features with aspect ratios (length/diameter) in the 1,000 to 10,000 range.

This work was done by Jeffrey Sakamoto of Caltech for **NASA's Jet Propulsion Laboratory**, *and Todd Holt and David Welker of Paradigm Optics, Inc. Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-41906, volume and number of this NASA Tech Briefs *issue, and the page number.*

Measuring Vapors To Monitor the State of Cure of a Resin

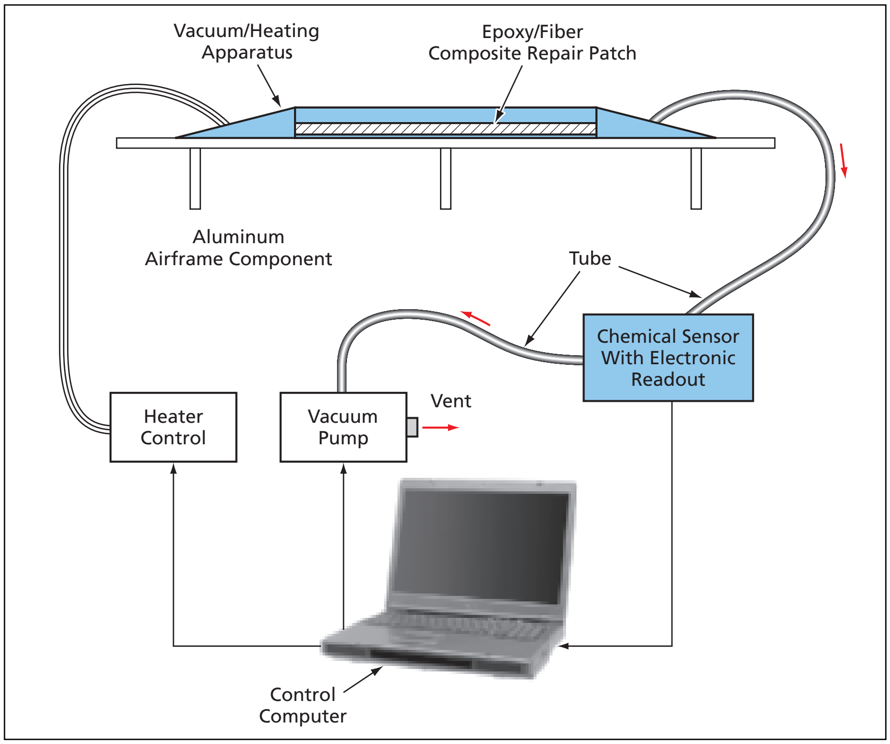
Excess curing time would no longer be needed as margin against uncertainty.

Langley Research Center, Hampton, Virginia

A proposed noninvasive method of monitoring the cure path and the state of cure of an epoxy or other resin involves measurement of the concentration(s) of one or more compound(s) in the vaporous effluent emitted during the curing process. The method is based on the following general ideas:

- The concentrations of the effluent compounds in the vicinity of the curing resin are approximately proportional to the instantaneous rate of curing.
- As curing proceeds at a given temperature, subsequent decreases in the concentrations are indicative of approaching completion of cure; that is, the lower are the concentrations, the more nearly complete is the cure.

The method could be utilized as the basis of a means of controlling the curing process to optimize the properties of the cured resin. It also could be utilized to minimize the cost of the curing process by ensuring a complete cure without the need to provide for excess curing time as margin against uncertainty in a prior estimate of required curing time.



Curing of Epoxy in a composite patch on an aluminum airframe component would be monitored by measuring concentrations of vaporous effluent compounds. The measurements could serve as feedback for controlling the vacuum pump and the heater.

A system to implement the method would include a sensor that produces electronic readouts of the concentrations of effluent compounds of interest. This sensor could be any of a variety of instruments, ranging from general-purpose full-size laboratory instruments capable of rapidly analyzing many compounds to microelectromechanical (MEMS) devices designed to detect effluent compounds specific to one epoxy. Either continuously or at regular intervals, the sensor would sample the effluent. Depending on the specific curing process, the sampling could occur at room temperature, at elevated temperature, under vacuum, or at atmospheric pressure: for example, in a case involving curing in a vacuum/heating apparatus, the sensor could be placed in the unheated tube from the vacuum bag to the vacuum pump.

The concentration(s) of the compound(s) of interest, and, thus, the rate of production of effluent would be monitored electronically and digitized to make a record of the curing process. Once the concentrations of the effluent compounds of interest decreased to predetermined levels, the cure would be considered complete and the operator would be so notified by the sensor circuitry. Alternatively, as depicted schematically in the figure, the sensor could be integrated into a control loop that would turn off the curing apparatus upon completion of the cure. Further, the control loop could be configured for active control to maintain the rate of curing at a predetermined level by monitoring the effluent-production rate and automatically adjusting the temperature and/or the pressure of the partial vacuum.

This work was done by K. Elliott Cramer, Daniel F. Perey, and William T. Yost of **Langley Research Center**. *Further information is contained in a TSP (see page 1).*
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