Bio-Medical

Microwave Sterilization and Depyrogenation System

Lightweight and portable systems can be deployed to provide medical-grade water.

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A fully functional, microgravity-compatible microwave sterilization and depyrogenation system (MSDS) prototype was developed that is capable of producing medical-grade water (MGW) without expendable supplies, using NASA potable water that currently is available aboard the International Space Station (ISS) and will be available for Lunar and planetary missions in the future. The microwave-based, continuous MSDS efficiently couples microwaves to a single-phase, pressurized, flowing water stream that is rapidly heated above 150 °C. Under these conditions, water is rapidly sterilized. Endotoxins, significant biological toxins that originate from the cell walls of gram-negative bacteria and which represent another defining MGW requirement, are also deactivated (i.e., depyrogenated) albeit more slowly, with such deactivation representing a more difficult challenge than sterilization.

Several innovations culminated in the successful MSDS prototype design. The most significant is the antenna-directed microwave heating of a water stream flowing through a microwave sterilization chamber (MSC). Novel antenna designs were developed to increase microwave transmission efficiency. These improvements resulted in greater than 95-percent absorption of incident microwaves. In addition, incorporation of recuperative heat exchangers (RHxs) in the design reduced the microwave power required to heat a water stream flowing at 15 mL/min to 170 °C to only 50 W. Further improvements in energy efficiency involved the employment of a second antenna to redirect reflected microwaves back into the MSC, eliminating the need for a water load and simplifying MSDS design.

A quick connect (QC) is another innovation that can be sterilized and depyrogenated at temperature, and then cooled using a unique flow design, allowing collection of MGW at atmospheric pressure and 80 °C. The final innovation was the use of in-line mixers incorporated in the flow path to disrupt laminar flow and increase contact time at a given flow rate.

These technologies can be employed in small-scale systems for efficient production of MGW in the laboratory or in a range of larger systems that meet various industrial requirements. The microwave antennas can also be adapted to selectively sterilize vulnerable connections to ultra-pure water production facilities or biologically vulnerable systems where microorganisms may intrude.

This work was done by James R. Akse, Roger W. Dahl, and Richard R. Wheeler, Jr., of UMPQUA Research Co. for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18455-1.

Quantifying Therapeutic and Diagnostic Efficacy in 2D Microvascular Images

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VESGEN is a newly automated, user-interactive program that maps and quantifies the effects of vascular therapeutics and regulators on microvascular form and function. VESGEN analyzes two-dimensional, black and white vascular images by measuring important vessel morphology parameters. This software guides the user through each required step of the analysis process via a concise graphical user interface (GUI). There are control options ranging from “one-click” analysis given a primary output, to step-by-step control over each image and algorithm used in an analysis. An option is provided to select a vascular tissue type, which determines the general collections of algorithms, intermediate images, and output images and measurements that will be produced. The UI automatically restructures itself to provide customized user controls for studying the requested type of tissue.

Three major types of vascular tissues can be analyzed: branching trees, networks, and tree-network composites. Parameters measured include vessel diameter, length, branchpoints, density, and fractal dimension. For tree type vessels, those measurements, as well as the number and tortuosity of vessels, are reported as dependent functions of vessel branching generation. VESGEN uses the fundamental image-processing concepts of 8-neighbor pixel connectivity, skeleton and distance map to create typically 5 to 12 (or greater) generations of vascular branching from a single parent vessel. For network type vessels, measurements of avascular regions are also made. Measurements of tree-network composites combine aspects of tree and network analyses.

Primary applications of the VESGEN code are 2D vascular images acquired as clinical diagnostic images of the human retina and as experimental studies of the effects of vascular regulators and therapeutics on vessel remodeling. Applications of VESGEN will be extended to predictive modeling studies of the response of human normal and pathological microvasculature to vascular therapeutics and regulators and to 3D vascular trees that are characteristic of organs such as the lung and brain.

VESGEN is written in Java as a plug-in for ImageJ (a free, publicly available image-processing software from National Institutes for Health). The software can be further modified for specific applications, or as an ImageJ-independent, standalone code. The current VESGEN program is at approximately Technology Readiness Level (TRL) 4-6, requiring only user knowledge of image pre-processing to binarize the vessels. The sole user input requirement is a binary (black/white) digital image in which the vascular architecture (i.e. vascular morphology or pattern) appears in black. An optional, but very useful and desirable, user input requirement is the microscope calibration factor, so that the quantified results output can be specified in physical units such as microns in addition to pixels.

This work was done by Patricia Parsons-Wingerter, Mary B. Vickerman, and Patricia A. Keith of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18277-1.