the masking of speech, impeded crew member reaction/response times, and increase the possibility of human error. Research also shows that high levels of noise disrupt sleep patterns by delaying the onset of sleep, awakening one from sleep, and interfering with rest due to the reduction in the amount of deep sleep (Salvendy, 1997).

Noise abatement and control techniques include:

- *Source control:* These methods include balancing rotating parts, using rubber mountings and surface dampening, tightening loose connectors that could cause component rattle, and avoiding resonances.
- *Path control:* Methods of controlling noise traveling down passageways, through ventilation ducting, etc. include increasing distance between source and crew members by design layout, enclosing the source, or placing intervening structures in the noise path.
- *Noise attenuation/active noise control:* These methods include employing baffles, mufflers, absorptive materials on bulkheads and decks, and other acoustical treatments. Noise attenuation can also be achieved with noise-cancellation speakers.
- *Receiver control:* These methods include implementing noise-isolating devices and active noise control at the receiver end (ear). Personal hearing/ear protection such as inserts, muffs, or both conserve hearing but can interfere with voice communications and sound signals (audible alarms) (Sanders and McCormick, 1993). Active noise control at the receiver end (the human) includes noise-canceling ear buds or headphones. These interfere less with voice communications than noise isolating devices and feature up to 85% noise attenuation, but they can be uncomfortable.

Vibration

Vibration control establishes a safe and satisfactory working and living environment with respect to human response to excessive vibration, motion sickness, vibration-induced injury/illness, reduced performance, and comfort factors (Griffin, 1990).

The human body is exposed to whole-body vibration and to vibrations applied to specific body parts such as head or limbs (Salvendy, 1997). Designers should be primarily concerned with vibration transmitted to the body through supporting surfaces such as the buttocks or feet (Sanders and McCormick, 1993). Research shows that mechanical vibration interferes with work quality, productivity, safety, health, and comfort, and can induce motion sickness. Vibration can modify crew member perceptions (e.g., reading text and instruments, the perception of depth and distance), influence body control movements (e.g., tactile sense, head/hand movements, manual tracking, reaching), and impair speech. These factors can result in impeded crew member reaction/response times and can increase the likelihood of human error (Griffin, 1990; BS 6841, 1987).

Vibration control techniques are similar to those employed in noise control. These techniques include source control, path control, and receiver control (Sanders and McCormick, 1993; Griffin, 1990).

Thermal Environment

The objective of designing with the thermal environment in mind is to provide conditions that crew members find satisfactory and to support human performance. To achieve this, temperatures are controlled within a tight range and conditions should be such that personnel are unaware of changes (Salvendy, 1997; Sanders and McCormick, 1993). The human body thermo regulates itself in different environments by producing or losing extra heat to maintain its core comfort level. Yet studies indicate unfavorable thermal environments impact the body's physiology and can cause extreme reactions such as heat stroke, exhaustion, and hypothermia. Less extreme physiological responses adversely impact human performance as well. Performance degradation causes increased energy expenditure, decreased work capacities, reduced work intervals, decreased quality and productivity, reduced hand/arm control manipulation capabilities, stiffness,