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**Technical Evaluation of the UH-60Q:  
Medical Oxygen System**

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## Introduction

The UH-60Q prototype MEDEVAC Black Hawk is configured to provide day/night, adverse weather, emergency movement of patients. The Materiel Need Statement for the UH-60Q directs that the aircraft be capable of performing medical evacuation in several mission profiles (Department of the Army, 1992). These include Southwest Asia, Europe, MAST, and Persian Gulf scenarios that are summarized in Appendix A. The U.S. Army Aeromedical Research Laboratory (USAARL) was tasked by the Utility Helicopter Program Manager to evaluate the UH-60Q prototype aircraft in flights that simulate the typical mission profiles. This information is needed to determine functional requirements for future operational and user tests of the UH-60Q. This report details the results of technical evaluations of the medical oxygen system on the UH-60Q aircraft. An analysis of other features of the medical interior and details on the performance of the aircraft system in mission scenarios is detailed in other reports.

The UH-60 aircraft, serial number 86-24560, is configured as the Proof of Principle Aircraft YUH-60A(Q). This helicopter is equipped with an enhanced medical interior, enhanced avionics and visual displays, and an externally-mounted rescue hoist.

The objective of this report is to describe the results of performance tests on the medical oxygen system. This information will be useful to the Utility Helicopter Project Manager when evaluating how each component of the medical interior enhances or degrades the ability of a typical flight medic to perform his duties.

## Materials and methods

The medical oxygen system on the prototype aircraft includes an oxygen generator and support equipment. The oxygen generator is a molecular sieve oxygen generator system (MSOGS) with oxygen storage capability. It requires a compressed air source and electrical power to operate. The unit, manufactured by Litton Instruments and Life Support, includes an oxygen sensor that directs only high concentration (94% or greater) oxygen to the patient or storage system. It is capable of producing 27 lpm of greater than 90% oxygen. Oxygen that is produced in excess of the immediate patient requirements is stored in a backup oxygen supply (BOS). The BOS is a system of two storage tanks that are capable of storing 262 liters of oxygen at 450 psi. The Litton oxygen generator has previously been evaluated at the U.S. Army Aeromedical Research Laboratory (Squire, Bruckart, Quattlebaum, and Johnston, 1993) and is shown in Figure 1.

In the prototype aircraft, compressed air is obtained as bleed air from the aircraft engines, routed through a heat exchanger, and provided to the Litton MSOGS. Oxygen produced by the unit is regulated at the unit and supplied at a lower pressure (approximately 40 psi) to support equipment including a flow meter, oxygen concentration analyzer, and six

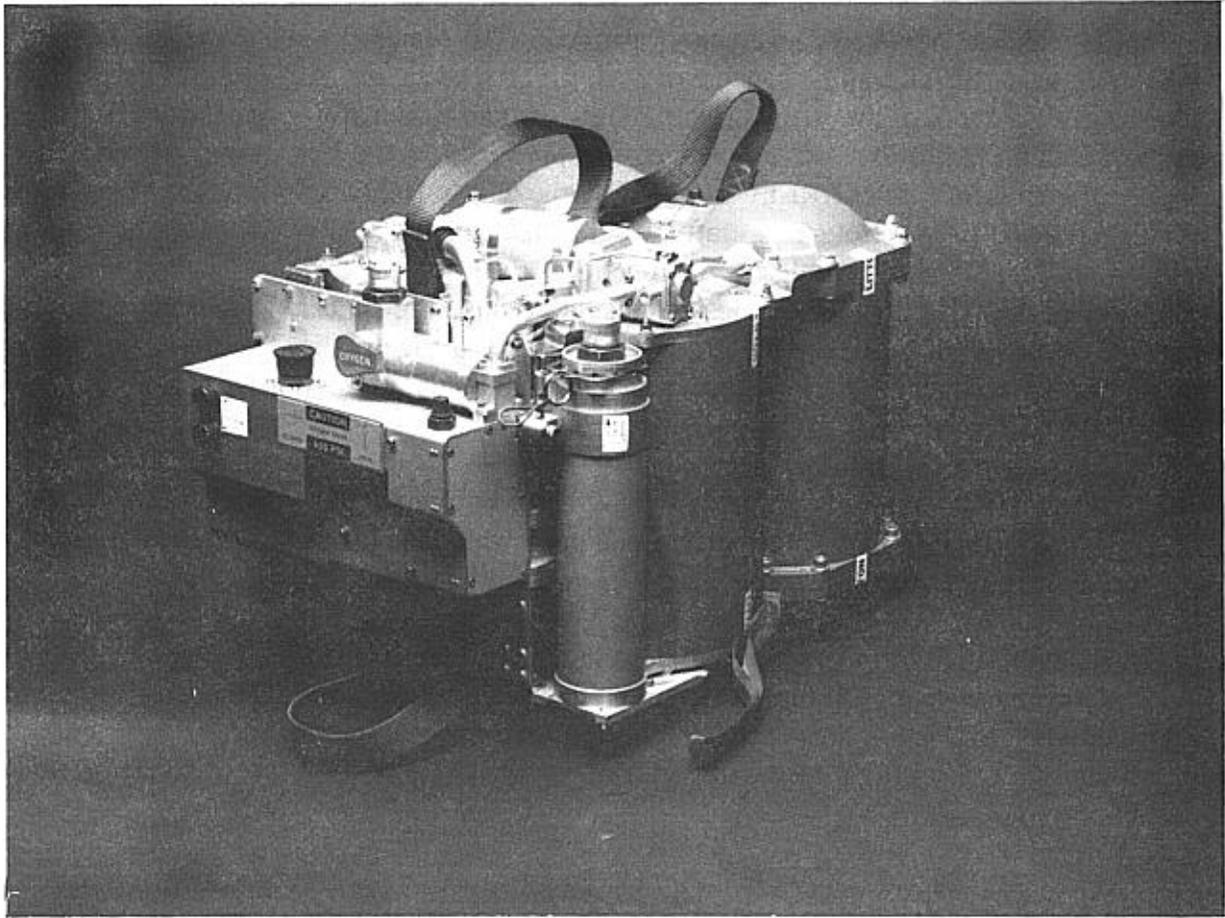


Figure 1. Litton molecular sieve oxygen generator.

flow controllers. The support equipment has been assembled and designed by Air Methods, Inc. for inclusion in the prototype aircraft. The medical aidman control panel, includes light emitting diode (LED) displays of the oxygen flow, oxygen concentration, and oxygen supply quantity. The oxygen outlets include six (three per side) flow selector valves, two (one per side) quickfit connectors for humidified oxygen, and two (one per side) crew oxygen outlets suitable for use with a nasal canula or rebreathing mask. These oxygen outlets, shown in Figure 2, are located on the bulkhead in front of the main cabin door on each side of the aircraft.

The performance of the molecular sieve oxygen generator was evaluated by measuring available bleed air pressure and temperature, oxygen flow, and oxygen concentration when the unit is operated with bleed air provided by the auxiliary power unit (APU). Limitations on the airworthiness release for the aircraft prevented operation of the unit in flight.



Figure 2. Medical oxygen outlets.

The performance of the support equipment was evaluated by comparing the displayed oxygen flow and concentration with the measured flow and concentration from calibrated flowmeters and an oxygen sensor. The oxygen flowmeters also were used to compare the selected and actual flow for the oxygen selector valves.

The ability of the unit to store oxygen was evaluated by fully charging the BOS, shutting off the generator, and noting the number of liters delivered by the BOS. Leaks from the system were evaluated by noting the change in stored oxygen pressure as a function of time.

### Results

The medical oxygen system is capable of producing high concentration oxygen and delivering it to a simulated patient. The measured pressure and temperature of bleed air, from the APU, at the inlet of the MSOGS unit was 39 psi and 92.6 degrees F respectively. The maximum pressure in the BOS was 330 psi which was achieved 37 minutes after the MSOGS began charging the BOS (with no oxygen flow to the patients). The BOS was drained at a constant flow of 6.2 liters per minute for 26.25 minutes, indicating a total volume of 162.75 liters. The indicated concentration of oxygen delivered by the MSOGS was 94% at all times.

The LED displays of the oxygen concentration, BOS pressure, and oxygen flow did not operate properly during the testing. Each display flashed a number that did not correlate with the actual value for the parameter. No trend was noted in comparing the changes in the flashing numbers to changes in the actual parameter being measured.

There was no correlation between the selected and measured flow of oxygen delivered to the patients. A comparison of the selected and measured oxygen flow are presented in Table 1. This table also includes bleed air (inlet) and oxygen (outlet) temperature, pressure, and concentration for the MSOGS.

**Table 1.**  
Comparison of displayed and measured oxygen flow for various flow settings.

Bleed air temp. (°F)	Bleed air press. (psi)	Outlet air (oxygen) temp. (°F)	Outlet air (oxygen) press. (psi)	Selected flow (lpm)	Actual flow (lpm)	Oxygen concentration
92.6	30-39	81.8	15	17	5.1	94
93.2	30-39	83.3	15	34	10.2	94
95.0	30-39	85.1	14	51	15.3	94
96.4	30-39	86.9	15	70	20.4*	94
96.4	30-39	85.8	12	90	25.5*	94

\*intermittent BOS light indicates that some flow may be from backup supply.

There were significant leaks in the oxygen delivery system. The loss of BOS pressure as a function of time is shown in Figure 3.

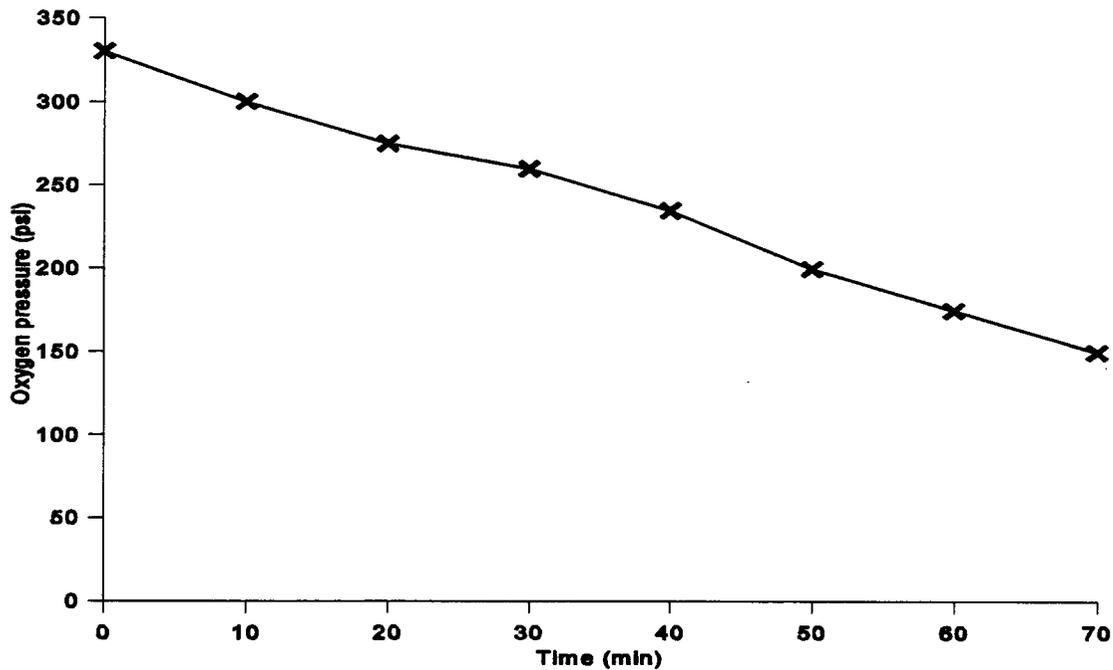


Figure 3. Leakage from the backup oxygen supply is shown as the change in pressure over time.

### Discussion

The molecular sieve oxygen generator in the prototype MEDEVAC aircraft is capable of producing high concentration oxygen from bleed air. The bleed air temperature and pressure were sufficient to produce 15 to 20 lpm continuous oxygen flow or charge the backup oxygen supply to store 162.75 liters of 94% oxygen. Laboratory evaluation of this unit showed it capable of an outlet flow of 27 lpm or BOS storage of 262 liters of oxygen (Squire, Bruckart, Quattlebaum, and Johnston, 1993). The difference likely is the result of lower inlet pressures for engine bleed air (30-39 psi) compared to the compressed air (typically 60 psi) used in the laboratory evaluation. In-flight testing is required to determine if the MSOGS performance with different bleed air inlet pressure at altitude.

The operational requirements document for the MSOGS requires the unit provide 3 lpm of high concentration oxygen, to at least two-thirds of the litter stations, with a 20-minute oxygen reserve. The unit, as it is installed currently, is capable of meeting the flow requirement (12 lpm), but limited to 13.6 minutes reserve from a fully-charged BOS.

The LED displays in the prototype aircraft do not function properly. The concentration of oxygen that is delivered by the MSOGS is regulated by an oxygen analyzer in the unit. If the unit is not capable of producing oxygen in excess of a preset concentration, then no gas will be delivered. Hence the presence of a second oxygen analyzer in the aircraft is redundant and potentially confusing to operators. The oxygen concentration analyzer should be eliminated from the design since it offers no new information to the operator.

The selected flow did not match the actual flow for the oxygen selectors. These selectors are calibrated to deliver a set flow given a minimum supply pressure. Since the supply pressure was 12 to 15 psi, it is likely that these selectors required a greater supply of pressure to regulate flow. If the regulated pressure is maintained, the total flow is the sum of the selected flows. Recommend the inoperative flow sensor be eliminated from the design and the oxygen pressure be regulated to ensure sufficient supply pressure is maintained for the oxygen selectors. One means of accomplishing this is to eliminate excess flow selectors (only four required) and limiting the total flow through the four selectors to less than the production capacity of the MSOGS. This has the added benefits of reducing equipment costs and simplifying the operation of the system for the medical aidman.

There was significant leakage of oxygen from the oxygen storage system. Prior evaluation of the unit showed it capable of maintaining BOS pressure for several days when fully charged. The regulator for the BOS should be located as close to the generator as possible to minimize the potential for leaks in the high pressure (up to 450 psi) stored oxygen. To prevent the loss of oxygen from low pressure fitting, a solenoid, to shut-off flow from the BOS when aircraft power is off, may be required. Final design of the oxygen system and procedures for operating the MSOGS require hazard analysis to ensure procedures are available to detect and prevent oxygen leakage.

### Summary

The MSOGS in the prototype UH-60Q MEDEVAC aircraft is capable of producing and storing high concentration oxygen from bleed air. The unit was capable of producing 15 to 20 lpm of 94% oxygen and storing 162.75 liters of oxygen. This performance is less than expected from laboratory testing, and likely the result of lower inlet pressure. The unit currently is able to provide the required oxygen flow for the aircraft, but only two-thirds of the stored oxygen required. In addition, in-flight tests are required.

The LED displays do not function. The oxygen concentration analyzer is redundant and the oxygen flow display could be eliminated by regulating oxygen pressure and limiting total flow. The oxygen regulator should be located as close to the BOS as practical to reduce oxygen leakage. A solenoid may be required to stop all oxygen flow from the BOS when aircraft power is off.

## References

- Department of the Army. 1992. Appendix 1, UH-60A Black Hawk materiel need, production, dated 1979, (MN) (P) for Dustoff Black Hawk (UH-60Q).
- Department of the Army. 1979. UH-60A Black Hawk Materiel Need, Production, dated 1979 (MN) (P)
- Squire, B. E., Bruckart, J. E., Quattlebaum, M. D., and Johnston, L. W. 1993. Laboratory test and evaluation of the Litton Model F15E molecular sieve oxygen generating system. Fort Rucker, AL: U. S. Army Aeromedical Research Laboratory. USAARL Report No. 93-22.

**Appendix A.**  
**Mission profile summaries.**

**A. AEROMEDICAL EVACUATION (SOUTHWEST ASIA).** The UH-60Q, collocated with a forward support medical company in direct support to a maneuver brigade, receives a mission to transport a trauma treatment team from the forward support medical company forward to a battalion aid station and then evacuate six litter patients and one ambulatory patient from the battalion aid station to the division clearing station located in the brigade support area (BSA). The UH-60Q departs the BSA with the trauma treatment team and flies at an airspeed of 120 knots using contour flight technique for 67 nautical miles (nm) and then slows to an airspeed of 30 knots using NOE flight technique for the last 3 nm to the battalion aid station. The trauma treatment team is off-loaded and the patients are loaded into the aircraft. (20 minutes allocated for loading and unloading) The UH-60Q departs the battalion aid station using NOE for the first 3 nm and then transitions to contour flight for the remaining 67 nm to the BSA. The patients are off-loaded at division clearing station (10 minutes allocated) at which time the aircraft is ready for the next mission. Total time for the mission, to include patient loading and unloading times, is approximately 118 minutes.

Event	Distance (nm)	Speed (kts)	Flight mode	Time (min)
1 - 2	70	120/30	LL/NOE	44
Load patients			Landed	20
2-3	70	30/120	NOE/LL	44
Unload patients			Landed	10
<b>TOTAL</b>	<b>140</b>			<b>118 (1.9 hr)</b>

**B. AEROMEDICAL EVACUATION (MAST).** A UH-60Q located at a military installation receives a night MAST mission to transfer two patients involved in a traffic accident from a small community hospital to a medical center capable of providing life saving (definitive) medical treatment. The gaining hospital requests the mission and provides two nurses and a critical care physician to assist in the enroute care of the patients. The weather is marginal but acceptable. The small community does not have an airport or weather reporting capability and is not situated along the FAA enroute and terminal flight system. After pre-mission planning, the crew flies to the medical center (8 nm, 125 kts, low level) to pick up additional health care providers (5 minutes for loading). The crew uses onboard navigational equipment to locate and fly to the community hospital (80 nm, 120 to 145 kts, contour or low level). Unforecast weather was encountered at the pickup site. After landing, the health care team goes into the hospital to obtain patient briefings and execute transfer of patient responsibility (10 minutes for loading). The physician and the medic attend the adult patient while the nurses attend the baby. Once

loaded, the crew departs for the medical center. The patients require constant enroute treatment and monitoring on the return flight. The health care providers must use white light to provide appropriate care and must talk back and forth constantly. The female patient's condition deteriorates requiring the physician to contact the medical center to alert the operating room personnel of the requirement for immediate surgery upon arrival. Upon landing at the hospital helipad, the patients are off loaded and moved into the hospital. The flight crew returns to the military installation (8 nm) and mission is complete. Total mission time is 2 hours.

Event	Distance (nm)	Speed (kts)	Flight mode	Time (min)
1 - 2	8	125	LL	5
Load personnel			Landed	5
2-3	80	120-145	LL	40
Load patients			Landed	10
3-4	80	145	LL	35
Offload patients			Landed	10
4-5	8	125	LL	5
<b>TOTAL</b>	<b>176</b>			<b>120 (2 hr)</b>

C. AEROMEDICAL EVACUATION (PERSIAN GULF). Low level flight for a distance of 200 nm with an airspeed of 110 to 120 kts. Hoist rescue from a hover of less than 70 feet (25 minutes allowed) followed by 170 nm low level flight at 110 to 120 nm. At this point, the patients are offloaded and the aircraft flies 50 nm (low level) at an airspeed of 110 to 120 kts.

Event	Distance (nm)	Speed (kts)	Flight mode	Time (min)
1 - 2	200	110-120	LL	120
Rescue			Hover	25
2-3	170	110-120	LL	105
Unload patients			Landed	
3-4	50	110-120	LL	25
Offload patients			Landed	10
<b>TOTAL</b>	<b>420+</b>			<b>275-305 (5.1 hr)</b>

Adapted from Annex B, Appendix 1, UH-60A Black Hawk Materiel Need, Production, dated 1979 (MN) (P)