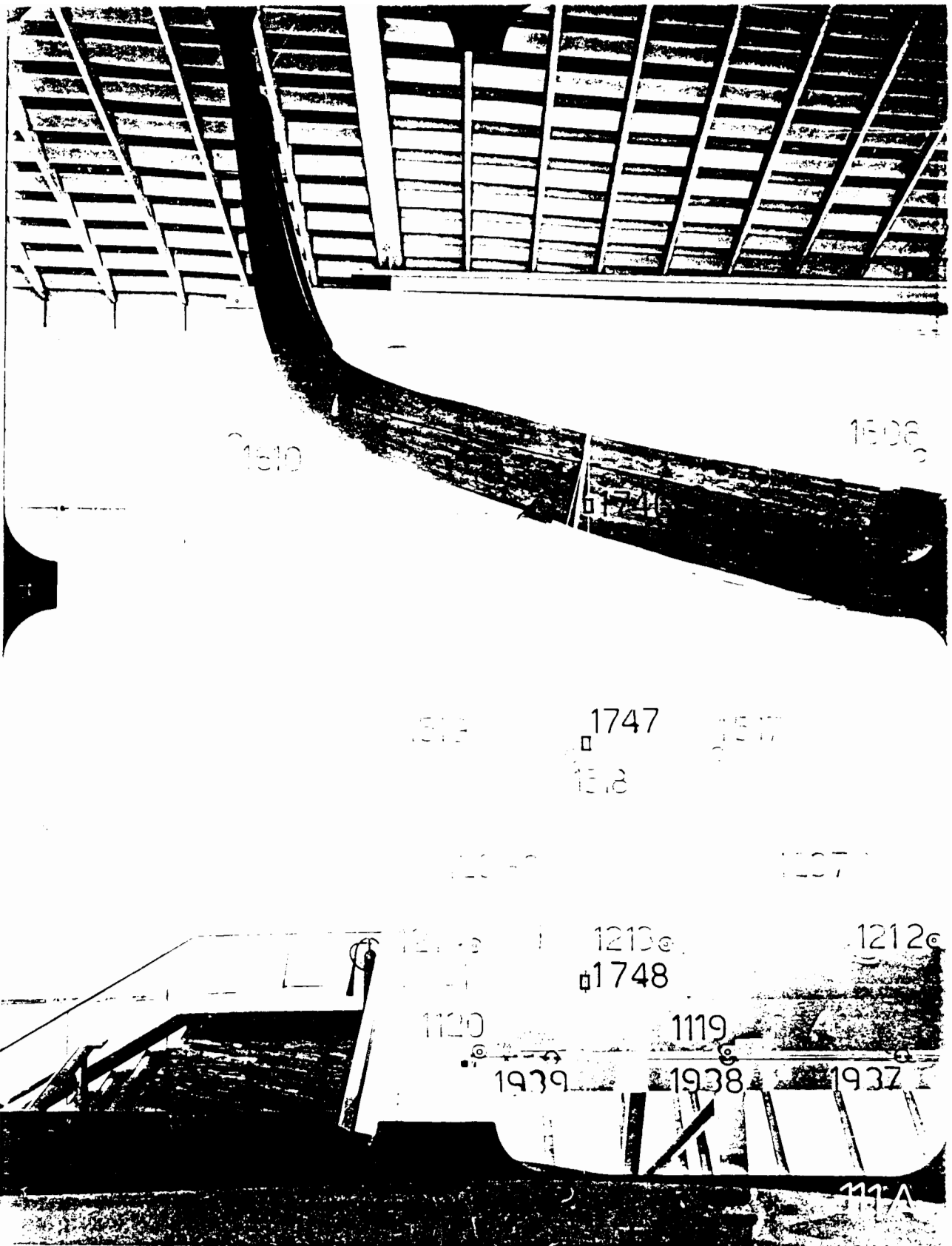
106B



1737 1736 1233 1231 1203 1203 1207 1730
 1115 1210 1735 1113
 1732 1731 1730 1729 1728 1727 1725 1725 1724
 1738 1736 1731



110A



1510

1506

1747

1512

1747

1517

1518

1212e

1212e

1212e

1212e

1212e

1748

1120

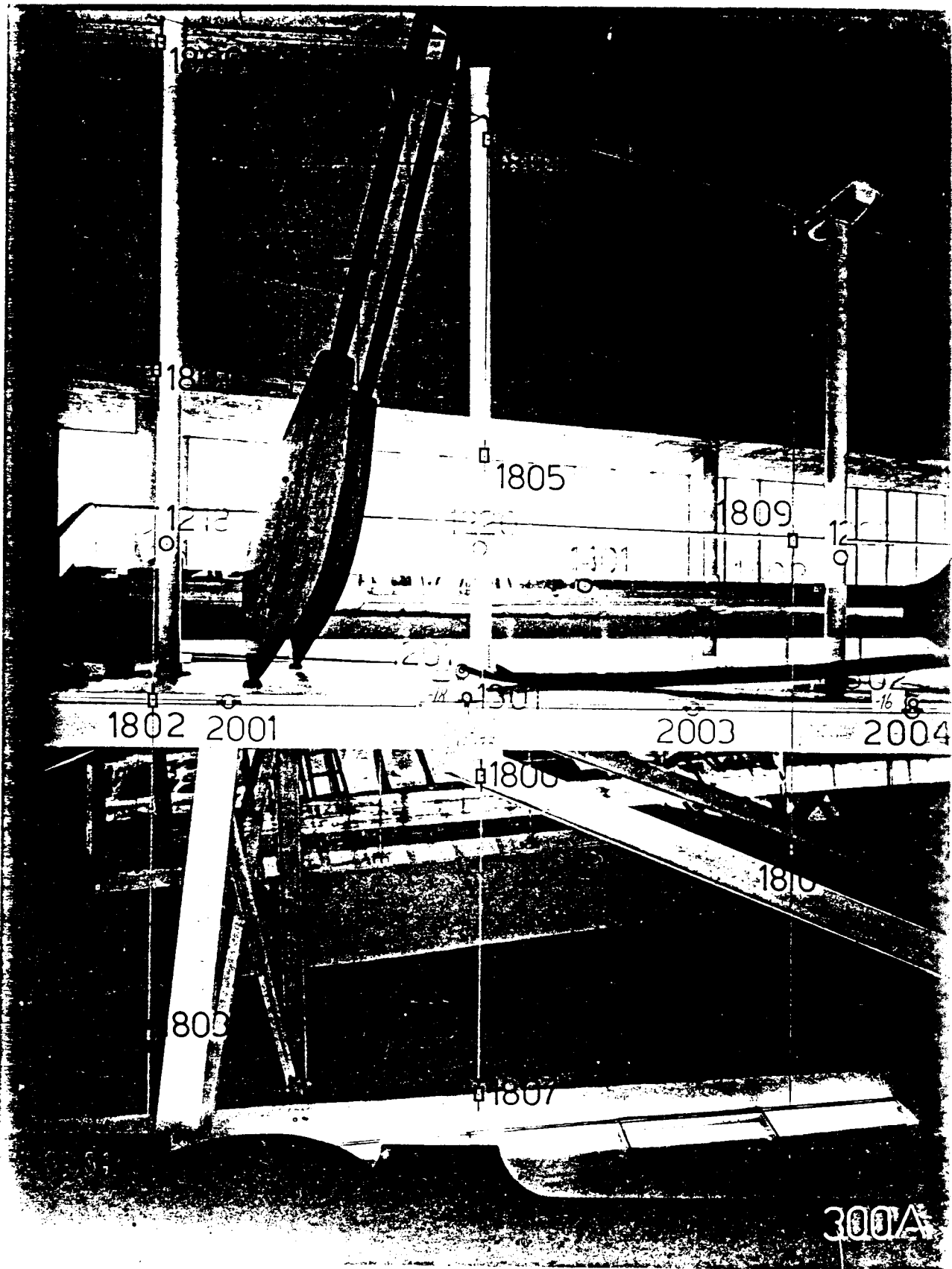
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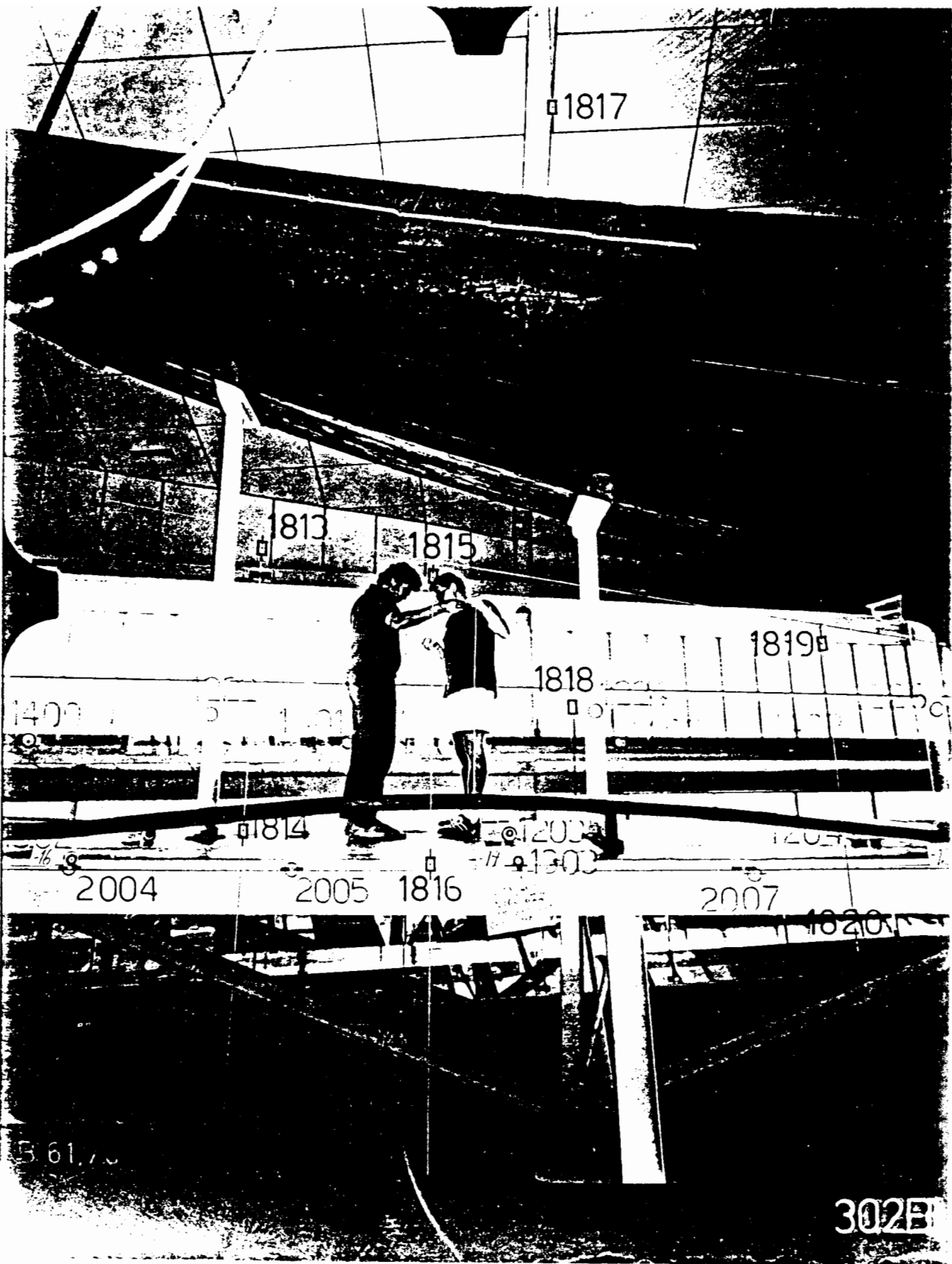
1939

1938

1937

111A





1817

1813

1815

1819

1818

1814

2004

2004

2005

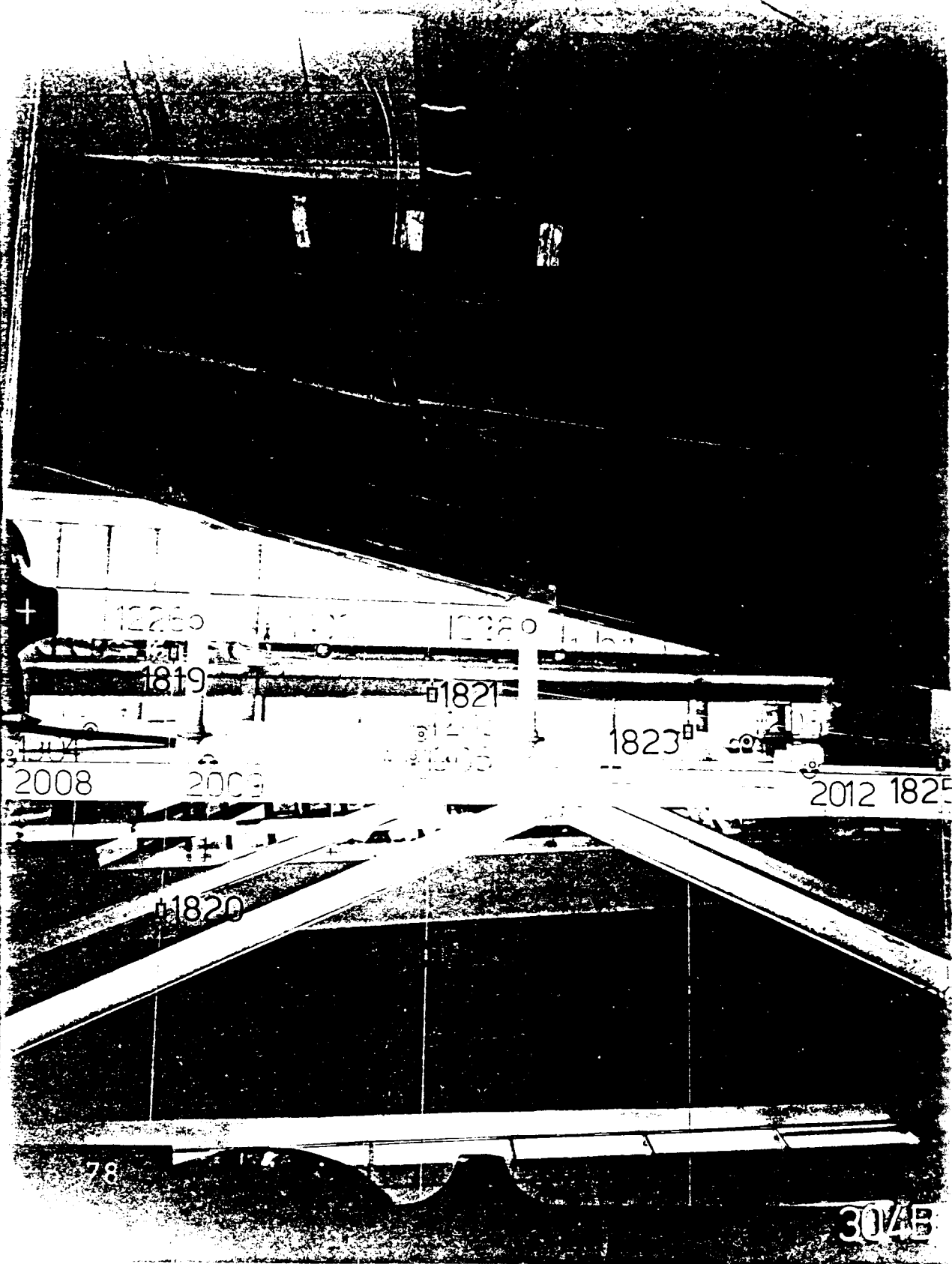
1816

2007

1820

36173

302B



12260

12260

1819

1821

1823

2008

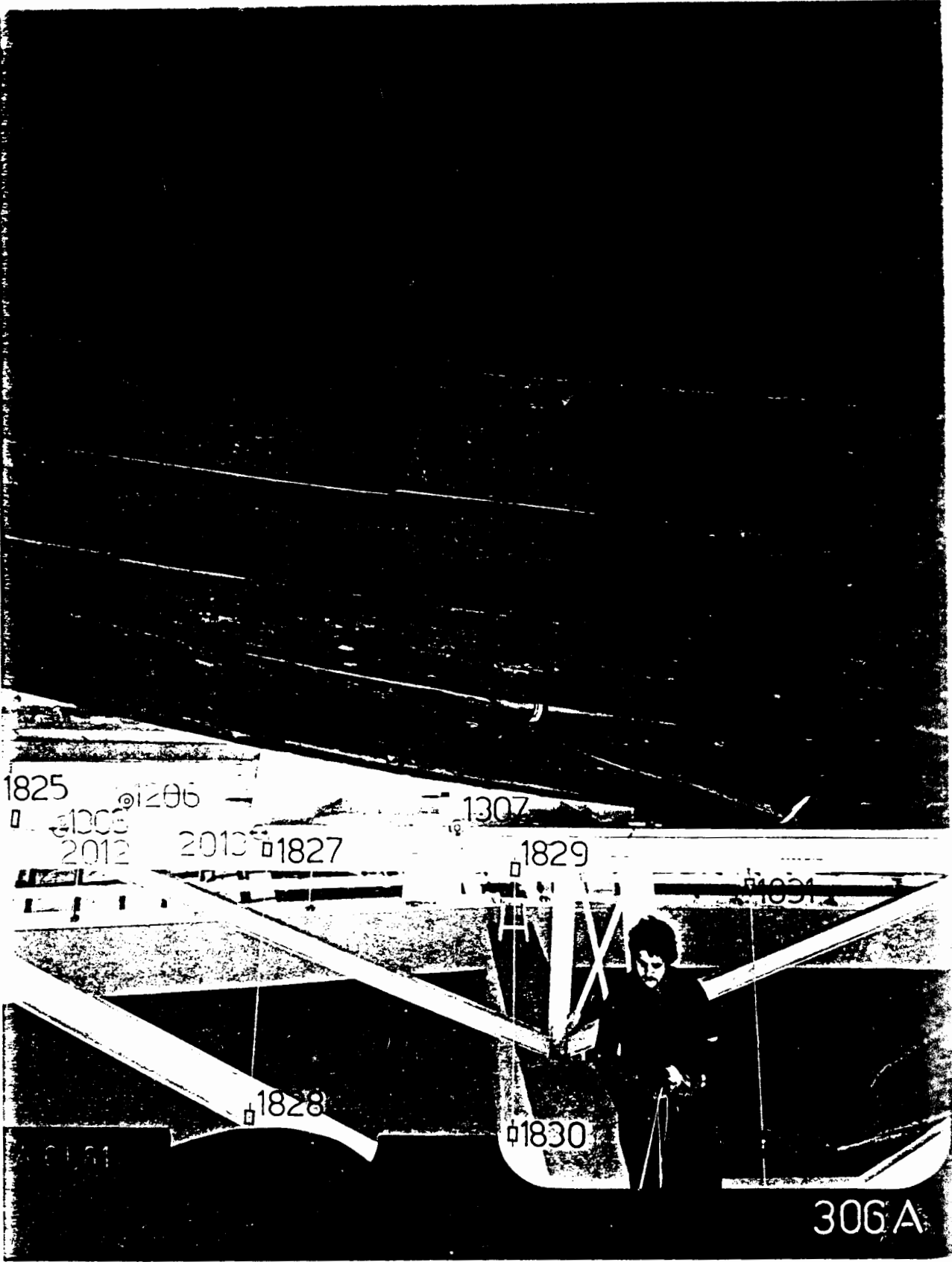
2009

2012 1825

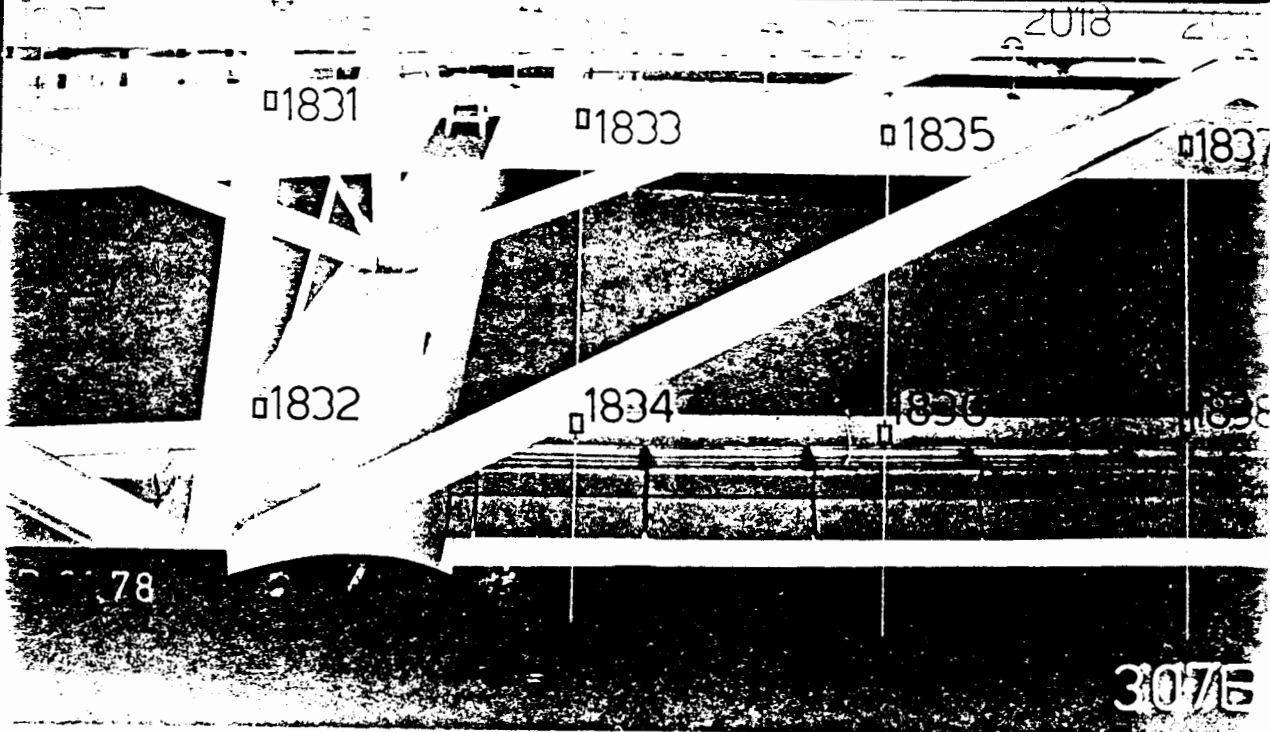
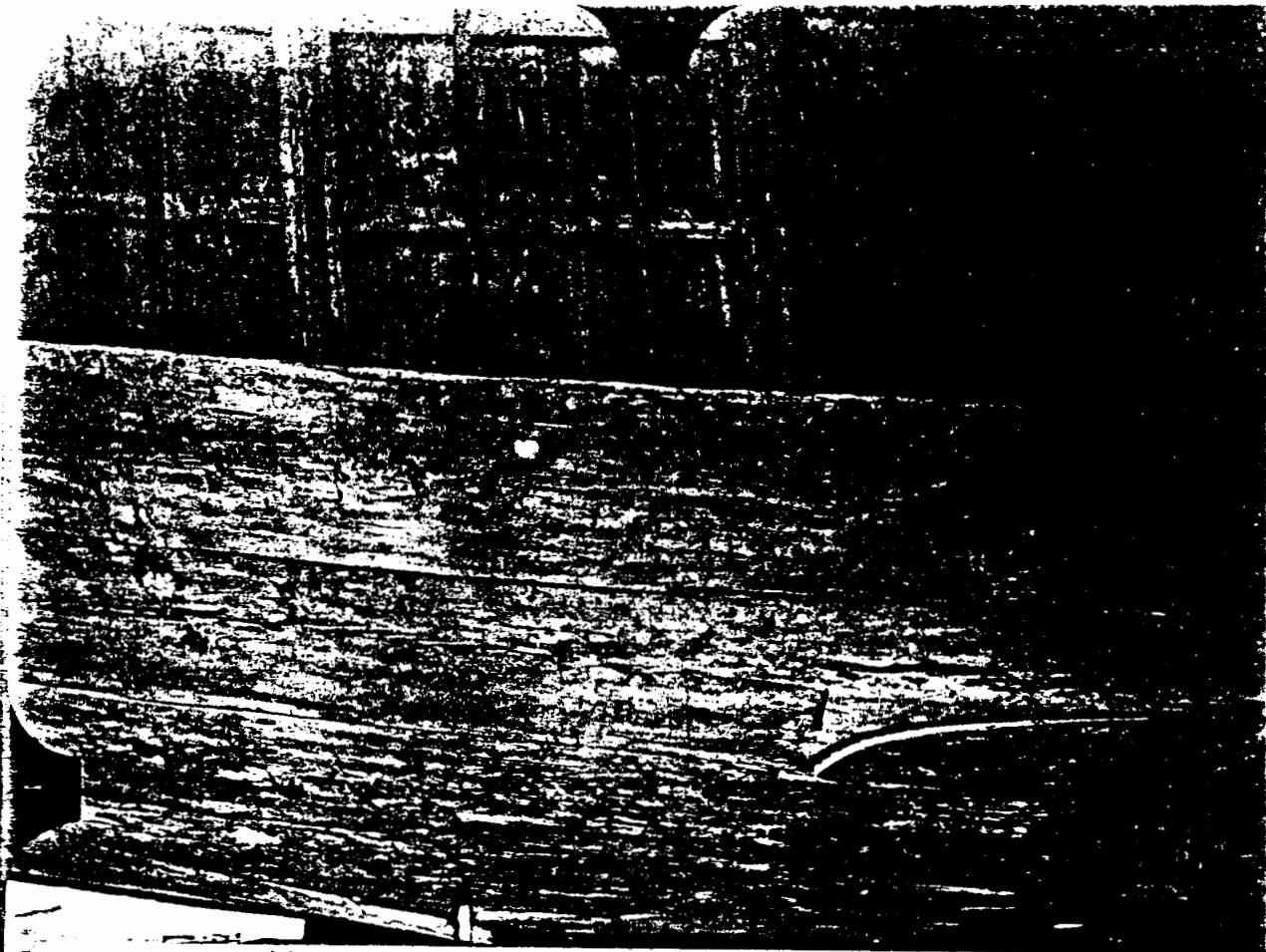
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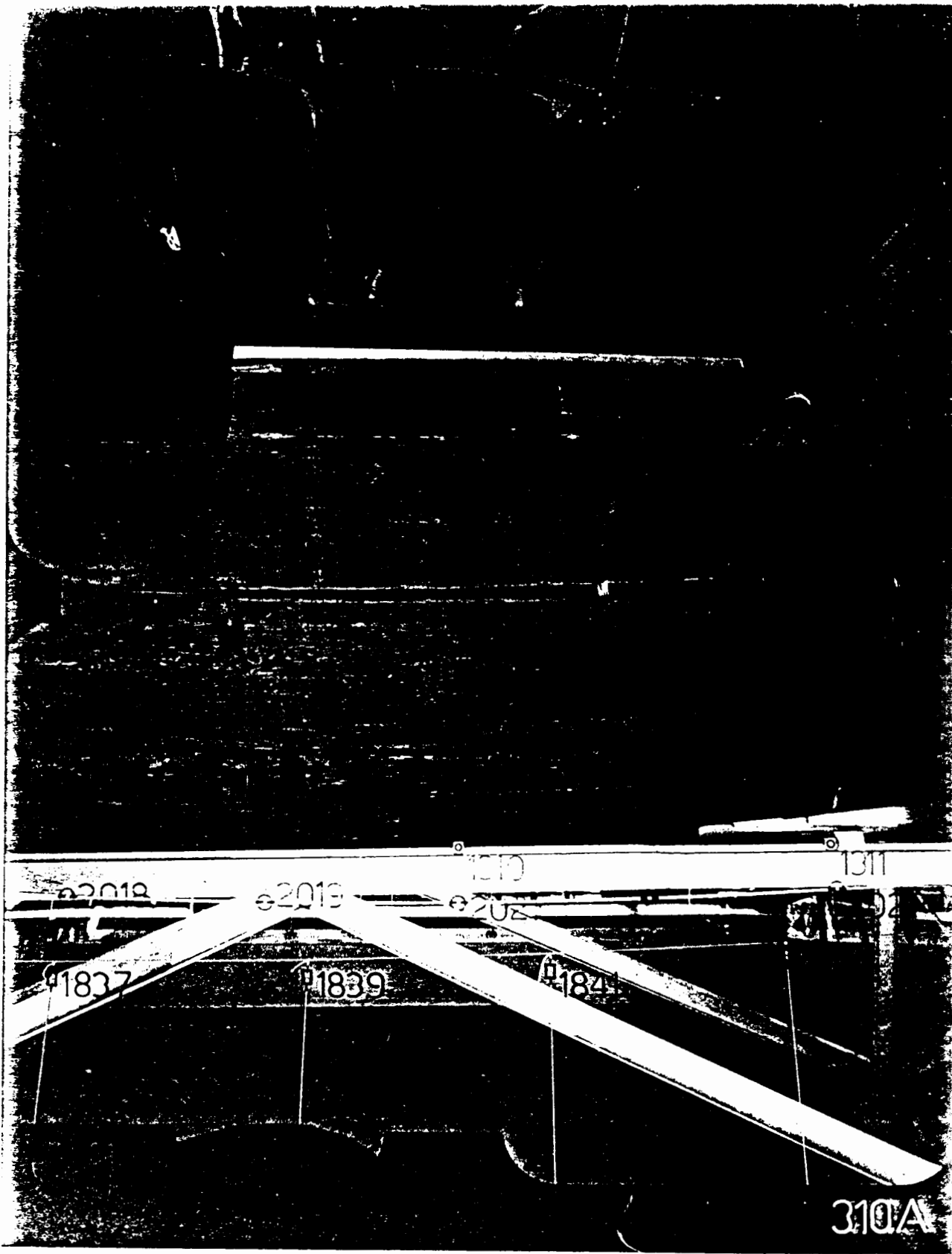
78

304B



306A





2018

2019

2020

1310

1311

1837

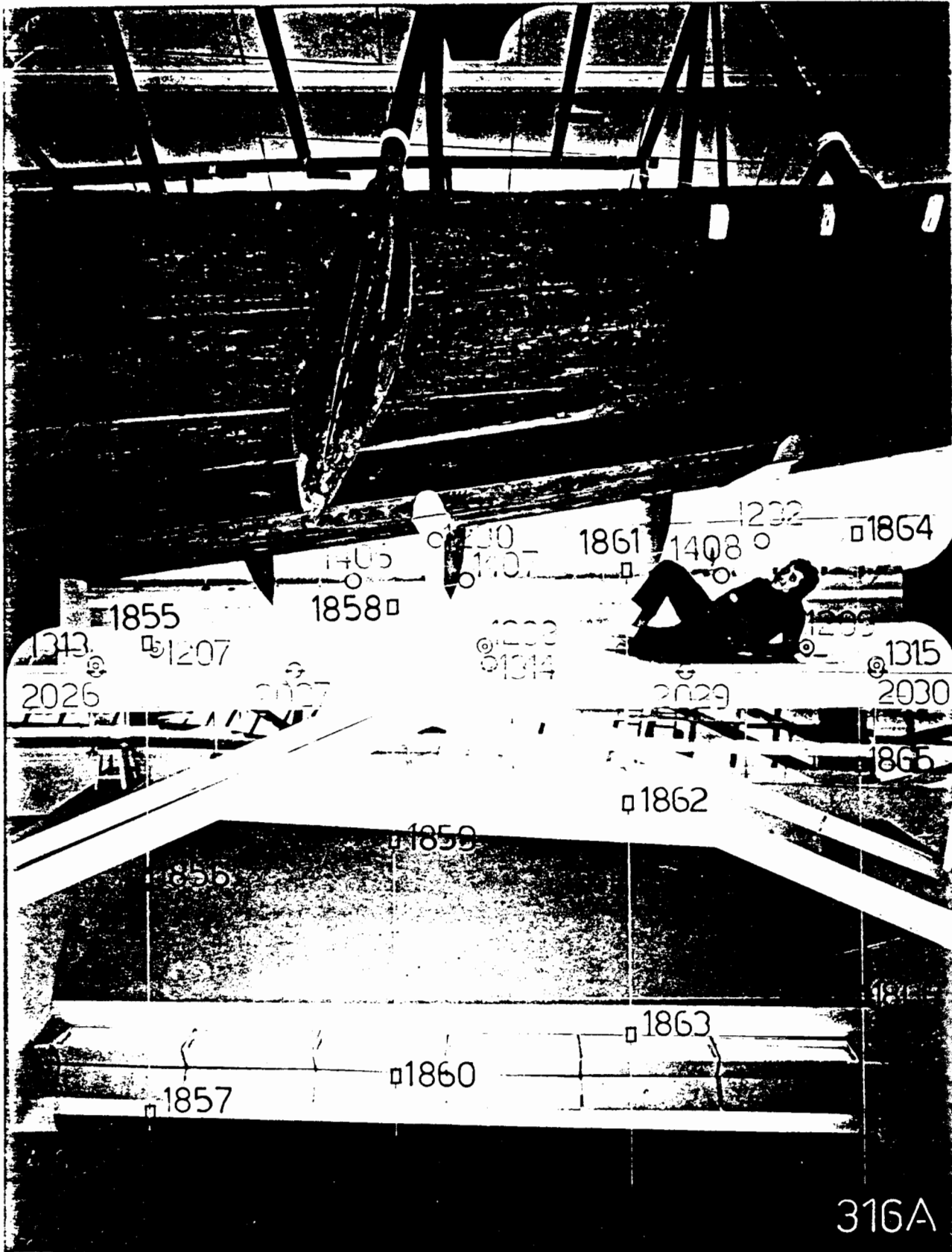
1839

1841

310A

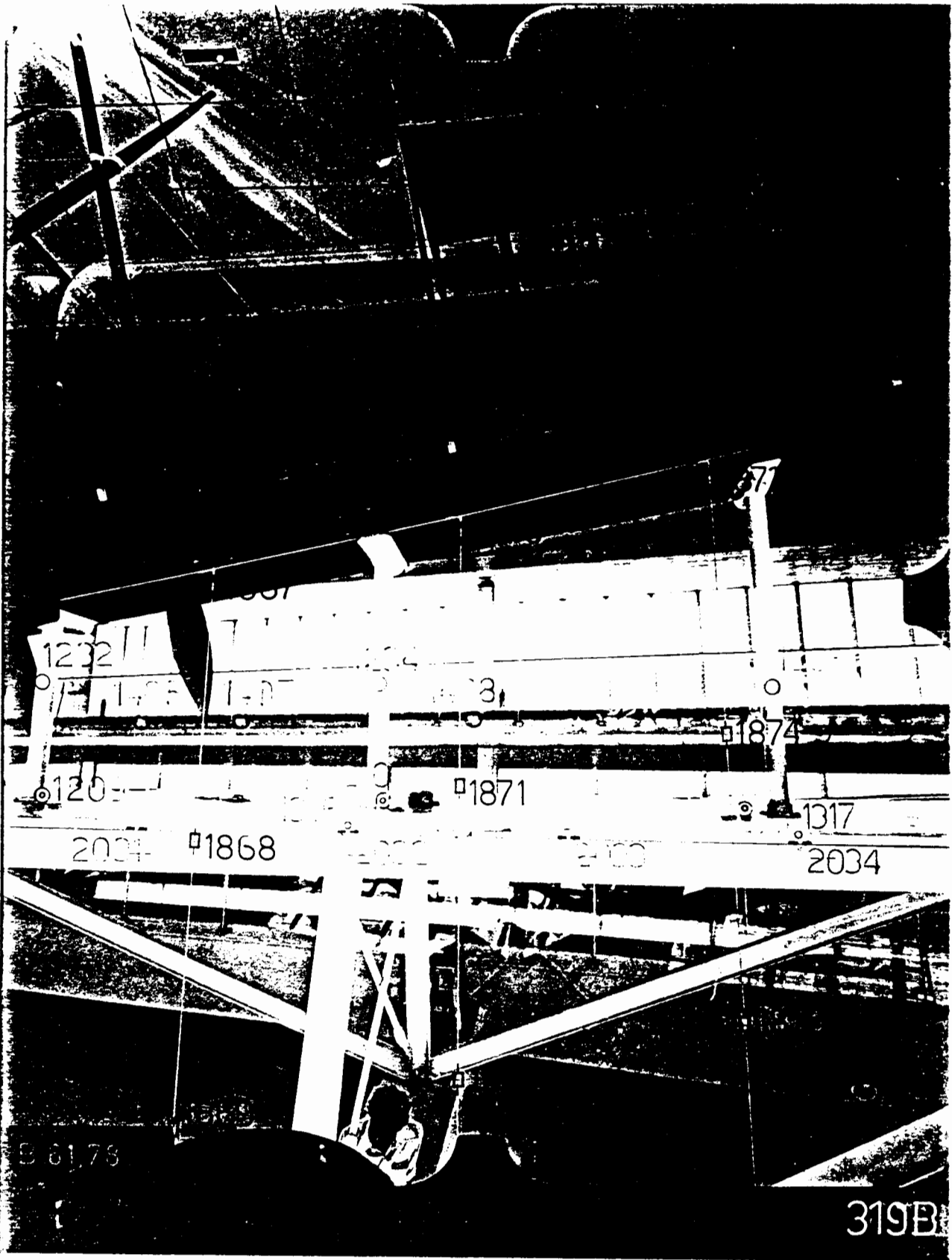


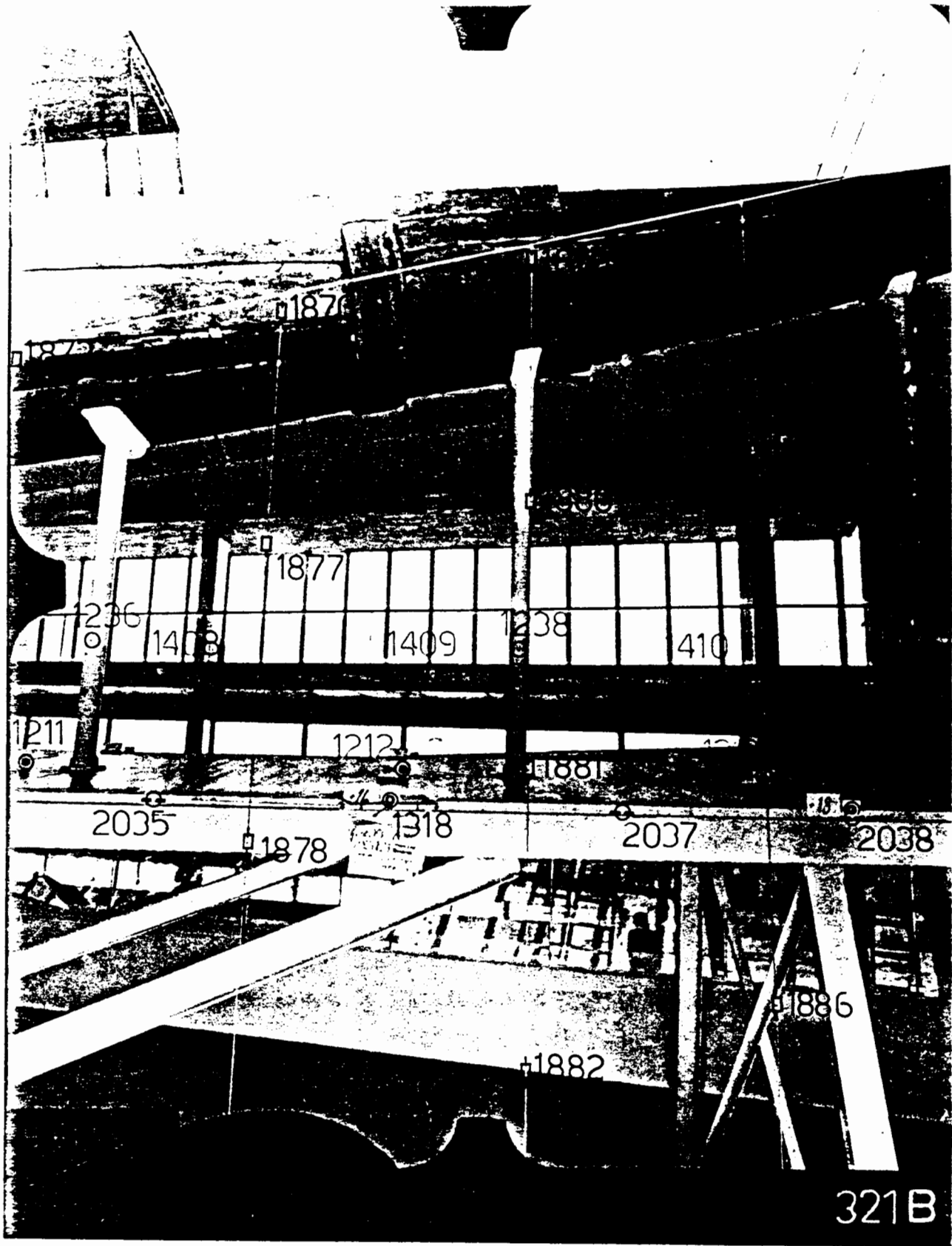
314B



1405 1861 1408 1232 1864
1855 1858 1232 1315
1313 1207 1314 2029 2030
2026 1865
1856 1862
1859
1857 1860 1863

316A





1876

1876

1880

1877

1236

1408

1409

1238

410

1211

1212

1881

2035

1878

1318

2037

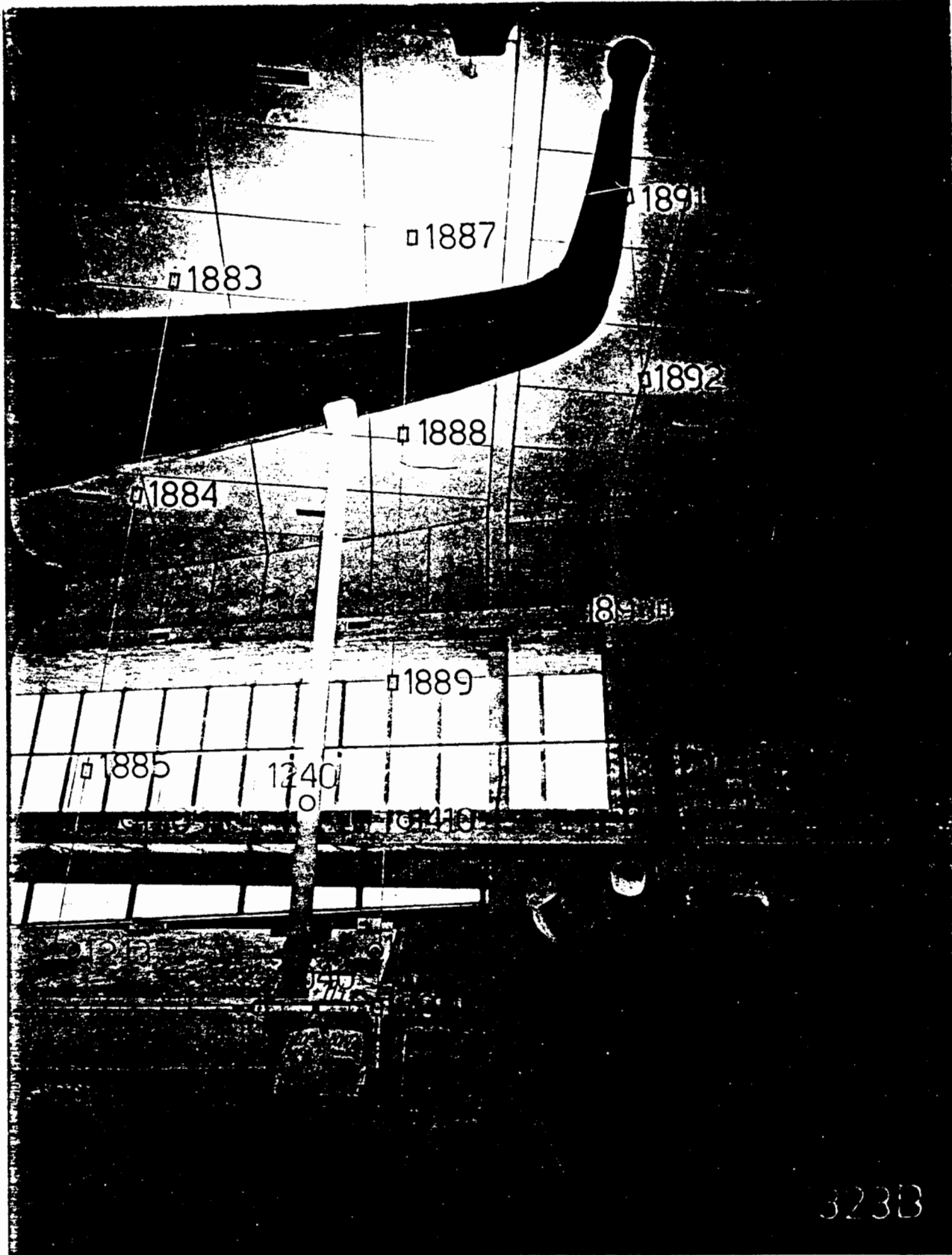
1816

2038

1886

1882

321B



323B