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AEROMEDICAL EVALUATION OF THE ARMY MOLECULAR SIEVE  
OXYGEN GENERATOR (AMSOG) SYSTEMS

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engine bleed or compressed air at 40 PSIG, 20 to 22 liters per minute (LPM), normal temperature 70°F, pressure 760 Torr, dry (NTPD). Ninety-four percent (94%) oxygen is expected to support both physiologic needs and provide denitrogenation capabilities for US Army aircrew. Argon is concentrated to levels of 6-8% and is considered to be low; however, physiologic effects have not been fully defined. In-flight studies and toxicology evaluation are continuing.

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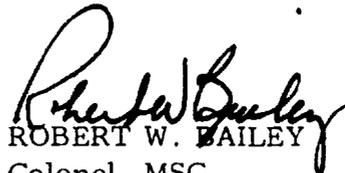
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## SUMMARY

The US Army Aeromedical Research Laboratory (USAARL) was tasked by The Surgeon General to evaluate available oxygen systems to meet a Required Operational Capability (ROC) for helicopter usage. Advanced technology for oxygen generators indicated a significant breakthrough in molecular sieve capabilities. Two Army molecular sieve oxygen generators (AMSOG) were obtained configured for the two man aircrew OV-1 Mohawk observation aircraft. Initial aeromedical evaluation using bench and hypobaric chamber methods indicates a capability of 90-94% oxygen at 20-22 liters per minute (LPM), normal temperature 70° F, pressure 760 Torr, and dry (NTPD). Argon has also been identified as increased. Physiologic effects of the Argon admixture are considered nonsignificant although not fully defined. Studies to include in-flight aeromedical studies and toxicologic evaluation are continuing to fully define the operational aspects of this technology.

  
ROBERT W. BAILEY  
Colonel, MSC  
Commanding

## AEROMEDICAL EVALUATION OF THE ARMY MOLECULAR SIEVE OXYGEN GENERATOR (AMSOG) SYSTEMS

### BACKGROUND

The US Army Aeromedical Research Laboratory (USAARL) was tasked by The Surgeon General to evaluate oxygen systems to meet a proposed Required Operational Capability for helicopter rescue missions. During this evaluation advanced technology for oxygen generation was explored. With the constraints of weight, size and electrical power in US Army aircraft, the molecular sieve generator appeared to meet the operational needs. Two molecular sieve oxygen generator systems were obtained for evaluation. The design of these initial prototypes was predicated on direct replacement of current oxygen equipment for the two man crew OV-1 Mohawk surveillance aircraft. Application to other fixed and rotary wing aircraft is to be developed following initial evaluation. This report provides the Phase I (bench) evaluation of the two man Army Molecular Sieve Oxygen Generator (AMSOG) Systems.

### SYSTEM DESCRIPTION

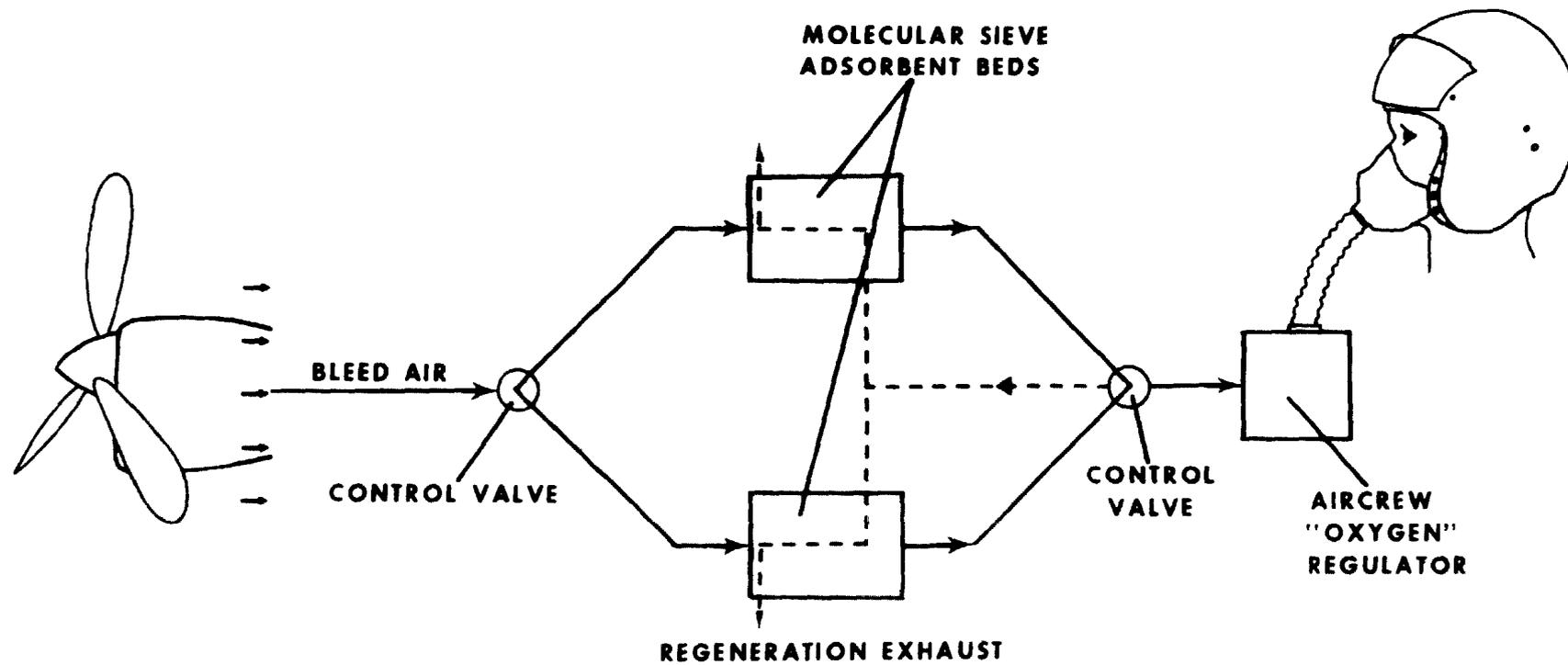
Engine bleed air is passed through a system of absorbent beds of molecular sieve. The nitrogen is absorbed resulting in an oxygen rich effluent. The bleed air provides the flow and pressure required for system operation. Electrical power 28 VDC or 115V 400 Hz power is required from aircraft system for control of valves. Particulate and droplet filters are installed upstream of the system. The absorbent beds are recycled by use of oxygen rich output air. The schematic diagram (Schematic I) is simplified to demonstrate basic system description.

### MATERIALS AND METHODS

Phase I (bench) evaluation of the Bendix and Garrett AMSOG utilized a 12 cubic feet per minute (CFM) two stage air compressor as the source of "bleed air pressure". The pressure was varied by valve to the AMSOG. Flow was controlled by flow limiting orifices (Gelman) and calibrated flow meters (Fischer and Porter). The delivered oxygen concentration was determined by a Beckman E-2 fast response paramagnetic analyzer.

Contaminant analysis of AMSOG was monitored by a JOEL DMS 100-231 gas chromatograph-mass spectrometer and a modified Varian EM 600 mass spectrometer.

Phase II (hypobaric chamber) utilized the equipment, as previously described, in the hypobaric chamber to determine oxygen delivery during climb to altitude.



**SCHEMATIC  
ARMY MOLECULAR SIEVE OXYGEN GENERATOR  
(AMSOG)**

The Garrett system was evaluated in one configuration. The Bendix system was evaluated in two configurations identified as Bendix and Bendix II. The Bendix II system indicates a proprietary change in molecular sieve configuration and type to meet the stated needs of the US Army to increase oxygen percentage available at low altitude (sea level).

## RESULTS

The results are plotted in graph form. Figures 1 through 8 provide the measured values of percent oxygen delivered at varied flow requirements liter per minute (LPM) corrected to 70°F, 760 mm Hg, dry (NTPD). The data presented is that obtained from the Bendix II and Garrett systems. Altitudes are indicated in 1000 feet increments (K).

Figures 9 through 15 reflect the data collected from the Garrett and original Bendix systems. Figures 9 and 10 demonstrate the increased oxygen percentage produced with increasing altitude at varied inlet supply pressure and fixed flow [27.92 LPM (NTPD)].

Figures 11 and 12 indicate the oxygen delivery during two climb rates under constant flow and inlet pressure. This data is for the original Bendix molecular sieve configuration and the Garrett system.

Figures 13 and 14 indicate the bed efficiency measuring oxygen percent at fixed flow rates at random intervals during the period of evaluation. This data again is the original Bendix molecular sieve. The data is indicative of the ageing changes of the molecular sieve bed.

Figure 15 demonstrates the Argon concentration by the original Bendix and Garrett systems under constant flow and inlet pressures.

## DISCUSSION

The AMSOG systems evaluated demonstrate complex interaction of inlet pressure, flow rates and altitude.

As is shown, the systems provide essentially a physiologic curve of oxygen with the higher flow rates. With flows of 20 to 22 LPM (NTPD) and 40 psi supply pressure the Bendix II system provides 94% oxygen at sea level (Figure 1). At 25,000 feet lower supply pressure is tolerated by system while maintaining the 94% oxygen output (Figure 7). The Garrett systems have a less concave curve but supply lower oxygen concentration at the lower altitudes. Both systems demonstrate a slight dip in initial oxygen percent during hypobaric chamber climb at 1000 and 4000 feet per minute. This data, however, compares the original Bendix and Garrett (Figures 11 and 12).

# BENDIX II

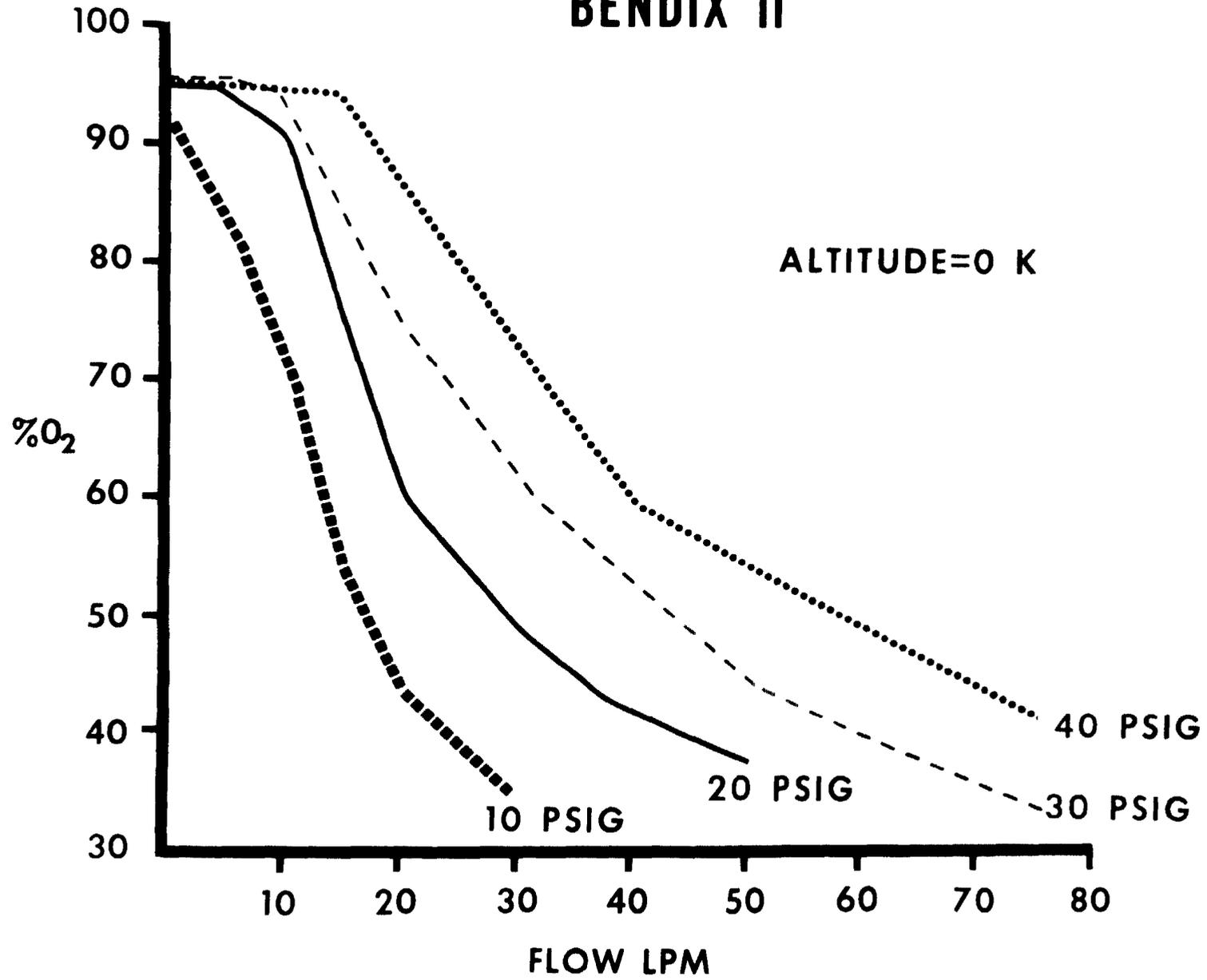


Figure 1

# GARRETT

ALTITUDE=0 K

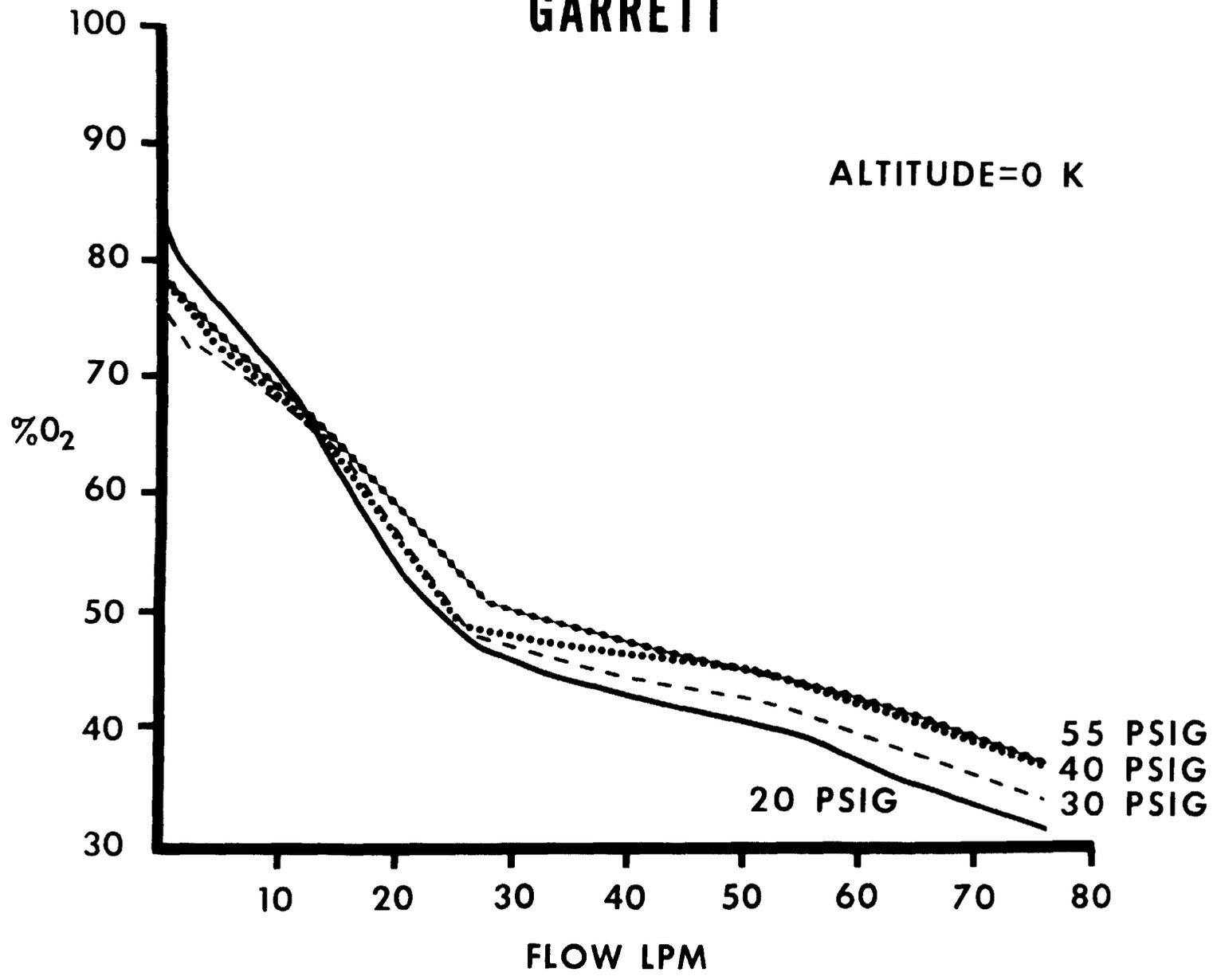


Figure 2

# BENDIX II

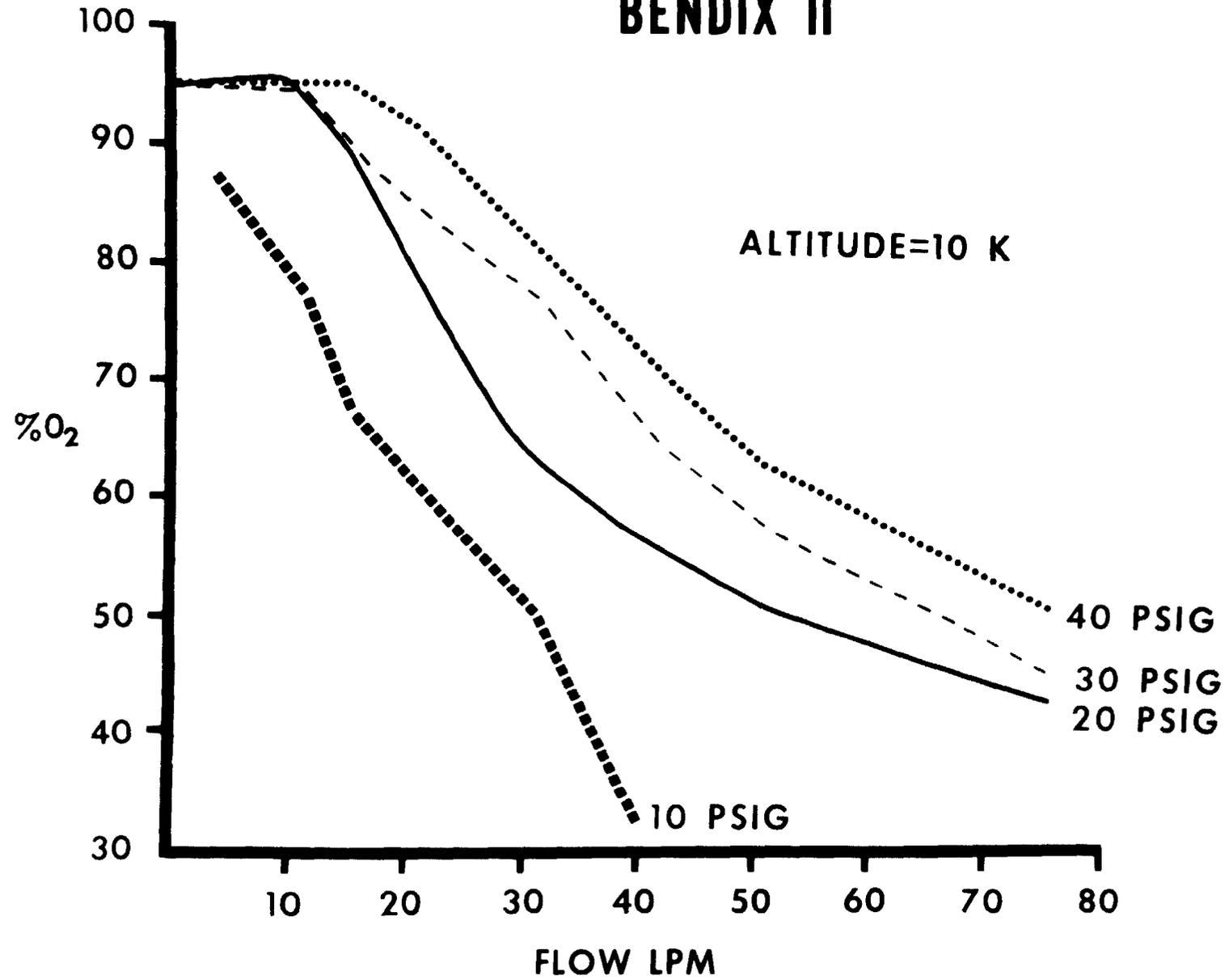


Figure 3

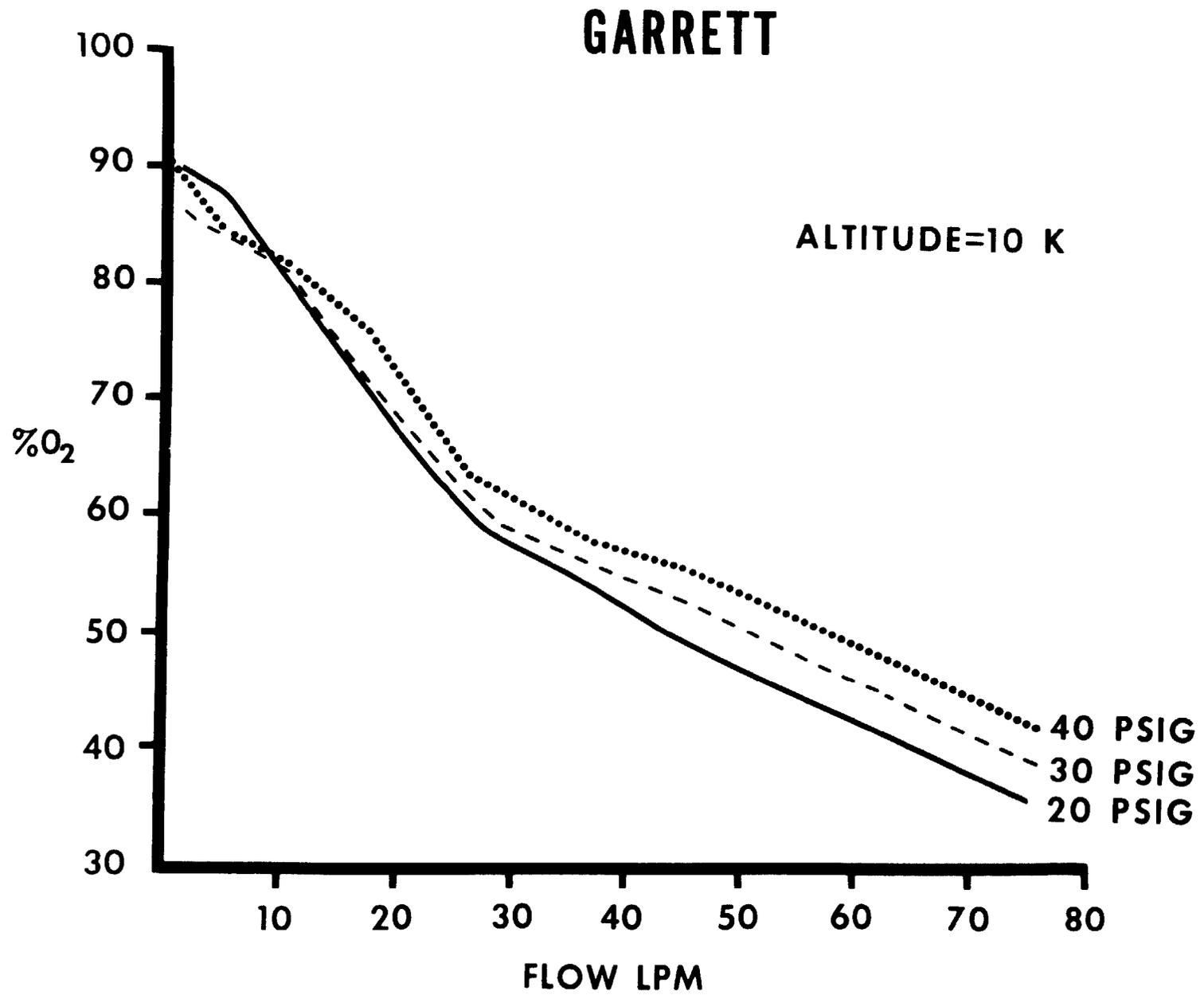


Figure 4

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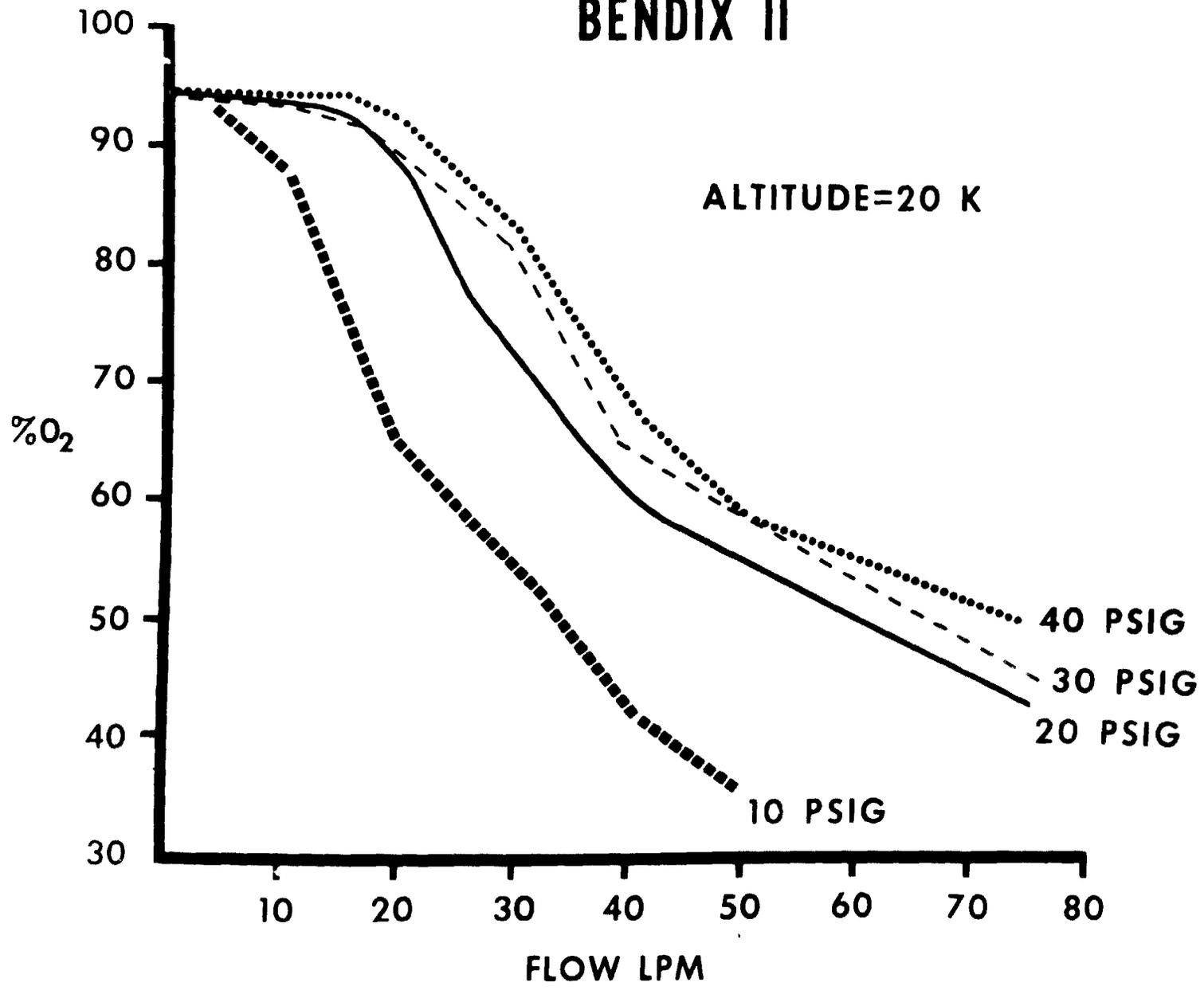


Figure 5

# GARRETT

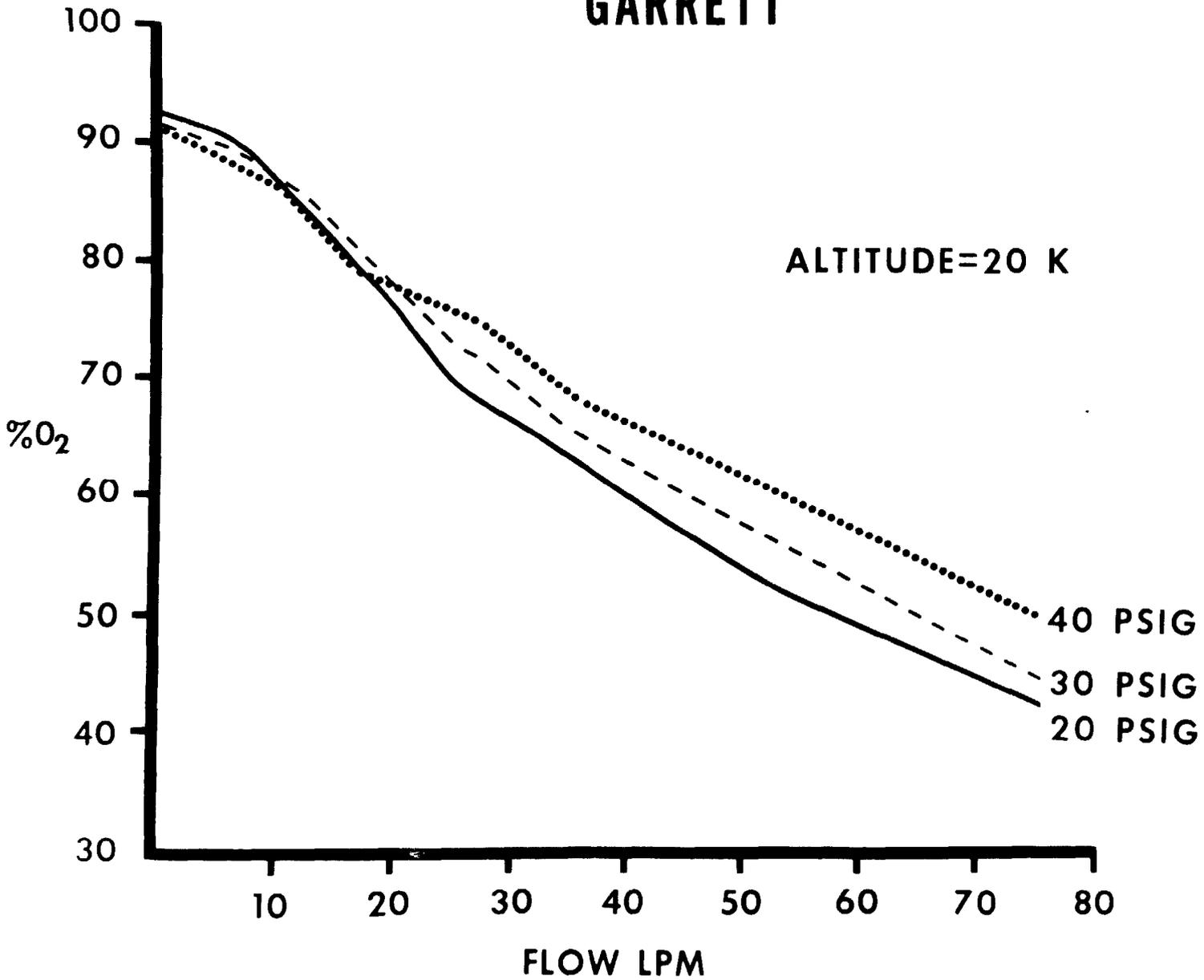


Figure 6

# BENDIX II

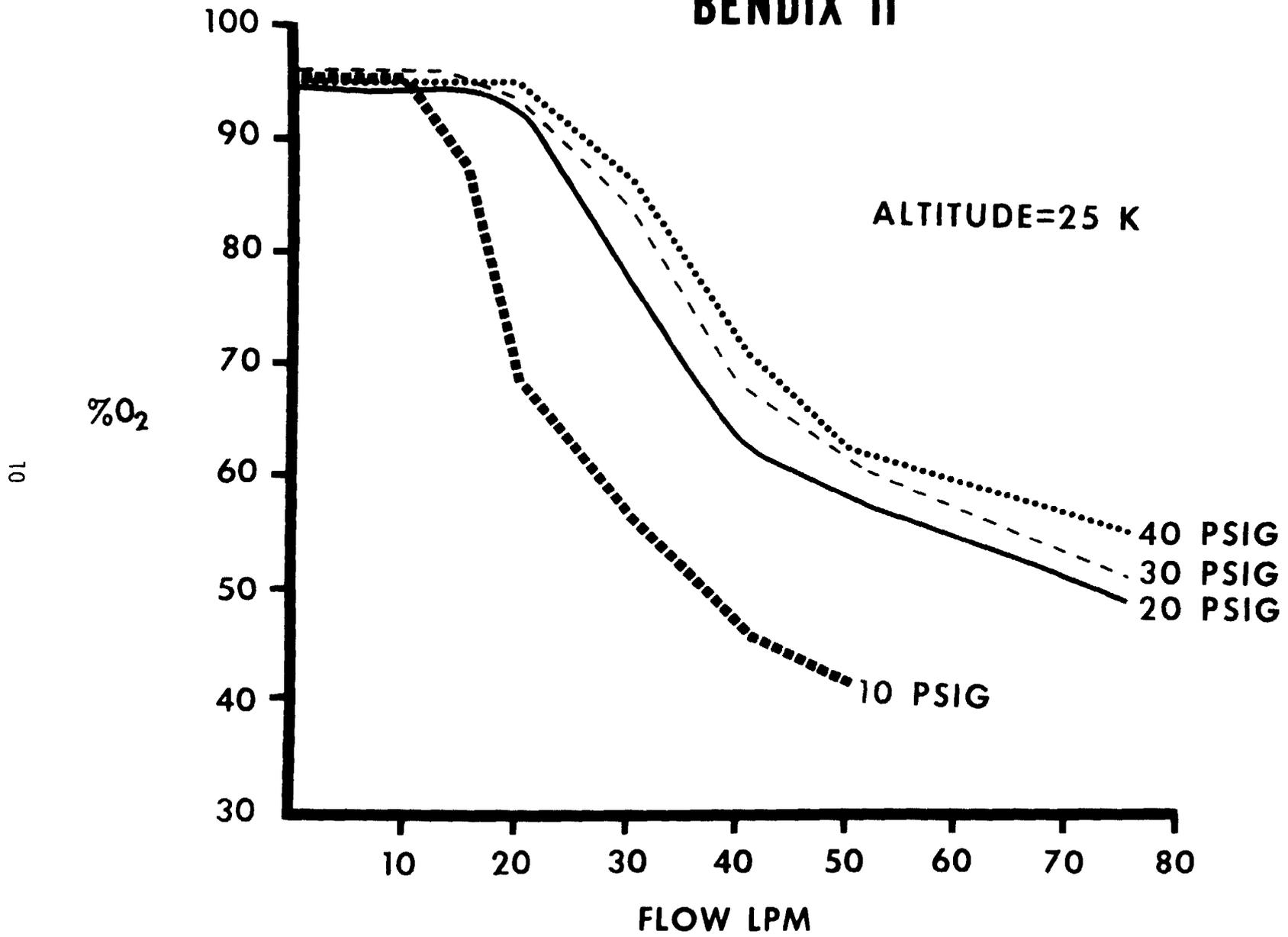
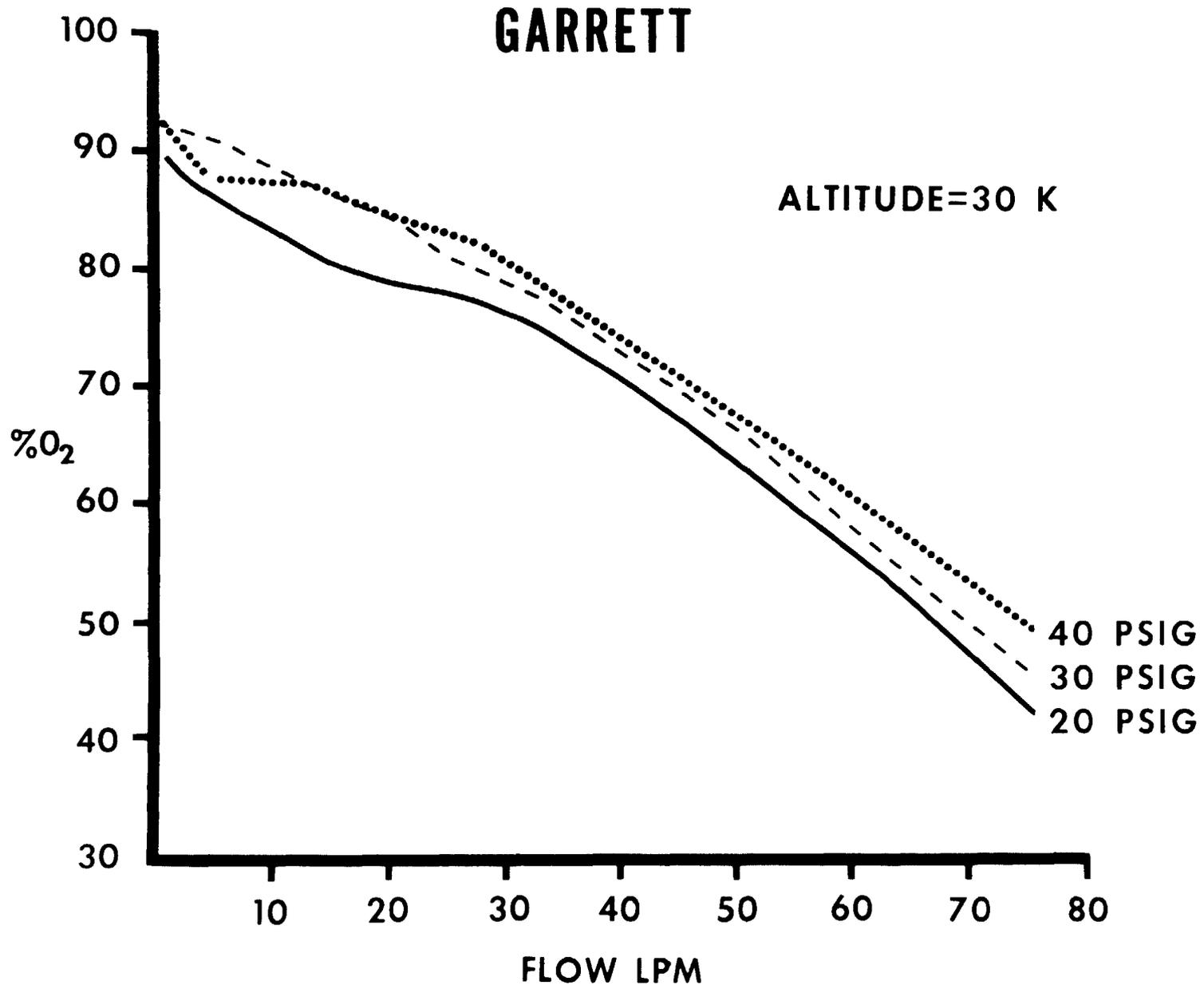


Figure 7



11

Figure 8

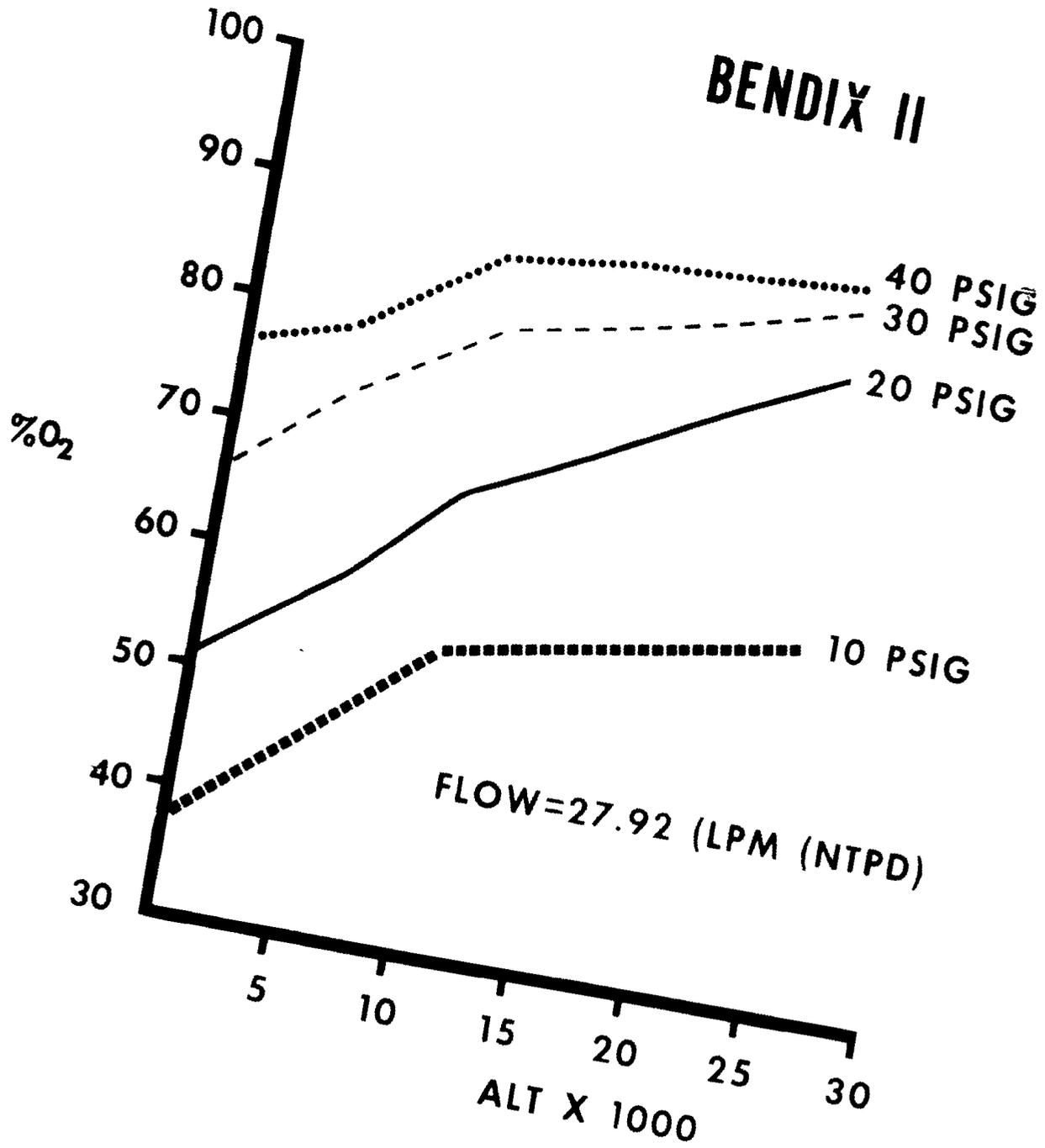


Figure 9

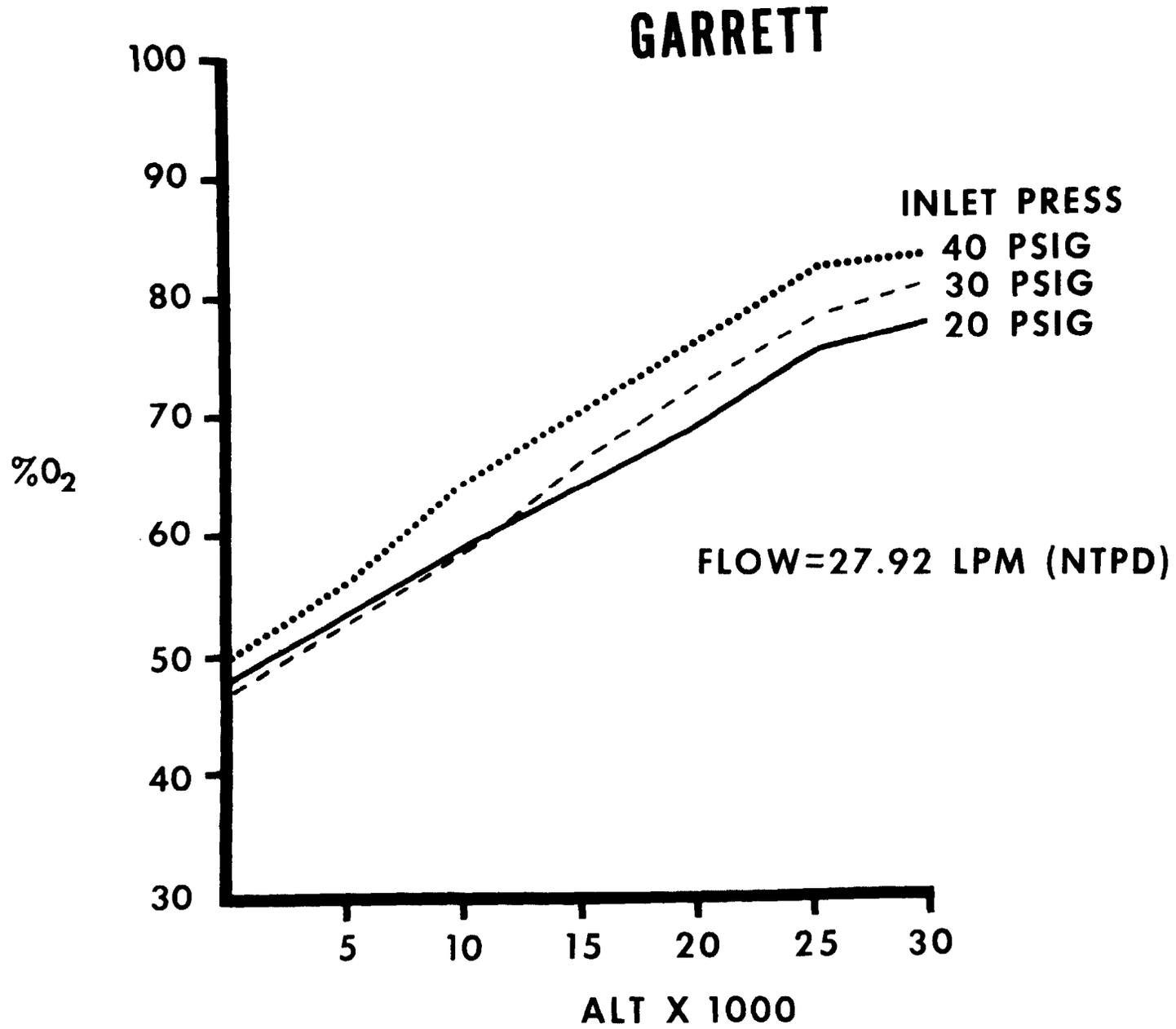
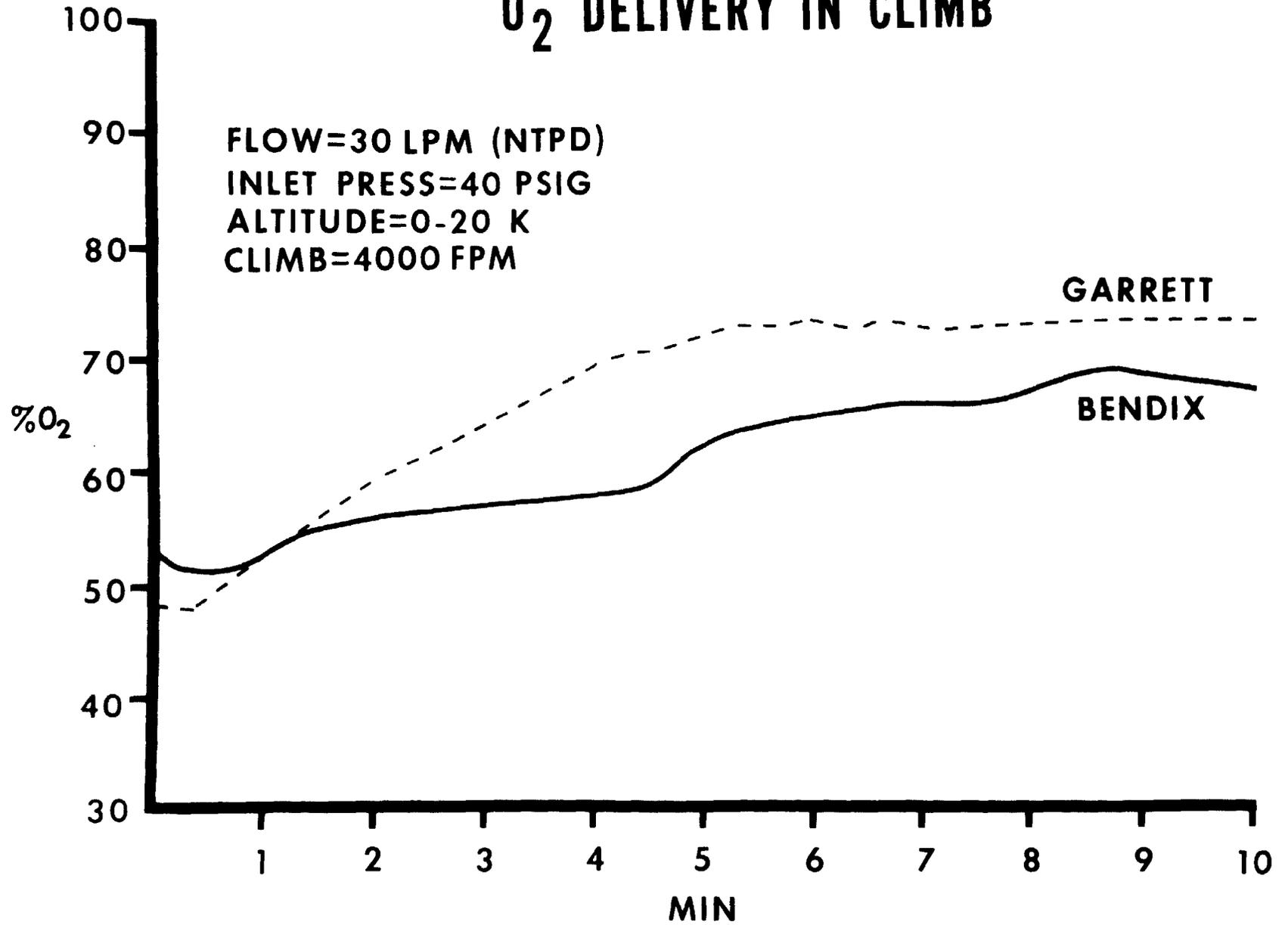


Figure 10

# O<sub>2</sub> DELIVERY IN CLIMB



14

Figure 11

15

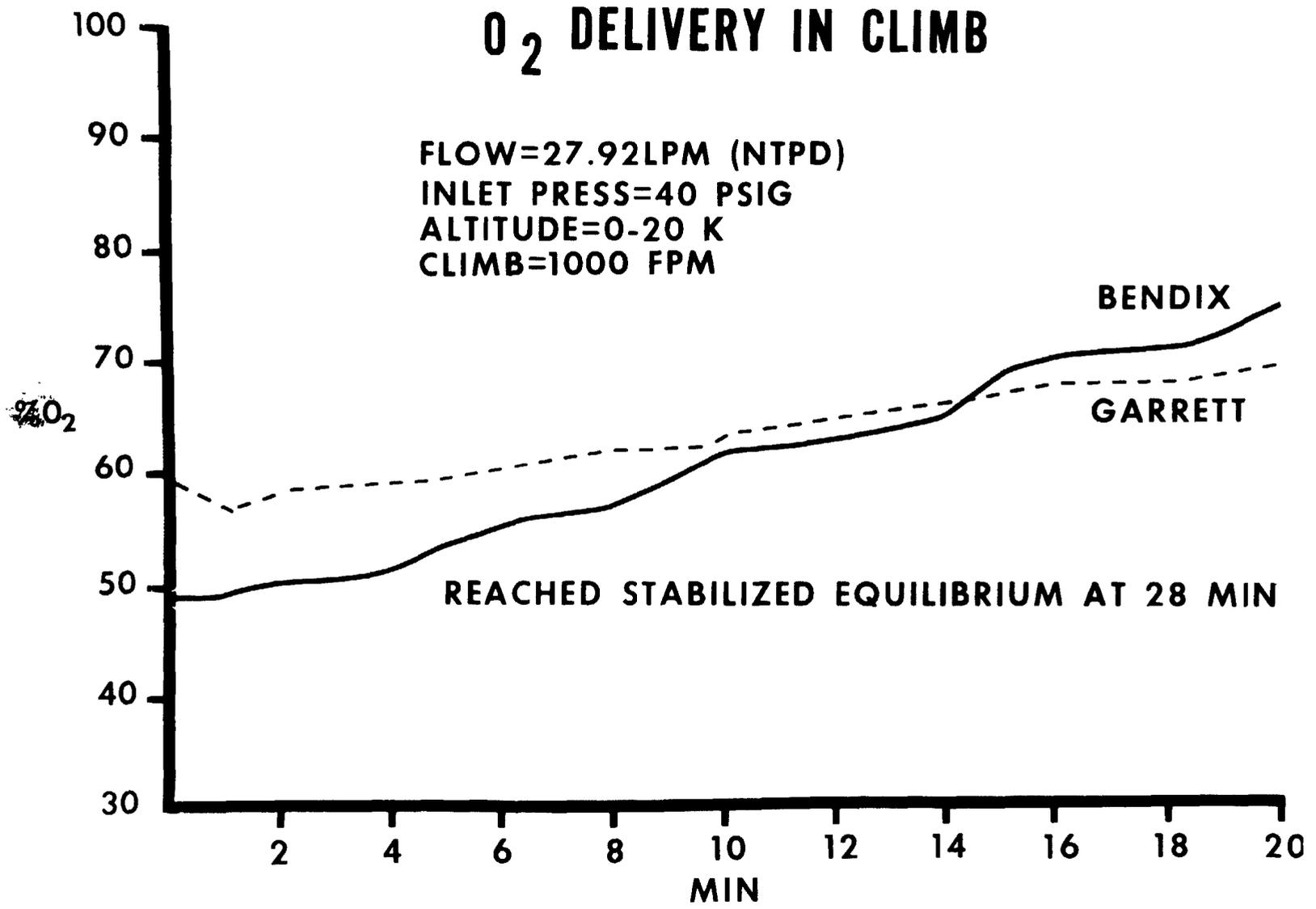


Figure 12

# BED EFFICIENCY

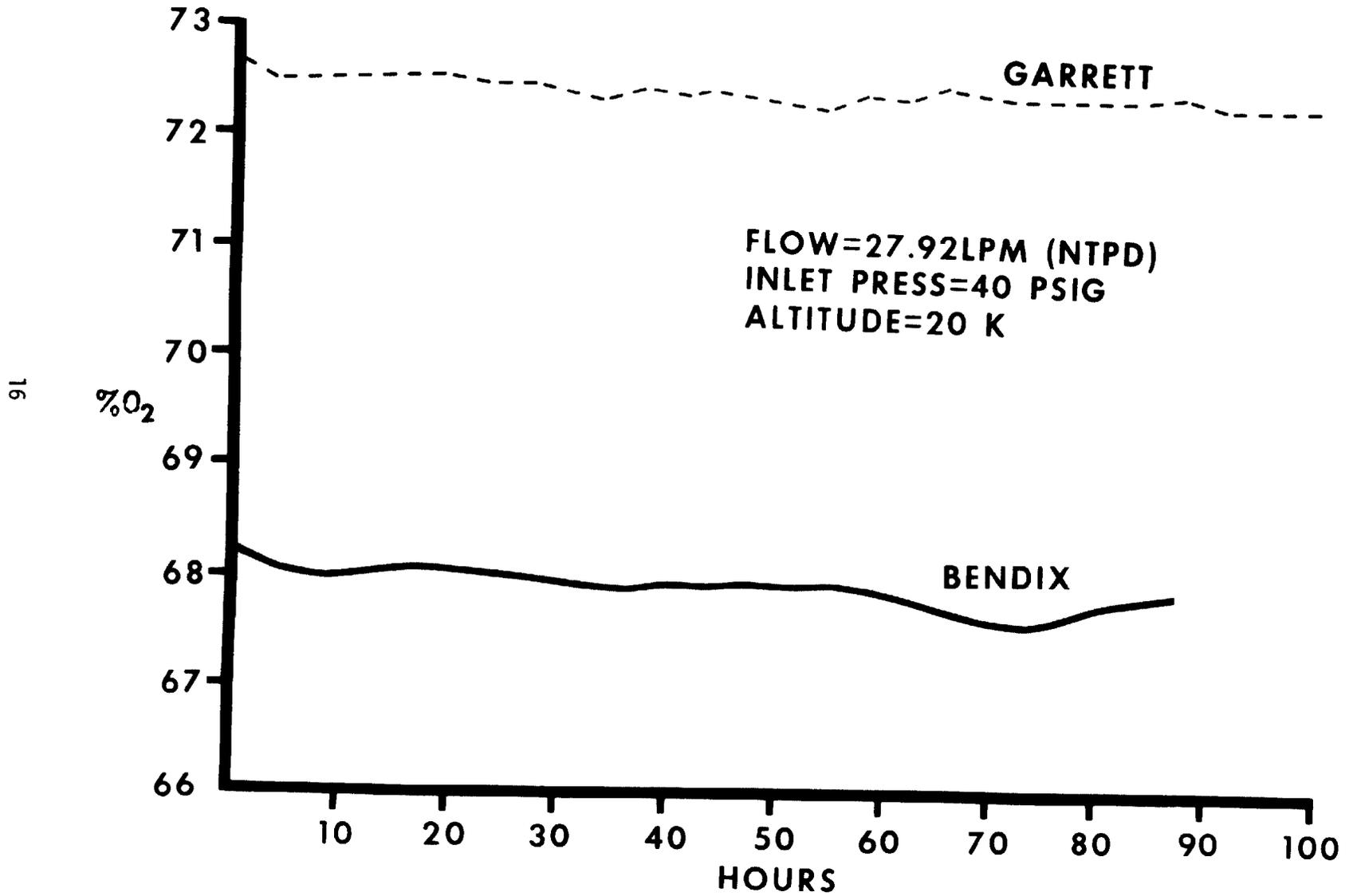


Figure 13

# BED EFFICIENCY

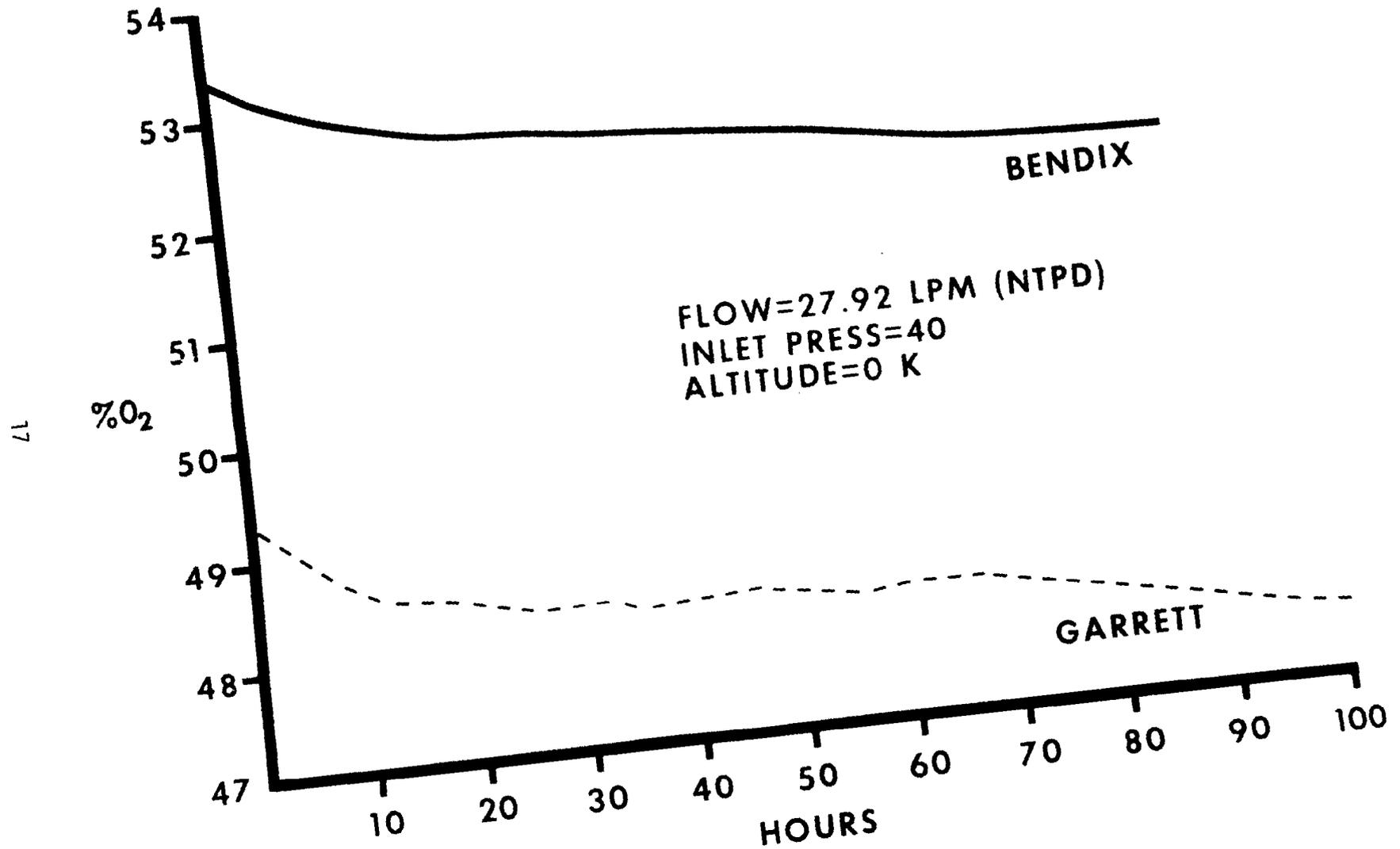


Figure 14

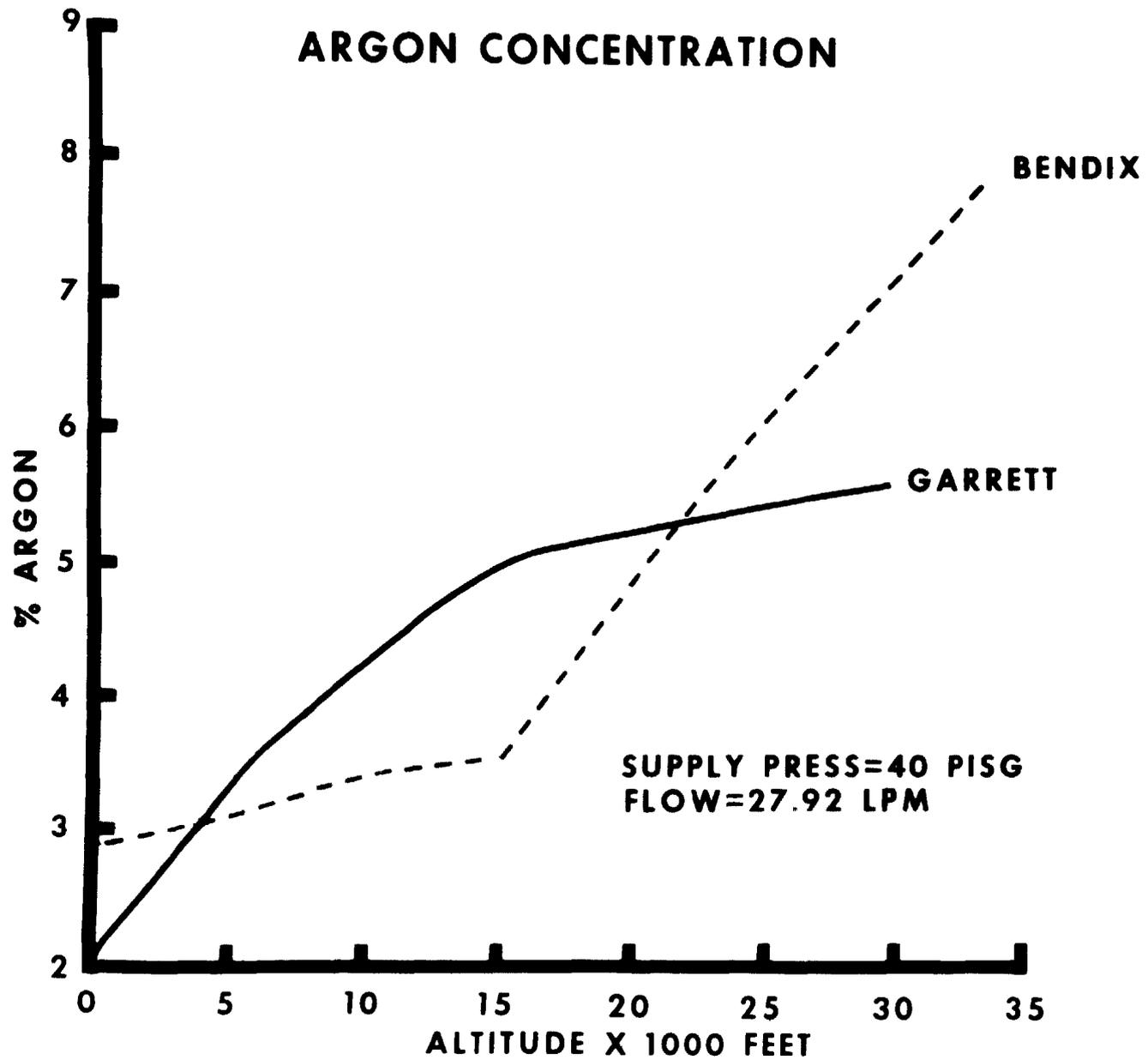


Figure 15

After 85 hours at an altitude of 20,000 feet there was a minimal decrease in bed efficiency.

At sea level, both systems demonstrate a slow loss of efficiency (Figure 15). This finding is considered to possibly reflect the relative humidity and pressure effects. A further evaluation of this idiosyncrasy is required.

Table 1 reviews the aeromedical questions arising from this initial evaluation.

TABLE I

AMSOG AEROMEDICAL DESIGN PARAMETERS

I. PHYSIOLOGIC REQUIREMENTS

1. Physiologic and/or denitrogenation oxygen requirements.
2. Delivery pressure (to include: crew regulators, pressure breathing capabilities, and safety pressure).
3. Reserve/bailout source (chlorate candle).

II. BLEED AIR CONSIDERATIONS

1. Pressure and quantity available effect on A/C power, minimal power setting for adequate oxygen delivery.
2. Temperature (input to AMSOG, output to crew).
3. Contaminants - engine toxic gases, oil, water, particulate matter, engine fire, CBR protective requirements.

III. FAILURE MODES

1. Component failure - type of indicator, emergency/reserve O<sub>2</sub>.
2. Loss of one engine or two engines.
3. Primary electrical failure.

The needs of the various services must determine the percentage of oxygen necessary for physiologic needs in addition to the requirement for denitrogenation. The AMSOG delivery pressure of approximately 60% of inlet pressure will require consideration of regulator design, pressure breathing and safety pressure requirements. A reserve/bailout source for the US Army would appear to be best served by a chlorate candle source with appropriate failure mode indicators.

Bleed air usage requires consideration of pressure available at various power settings. In the OV-1, baseline data would indicate a need for 90% N<sub>1</sub> to insure adequate supply pressure and flow at sea

level. Temperature does not appear to be a problem based on initial limited data.

The contaminants of the OV-1 bleed air have been screened by mass spectrometry. Thirty components have been qualitatively identified. This data will be quantitated and discussed in subsequent reports.

The failure modes in use of a system no longer self contained and which is now dependent on engine bleed air and the aircraft electrical system must be considered in the total aircraft system design.

Lastly, chemical warfare must be considered. With the addition of filters, further pressure losses (inlet or outlet) would be anticipated.

Data analysis is continuing and will be presented as available.

#### SUMMARY

This report reviews the bench and hypobaric chamber evaluation of the Bendix and Garrett two man Army molecular sieve oxygen systems designed specifically for the unpressurized OV-1 Mohawk aircraft. The technology demonstrated can be applied to various US Army aircraft both fixed and rotary wing. The Bendix II AMSOG is capable of producing 90-94% oxygen at 20 LPM flow at sea level and should support denitrogenation. Argon levels are considered to be low; however, physiologic consequences have not been fully determined to date. USAARL is continuing the efforts to develop the AMSOG as a complete oxygen system for fixed and rotary wing US Army aircraft.