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example, stated that they didn't hear the horn or that they didn't remember hearing it.

In terms of eliciting effective pilot response, a tactile stall warning device such as a stickshaker would appear to be generally superior. In comparative simulator tests conducted by the FAA<sup>9</sup> of aural stall warners (continuous and interrupted horn signals) and the tactile device (stickshaker), it was found that with respect to alerting the pilot, the stickshaker was 99 percent effective, the interrupted horn 84 percent effective, and the continuous horn only 64 percent effective. The primary advantage of the stickshaker is that, in acting upon the pilot directly, it provides the stall warning automatically.

Improved stall warning, of course, can resolve only part of a more complex problem inextricably related to both the man and the machine. Directed research and development, improvement, and innovation with respect to design as well as to pilot's training and educational curricula are necessary if the stall/spin enigma is to be adequately resolved. In the case of the machine, for instance, consideration might be given to the applicability of certain STOL<sup>10</sup> concepts, to modification kits intended to improve handling characteristics, to fundamental design changes for improving stall/spin characteristics, and to those general requirements necessary to ensure that performance of present-day aircraft reflect the application of design standards, and criteria consistent with today's technology.

With respect to the pilot, emphatic training measures are necessary in connection with all the fundamentals of airplane performance pertinent to the takeoff and landing, particularly as related to operational situations which may easily precipitate a stall, e.g., premature lift-off, inadequate short- or soft-field techniques,

<sup>9</sup>Experimentation and Evaluation of Improved Stall Warning Equipment, Report No. NA-69-35, December 1969, Federal Aviation Administration, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, 08405.

<sup>10</sup>Short takeoff and landing.

misuse of flaps, etc. The prevention of engine failure or malfunction as a result of a pilot's own actions, together with the recommended procedures to be followed in the event of an engine failure, should be stressed. Special effort should be made to further educate pilots regarding the applicability and significance of current Federal regulations relating to careless or reckless operations, buzzing, low passes, etc., and the inherent dangers in such operations. Finally, in view of the trends which have been evidenced in airplane design during the past two decades, an evaluation should be made of the feasibility of requiring at least minimal spin training of all pilot applicants.

## RECOMMENDATIONS

The realization of further significant reductions in the relative numbers of stall/spin accidents will require the coordinated efforts of the general aviation community as a whole. The National Transportation Safety Board recommends that the Federal Aviation Administration, in addition to direct participation in all related programs, subsequently serve to organize, direct, and integrate such efforts toward unified objectives.

On March 23, 1972, the Federal Aviation Administration issued Notice of Proposed Rule Making No. 72-9, "Certification, Pilots and Flight Instructors," in order to revise and upgrade Part 61 of the Federal Aviation Regulations (FAR) dealing with this subject. In this NPRM, it is pointed out that although Part 61 has been amended over the years, no basic changes to pilot training and certification standards have been made since these were initially introduced in 1938. The NPRM also references the general consensus which exists regarding the need for such changes, in order to make these regulations compatible with the relatively complex operation of modern-day aircraft.

In view of the potential of enhanced pilot training for reducing stall/spin accidents, the following recommendations, where applicable,

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should be considered in context with the above proposed rulemaking. The National Transportation Safety Board specifically recommends that:

- 226 1. The Federal Aviation Administration issue an Advanced Notice of Proposed Rule Making to explore the potential of reducing stall/spin accidents through innovation in ground and flight training curricula.
- 227 2. The Federal Aviation Administration, together with the National Aeronautics and Space Administration, conduct further study, including operational flight tests, of the relative effectiveness between the current, most widely utilized stall warning devices (horns, lights, etc.) and the so-called improved stall warning equipment, e.g., angle-of-attack indicators, stick-shakers, etc., as found in some of the more sophisticated general aviation aircraft.
- 228 3. The Federal Aviation Administration, the Aircraft Owners and Pilots Association, the National Pilots Association, the National Association of Flight Instructors, the Flight Safety Foundation, and the National Business Aircraft Association, through an individually appropriate medium (Advisory Circular, personal contact, magazine, etc.), specifically advise pilots to guard against the occurrence of a stall/spin accident subsequent to an engine failure or malfunction. Special emphasis should be given to the potential occurrence of the latter as a result of "improper operation of powerplant or powerplant controls," "inadequate preflight preparation and/or planning," "mismanagement of fuel," and other causes characteristically attributed to the pilot. Maintenance personnel should also be advised of the history of stall/spin accidents precipitated by engine failure or malfunction due to "inadequate maintenance and inspection."
- 229 4. The Federal Aviation Administration issue a Notice of Proposed Rule Making in connection with minimum safe altitudes in FAR Part 91.79 (c) which, except in the case of operations involving fish spotting,

aerial mapping/photography, pipe patrol, etc., would increase minimum altitudes over "open water or sparsely populated areas" to 500 feet, the same that permitted over other noncongested areas.

- 230 5. The Federal Aviation Administration conduct further statistical review, technical evaluation, and operational testing of the aircraft which, based on application of Chi-Square test according to kind of fly exhibited a "very high" stall/spin frequency of occurrence.
- 231 6. The Federal Aviation Administration together with the National Aeronautics and Space Administration conduct an optional study of takeoff and landing safety based on actual stall/spin case histories evaluate the situational judgments and techniques of typical general aviation pilots in these phases of flight. The project would model or synthesize circumstances or contingencies which directly or indirectly often result in a stall/spin, including engine failure/malfunction, go-around, short-field takeoffs, etc.
- 232 7. The Federal Aviation Administration the National Aerial Applicators Association initiate additional study and research in connection with aerial application and associated crop-control activities. The objective would be to reduce stall/spin hazards unique to this kind of flight through enhanced operational techniques innovative airplane design and improved stall-warning equipment.
- 233 8. The Federal Aviation Administration General Aviation Manufacturers Association, and the National Aeronautics and Space Administration conduct a joint study to determine the potential and feasibility for reducing stall/spin accidents through enhanced airplane design consistent with current technology. Specific considerations for example, might be given to applicable STOL technology, improved

stall warning equipment, modification kits aimed at improving the handling characteristics of present aircraft, direct lift systems, etc.

2349. The Federal Aviation Administration evaluate the feasibility of requiring at least minimal spin training of all pilot applicants.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

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/s/ FRANCIS H. McADAMS  
Member

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