

EWA POTRZEBNICKA

## THE DEACIDIFICATION OF LIBRARY MATERIALS AT THE NATIONAL LIBRARY OF POLAND

The holdings of the National Library of Poland have been predominately produced on mechanical pulp paper, whose long-term storage causes great difficulties.

In the mid-19th century, mechanical pulp paper became the fundamental medium for information storage, enabling substantial access to it. Unfortunately, over the decades the deterioration of its structure started to be visible even to the eye, which led to intense research in chemistry in the second half of the 20th century aimed at determining the durability of this material. The question of paper and cellulose degradation became an important topic for librarians, archivists, and materials science. At this point, it ought to be mentioned that as far back as in 1887 Polish naturalists – prof. Karol Jurkiewicz and Aleksander Marian Weiberg, PhD<sup>1</sup> – pointed out that highly acidic papers offer virtually no chance for long-term durability, and in 1936, the founder of the Polish school of paper conservation, prof. Bonawentura Lenart, a collaborator of the National Library, strongly criticised the paper produced at that time,<sup>2</sup> calling for the introduction of a standard for printing at least “one monumental copy for research libraries” on high-quality paper.

As a matter of fact, acidification occurred in the paper as early as at the manufacturing stage, however, its high level did not affect the popularity of this material or its industrial usefulness. The value of the new technology consisted in its massive production capacity and low price. Nevertheless, libraries and archives

---

1 Jurkiewicz Karol, Weiberg Aleksander Marian, *Badania nad papierami krajowymi ze względu na ich własności fizyczne i skład chemiczny, Część I: Papiery dokumentowe*. Druk K. Kowalewskiego [Research on Domestic Types of Paper in Terms of their Physical Properties and Chemical Composition. Part I: Document Papers. Printed by K. Kowalewski], Warszawa, 1887.

2 B. Lenart, “O trwały papier książkowy” [For a Durable Book Paper], *Przegląd Biblioteczny*, issue 10, 1936, p. 200.

have suffered the consequences of masses of information being recorded on low-quality and quickly degrading paper up to this day. This is why the question of paper durability and the state of preservation of library and archival materials are intertwined and of great importance for any institutions that are in charge of long-term storage of holdings on a statutory basis.

Mechanical pulp paper contains varying amounts of cellulose, hemicellulose, and lignin, and many other components of a smaller percentage share in the total paper mass, which makes its degradation a highly complex process provoked by a series of sequential and simultaneous chemical reactions.<sup>3</sup> The paper decomposition is also influenced by many external factors. The conclusions are dramatic: paper degradation cannot be undone, but only stopped.

The Polish librarian and conservationist communities were no strangers to the threats of using mechanical pulp paper, thanks to the excellent contributions of prof. Bronisław Zyska who was examining the durability of paper in 19th- and 20th-century books between 1985-1994.<sup>4</sup> He published a dozen books, including a series of monographs entitled *Protection of Library Holdings against Destruction*,<sup>5</sup> which paved the way for the programme of saving 19th- and 20th-century writing. A journal edited and published since 1998 by the National Library of Poland dedicated exclusively to the protection and conservation of library holdings has had a wide reach up to the present, addressing issues related to conservation policy, examples of conservation activities, as well as physics, chemistry and microbiology.<sup>6</sup> Even its first issue featured articles on the durability of the paper used in Polish 19th-century<sup>7</sup> prints and other kinds of printing paper.<sup>8</sup>

Considering the results of research conducted throughout the world and the scientific achievements related to mechanical pulp paper degradation, including the findings of the European Commission on Preservation and Access (ECPA) established in 1994 to support the activities aiming to preserve the holdings of European archives and libraries,<sup>9</sup> the IFLA and UNESCO recommendations, and the

3 Andrzej Barański, "Problem kwaśnego papieru. Koncepcje badawcze, uwarunkowania i działania praktyczne" [The question of acidic paper. Research concepts, conditions and practical action] in *Kwaśny papier* [Acidic Paper], Kraków, 2001, p. 67.

4 Bronisław Zyska, "Permanence of paper in Polish books of the period 1900-1994", *Restaurator*, no. 17, 1996, pp. 214-228; Bronisław Zyska, *Trwałość papieru w drukach polskich z lat 1800-1994. Wyniki badań* [Durability of Paper in Polish Prints of 1800-1994. Research Results], Wydawnictwo Uniwersytetu Śląskiego, Katowice, 1999.

5 Bronisław Zyska, *Ochrona zbiorów bibliotecznych przed zniszczeniem* [Protection of Library Holdings against Destruction], vols. 1-4, University of Silesia, Katowice, 1991-1998.

6 *Notes Konserwatorski* [Conservationist Notebook], National Library of Poland, Warszawa, issues 1-15, 1998-2012.

7 Bronisław Zyska, "Ocena trwałości papierów w drukach z XIX wieku" [Assessment of paper durability in 19th-century prints], *Notes Konserwatorski*, 1998, p. 51.

8 Józef Dąbrowski, "Papier drukowy i jego trwałość" [Printing paper and its durability], *Notes Konserwatorski*, 1998, p. 103.

9 In 1995, the Association for the Protection of Archive and Library Collections was founded, inspired

over 10-years' experience of the Library of Congress in deacidification,<sup>10</sup> we can ascertain that the years 1998 and 1999 were a breakthrough period in Poland when it comes to initiatives undertaken and pursued in connection with the acidification of library and archival materials, discussed in detail in the reference literature.<sup>11</sup> Their goal was not only to conduct a propaganda and information campaign in order to draw attention to the threats related to the decomposition process that paper produced in the 19th and 20th century is subject to, but also to establish the basic principles of programmes and funds that would enable them to save the deteriorating library and archival materials of the 19th and 20th centuries.

The actions aimed at launching a program for the protection of the national writing were directly inspired and conducted by the then-directors of the National Library, the Jagiellonian Library and the Head Office of the State Archives as well as chemistry professors of the Jagiellonian University.<sup>12</sup> As early as in November 1998, a team appointed by the Ministry of Culture and Arts to prepare the programme for the protection of the written national heritage of the 19th and 20th centuries submitted the outline of such a programme. In June 1999, a financing agreement and implementation schedule were signed between the participating ministries and the head of the State Committee for Scientific Research.

The programme was adopted by the Council of Ministers on 17 November 1999, pursuant to point 11 of the Memorandum of Understanding no. 46/99 of the Meeting of the Council of Ministers. Its full name was: "Acidic paper. Saving endangered library and archival collections by mass-treatments." Its time frame was projected for the years 2000–2008. The Ministry of Culture and National Heritage was its managing body, while the National Library became the programme coordinator.

The long-term government programme "Acidic paper..." was a completely origi-

---

by the ECPA, launched a year before, see: Joanna Pasztaleniec-Jarzyńska, „Stowarzyszenie na Rzecz ochrony Zasobów Archiwalnych i Bibliotecznych” [Association for the protection of archive and library collections], *Notes Konserwatorski*, issue 2, Warszawa, 1999, p. 97.

- 10 T. Łojewski, "Działalność Biblioteki Kongresu USA w dziedzinie odkwaszania książek, Ochrona Narodowego zasobu Biblioteczny" [The activity of the US Library of Congress in book deacidification, protection of the National Library Resource], in SBP, *Materiały i dokumenty ze szkolenia dyrektorów bibliotek, których zbiory tworzą Narodowy Zasób Biblioteczny*, Kraków, April 2001, p. 38.
- 11 A. Barański, J. Grochowski, K. Zamorski, "Kalendarium i założenia realizacyjne wieloletniego programu rządowego na lata 2000-2008: Kwaśny Papier. Ratowanie w skali masowej zagrożonych polskich zasobów bibliotecznych i archiwalnych" [Calendar and implementation principles of the long-term government programme for 2000-2008: Acidic paper. Saving endangered library and archival collections by mass-treatments], *Notes Konserwatorski* 4, Warszawa, 2000, p. 9.
- 12 A. Barański, J. Grochowski, A. Manikowski, D. Nałęcz, K. Zamorski, "O potrzebie ratowania dziedzictwa kultury polskiej w zbiorach bibliotecznych i archiwalnych XIX i XX wieku. Memorial" [On the need to save the Polish cultural heritage preserved in 19th and 20th-century library and archive collections. A memorial], *Notes Konserwatorski* 4, issue 2, p. 100. It contained the following attachments: 1. Standards for durable paper, 2. Foreign programmes of research on acidic paper, 3. Information on the Regional Laboratory of Physicochemical Analyses and Structural Research at the Jagiellonian University.

nal programme and made no direct reference to any previous models. Its experimental nature must be underlined, however, it also ought to be mentioned that the programme prepared by Polish scientists and adopted by the government of Poland in 1999 coincided in most of its principles with the contemporary research tendencies in the field of national heritage protection, which defined the scope of research for each information storage medium (published in 2000).<sup>13</sup> The Polish programme was established for library and archival materials produced in the 19th and 20th centuries only. The general objective of the programme was to gather thorough information on mass deacidification technology, conduct preliminary research in this field, determine the exact costs of the operations and launch a deacidification campaign in the Polish libraries and archives. The implementation of the principles of the long-term government programme “Acidic paper. Saving endangered library and archival collections by mass-treatments,” financed by the Polish government, created an opportunity for the successful preservation of Polish 19th- and 20th-century writing for the society.

The research on printing paper durability was launched in Poland and worldwide approximately at the same time that wood pulp was introduced to the production of paper.<sup>14</sup> It provided a basis for the selection of appropriate research methods used to assess the state of preservation of 19th- and 20th-century collections. Within the programme, it was decided to examine the state of preservation of the book collections of five libraries and paper-based archival materials stored at three major state archives. Within this programme a study was undertaken of the conservation status of five library collections: the National Library, the Jagiellonian Library, the Pomeranian Library in Szczecin, the Silesian Library and the Ossoliński National Institute in Wrocław, as well as in the paper archives in the three large state archives: the State Archives in Warsaw, Olsztyn State Archives and the State Archives in Poznań.

The investigation was to be conducted using the popular Stanford method,<sup>15</sup> as its adaptability and openness to modifications had been acknowledged as great advantages.<sup>16</sup> The results of the research, published in 2006,<sup>17</sup> confirmed the

13 H.J. Porc, R. Teygler *Preservation Science Survey*, Council on Library and Information Resources, Washington, 2000.

14 B. Zyska, *Nad trwałością papierów drukowych* [On the Durability of Printing Papers], Katowice, 1993.

15 E. Potrzebnička, “Współczesne metody oceny stanu zachowania zbiorów” [Contemporary assessment methods for the state of preservation of collections], *Notes Konserwatorski*, issue 3, Warszawa, 1999, p. 40; S. Buchanan, S. Coleman, “Deterioration survey of the Stanford University Libraries Green Library Stack Collection,” in *Preservation Planning Program. Resource Notebook*, Washington, 1982.

16 W. Sobucki, B. Drewniewska-Idziak, A. Michaś, K. Panoszewski, “Zasady charakteryzowania stanu zachowania zasobów bibliotecznych i archiwalnych” [Rules on how to describe the state of preservation of library and archive collections], *Notes Konserwatorski*, issue 5, Warszawa, 2001, p. 47.

17 *Stan zachowania polskich zbiorów bibliotecznych i archiwalnych z XIX i XX wieku* [State of Preservation of the Polish Library and Archive Collections of the 19th and 20th Century], collection edited

dramatic situation of 90% of 19th- and 20th-century book collections, which required deacidification, along with all of the archival resources from that period. Materials published after 1860 proved to be particularly threatened with destruction, while Cracow and the industrial part of Lower Silesia were indicated as the territories most affected by the problem. Research confirmed the necessity of implementing the investments anticipated in the paper deacidification programme. The examination of the state of preservation of Polish book collections carried out between 2001 and 2005 by the National Library is still viable, especially in terms of planning further mass conservation, and should be taken into account by other Polish book depositories that store library materials that form a part of the national cultural heritage.

The research programme also included biological protection of the holdings and comparative studies on paper deacidified using various methods (Department of Paper and Leather Conservation of the Nicolaus Copernicus University in Toruń), as well as technological research on papers of an archival quality at the Polish Security Printing Works in Warsaw (Institute of Pulp and Paper in Łódź).<sup>18</sup>

The cost of the programme came to ca. 70 million PLN, 80% of which was spent on the purchase of deacidification installations and other deacidification-related works conducted by the end of 2008.<sup>19</sup> Launching the mass conservation of endangered 19th- and 20th-century library and archive resources in Poland, which made it possible to save the most valuable original items, has been the most notable achievement of the programme. Within the initiative, eight deacidification installations were put into operation. At the National Library and the Jagiellonian Library, the renowned *Bookkeeper* systems have been launched, in which virtually all paper-based materials may be deacidified in vertical and horizontal treatment chambers as well as through spraying. Furthermore, in both libraries C900 (*Neschen*) devices are used for the deacidification of isolated pages and sheets of documents. Also, four conservation workshops at archives have been equipped with the C900 devices.

The purchase of installations for the deacidification of paper-based collections is a major success of the programme, since companies owning patent rights to the technologies prefer to perform such services themselves. Moreover, the *Bookkeeper* installations acquired for the Jagiellonian and the National Library are the

---

by B. Drewniewska-Idziak, National Library of Poland, Warszawa, 2006.

- 18 W. Sobucki, "Problematyka badawcza w programie 'Kwaśny Papier'" [Research issues in the 'Acidic Paper' Programme], in *Wieloletni Program Rządowy na lata 2000-2008. Kwaśny papier, Odkwaszanie zbiorów bibliotecznych i archiwalnych w Polsce, Podsumowanie*, National Library of Poland, Warszawa, 2008, p. 11.
- 19 W. Sobucki, "Polski program rządowy 'Kwaśny papier' – najważniejsze osiągnięcia" [The Polish government programme 'Acidic paper'. Major achievements], in *Przeszłość dla Przyszłości, Masowe zabezpieczanie zasobów bibliotek i archiwów, Wystąpienia wygłoszone podczas konferencji Przeszłość dla Przyszłości, Masowe zabezpieczanie zasobów bibliotek i archiwów*, Tomasz Łojewski (ed.), Jagiellonian Library, Kraków, 2010, p. 9.

first pieces of deacidification equipment ever sold to libraries.

Within the programme, 12 microfilm and digital imaging studios, mostly at state archives, have been upgraded and equipped with modern machinery.

Other achievements include the establishment of the Paper Degradation Laboratory at the Faculty of Chemistry of the Jagiellonian University, which soon became a renowned research centre in this field on a worldwide scale. Scientists from Cracow, focused on issues related to acidic paper, conduct research and publish their results in internationally acknowledged journals. They also take part in numerous international projects.

The influence that the programme has had on expanding the knowledge about the protection of collections at libraries and archives cannot be understated. It was the subject of around 200 published research and popular science articles as well as several master's theses, one habilitation and two PhD dissertations. The overview summarising the programme featured a bibliography of publications on the long-term government programme "Acidic paper."<sup>20</sup> It can be argued with all certainty that the programme has improved the quality of the protection of holdings in libraries and archives, and turned Poland into an important centre of mass conservation on a worldwide scale.

It also ought to be mentioned that significant new developments appeared in science and technology during the initial stage of the programme's implementation that had to be taken into consideration in its revisions. In 2006, the ISO 11799 standard of 2003 was adopted in Poland, with its requirements on storage conditions of archival and library holdings. The standard specified the properties of general-purpose inventory locations used for long-term storage of collections. Considering this, the programme task to "prepare the rules and standards for safe storage of holdings [...]" had to be eliminated. Similar decisions had to be made, as the production of non-acidic cartons and cardboards was launched at the Institute of Pulp and Paper in Łódź and in connection with recognition research on so-called alternative papers. The implementation of such tasks had been rendered unnecessary because of the current assessment of the dynamically growing paper market in Europe and in Poland. For by the end of the 20th century, paper mills were producing alkaline paper only.

Consciously planned and discussed in detail by a team of experts, the changes were incorporated into the Programme Update for 2007-2008, adopted by the Council of Ministers on 24 July 2007.

Once the programme was terminated, ensuring appropriate funding for maintenance of the deacidification equipment became the priority for the institutions where it had been implemented. This consisted not only in providing funds for

20 "Bibliografia publikacji wydanych na temat WPR 'Kwaśny papier'" [Bibliography of publications about the long-term government programme 'Acidic Paper'], B. Berlińska (ed.), *Wieloletni Program Rządowy na lata 200-2008. Kwaśny papier, Odkwaszanie zbiorów bibliotecznych i archiwalnych w Polsce, Podsumowanie*, National Library of Poland, Warszawa, 2008, p. 98.

exploitation and consumables, but also for the equipment operation and employees who would prepare library materials and pass them on for deacidification, in accordance with the adopted procedures, on an ongoing basis. The National Library managed to cope with this challenge through optimising the equipment operation by introducing a two-shift work arrangement in 2008. The first stage of forming the team responsible for the operation of equipment for the deacidification of library materials took place at the Department of Conservation of Library Collections, which had nearly 80 years of practical experience in handicraft conservation works. The effects obtained in the early stage of operation of the sheet deacidification device C900 were astonishing for the staff implementing the programme, who previously performed all conservation work using traditional methods. Before the sheet deacidification device was put into operation at the National Library, ca. 300 sheets of 19th- and 20th-century documents used to be conserved annually, while with the mass conservation, this number grew over a thousand times.

The purchase of the first device for the National Library was preceded by expansion and adaptation of the existing laboratory and technical building located within the main library complex.<sup>21</sup> Once the book deacidification installations were purchased, it became necessary to hire further employees to operate the equipment. At the end of 2006, a new organisational unit was created, dedicated exclusively to mass conservation tasks – the Department of Mass Conservation of Library Collections. It was the first specialised unit to combine traditional and mass conservation methods. The paper conservationists employed at this Department assess the state of preservation of the holdings and paper, which is indispensable to selecting and applying the right procedure. The correct operation of the chemical processes that take place in both installations is monitored on a continual basis by the chemical and microbiological laboratory located within the National Library Structure. In order to ensure continuity of the deacidification at both installations, the department has to cooperate on an ongoing basis with all the other units of the library where 19th- and 20th-century materials are stored.

For the National Library, the priority is to deacidify any archival copy (for each category of library holdings) that forms part of the National Library Resource and which requires special protection under the Polish law.<sup>22</sup> Despite the closed time-period restriction to materials produced in the 19th and 20th centuries, the most valuable resources of the National Library destined for deacidification (ca. 4 million items) do not form a closed group with a pre-determined number of elements, as many literary legacy materials and archives of Polish writers are be-

---

21 A. Lipińska, "Działalność Zakładu Konserwacji Masowej Zbiorów Bibliotecznych" [Activity of the Department of Mass Conservation of Library Collections], *Wieloletni Program Rządowy na lata 2000-2008. Kwaśny papier, Odkwaszanie zbiorów bibliotecznych i archiwalnych w Polsce, Podsumowanie*, National Library of Poland, Warszawa, 2008, p. 48.

22 Act of June 27, 1997 on Libraries (the Journal of Laws No. 85), item 539 as amended.



ing constantly added to the Collection of Polish Contemporary Literature. The number of library materials is also growing in a collection entitled *Archives of Polish jazz aimed at preserving the memory of this extraordinary enclave of freedom, Polish pre-1989 jazz*. The documents obtained by the National Library to form a part of these archives had been written almost exclusively on acidic paper. All manuscript documents, typescripts as well as flyers, posters, unbound newspapers and periodicals, brochures, i.e. all items consisting of single sheets, are deacidified in the C900 device. The process takes place in a watery environment, magnesium hydrogen carbonate being the deacidifying agent. The mixture also contains fixative compounds for inks and stamps as well as a paper reinforcement component. The C900 device is designed to deacidify sheets transported on special rolls, which are subsequently immersed in a recipient with deacidifying liquid, to be taken off after ca. 3-4 minutes. Also, manual deacidification posts have been opened for sheets with serious mechanical damages, foxed and brittle. The operation is conducted in cuvettes, by means of the same working solution. The deacidification process is preceded by mechanical cleaning of the paper, where any dust, rust, unnecessary and unprofessional backing or repairs are removed. Upon deacidification, all leaves are dried in room temperature and straightened in surface presses. Then, many library materials require further treatment aimed at removing any damages or cracks on the paper surface. Very brittle leaves, with particularly extensive damages or degraded substrate, are subjected to one or two-sided lamination. Holdings indicated by conservationists as exceptionally valuable are conserved with traditional methods. In total, nearly 3 million (2,792,854.16) leaves as converted to the A4 format were deacidified from 2005 through mid-2014. Almost 700 (673,513.69) thousand leaves as converted to the A4 format were subjected to conservation, while lamination was performed on nearly 70 thousand (66,796.58) leaves.

Once the program was terminated, a clear decline in sheet deacidification was observed in the following three years due to two factors: lack of systematic supply of library materials for deacidification and a shift in priorities towards traditional treatment. With an intervention undertaken in 2012, the number of sheets subject to deacidification has systematically increased, giving grounds for achieving optimum results in mid-2014.

Deacidification of bound and large-format books, bound newspapers, periodicals or non-standard materials such as brochures and archival documents is conducted using the Bookkeeper technology. This method was developed in the US and is offered by the Preservation Technologies L.P. company. The deacidifying substance is fine-crystalline magnesium oxide suspended in perfluoroheptane. A superficially active substance is added to the suspension, which facilitates its penetration into the pores of the paper. The magnesium oxide neutralises the acidic substances in the paper, while its excess creates an alkaline reserve. The installation is composed of 6 vertical, two-level reactors with space for up to 18 books no larger than 33x26x7 cm and a horizontal reactor used to deacidify unwieldy



items. The deacidification process consists of three stages: loading the books to the reactor, a 20-25 minute bath in the suspension and vacuum drying. The entire process takes place in a closed circuit, and the reagents used are non-toxic, non-flammable, safe and ozone-friendly. Furthermore, once the deacidification cycle is completed, the perfluoroheptane is largely recovered in the drying stage and re-used in further deacidification.

The chemical compounds used in this method enable deacidifying both leather and plastic-bound books, and no previous selection according to the type of glue or ink is required. However, preliminary selection must be conducted in terms of the state of preservation: books handed over for deacidification in vertical reactors should be in a satisfactory technical condition and their bindings must not be detached from the book body. For those library materials that fail to comply with these requirements or that cannot be deacidified with the C900 method (manuscripts, gouache paintings, drawings, cartographic collections etc.), a post has been created for manual deacidification with a preparation applied using the Bookkeeper technology. To summarise the effects of the works performed with the Bookkeeper technology since it was introduced in June 2007 – 542,465 volumes have been deacidified in total, weighing 211,201.03 kg, including 495,124 volumes deacidified for the National Library, weighing 184,708.73 kg.

With the mass deacidification technologies applied at the National Library in Warsaw, the process of acidification has been stopped in over 60% of the books, prints of the Wilanów collection, over 30% of the posters, sheet music, music prints, maps, and 6% of the manuscripts, periodicals and bibliographic collections – materials forming part of the National Library Resource. Another success resulting from the mass conservation campaign conducted at the National Library, especially significant for its invaluable and deteriorated holdings, is the number of 700 thousand leaves subject to conservation throughout nearly 9 years, which corresponds to ca. 80 thousand leaves annually. This should be compared to the results obtained for the 19th- and 20th-century holdings before mass deacidification was launched, amounting to ca. 300 leaves a year. These achievements confirm the legitimacy and efficiency of the mass deacidification performed at the National Library of Poland in Warsaw.

#### SUMMARY

In the mid-19th century, mechanical pulp paper became the fundamental medium for information storage, enabling substantial access to it. Unfortunately, over the decades the deterioration of its structure began to be visible even to the eye, which led to intense research in chemistry in the second half of the 20th century aimed at determining the durability of this material. The question of paper and cellulose degradation became an important topic for librarians, archivists, and materials science.

The paper presents the developing interest in this issue in the Polish scientific and librarian community, as well as the multi-faceted and effective consequences of actions taken in response. This article presents a summary of the eight-year period of the de-acidification of paper conducted in the National Library of Poland, starting in 2007-2008.



Neschen C-900 treatment. After the bath in the deacidifying solution the sheets are transported to the air drying channel of the C-900 unit. At the end of the process the paper should be humid enough to allow flattening under pressure between cardboards (photo: Bartosz Szymański).



Neschen C-900 treatment. The objects on a steel band are submerged in a deacidifying solution containing alkaline agent ( $Mg(HCO_3)_2$ ), methyl-hydroxyethyl-cellulose and fixing agents: Mesitol NBS and Rewon EL. It is a machine version of the Bückeburg process (photo: Bartosz Szymański).



The Bookkeeper treatment. The deacidifying agent is MgO (as a fine powder) suspended in perfluoroheptane. Since no water is used in the process, it allows to treat books without dismantling them. The books attached to plastic frames are treated in the vertical reactors (photo: Bartosz Szymański).



The Bookkeeper installation of the National Library. In addition to the vertical reactors there are also two horizontal reactors for treatment of single sheets or heavily damaged or fragile objects. The whole process is fully automated and computer controlled (photo: Bartosz Szymański).