MICROWAVE DRYING OF PAPER DOCUMENTS

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In recent years Central Europe suffered from extensive flooding. A number of libraries in Prague were flooded in August 2002. Thanks to enormous help of volunteers 3 thousands of cubic meters of documents, books and archival records were washed and frozen in plastic bags waiting for drying and restoration. Drying of all this documents would take decades using current drying technology, e.g. vacuum freezing (lyophilization) or hot wet air drying. In order to rescue the affected documents as soon as possible, the Czech Center of Microwave Technology (CCMT) at the Academy of Sciences in Prague was in charge to develop fast and safe method for drying of flooded paper documents and books. CCMT decided to modify the existing MW technique of drying of chemical substances to allow the drying of books and documents. Books or documents of high historical value usually contain various type of materials like leather binding, gold-plated letters, color prints, metal parts (clips, rings bindings), plastics, various adhesives and types of binding, i.e. materials with different ability to couple with microwaves. It was necessary to develop a method which will prevent the occurrence of "hot spots" and local overheating which can cause undesirable and irreversible changes to the document.

Therefore a new advanced microwave technology has been developed using a continuous dryer equipped with absorption filters and combined with an air cooler. Principle of the new technology consists in using microwave absorption filters made from porous ceramic slabs. They are special porous ceramic materials, which partially absorb microwaves but they are also partially transparent for microwaves. They reduce intensity of microwave radiation to such an extent that it is sufficient for drying of moisture but not sufficient for overheating or creating of "hot-spots" or to cause other kinds of damages including red-heating of metal objects. Microwaves penetrate through the ceramic filters with a reduction of high intensity spots and are preferentially absorbed by the moisture creating internal regions of high pressure and forcing moisture to the surface. Then moisture is absorbed by porous ceramics and evaporates very fast from the surface in the form of steam even though the drying temperature is much lower than 100^{o}C and does not exceed 60-70^{o}C. The power is distributed volumetrically and usual temperature profile is inverted, i.e the temperature gradient (**heat transfer**) and the moisture (**mass transfer)** operate simultaneously. The basic structure of the dried paper is not damaged. Possible irreversible damage of paper by overheating is eliminated by moving documents on a conveyer which almost eliminates non-homogeneity of microwave field. The temperature and moisture content is regularly checked each 10 minutes, thus preventing overheating and over-drying.

`The technology has been tested on 2200 flooded books and documents of historical value within one month. All books and documents were recovered in high quality without any damage of gold printing, colored reproductions, metal containing objects and other components sensitive to microwaves as documented by photos and a short videofilm. Moreover, the technology also proven to kill moulds and their spores and therefore an additional disinfection was not necessary.