

HOUSEBOAT GENERATOR STACK EXHAUST DESIGN

Since 2001, significant efforts have been applied to define the scope of the carbon monoxide poisoning risk in houseboats. Initial efforts focused on removing the risk to people in the water under or around the swim platform at the rear of the boats. The Coast Guard encouraged various investigations that resulted in a recommendation to re-locate the generator exhaust outlet from the transom to the side of the boat. The Emission Control device was introduced that initially appeared promising as an ultimate solution to lower CO emissions to a safe level. Subsequently, however, maintenance issues developed that indicated this control might not be effective in all applications. The next step was design of a control to remove the carbon monoxide completely from the areas frequented by occupants of the boat. The resulting dry stack exhaust system has been demonstrated to be effective in this regard under most circumstances. Many houseboat manufacturers have added stack exhaust systems to their generators either as a standard item or an option. Recently one generator manufacturer has introduced a series of generators that demonstrate a 99% reduction in CO at the exhaust outlet through use of improved combustion and emission control technologies. This generator is being introduced and real-world maintainability and reliability data should be available in the near future.

Houseboat manufacturers and owners should be aware of the continued CO hazards associated with houseboat designs with a water-level, gasoline-powered generator exhaust terminus (whether directed into the enclosed air cavity under the stern deck or to the side in occupied or accessible areas). National Institute for Occupational Safety and Health (NIOSH) researchers have investigated CO-related poisonings and deaths on houseboats across the United States since the fall of 2000. These investigations have measured hazardous CO concentrations on many recreational boats. Over 550 boat-related CO poisonings and over 100 deaths have, been documented in the U.S during the last 20 years. Nearly half of these poisonings occurred on houseboats, with more than 200 attributed to generator exhaust alone.

Through an interagency agreement with the U.S. Coast Guard, NIOSH has evaluated boat related CO poisonings and the effectiveness of vertical exhaust stacks on houseboat gasoline-powered, generators. These evaluations have demonstrated the exhaust stack's effectiveness in routing CO away from houseboat occupants and dramatically reducing the hazard associated with CO poisoning from generator exhaust. Recently some houseboat manufacturers have encountered problems in designing stack exhaust systems that produce the desired result of separating exhaust gases from cooling water, and directing the gases up the stack to an outlet removed from the occupied spaces on the boat. The NIOSH team has developed the guidelines listed below to aid manufacturers in developing effective exhaust stacks.

Exhaust Stack Design Considerations:

- **Use an exhaust pipe that is 2" ID or greater--** In many instances, small stack diameters (less than 2" inside diameter) have resulted in marginal to poor performance. On the other hand, stack diameters exceeding 2" ID have generally not indicated a problem.'

- **Minimize the number of elbows and bends**-- The number of bends and elbows between the water separator and the stack terminus should be minimized to reduce restrictions and the amount of turbulent air flow. Increasing the number of elbows and the distance that the exhaust gases must travel increases the frictional and fitting losses in the system. Since exhaust gases and fluid flow will travel the path of least resistance, careful attention should be made to determine what necessary pressure differences are required to balance the exhaust system. In addition to proper stack design, proper design of the water outlet and water separator is necessary to prevent water from traveling up the stack.
- **Choose the appropriate water separator muffler**--Another problem has been improper selection of the water separator muffler to be installed. There are many models of these units. Close attention to selecting the proper model (working with the separator manufacturer) is essential to good performance.
- **Avoid using horizontal runs (where water can collect)**--The hose or other plumbing from the water outlet of the muffler should have a gradual slope down to the water drain through hull fitting. Do not allow sags or low places in the water drain line (where water can collect). This also applies to the plumbing in the exhaust side of the system.
- **Extend the stack well above the upper deck of the boat**--For best performance, the top or exit of the exhaust stack should be 9 feet above the top deck level while minimizing the total length of the exhaust runs.
- **Properly position the water drain**--Positioning the water drain below the waterline has been erroneously blamed for poor performance. Although there is a limit, water drains a few inches below the water line are okay if the water outlet of the muffler is far enough above the water line.

Houseboat manufacturers, rental companies, and owners should consider retrofitting their gasoline-powered generators with engineering controls to reduce the potential hazard of CO poisoning and death to individuals on or near the houseboat. If the stack exhaust is not designed properly, the performance could be hindered. Rather than hazardous exhaust gases passing through the stack to a height well above the upper deck, high static pressure in the stack could force exhaust gases to pass out the side terminus near the water line. **Genset engine manufacturers, water separator manufacturers, and other exhaust system component suppliers, must be consulted during the design process to minimize the risk of problems in the production system.** Properly designed and installed exhaust stacks have performed well during all NIOSH evaluations, and they are successfully being used to prevent CO poisonings on hundreds of houseboats across the U.S.

Stack exhaust systems have proven to be effective in reducing CO in the exhaust from gasoline powered generators to very safe levels. Proper design and installation of these systems is essential.