Research Note

The Ruins of the Gas Chambers: A Forensic Investigation of Crematoriums at Auschwitz I and Auschwitz-Birkenau

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Combining engineering, computer, and photographic techniques with historical sources, this research note discusses the gas chambers attached to crematoriums at Auschwitz I and the Auschwitz-Birkenau death camp. Among other things, the authors identify the locations of several of the holes in the roofs through which Zyklon B was introduced: five in Crematorium I and three of the four in the badly damaged Crematorium II. The authors began their project before David Irving's libel suit against Penguin Books and Deborah Lipstadt, proceeding simultaneously with, but independently of, the trial. The defense presented the first version of the authors' report during Irving's subsequent application to appeal. Irving's application was rejected by the court.

Introduction

Zyklon B, a solid carrier for the poison gas hydrogen cyanide, was introduced through holes (sometimes called vents) in the roofs into the gas chambers of Crematorium I at Auschwitz and Crematoriums II and III in Auschwitz-Birkenau. Holocaust-deniers have focused on the issue of the holes in the roof of Crematorium II, claiming that no apertures can be observed today. The slogan "No Holes? No Holocaust!" is often repeated.[1] Our research was undertaken to establish the facts of the matter and got underway before the slogan resurfaced in 2000 during the libel trial initiated by David John Cawdell Irving against Penguin Books Ltd. and Prof. Deborah Lipstadt.

This study by members and associates of the Holocaust History Project[2] identifies (among other things) three of the four holes in the roof of Crematorium II and offers a probable location of the remaining hole, currently covered by rubble. We believe that it is the first to add physical confirmation to the testimonial and photographic evidence for the location of the holes. To the best of our knowledge, it presents the first attempt to employ computer vision techniques to analyze the crematorium photographs. We have used the modern numeration for the crematoriums in the Auschwitz camp complex: Crematorium I (Auschwitz main camp); Crematoriums II, III, IV, and V (Auschwitz-Birkenau camp).

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Part I describes the physical findings and their relation to testimonies and to a ground-level photograph taken during the construction of Crematorium II. Part II covers some additional findings in that gas chamber. Part III discusses some of the aerial photographs in which the gas chamber appears. Part IV addresses the gas chamber in Crematorium I at the main camp, and Part V presents a short overview of material from the realm of computer vision, which will help readers to understand some of the computer renderings in the paper. The analysis of the photographs, combined with the new physical findings and two key testimonies that have gone largely unnoticed, has resulted in some new conclusions about the Zyklon holes in Crematoriums I and II.

The search for the holes is quite a complex task, as both Crematoriums II and III were dismantled in late 1944 and later dynamited by SS sappers in January 1945 before they fled Auschwitz. The structures suffered considerable further deterioration in the following decades (see Figures 1a, b, and c).

Part I: The Crematorium II Gas Chamber

The Layout

Crematorium II was completed on March 31, 1943,[3] and served as one of the major killing installations in Auschwitz-Birkenau until dismantled in late 1944; it was dynamited by the fleeing SS in January 1945. The mass murder by hydrogen cyanide has been reported by survivors and former members of the SS. These testimonies are supported by many documents; neither this literature nor the well-known chemical studies that recovered substantial amounts of cyanic compounds in the chamber's walls are pertinent to the present discussion.[4]

The killing process began by tricking the victims into a semi-subterranean gas chamber camouflaged as a shower room. Once the victims were inside and the door locked, SS-men protected by gas masks poured one or more canisters of Zyklon B (a porous carrier for the lethal gas hydrogen cyanide) into each of four openings in the chamber's roof. Unlike the procedure used in some of the other gas chambers, Zyklon B in Crematoriums II and III was not simply poured onto the floor, but lowered in a removable container into a sturdy wire mesh column. This container, or as we call it below, "inner core," allowed the removal of the Zyklon pellets after the victims had died.[5] "Wire mesh introduction devices" ("*Drahtnetzeinschiebvorrichtung*[*en*]") are listed in the crematorium's inventory.[6] The removable core was necessary because the chamber had neither doors nor windows leading to the outside, save for one door that led from the hall in which the victims undressed. This mechanism allowed safe retrieval of the pellets, which might still be releasing gas after the victims were dead. Small brick "chimneys" were built over the holes in the roof.

After several minutes, perhaps twenty, the victims were dead and the inner core of the introduction apparatuses holding the partially spent Zyklon B pellets was

pulled out. For fifteen minutes or more a strong ventilation system cleared the air in the chamber, whereupon the door was opened and "Sonderkommando" prisoners transferred the bodies to the furnace room using the corpse-lift installed for that purpose. A solemn testimony to the number of victims is the number of "stokers" mentioned in the SS labor-deployment reports: Crematoriums II and III employed up to 220 each.[7]

The inner measurements of the gas chamber of Crematorium II (and that of Crematorium III) are 30×7 meters, with its external brick walls being 0.5 m thick. The roof slab is 8 m wide. The inside height was 2.4 m. The total volume of the chamber was therefore 504 cubic meters. Seven steel-reinforced concrete columns, or pillars, with a cross-section of 0.4×0.4 m, supported the roof. These held a central support beam that ran the entire length of the chamber. The beam's cross-section was 0.4 m wide ×0.55 m high. The distance between the centers of the pillars was 3.8 m, while the distance between the centers of the two outermost pillars and the north and south walls was 3.6 m.[8]

The gas chamber's long axis is aligned almost exactly from south to north. We have numbered the seven support columns, as well as the four holes in the roof, in ascending order from south to north. Schematic drawings of the roof and the chamber are presented in Figures 2a and 2b.

To examine photographs from a vantage point to the south of Crematorium II, the windows on the south wall of the main building are useful for locating the gas chamber. We number those ten full-size windows in ascending order from west to east. Window 2 is located directly over the roof of the gas chamber (though in Figure 3, Window 3 appears to overlook it). The same killing process took place in Crematorium III, which, save for some minor differences, was a mirror image of Crematorium II. The gas chamber of Crematorium III, however, is unlikely to yield further information due to the condition of that structure (see Figure 1b).

Previous Knowledge

Three kinds of evidence have long indicated Zyklon B introduction holes in the roof of the gas chamber of Crematorium II, as well as the small brick "chimneys" built over them.

a) The aforementioned testimonies of survivors and former members of the SS.
b) The information contained in a photograph, taken by a member of a photography team of the Waffen SS and Police Central Construction Board (Zentralbauleitung der Waffen SS und Polizei), showing three of the Zyklon "chimneys" protruding over the roof (Figures 3 and 4). This photograph was taken in early 1943, shortly before construction was completed. Directly below Window 4 can be seen the brick "chimneys" enclosing the wire mesh introduction devices for Holes 1 (right) and 2 (left). The shape under Window 5 is not an introduction chimney but a portal, discoloration, or another shape on the wall of the crematorium proper. Additionally, a lighter shadow

appears near the middle of the gas chamber, under the east edge of Window 3. This does not correspond to an introduction port either. It may be an object on or near the roof of the gas chamber. It is lower and narrower than "Chimneys" 1 and 2. Also, while "Chimneys" 1 and 2 have at the right of their dark shadows shades of gray that are measurably lighter than the wall behind, the shade of gray to the right of the unidentified form is not clearly distinguishable from the wall. This can be verified by scanning the image and examining the gray levels (i.e., intensities).

The top of the western edge of Chimney 4 can be seen more clearly in Figure 4 just to the left of a locomotive's smokestack. Its lower half is obscured by snow-covered earth, its southern face by the smokestack. Chimney 3 is entirely occluded by the smokestack. David Irving has speculated that the holes are really "drums containing sealant,"[9] but it is obvious that this cannot be the case: a cylindrical object would produce a gradual light pattern, while the objects above display a sharp change between uniform light and uniform shadow.

We have constructed a three-dimensional computer model of the Crematorium II building and its gas chamber (Figure 5). The dimensions and locations of the features that we modeled have been variously reconstructed from the building's blueprints (e.g., the windows), the surviving ruins (e.g., the location of three of the four holes), or both (the dimensions of the roof). The blueprints are published in Pressac.[10]

The "Train Photograph" is consistent with the physical evidence we discovered in the chamber (discussed below). This emerges from a reverse engineering exercise: Is there a camera location from which the given photograph will be identical with the (virtual) photograph of our model? An affirmative answer would lend credibility to the model. This sort of analysis is also applied to the Zyklon holes of Crematorium I (see Part IV, below). Both comparisons demonstrated an excellent match between the wartime photographs and the model our physical findings suggested.

The exact location of the train in the foreground is not known, but by triangulation and by using the principles of projective geometry,[11] it can be placed approximately 104.3 m south and 45 m west of the south-west corner of the gas chamber.

The correlation is unmistakable; from the photograph, sizes can be estimated almost to the centimeter. Perhaps this point is best made with an overlay of the photograph by a wireframe showing a skeletal view of the building and gas chamber (Figure 6).

c) Several aerial photos of the Birkenau complex taken by American and British planes during 1944 (see Figure 7). The clearest of these photographs were taken during an American overflight on August 25. Crematoriums II and III

appear at the edge of precisely one frame, number 3185; in the next, 3186, Crematorium II alone is visible, with Crematorium III having been cut off by the trajectory of the aircraft.

As analyzed by an expert on aerial photo interpretation, Carroll Lucas,[12] these two frames "provided the best quality photography acquired over the site" and therefore are of special interest. Frame 3185 exhibits the better contrast of the two, 3186 being slightly overexposed. The photographic resolution was "on the order of 4–6 feet (1.25–1.85 meters)" Lucas judged. The locations of the four observed "smudges" on the roof correspond very well with the Train Photograph, and with the current physical evidence (described below). The smudges are too large to belong just to the holes themselves. They probably correspond to the tamping down of a trail on the roof by the SS men detailed to introduce the canisters (see Part III).

The photograph shows the smudges alternating slightly, Holes 1 and 3 to the west, 2 and 4 to the east. A Sonderkommando survivor, Henryk Tauber, considered a reliable witness on technical issues, testified that the holes in Crematorium II were on alternating sides. Interestingly, he is "corrected" by Pressac,[13] who suggested that Tauber confused Crematoriums II and III; the Zyklon holes, however, alternated sides in both crematoriums, although they were considerably farther off center in Crematorium III (exposure 3185 of August 25, not reproduced here). That the holes alternate in Crematorium II is supported by the aerial photograph, the Train Photograph, the physical findings, and Tauber's testimony. This has been overlooked so far by historians and Holocaust-deniers alike, resulting in faulty analyses of the photographs.

* * *

Were the wire mesh Zyklon insertion devices attached to the concrete support pillars? This hypothesis might appear reasonable, but we have found little support for it and strong evidence against it. Mr. Gideon Greif of Yad Vashem, an expert on the Auschwitz-Birkenau Sonderkommando,[14] contacted at our request two Sonderkommando survivors who worked in Crematoriums II and III. Mr. Shaul Chazan and Mr. Lemke Phlishko both stated that the devices were not attached to the support columns. We are not aware of any other testimony to that effect.

It has been hypothesized that the devices were attached to the sides of central pillars numbers 1, 3, 5, and 7 for reasons of structural support. This would yield a north-south distance of exactly 7.6 m between chimneys, and, if attached to alternating sides of the pillars, an east-west separation of approximately 1 m. The aerial photographs do not support this hypothesis; in particular, the staggered smudges on Crematorium III suggest an east-west spacing of about 2.5 m, and the smudge corresponding to Chimney 4 on Crematorium II is considerably south of where this predicts.

We contend that the introduction structures were supported by four iron bars on each corner and did not require the support of the concrete pillars. The presence of four such bars, as described by the witness Erber,[15] is further evidence that the introduction devices stood on their own and were not attached to the concrete pillars.

It has been further hypothesized that the difficulty of locating the four holes may have reflected their having been filled in before the destruction of the chamber. This does not seem likely for Crematoriums II and III. The original roof consisted of three layers: a thick stone aggregate concrete slab underneath; a thinner, finer, sand-aggregate concrete mixture above; and waterproofing bituminous tar paper in the middle. It is unlikely that the SS would have thought it necessary to duplicate this work, or that they could have done so in four places without leaving a trace. There are considerable areas of the original ceiling visible from under the slab but these show no signs of tampering. In Crematorium I the holes were filled when the structure was converted to a bomb shelter for the SS (date unknown).

The concrete roof is reinforced with crisscrossed steel rods known as rebar in the construction trade. But what is new is that this rebar lattice has provided corroboration of the location of the Zyklon holes: holes planned at the time the concrete was poured would not have had rebar extending through them. As examples, Figure 8a depicts a typical rebar pattern in the roof over the cellar in the crematorium where the victims were ordered to undress, and Figure 8b shows both uncut rebar and rebar that has been cut and bent at the edge of a hole.

One current opening in the roof, near the approximate middle on the west side, does not correspond to any known Zyklon hole (Figure 9). Nothing marks this location on any known contemporary photograph, and a piece of rebar clearly ran across the hole before being cut and bent out of the way. This establishes that it was not a Zyklon hole. It is not known who made this hole, and we have no reason to believe that it was made before the liberation of the camp by the Red Army in January 1945. Clearly it was not made in an attempt to "fake" a Zyklon hole, or else the rebar would not have been left sticking out. This hole can be ignored for our purposes.

Recent Findings

Our research between 1998 and 2000 turned up strong physical evidence of Holes 1, 2, and 4 in the gas chamber roof. This is corroborated by documentary, photographic, and testimonial evidence as described above.

We call attention to the following:

a) The physical evidence itself. This consists of clear signs of openings; straight cast edges in the concrete of the roof; rebar cut cleanly (i.e., not stretched by the explosion); the absence of rebar in the area within the holes; and the presence of rebar bent inwards at the edges of the holes.

The form of the rebar, most importantly, cannot be explained as a consequence of the explosion that destroyed the roof. Such an explosion would

have bent the rebar outward and upward, as well as thinning it through stretching. The ends of the rebar are hooked around perpendicular rebar to form a square aperture (Figure 16). This indicates creation of those holes when the concrete roof was originally poured in early 1943.

b) The east-west placement of the three holes found so far follows a clear pattern. Their edges are all 30 centimeters distant from the side of the central beam (making their centers 75 cm from the beam's center). The outer edge of each hole is 300 cm from the corresponding edge of the roof slab. These distances can be measured today to within approximately 1 cm. The probability of such a placement being coincidental is very remote.

We mention that certain Holocaust-deniers, upon seeing a preliminary draft of this paper, argued that dynamite explosions created the holes when the roof tore apart from the concrete support pillars. This is however impossible, for the following reasons:

- The concrete support pillars were not attached directly to the roof, but to the central support beam.
- While the concrete support pillars are in the center of the roof, the holes are not; as we have observed, a space of 30 cm separates their nearest edge and the central support beam.
- Not all the holes are found at the same longitudinal (i.e., north-south) locations as the support pillars.

c) The location of the holes is consistent with the August 25, 1944, aerial photographs.

d) The location of the holes matches precisely with the Train Photograph (recall Figures 5 and 6).

e) The alternating arrangement of the holes is consistent with the aforementioned testimony of Tauber and with maintaining structural integrity. Such spacing would also allow a more even dispersion of the cyanide gas.

In the following treatment, all distances are from the center of the objects identified (holes, pillars, central support beam) except where otherwise specified. North-south distances are from the southern end of the roof slab—not the south wall, since the roof shifted considerably when it collapsed after the explosions destroyed the gas chamber (Figures 10a and 10b). In general, the most reliable indicator of pre-explosion placement is the eastern edge of the roof, as it is broken almost entirely into large sections, is clearly visible along its length, and has an unmistakable southern corner. The relative distances of some features changed as the holes moved with the roof relative to the pillars.

Hole 1 is the opening in the roof near Pillar 1 (Figure 11a). The pillar remains standing and protrudes through the surface of the roof (Figure 10b), which shifted as it collapsed. While it might appear at first glance that the opening could just as easily have been created by the explosion, careful examination proves

this was not the case. Portions of straight, flat edges and a 90-degree angle survive intact, though most of the concrete around the edge was damaged by the explosion. The center of this hole is 4.1 m from the southern end of the roof slab, and 0.75 m west of the roof's center. We estimate its size at approximately 0.5 m square; this places its eastern edge at 0.3 m west of the west edge of the central support beam.

The roof's lower portion was a thick layer of concrete, over which was laid waterproofing tar paper, and which was finally topped with a thin upper layer of sand-concrete. For the middle layer, brushing tar over the tar paper was necessary to ensure waterproofing. Of the original concrete edge of the hole only a few centimeters of the intact lower layer remain in one corner, but a careful examination of that location reveals two clear drip marks where tar was brushed over the edge (Figure 11b, right). This demonstrates that the hole in the concrete was already there during the waterproofing step, while the roof was still being constructed.

Hole 2 is an opening (Figure 12) that lies in an area of the roof more thoroughly destroyed by the explosion. We suggest that this hole can be identified by several characteristics. These include clean-cut rebar, short but apparently manufactured straight edges of concrete that meet at a 90-degree angle, rebar bent inwards at the edges, and, most notably, the absence of rebar in its open area (Figures 13 and 14). The center is 11.5 m from the southern end of the roof slab and 0.75 m from the central beam. Its size is again estimated at 0.5×0.5 m. The eastern edge of the hole is 3 m from the eastern edge of the slab.

Hole 3's projected location is in an area of the roof that is badly damaged and covered with rubble (Figure 15). Preliminary research suggests that the hole itself may have been damaged when the roof collapsed on a portion of its own support structure. This hypothesis, however, requires further investigation. At the time this study was conducted, the researchers did not have permission to conduct the large-scale movement of rubble necessary to identify the third hole, but they are hopeful that permission may be forthcoming.

Hole 4 can be identified by a pattern in the rebar (Figure 16) at the very northern end of what remains of the roof. This was not its very northern end in 1943. To understand the location of this hole, one should observe that the northernmost 4 m of the roof were folded back and under 180 degrees by the explosion and subsequent collapse. That portion of the roof is now lying upside-down beneath the roof slab that originally lay to its south (Figures 17 and 18).

There is no question that part of the roof has folded underneath itself: that it is upside-down emerges from four observations. First, the rebar along the roof's north-south axis is still largely intact at the folds and can be observed running unbroken from the top portion of the roof, 180 degrees around, and through concrete into the bottom portion (i.e., between 3 and 6). Second, when the tar waterproofing was spread atop the concrete slab, it ran over the edge; the drips are visible to this day;

on the edge of this portion of the roof, the tar can still be seen, flowing, as it were, upward. Third, the upper part of "Section 6" (Figures 17 and 18) is the *inner* side of the roof, as seen in the imprint of the formwork. And fourth, the process of elimination: nothing resembling the missing northernmost roof slab (about 4 m in length) can be found anywhere else.

Hole 4 can be identified by the unimpeded square opening set in the rebar in 1943. The surrounding edges were shattered by the explosion and the folding of the roof, leaving only the telltale rebar latticework. Its measurements are 0.5×0.5 m. It is possible to measure this hole's distance from the east edge of the roof with great precision: a single unbroken strand of rebar can be traced from that edge, through several pieces of concrete, to the hole itself. That distance is 3 m, with an error margin of approximately 1 cm. Like Hole 2, the center of Hole 4 is located 0.75 m east of the roof's center. Its north-south location is subject to some error due to breaks in the roof slab to its south and an uncertainty concerning the whereabouts of the roof's northern edge (also, now, to the south of the hole). We estimate its location at 25.5 m from the southern edge of the roof slab, with an error margin of perhaps as much as 1 m.

Holocaust-deniers have argued for some time that all holes in the roof of the gas chamber were created after the war. Setting aside the obvious problems with such an argument, the rebar going around, but not through, Hole 4 effectively rebuts this claim. In particular, the reader will observe that at the eastern side of the hole the rebar was bent into loops so as not to pass through the hole—see area of the lower circle on Figure 16. Both ends of one loop remain firmly embedded in a large chunk of concrete to the east of the hole, contradicting any claim of tampering after the war. It is not merely the existence of Hole 4 that is significant, nor its placement precisely where corroborating evidence points. The deliberately looped rebar proves that this hole, as almost certainly the other three, was cast at the time the concrete was poured in January 1943. The homicidal intention of the crematoriums can be placed at no later than this date, a date literally set in stone.

Part II: Additional Findings

The gas chamber in Crematorium II in Birkenau was built following conventional construction methods of the time. Several unusual features, however, were encountered during our research visits. Those not explained previously will be discussed now. We do not touch upon the crematorium proper or on the undressing chamber in this study.

The gas chamber was a fairly simple structure. The floor was cast reinforced concrete with appropriate drainage outlets. The seven support columns are also of reinforced concrete mounted on column footings under the floor slab. The walls are hard-fired conventional brick held together with mortar. The columns are attached to a reinforced concrete beam that spans the entire length of the gas chamber. The roof is cast reinforced concrete with a single layer of damp-proofing and a 2 cm fine

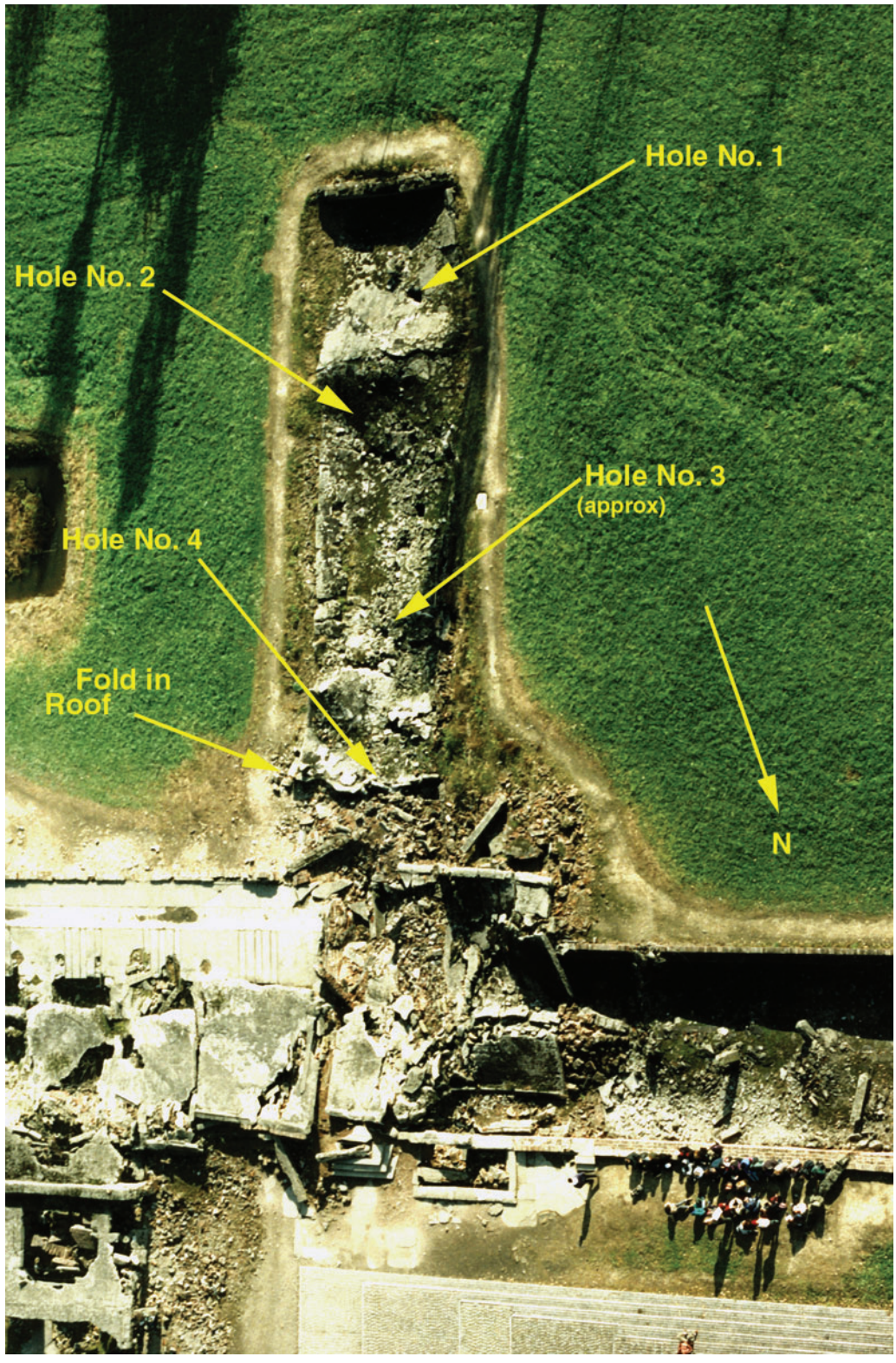

Figure 1a. Aerial photograph of the gas chamber in Crematorium II (courtesy of Wojciech Gorgolewski).

Figure 1b. Ruins of gas chamber in Crematorium II today.

Figure 1c. Ruins of Crematorium III today.

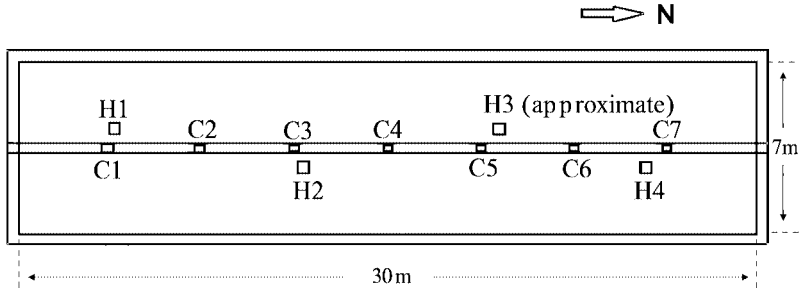

Figure 2a. Scheme of Crematorium II gas chamber from above. C1–C7 mark support pillars, H1–H4 Zyklon holes. Because roof shifted when dynamited, relative distances (e.g., between C1 and H1) differ today (see Figure 10 and relevant discussion).

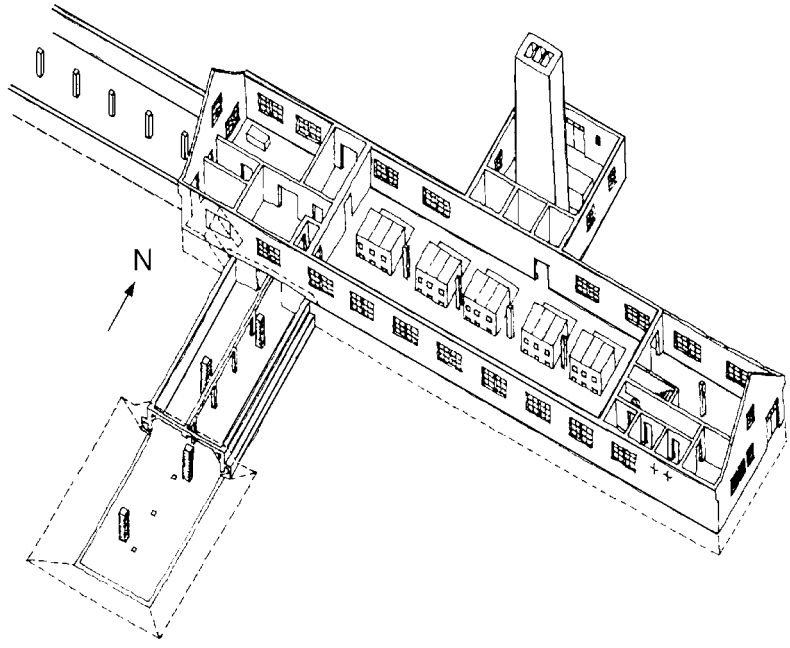

Figure 2b. Schematic drawing of entire crematorium; dotted lines around gas chamber show embankment. Thanks to Marc Downing. 2b appeared earlier in Robert Jan van Pelt, *The Case for Auschwitz* (Bloomington: Indiana University Press, 2002), p. 190.

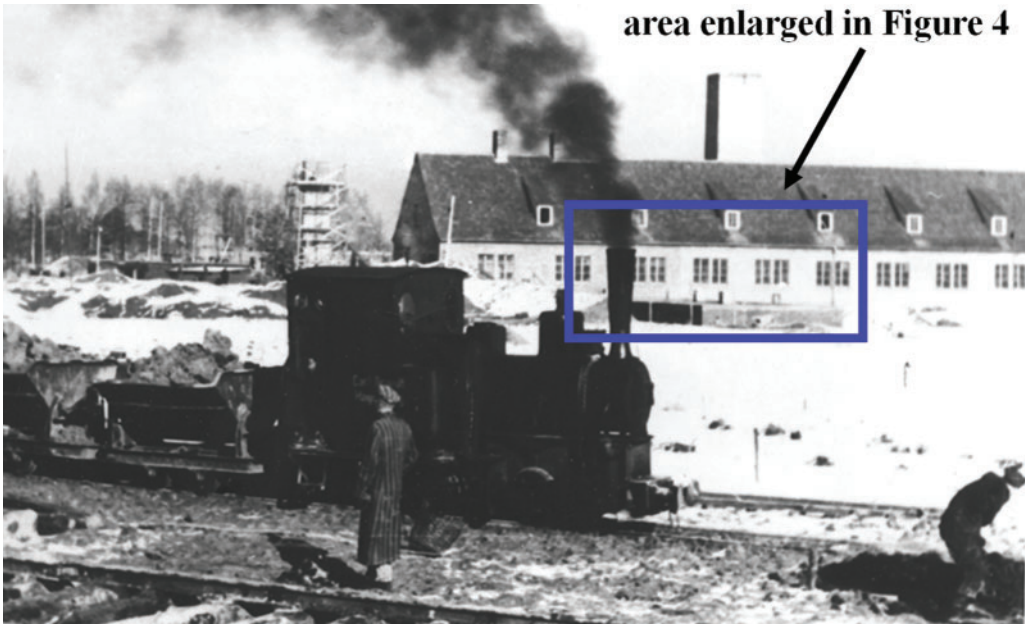

Figure 3. Photograph by team under SS-Unterscharführer Dietrich Kamann during construction of Crematorium II. Gas chamber visible in front, and three Zyklon "chimneys" can be identified. Hereafter the "Train Photograph." Courtesy of Auschwitz State Museum, PMO neg. no. 20995/494, Kamann Series; and Yad Vashem Archive.

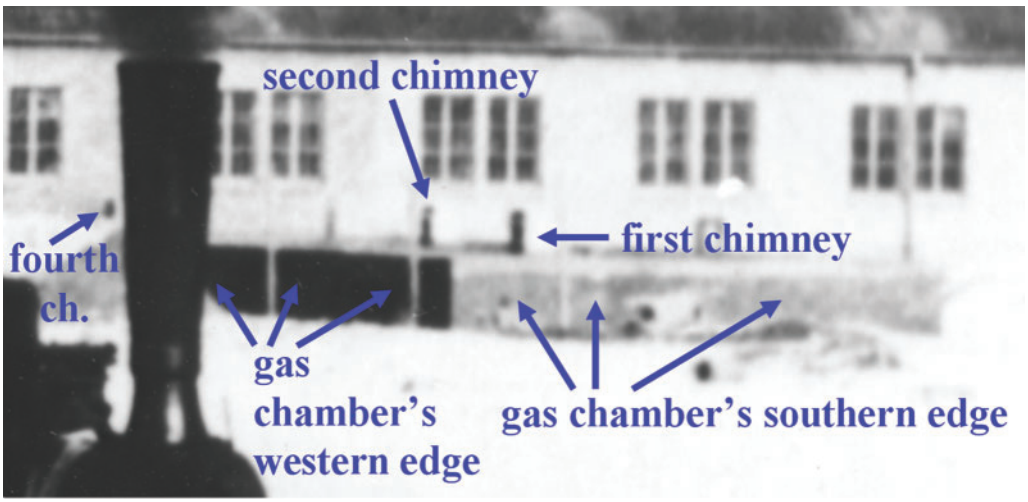

Figure 4. Detail of Figure 3. Third Zyklon "chimney" occluded by locomotive's smokestack. Photograph somewhat skewed (roof's edge slopes). After correction for skew, the three chimneys appear identical in height. Note also gas chamber semi-subterranean. Part of western edge obscured by camouflage earth embankment with triangular cross section (left of photograph), further discussed in Part III.

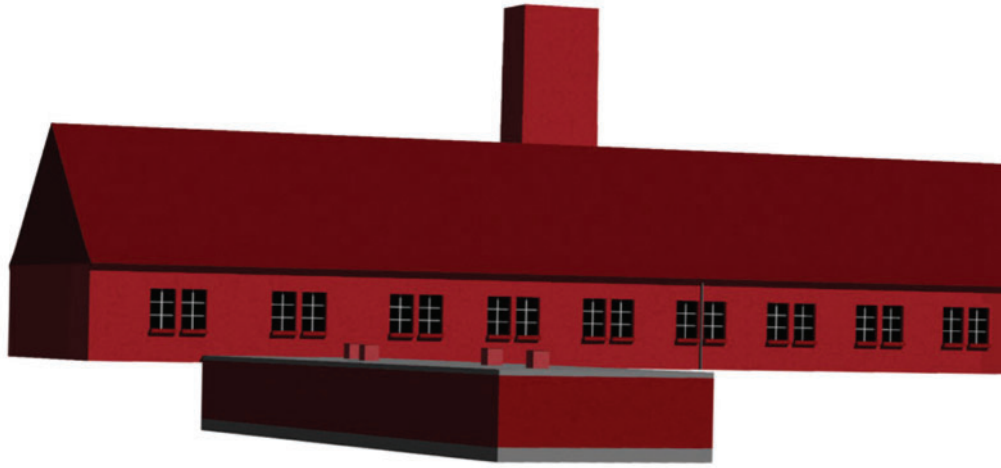

Figure 5. Computer rendering of Crematorium II from point of view of Train Photograph (Figures 3 and 4). Note zigzagged arrangement of Zyklon holes, e.g., apparent proximity of Holes 3 and 4. See also Figure 6 and Part V.

Figure 6. Overlay of Train Photograph and wireframe of our computer rendering, including chamber's inside, concrete support pillars, and Zyklon introduction shafts.

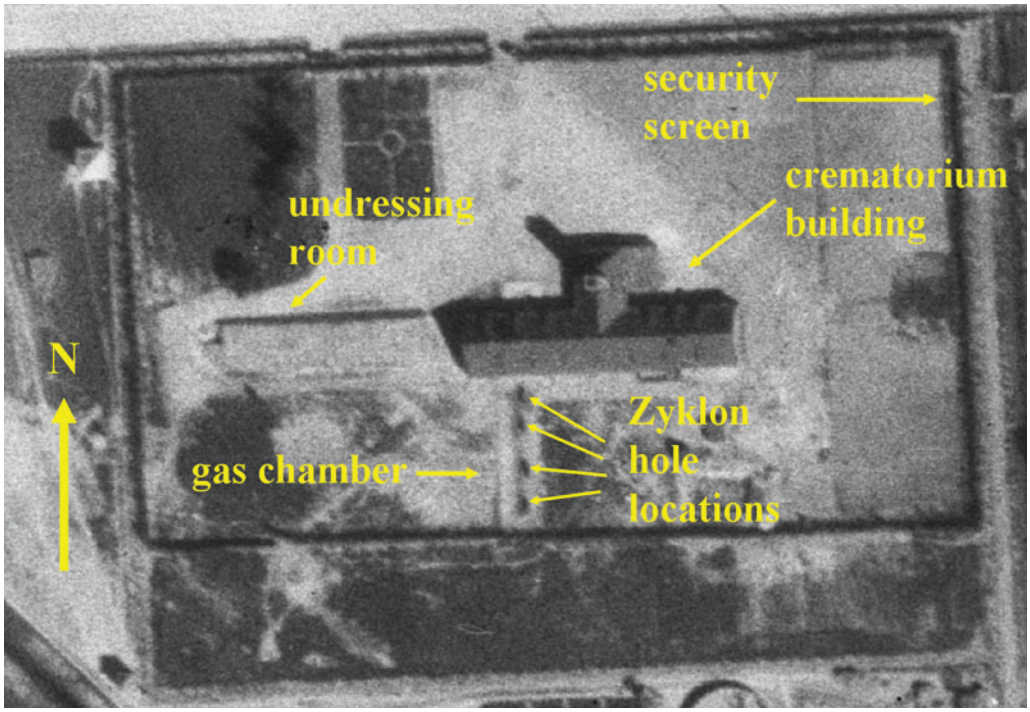

Figure 7. Detail of photograph of Crematorium II taken from American reconnaissance plane, August 25, 1944 ("August 25 Photo"). Heaped earth obscures east edge of gas chamber, making holes appear farther east. Holes alternate west-east-west-east (from south). National Archives and Records Administration (NARA), RG-373, Records of the Defense Intelligence Agency (DIA), Mission: 60PR/694 60 SQ; can. F5367, exposure 3186. Scale: 1/10,000; focal length: 12 inches; altitude: 30,000 feet.

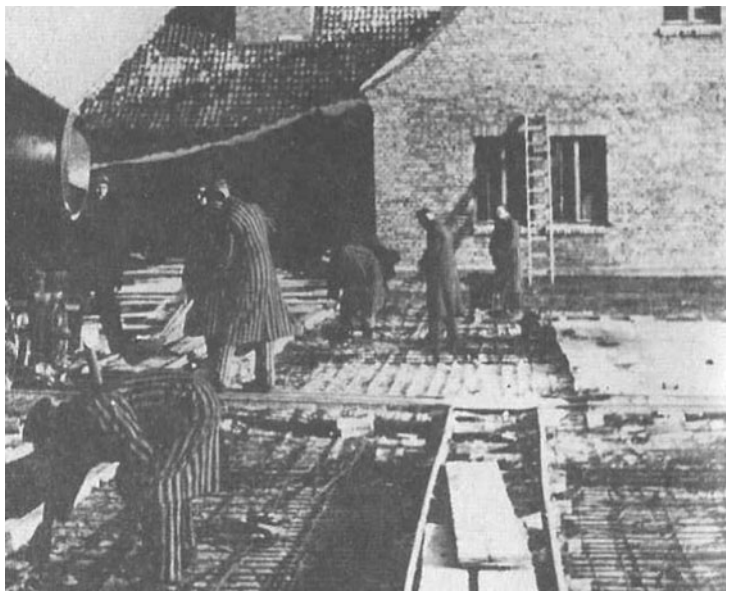

Figure 8a. Workers laying roof of "undressing room" of Crematorium II. Note crisscrossed steel bars, or rebar. Detail. Courtesy of Auschwitz State Museum, Ludwick Series, PMO neg. no. 298; and Kamann Series, 20995/498; and Yad Vashem Archive (Kamann Series).

Figure 8b. Area of Zyklon Hole 1, Crematorium II. Tarpaper separating concrete layer below and sand-cement layer above is visible. South to north view.

Figure 9. Hole cut for unknown purpose in Crematorium II roof, likely after liberation in January 1945.

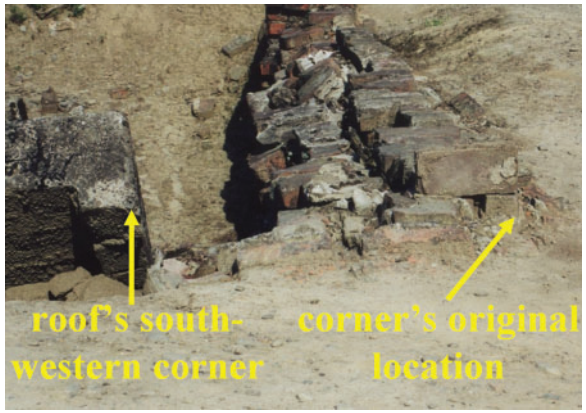

Figure 10a. West-east view of southern edge of Crematorium II gas chamber. Note how roof detached, shifted north, and tipped into hole (for comparison, brick length 23 cm). The shift left the first Zyklon hole farther north relative to first (southernmost) support pillar.

Figure 10b. Northeast-southwest view. Broken top of first support pillar pierces fallen roof.

Figure 11a. First (southernmost) Zyklon hole, overview. Taken from east looking west. Observe square form, with no rebar present; although damaged in explosion, hole clearly visible.

Figure 11b. First (southernmost) Zyklon hole, detail. Taken from below, showing residue of dripping tar. Surviving crawl space approx. three feet here.

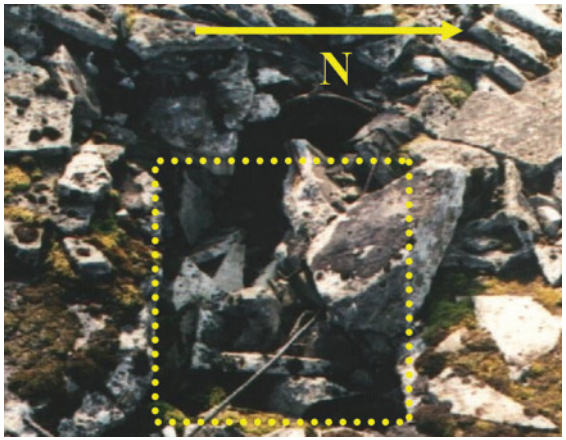

Figure 12. Second (from south) Zyklon hole, east to west view. Chunk of concrete torn away by explosion lies atop northern edge; western edge completely shattered. Outline of hole superimposed.

Figure 13. Straight edge and inward-bent rebar on southern side of second Zyklon hole. Such bending could not result from the explosion, which lifted the roof upwards.

Figure 14. Inwardly bent rebar at north and east edges of second Zyklon hole, partially destroyed in explosion.

Figure 15. West-east view of hypothesized location of third Zyklon hole.

Figure 16. Remains of fourth (seen from south) Zyklon hole. Rebar skirts two sides, ends at other two sides bent inward and looped back. Note rotated roof slab showing formwork on inner side.

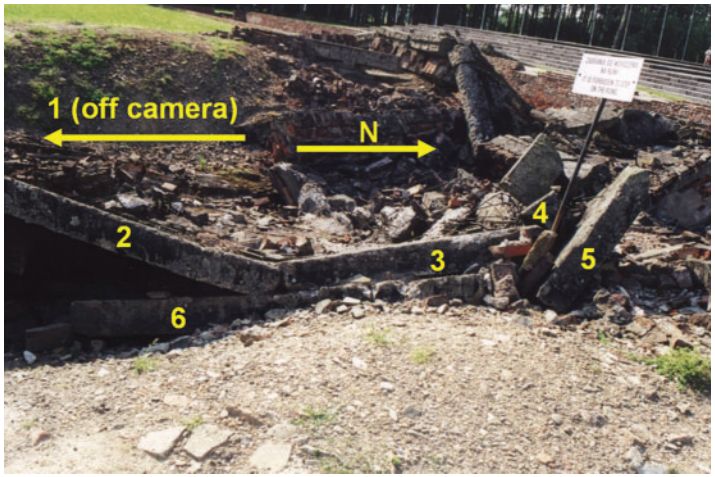

Figure 17. Close-up of fold area from eastern side. (Leaning sign on right is contemporary sign.)

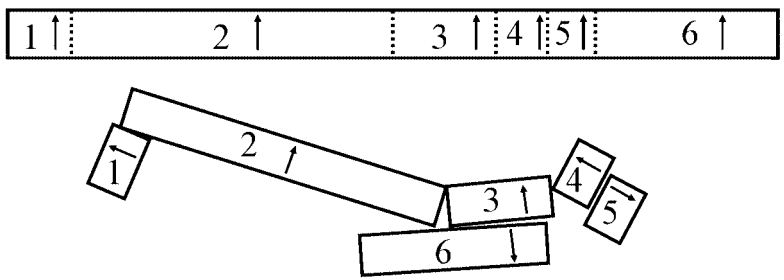

Figure 18a. How northern part of roof folded during explosion. Portion labeled 1 not in photograph. Fourth Zyklon hole 3 m west on portion 4. For exact scales see Figures 16 and 17. Eastern part of portion 4 shattered. Portions 5 and 6 were flipped over by the explosion (compare Figures 16, 17, and text).

Figure 18b. Rebar stretched to a point at Zyklon hole 1, Crematorium II.

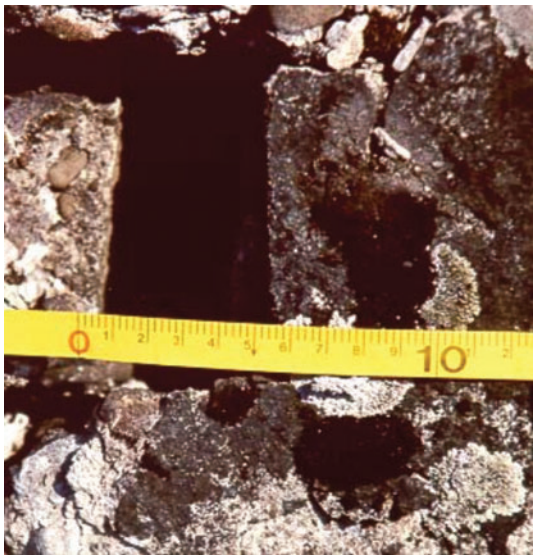

Figure 19. Cast aperture roof slab (centimeters).

Figures 20a, b, and c. Three of the indentations in the gas chamber ceiling; in 20b (center), rusted rebar just touches inner edge; in 20c (bottom), wood block survives.

Figure 21. Bakelite supports on central support beam of Crematorium II.

Figure 22. Rear of probable false showerhead found beside ruins of gas chamber of Crematorium II.

Figure 23. Front of probable false showerhead.

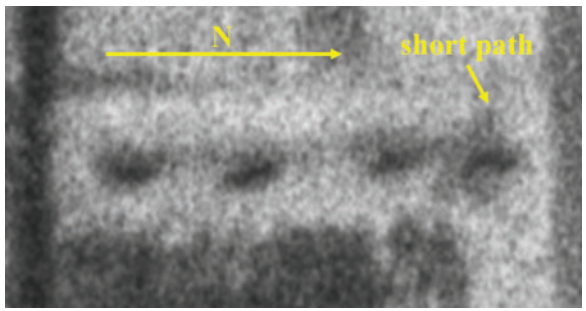

Figure 24. Enlarged detail of August 25 photo showing gas chamber rotated ninety degrees compared to Figure 7 so that edge of crematorium building is to right, security screen (likely a wattle fence) to left. Note darkened path along Zyklon hole locations, and short path extending west from the northernmost hole. Paths correspond to movement of SS personnel (see below).

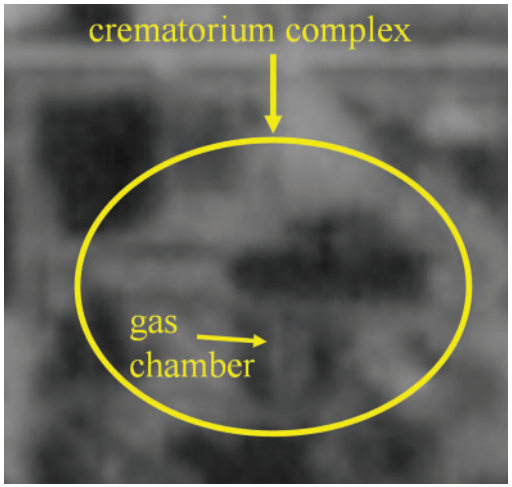

Figure 25. Detail of Luftwaffe photograph, Crematorium II area. The photo is of low quality but dark path along middle of the roof (compare Figures 7 and 24) slightly visible. NARA, RG-373, Auschwitz Box, envelope 17, security set GX DT/TM-3/Germany-East Auschwitz/neg. no. 38 N50 K19.

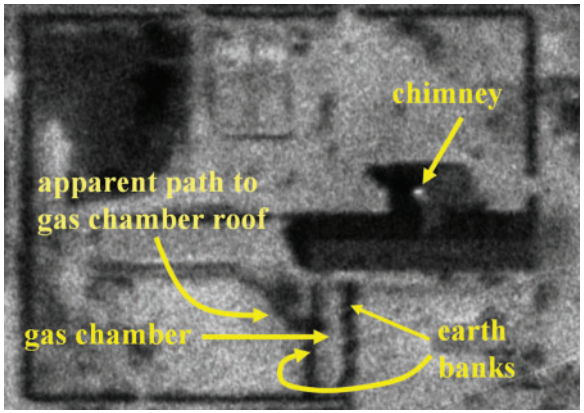

Figure 26. Detail of American aerial photograph taken on May 31, 1944, of Crematorium II area. Sunlight coming from east. Note camouflage earth banks against eastern and western edges of gas chamber, consistent with that appearing in left of Figure 4. Note also apparent path leading to gas chamber roof. In this photograph (as in Figure 4) roof is bare; dark line running along center in Figures 7, 24, and 25 consequently not visible: lines were likely the result of earth which was added later being compacted by personnel moving on roof (items 2 and 3 in Lucas' analysis). It is impossible to observe the holes' covers themselves (60×60 cm, the entire gas chamber being 30 m long). Resolution of this photograph lower than August 25 photograph. The camera actually looks down into chimney; the bright area, which does not appear in the August 25 photograph, may indicate cremation taking place. NARA, RG-373, DIA, Mission: 60 PRS/462 60 SQ; can: D1508, exposure 3056. Scale: 1/16,167; focal length: 20 inches; altitude: 27,000 feet.

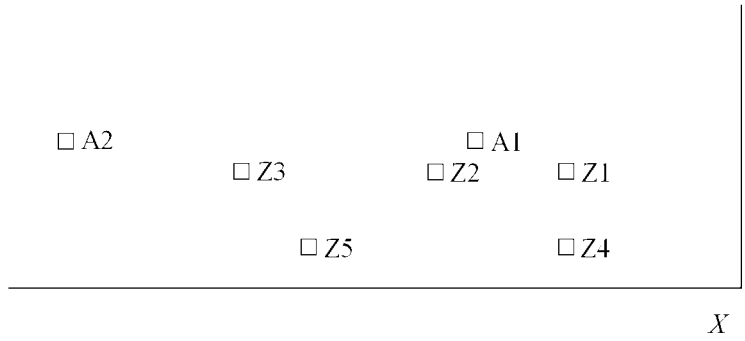

Figure 27. Schematic diagram of Zyklon holes and air vents of Crematorium I gas chamber. "X" marks approximate location of the photographer who took the image in Figure 28 (see further discussion below). Distance between left edge of Z4 and right edge of Z5 is 8.5 m.

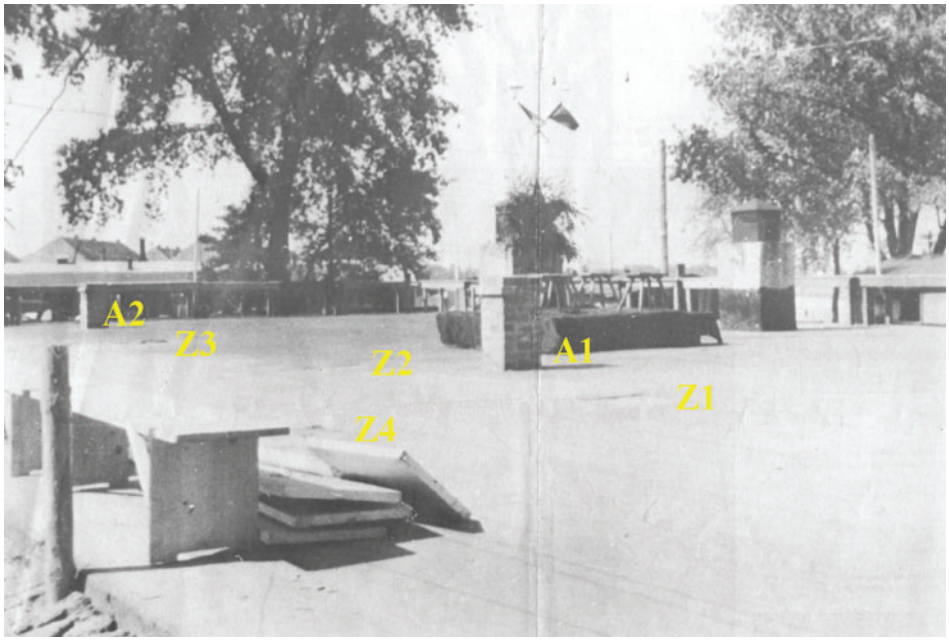

Figure 28a. Photograph of the Crematorium I roof ("pre-restoration photograph") taken before chamber restored (Auschwitz State Museum, Stanislaw Luczko Series, sygn. 5149). Z5 lies outside the picture (see Figures 30a and 33). Z1–Z4 easily identifiable by sealing marks.

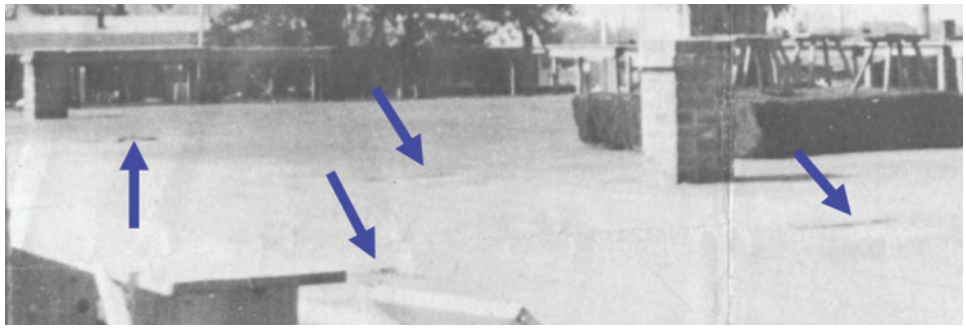

Figure 28b. Close-up of the Crematorium I roof with enhanced contrast and arrows marking the most discernable areas of the sealed holes.

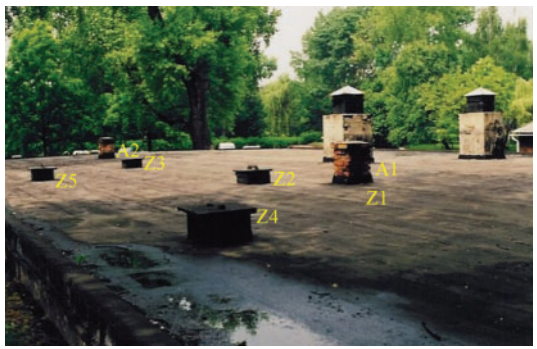

Figure 29. The roof today, with the same notations as Figures 27 and 28. Z1 was not reopened, but its location can be determined from Figure 28 and from measurement inside the chamber (see Figure 31 and relevant discussion).

Figure 30a. Detail of current photo. Z5 lies outside the image (only the very corner of the wooden cover and its shadow are visible).

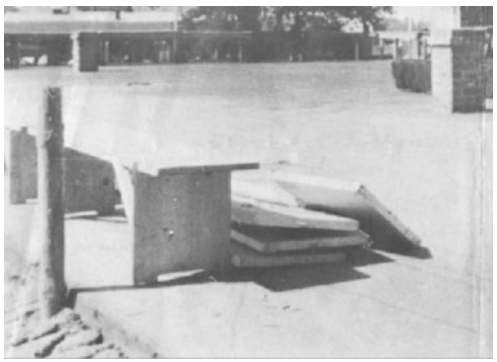

Figure 30b. Detail of pre-restoration photo, scaled and aligned. Images do not correspond exactly because they were not taken from exactly the same point (see Figure 33 and relevant discussion). The roof appears higher today (30a) due to added waterproof coating.

Figure 31. Sealed Zyklon hole Z1, which was not reopened during post-war restoration. Photograph taken inside chamber. It is not possible today to see the sealing signs on the roof, which was covered with heavy tarpaper.

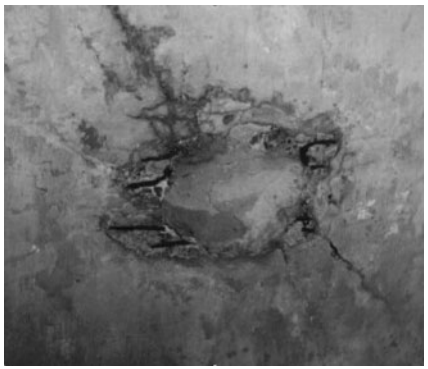

Figure 32a. Sealed ventilation openings in Crematorium I ceiling. These openings housed circular vents used to replace the air in the gas chambers.

Figure 32b. Sealed ventilation openings in Crematorium I ceiling. It is not known why some rebar crosses opening.

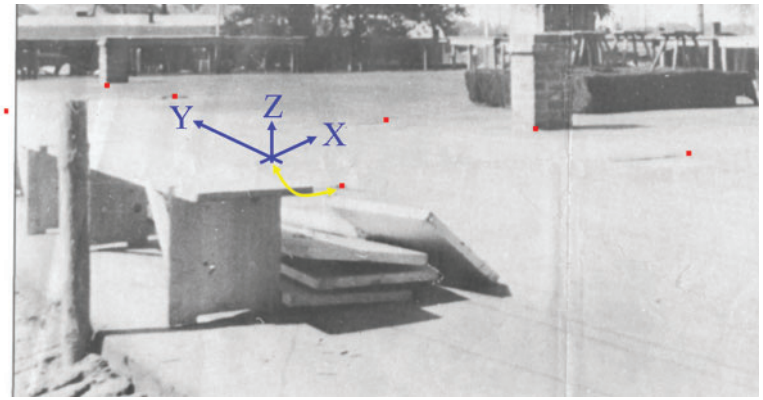

Figure 33. Rendering of measured points (hole corners) against pre-restoration photo, matched via mathematical camera model. Computation based on coordinate system sketched in blue and positioned at Z4 corner. Rendered points, marked by red squares, correspond to locations of air vents and Zyklon holes taken in roof's current condition. Match between photo and rendering proves Zyklon holes were indeed reopened at original locations. Z5 located outside photograph, consistent with its rendering (red square to left of photo).

sand-concrete topping. The total thickness of the slab is 20 cm. The design is not remarkable except that the surface of the floor is approximately 1.6 m underground and the top of the roof is 0.8 m above ground (due to the uneven placement of the fill dirt, the exact height of "ground level" varies).

The drawings and the remains of the gas chamber in Crematorium II reveal several other unusual features (some never before discussed):

a) There are neither windows nor any form of natural illumination or ventilation in the chamber.

b) There are no stairs or ramps leading down into the chamber.

c) Access to the chamber was possible only through a door on the eastern portion of the north wall that connected to the actual crematorium.

(Points a, b, and c have been amply discussed elsewhere.)

d) The brick walls on the east and west sides have large, hollow channels that run for their entire length.

e) A number of small wire loops 60 cm apart are attached to the ceiling along the full length of the chamber, on both sides of the support beam, and 100 cm from the brick walls.

Points d and e have also been described elsewhere. According to Pressac's analysis of the original construction drawings, the ventilation ducts inside the brick wall were employed to replace the air in the gas chamber, whereas triangular ducts formed of plywood fixed to the ceiling and to both the north and south walls were designed to introduce air into the chamber. The chamber's ventilation system has been extensively discussed.[16]

f) The remnants of three large, square holes (1, 2, and 4) can be seen on the surface of the roof. The approximate location of Hole 3 has been described in Part I of this study.

g) Steel reinforcing bars (rebar) in the roof were cut during the construction phase (some are also cut and bent in an L-shape) at the points where they intersect the introduction holes. Rebar of 12–15 mm diameter was laid in the roof in rows approximately 15 cm apart in both south-north and east-west directions, forming a nearly square grid on to which concrete was poured. The grid was anchored to the central beam and to a peripheral rebar structure with traditional U-bends. Explosive forces caused breaks in the grid when SS sappers demolished the chamber. Many of the broken bars were drawn and stretched out to a sharp point by the explosive forces, whereas other bars appear purposely cut to form a square pattern precisely 50×50 cm where the Zyklon B introduction holes are still found.

h) A small rectangular 4×10 cm aperture was cast at the same time, penetrating the roof into the chamber below (Figure 19). The aperture is 3 m north of column 5, and 2.65 m from the eastern edge of the roof slab. The function of this hole remains unknown. It was possibly fitted with a removable gasket

that allowed the insertion of a detector to test the concentration of gas: it is known that the crematoriums were equipped for this purpose.[17]

i) A number of small (approximately 10×15×4 cm), rectangular cast indentations can be seen in the ceiling of the gas chamber. At least six of these are visible in those portions of the ceiling presently accessible from below. Some of the indentations have wooden blocks with visible rusted nails or screws. The indentations are uniformly placed and lined up on both sides of the support columns 2 m from the edge of the support beam, and extend from approximately 3 m north of the southern wall as far north as can be seen in the ruins. It is to the wooden blocks that fake showerheads reportedly were affixed (Figure 20).

   One important detail must be emphasized: the indentations containing the wooden blocks were *purposely* built into the ceiling of the gas chamber from the very moment the roof was built. It might be argued that these blocks were used as slab bolsters to support the reinforcing bar before concrete was poured onto the roof. Various arguments dispel this notion:

   - Supports for reinforcing bars are typically small pieces of broken concrete or stone that would be incorporated into the concrete mixture and would be invisible from below;
   - Concrete is a porous material with a highly alkaline solution in the pores; this solution keeps the rebar from rusting and weakening the structure: no engineer would deliberately use wood slab bolsters because that would allow water to reach the rebar;
   - Except for one upper corner in one of the indentations there is no rebar in the hollows formed by the wooden blocks.
   - The wooden blocks were carefully lined up in the same orientation and at exactly the same distance from each other and from the central beam.
   - The surviving wooden blocks all show signs of a screw or similar object inserted in their center as if to support something within the gas chamber.

j) A large number of small wooden support blocks are attached to both sides of the central reinforced concrete beam. Several of these blocks still have attached to them small Bakelite plastic supports of the sort used to carry electric cable. The support blocks are visible all the way to the southern end of the support beam, some 2–3 m beyond the first showerhead block. Electric wires were most probably carried on these supports to provide current for illumination. Analogous supports in other parts of the concentration camp (e.g., Crematorium I) bear electrical cables (Figure 21).

k) We found a small disk 8 cm in diameter imbedded in the path less than one meter to the east of the gas chamber. The disk shows many small perforations (more readily seen on the reverse side) in a manner consistent with the front plate of a showerhead. The holes are of such a minuscule size—many

do not seem to perforate the plate at all—that it is unlikely that much, if any, water could have flowed through them (Figures 22 and 23). The sheet metal shows signs of having been galvanized, which would have inhibited rusting and made a "showerhead" more convincing. There is no evidence of any plumbing facilities in the gas chamber of Crematorium II. Given the convergence of evidence from eyewitnesses and documentation held in the archives of the Auschwitz Birkenau State Museum,[18] this fixture undoubtedly formed part of the elaborate plan to keep the victims ignorant of their fate as long as possible.

Part III: Aerial Photographs

We now turn to some of the photographs taken from Allied and German airplanes, showing their relation to the physical layout of the crematorium, and especially to the Zyklon introduction holes.

It is impossible to observe the Zyklon holes themselves in any of the aerial photographs. To realize why, observe the gas chamber roof in Figure 24, which is the best suitable aerial photograph of Birkenau available. The gas chamber length is 30 m, while the holes' covers are about 60×60 cm. The low resolution and very strong granularity of the photograph don't allow direct observation of objects this size. However, certain phenomena associated with the holes can be identified. Also, given two overlapping photographs, both including the roof, the principle of stereo imaging may allow one to see more than is visible in a single image. We shall elaborate on this later. The best quality photo, and the one that has attracted most attention, was taken by an American plane on August 25, 1944; part of the photo is presented in Figures 7 and 24.[19] A photograph of lesser quality, but still of interest, was taken from a German airplane on July 8, 1944 (Figure 25). The four dark, irregular smudges on the roof of the gas chamber in Figure 24 correspond to the location of the holes both in the Train Photograph (Figure 3) and to the physical findings (see the main part of this paper). However, it is clear that they are too large, and not in the correct shape, to represent the actual holes. In order to interpret the photo, we obtained the advice of Mr. Carroll Lucas, a leading expert with more than fifty years in aerial and satellite photo analysis.[20]

Mr. Lucas analyzed the two August 25 photos showing the roof of Crematorium II. The appearance of an object in two overlapping photographs allows reconstruction of a three-dimensional picture by stereo imaging.[21] Mr. Lucas employed magnifiers, a Richards light table with an attached Bausch & Lomb Zoom 70 microscope with a stereo attachment, a Carl Zeiss N-2 mirror stereoscope, and an Abrams 2–4 stereoscope Model CB-1, to analyze the photo appearing in Figure 24 and the previous frame taken during the same flight. After careful study Mr. Lucas identified four small objects within the smudges, all slightly elevated above the level of the roof. Stereo imaging allows observation of even small objects in grainy images, very difficult or

impossible to detect in separate images, as is well demonstrated by "random dot stereograms."[22] In all probability, these correspond to the four "chimneys" above the holes in the roof, as clearly visible in the Train Photograph (Figure 4). Thus, the aerial photographs add further support to the witness testimonies and to the Train Photograph. With regard to the dark smudges and related findings Mr. Lucas summarized his conclusions as follows:

a) "The roof of the partially underground wing of the Crematorium contains four raised vents, possibly with covers larger than their exits."
b) "The four dark areas observed on the Crematorium II roof (on positive prints) are compacted soil, produced by the constant movement of personnel deployed on the roof, as they worked around the vents." This point will be discussed below.
c) "The thin dark lineation (on positive prints) interconnecting the dark areas is a path of compacted earth produced by personnel moving from vent to vent." (See Figure 24.)
d) "The dark area connecting this path to the edge of the roof from the vent nearest to the Crematorium roof is an extension of the path which shows where personnel gained access to the roof—possibly using a short ladder leaned against the roof." (See Figure 24.)
e) "The evidence provided by this analysis lends credence to the fact that the vents existed and were used in a way consistent with statements from multiple witnesses."

Some earlier aerial photographs—for example, one dated May 31, 1944—show neither the smudges nor the dark line along the center of the chamber. One possible explanation is that the camouflage in the Crematorium area in general, and the gas chamber in particular, changed over time. In the Train Photograph for example, one can clearly observe an as yet incomplete earth bank with a triangular cross-section located on the chamber's western edge, while there is no earth cover on the roof. Such earth banks are visible in the May 31, 1944, photograph as well (Figure 26), but they do not appear in the July 8 and August 25, 1944, photos.

It is therefore reasonable to assume that between May 31 and July 8, the earth banks were flattened and the roof covered with earth. This newly placed earth was compacted by the SS-men climbing onto the roof and walking between the holes, thus resulting in the dark path running through the chamber's center (item c in Lucas' analysis), and the short dark line extending west from the northernmost hole corresponds to the point at which the SS-men climbed on the roof (item d in Lucas' analysis). The path ends at the southernmost hole, indicating that the SS-men indeed climbed the roof at its northern end, and traversed it north-south-north. The SS-men spent more time moving in the vicinity of the holes, thus resulting in an area of compacted earth wider than the path that they treaded between the holes.

Further factors that may have contributed to the formation of the "smudges" in the photo:

a) Water may have been poured on the extracted Zyklon pellets in order to dissolve the Zyklon and reduce the danger of accidental inhalation. Hosing down the pellets would also cause the wet areas of the earth cover to appear darker and could also have caused a different growth pattern of grass on the roof, resulting in a darker color; this is supported by the fact that areas with greenery appear darker in the photo (Figure 7).

b) It is possible that the inner cores of the wire mesh columns into which the Zyklon was inserted were not inside the chamber when the aerial photograph was taken, but were temporarily removed and propped against the small chimneys that housed the Zyklon insertion devices. One possible reason for removing the inner core is that since the gas chambers were hosed down after each gassing,[23] it would have made sense to remove these inner cores while the hosing was taking place, in order to keep them dry. These inner cores, leaning on the small chimneys, could result in shadow patterns with an appearance such as that in the center of the smudges.

Part IV: The Zyklon Introduction Holes in Crematorium I

Before the gassing operations were moved to the Birkenau "bunkers" and the four large crematoriums, murder with poison gas took place at the main camp in the so-called "Old Crematorium" or "Small Crematorium" (after its use as gas chamber and crematorium stopped, the designation "Crematorium I" sometimes referred to the Birkenau crematorium now usually named "Crematorium II"; here, "Crematorium I" will refer to the "Old Crematorium"). The Zyklon B pellets were dropped into the chamber through holes opened in the ceiling. Camp survivors (such as Filip Müller) and former members of the SS (i.e., commandant Rudolf Höss, Pery Broad, and Hans Stark,[24] who described how he poured in the Zyklon with his own hands) testified about these gassings. As at the other gassing installations in the camp, cyanide compounds can still be detected in the chamber's walls, as forensic examinations by the Cracow Institute for Forensic Research demonstrate.[25]

The original purpose of the gas chamber when built by the Polish Army prior to the Nazi occupation was to serve as an ammunition depot. Therefore, its walls are protected by a heavy earth embankment (to channel the force of any blast upwards).

In late 1944, the gas chamber, which was no longer being used for killing, was converted into an air-raid shelter for the SS.[26] The conversion consisted mainly of sealing the Zyklon insertion holes, and adding dividing walls in the chamber to confine the effect of an exploding bomb. In addition, two small air vents were added (these are not to be confused with the larger air vents of the adjacent cremation room). After the war, the chamber was restored to appear as it did when it was used

for homicidal gassing; the dividing walls were removed, and four of the Zyklon insertion holes were reopened.

The purpose of this section is to correct some common misconceptions about the Crematorium I gas chamber, specifically, about the location of the Zyklon holes. Deniers often claim that these holes are "post-war fabrications." A key, but rarely cited, testimony is the account provided by the Pole Adam Zlobnicki: "I remember well that the introduction holes for Zyklon B, which are situated on the roof of the crematory, were also reconstructed in 1946/47. Those who reconstructed them had an easy task because the erstwhile introduction holes had left distinct traces. . . . Thus, they constructed in the same places again the openings for the little chimneys."[27] The "little chimneys" to which the witness refers are the low wooden structures built around the holes through which the Zyklon was poured; they were also reconstructed on the basis of postwar testimony (Figure 29).

Figure 27 is a schematic drawing of the gas chamber's roof, with Z1–Z5 marking the location of five Zyklon holes, and A1–A2 marking the location of the two aforementioned air vents. As we shall demonstrate, Z2–Z5 were reopened in the restoration process described by the witness Zlobnicki, while Z1 remained sealed. The roof has been covered since 1945 with heavy tar paper but the location of Z1 can be identified inside the chamber by the sealing marks, as shown in Figure 31. Before the Zyklon holes were re-opened, an important photograph of the crematorium roof was taken (Figures 28a and b). This image shows the location of four of the sealed Zyklon holes, and allows a comparison of them with the location of the restored holes.

The reader can see how the roof appears today in Figure 29. Figures 30a and b depict details from the current photograph (a) and the pre-restoration photograph (b) side by side.

It is easy to reconstruct the exact location of the Zyklon hole Z1 in the chamber's interior: it lies at the intersection of the straight line connecting Z2 and Z3, and the straight line perpendicular to the roof's longitudinal edge and passing through Z4 (see Figures 27 and 28). Exactly at this location there are clear signs of a square hole that was sealed (Figure 31). At two other locations holes were sealed, but these were circular ventilation openings (Figures 32a and b).[28]

Finally, in order to test Zlobnicki's testimony we have tried to locate a position from which the photograph of the roof (Figures 28a and b) aligns well with the measurements of the restored holes as well as the air vents A1 and A2 and the original Z1. This was achieved by simulating the mathematical model of a camera and using an optimization program that sought the best match of certain landmarks in the photo with their corresponding locations in the mathematical models.[29] The landmarks, depicted in Figure 33, are the most discernable corners of Z1–Z4 and A1 and A2. We have measured the corresponding locations of these landmarks on the roof in its present condition, using a measuring tape. The optimization program recovered an excellent match; the locations of the model's landmarks are marked by the small red

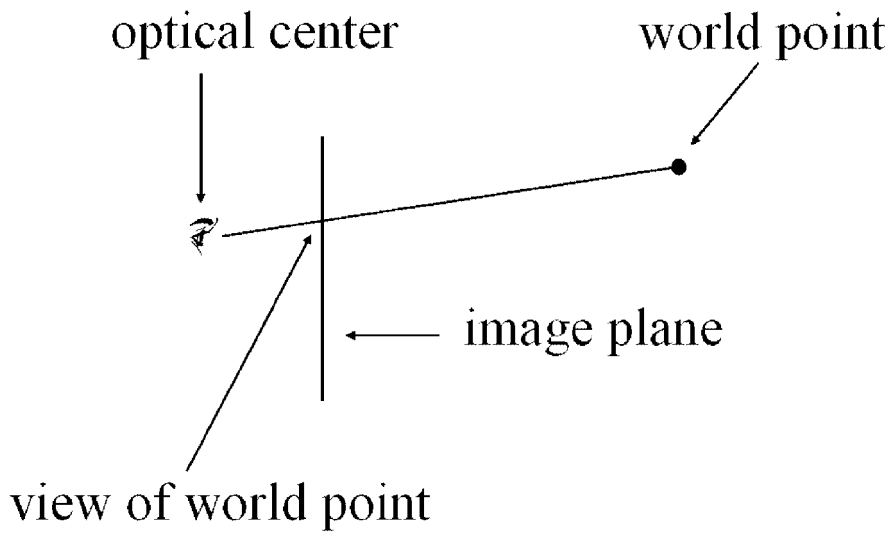

Figure 34. Projection of a world point onto its image in the camera/eye. In reality the image plane is located behind the optical center; however it is customary to draw it in front of the image plane to avoid reversing the order of real world objects.

squares, and they correspond very well with the photograph. The location of Z5 corresponds to the red square outside the photo (to the left) and indeed it is not visible in the photo (see also Figure 33). The photographer's location was determined to be at the following location, compared to the corner landmark of Z4, with a Cartesian coordinate system aligned with the roof, with its *x*-axis along the roof's horizontal (width) axis, *y*-axis along the longitudinal side of the roof, and the *z*-axis pointing upwards. Relative to this coordinate system, the recovered location of the photographer was at (–2.675, –5.575, 0.75 m), and the roof angles with respect to the camera's plane were 0.725 at the *x*-*y* direction, and 0.175 at the *y*-*z* direction (angles in radians). This means that the photographer was standing to the left and slightly to the front of the roof corner (see Figure 27), on the sloping earth embankment, which accounts for the low value of the *z* coordinate (possibly the photographer was also kneeling, or the camera was mounted on a tripod).

This rendering shows an excellent fit between the original and existing holes in the roof, proving that Zlobnicki's testimony is indeed accurate; the Zyklon holes existed in the roof, were sealed when the chamber was converted to an air-raid shelter, and (save for Z1) were reopened during the restoration process.

Part V: Perspective Projection and the Train Photograph

Readers may be confused by the appearance of the "chimneys" over the holes in the rendering depicted in Figures 5 and 6. Those familiar with perspective projections may expect that, since Holes 1–4 are in increasing distance from the camera, the

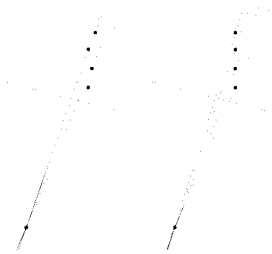

Figure 35. Rendering of the holes in their zigzagged arrangements (left) and as they would have appeared if they had been on a straight line (right). Distances in rendering on left correspond to those between holes in Figures 5 and 6.

apparent distances between them will be decreasing. Instead, Holes 1 and 2 are relatively close, but 3 appears far more distant from 2 than 2 is from 1, while Hole 4 is very close to 3.

The explanation for this lies in the zigzagged arrangement of the holes. To clarify, we present a short explanation of perspective projections. The act of capturing an image can be modeled by the diagram in Figure 34.[30] A point in the real world (the "world point") is projected onto a point in the "image plane." This latter point will be the intersection of the image plane with the straight line connecting the world point with the "optical center," or a human's eye. The rendering of the holes' locations in the Train Photograph according to the above model and the data presented in this paper appears in Figure 35.

Epilogue

During his British High Court of Justice action against Penguin Books and Deborah Lipstadt, David Irving made the issue of the Zyklon introduction holes central to his cross-examination of Professor Robert Jan van Pelt, an expert witness for the defense. Irving failed to create doubt: Mr. Justice Gray determined in his judgment that there was sufficient evidence that the holes had existed and that the gas chambers of Crematoriums 2 and 3 had served as homicidal facilities.

However, when Irving attempted to appeal the verdict by challenging once again the evidence concerning the gas chambers and by promising new evidence to support his case, Professor van Pelt contacted the authors of the present article, who by then had completed independent investigations of the ruins of the crematoriums. Van Pelt suggested that our work (this article's earliest draft) might be appended to his own expert report should the appeal go ahead. He also appended a report written by Paul Zucchi of Yolles Engineering in Toronto.[31] In that report Zucchi reviewed our work on the holes, concluding that "the authors present a strong and sustainable case that the openings [were installed] during the course of construction."

On June 21, 2001, Irving's barrister, Adrian Davies, told the Court of Appeal that he was withdrawing the promised "new evidence" on Auschwitz. Professor van

Pelt believes that it was the strength of the defense reports that deterred Irving. The Court of Appeal rejected Irving's request to obtain an appeal.[32]

Acknowledgements

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Notes

1. The "logic" suggests that if there were no holes, then the structures were not gas chambers; if the structures were not gas chambers, then Auschwitz was not used as an extermination camp; if Auschwitz was not used as an extermination camp, then the Holocaust did not happen. See Robert Jan van Pelt, *The Case for Auschwitz: Evidence from the Irving Trial* (Bloomington: Indiana University Press, 2002), pp. 3ff., 24ff., and 458ff.

2. The Holocaust History Project (http://www.holocaust-history.org) is a volunteer-based organization dedicated to making available documents and other materials related to the history of the Holocaust. Photos appearing in this article can be viewed, along with many others, at the Project's website.

3. Much basic information about the camp can be found in Yisrael Gutman and Michael Berenbaum, eds., *Anatomy of the Auschwitz Death Camp* (Bloomington: Indiana University Press in association with the United States Holocaust Memorial Museum, 1994).

4. Gideon Greif, *We Wept Without Tears* (in Hebrew) (Jerusalem; Tel Aviv: Yad Vashem; Sifre hemed, 1999) and "*Wir weinten tränenlos. . .*" (Frankfurt: Fischer Taschenbuch, 1999); Jean-Claude Pressac, *Auschwitz: Technique and Operation of the Gas Chambers* (New York: The Beate Klarsfield Foundation, 1989); van Pelt, op. cit.; Jan Markiewicz, Wojciech Gubala, and Jerzy Labedz, *A Study of the Cyanide Compounds Content in the Walls of the Gas Chambers in the Former Auschwitz and Birkenau Concentration Camps* (reproduced with permission of the Institute of Forensic Research in Cracow (originally Z *Zagadnien Sądowych z.* XXX [1994], pp. 17–27) in http://www.holocaust-history.org/auschwitz/chemistry/iffr/report.shtml, with introduction by Dr. Richard J. Green (http://www.holocaust-history.org/auschwitz/chemistry/iffr).

5. Gerald Fleming. *Hitler and the Final Solution* (Berkeley: University of California Press, 1984), pp. 187–88.

6. Pressac, p. 232.

7. Divided into two shifts of 110 and working around the clock. Labor deployment reports quoted in Danuta Czech's *Auschwitz Chronicles, 1939–1945* (London: Tauris, 1990). Some

are reproduced in http://www.holocaust-history.org/auschwitz/labor-force/ and http://www.holocaust-history.org/auschwitz/labor-force/19440802/.

8. Pressac, p. 327.

9. Claim by David Irving in the Irving vs. Penguin & Lipstadt trial. Report in *The Guardian*, January 27, 2000, and in the trial transcripts.

10. Op. cit., pp. 268–327, 490–91.

11. At several points the authors have relied on Olivier Faugeras's standard volume, *Three-Dimensional Computer Vision: A Geometric Viewpoint* (Cambridge, MA: MIT Press, 1993).

12. See lengthy report in John C. Zimmerman, *Holocaust Denial: Demographics, Testimonies, and Ideologies* (Lanham, MD: University Press of America), 2000, p. 292.

13. Pressac, p. 484.

14. Op. cit.

15. Fleming, p. 188.

16. Pressac, pp. 355–78.

17. See letter from contractor, reproduced in Jean-Claude Pressac with Robert Jan van Pelt, "The Machinery of Mass Murder at Auschwitz," in Gutman and Berenbaum, p. 231. We thank Professor William Samelson for translation.

18. Auschwitz Birkenau State Museum, File BW 30/43, p. 34.

19. See Renata Bogusławska-Świebocka and Teresa Cegłowska, eds., *KL Auschwitz: Documentary Photos* (Warsaw: Krajowa Agencja, 1980).

20. Mr. Lucas served in the United States Army Air Force between 1943 and 1946. From 1946 to 1956 he worked for the U.S. Geological Service, and between 1956 and 1981 the Central Intelligence Agency. Between 1968 and 1982 he held several positions within the CIA and NPIC (National Photographic Interpretation Center), including that of Executive Officer, NPIC. He was later manager of the Imagery Exploitation Division and senior analyst/consulting scientist for the Advanced Applications Division at the CIA, among other positions. We thank Prof. John Zimmerman of the University of Nevada for contacting Lucas for us.

21. As per Faugeras, op. cit.

22. Brian A. Wandell. *Foundations of Vision* (Sunderland, MA: Sinauer Associates, 1995).

23. Greif, p. 131.

24. Bernd Naumann, *Auschwitz: A Report on the Proceedings against Robert Karl Ludwig Mulka and Others Before the Court at Frankfurt* (Westport, CT: Praeger, 1966), pp. 45–46 (Stark's testimony); Yadwiga Bezwinska and Danuta Czech, *KL Auschwitz Seen by the SS* (Oswieçim: The Auschwitz-Birkenau State Museum, 1997), pp. 129–30 (Broad's testimony) and p. 71 (Höss's testimony); Filip Müller, *Auschwitz Inferno: The Testimony of a Sonderkommando* (London: Routledge & Kegan Paul, 1979), pp. 32–39 (Müller's testimony); Pressac, pp. 124 and 131.

25. Markiewicz et al., op. cit.

26. Pressac, pp. 156–57.

27. Cited from Franciszek Piper, "Gas Chambers and Crematoria," in Gutman and Berenbaum, p. 177, n. 16.

28. Pressac, pp. 124 and 131.

29. As per Faugeras, op. cit.

30. As per Faugeras, op. cit. Discussion of this topic took up several hours at the trial.

31. Available on our website at http://www.holocaust-history.org/irving-david/vanpelt/zucchi-review-comments.shtml.

32. Speaking for the Court on July 20, 2001, Lord Justice Pill said, in part, "... there were before the Court two applications to call fresh evidence in support of the application. The first, made well before the hearing, was to call evidence from Mr. Germar Scheerer (born Rudolf), who holds a diploma in chemistry, and Mrs. Zoe Polanska-Palmer, who was detained in Birkenau Camp.... In the event, that application to call fresh evidence was not pursued. We express our dismay at this combination of events [which required] the preparation of very detailed evidence (exposing the respondents to great expense in preparing a reply and the members of the Court to considerable pre-hearing reading) and the withdrawal of the application." See discussion in van Pelt, pp. 494–506.