APPLICATION OF THE MAXIMUM PRINCIPLE TO THE OPTIMAL CONTROL OF LIFE SUPPORT SYSTEMS

by

GOVINDASWAMY NADIMUTHU

B.E. (Mechanical)
Madras University, India, 1968

D.I.I.T. (Industrial Engineering)
Indian Institute of Technology, Madras, India, 1969

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Major Professor

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CHAPTER 1

INTRODUCTION

This report deals with the application of the maximum principle to the optimal temperature control of life support systems. A life support system is a system for creating, maintaining, and controlling an environment so as to permit personnel to function efficiently. The control of temperature is probably the most important role of the life support system.

The need for providing an automatic control system to an air-conditioning system has long been recognized [24, 42]. It is also a well-known fact that use of automatic control is necessary for the life support system of a space cabin or submarine or underground shelter [43, 44]. It appears that analysis and synthesis of the control systems for the air-conditioning and life support systems have so far been carried out by the classical approach [1,6,7,13,22,24,26,42,43,44,45] which is essentially a trial-and-error procedure or a disturbance-response (or input-output) approach in which extensive use is made of the transform methods such as the Laplace transform (s-domain), Fourier transform (ω-domain), and z-transform (discrete time-domain). Inspite of the extensive use of mathematics, the classical approach is essentially an empirical one [41].

An approach known as the modern (optimal) control theory, distinctly different from the classical one, to the analysis and synthesis of a control system has recently been developed [3,14,32,34,35,36,41]. It is based on the state-space characterization of a system. The state-space is the abstract space whose coordinates are the state properties of the system or the variables which define the characteristics of the system [41]. This approach involves mainly maximization or minimization of an objective function (functional) which is a function of state and control variables which are in turn functions of time and/or distance coordinate. The objective function is specified, constraints are imposed on the state and decision variables, and an optimal control policy is determined by extremizing the objective function by means of mathematical techniques such as the calculus of variations, maximum principle, and dynamic programming [2,3,41]. This modern approach is entirely theoretical in the sense that no trial-and-error is involved in 'adjusting the controller'.

A series of five papers containing the results of an original investigation of the temperature control of confined spaces such as those in any building and life support systems by means of the modern optimal control theory have recently been published in Building Science [17,18,19,20,21]. All these five papers are concerned only with open-loop control. Also, these papers deal only with problems of controlling systems subjected to an impulse heat disturbance with the minimization of the objective function, $S = \int_0^T dt$. The first of this series of articles, contains the derivation of the mathematical models of several different systems and the simulations of their behaviour and characteristics. In the second of the series, the most basic form of Pontryagin's maximum principle, which together with dynamic programming constitutes the bulk of the modern control theory, is outlined and its use is demonstrated by some numerical examples. The optimal control of a system with equality state variable constraints imposed at the end of the control action is considered in the third part. The fourth part