

# PHYSIOLOGICAL EFFECTS OF A MECHANICAL COUNTER PRESSURE SUIT

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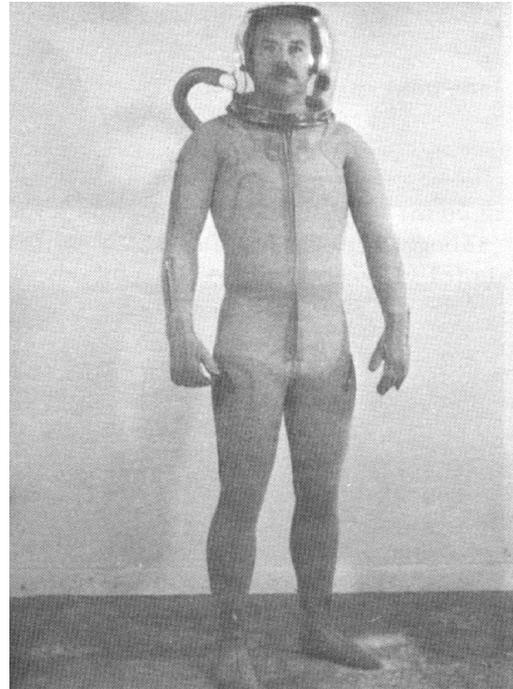
## INTRODUCTION

During extravehicular activity (EVA) life is normally supported by breathing oxygen at 222 mm Hg (4.3 psi) in a conventional full pressure suit, which pressurizes the entire body with oxygen. As an alternate approach, oxygen is delivered to a closed helmet at the same pressure while mechanical pressure is applied over the arms, legs and torso to balance the breathing pressure. If the mechanical pressure is supplied by a powerful elastic leotard, there are many advantages over the conventional space suit since no hard joints or bearings are needed. The concept and early experiments were published by Webb (1967, 1968), and the first demonstration of a complete elastic MCP suit was described by Annis & Webb (1971). There are other devices that apply force to the skin by elastic cloth and other means, such as with bladders that inflate under tightly fitted clothing. Elastic support hose and medical anti-shock trousers are two examples. They support circulation by aiding venous return to the heart. Another example is the anti-g suit, which is used in military aircraft to prevent blackout and loss of consciousness during pull up from a steep dive, or during tight turns at high speed. Bladders on the legs and over the abdomen inflate to prevent blood pooling in the lower body during the high-g maneuvers. This is an example of mechanical counter pressure (MCP), since the applied pressure counters the effects of the increased gravity field.

MCP garments have played another role. In World War II positive pressure breathing (PPB) was developed as a means of increasing blood oxygen tension to allow flying at altitudes higher than 40,000 feet. Without some form of counter pressure, PPB is limited to 20 – 30 mmHg. The British “jerkin” applied mechanical counter pressure to neck, trunk and proximal parts of the limbs, which allowed PPB at 80 mmHg for 10 minutes (Ernsting, 1966). A more complete solution is the partial pressure suit that provides counter pressure over the limbs and torso with non-stretch cloth and capstans to tighten the cloth. High breathing pressure allowed brief ascents to near-vacuum conditions, but circulatory problems, principally syncope, limited the degree of PPB and the duration of use (McGuire 1960). Specific circulatory problems included blood pooling, edema, and poorly perfused tissue.

The original elastic leotard developed by Webb showed major advantages over full pressure suits and the partial pressure suit in terms of increased mobility and dexterity, reduced metabolic cost of movement and excellent heat dissipation from the easy evaporation of sweat in near-vacuum conditions. Physiological heat dissipation promises significant reduction in the weight and complexity of life support equipment used for current EVA full pressure suits that require a cooling garment, stored refrigerant and machinery to dissipate heat. There was negligible blood pooling. This MCP garment, called a Space Activity Suit, was inherently safe, since punctures and tears would not cause the catastrophic loss of pressure of a full pressure suit.

Previous studies have documented that MCP is transmitted uniformly to skin and muscle tissues beneath a broad compression cuff or within pressure chamber (Hargens et al, JOR, 1987; Aratow et al, 1993). However vascular pressures remain relatively unchanged because blood continues to flow from the heart into tissues exposed the altered ambient pressure and back to the heart over a limited range of chamber pressures. The exact limits of overpressure and underpressure are unknown and form part of the basis for the present set of experiments. It is known that several hours of 30 mm Hg overpressure in passive muscle constitute a compartment syndrome and therefore, may risk tissue viability (Hargens et al, 1989). The limits of underpressure are less clear, but probably range between 40-50 mm Hg for several hours of lower body negative pressure, depending on activity level, age and gender (Aratow et al, 1993). In both cases, exercise improves tolerance to overpressures and underpressures by facilitating blood flow and venous return via action of skeletal muscle pumps (Hargens et al, Nature, 1987).



The goal of this research is to study the circulatory effects of wearing MCP garments for extended periods. Instrumentation will be noninvasive but yield quantitative data. Subjects will be inactive, which is the worst case condition, since the exercise of EVA will be a significant aid to circulation. The findings of this research program will be extremely useful to the further development of MCP garments and EVA suits in adverse pressure and gravity environments.

## CURRENT STATUS OF RESEARCH

### Methods

The objective of this research is to investigate the physiological effects of a mechanical counter pressure (MCP) garment on the human body. Quantitative measurements are obtained by over-pressurizing and under-pressurizing the MCP garment at various rates and for different exposure duration. Starting with the test subject's hand, the area of applied mechanical counter pressure is successively increased throughout the research project.

Mechanical Counter Pressure on the skin surface is adequate to maintain skin and muscle perfusion up to a certain limit of overpressure (defined as a garment pressure greater than ambient pressure). Localized areas of overpressure in an MCP glove are measurable, and their effects can be demonstrated:

- A recently devised fabric tensiometer, can measure the circumferential tension in elastic MCP garments; this allows a simple calculation of force applied to the part that is covered.  
$$P = T/r$$
 where P is pressure applied, T is the tension and r the radius of the part
- Measurement of pressure applied by an MCP glove using Flexiforce or similar sensors will correlate with the calculated pressure from the fabric tensiometer.
- Investigate the effects of wearing the existing MCP glove at overpressure levels of 20, 40, 60, 80, 100, 150 and 200 mmHg on local circulation.
- Measure blood perfusion in the skin and subcutaneous tissue with a laser Doppler instrument and muscle oxygenation by near-infrared spectroscopy (NIRS)
- Progressively increase areas to an arm, leg, multiple limbs and torso to examine local perfusion and tissue oxygenation impacts as well as systemic effects at overpressure levels of 20, 40, 60, 80, 100, 150 and 200 mmHg. Time at each exposure level will be limited by that taken to generate a significant decrease of perfusion or oxygenation.

Mechanical Counter Pressure on the skin surface is adequate to prevent edema, blister formation, or circulatory impairment up to a certain limit of underpressure (defined as a garment pressure less than ambient pressure). Using a Glove Box, which can be evacuated up to 222 mmHg below room pressure, localized areas of underpressure in an MCP glove are investigated.

- Verify applied MCP using the fabric tensiometer and pressure sensors.
- Measure skin and subcutaneous thickness by ultrasound, local perfusion in the skin and subcutaneous tissue with a laser Doppler instrument and muscle oxygenation by near-infrared spectroscopy (NIRS). Post-exposure limb girths will also be measured.
- Progressively increase areas to an arm, leg, multiple limbs and torso to examine local tissue thickness, perfusion and tissue oxygenation impacts as well as systemic effects at underpressure levels of 20, 40, 60, 80, 100, 150 and 200 mmHg. Time at each exposure level will be limited by that taken to generate a significant increase of tissue thickness or a decrease of perfusion or oxygenation.
- Post-exposure limb girths will also be measured.

### Results

Preliminary glove box tests and vacuum chamber tests at NASA JSC with a mechanical counter pressure glove have indicated that exposures to -220 mmHg up to 120 minutes with a properly sized glove do not cause any noticeable physiological effects (such as edema or petechiae). Even 60-minute exposures at an absolute pressure of 1 Torr did not cause any visible physiological effects. This research will identify and quantify physiological effects at off-design conditions. At the current time, the test setup is being completed and testing will start in the third quarter of 2000.

## INDEX TERMS

Spacesuit, EVA, Mechanical Counter Pressure, MCP