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Proof-of-Concept Automation of Propellant Processing

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Abstract

For space-based propellant production, automation of the process is needed. Currently, all phases of terrestrial production have some form of human interaction. A mixer has been acquired to help perform the tasks of automation. We have designed, built, and installed a heating system to be used with the mixer. Tests performed on the heating system verify design criteria. An IBM PS/2 personal computer has been acquired for future automation work. It is hoped that by the end of the next academic year, the mixing process itself will be automated. This is a concept demonstration task--proving that propellant production CAN be automated reliably.

Introduction

The research work deals with the autonomous production of propellants. Because 80% to 90% of a spacecraft's weight is propellant, it is advantageous to produce propellants in strategic locations en route to, and at, the desired mission destination. This will then reduce the weight of the spacecraft and the cost of each mission. Since one of the primary goals of the space program is safety, a totally automated propellant production system is desirable. This system would thereby eliminate the need for the constant human intervention currently required in production of many propellants. This enables the exploration of space to be more than the search for, and production of, propellants. As a proof-of-concept demonstration, one specific case was chosen for this study--composite propellant production; the principle is more important than the application.

Background

Currently, composite solid propellant production is done with constant human intervention. Using a control room, man has total control over all aspects of the propellant production. This is fine on Earth, but it is too costly in space. Thus, the need for automated composite propellant production exists.

Approach

We are currently completing testing of a heating system, which was designed by the student (Paul Schallhorn), for the one-pint mixer that is to be used for this project. Because composite propellant production requires mixing the ingredients at two constant temperatures (160 and 140°F), a self-contained water-heating system is required for space-based operation. Such a system is shown in Figure 1.1. This system provides the required temperatures and only needs an electric power source to drive the pump motor and heat the water heaters. This is not unrealistic considering that electricity is also required for the mixer and controlling computer.

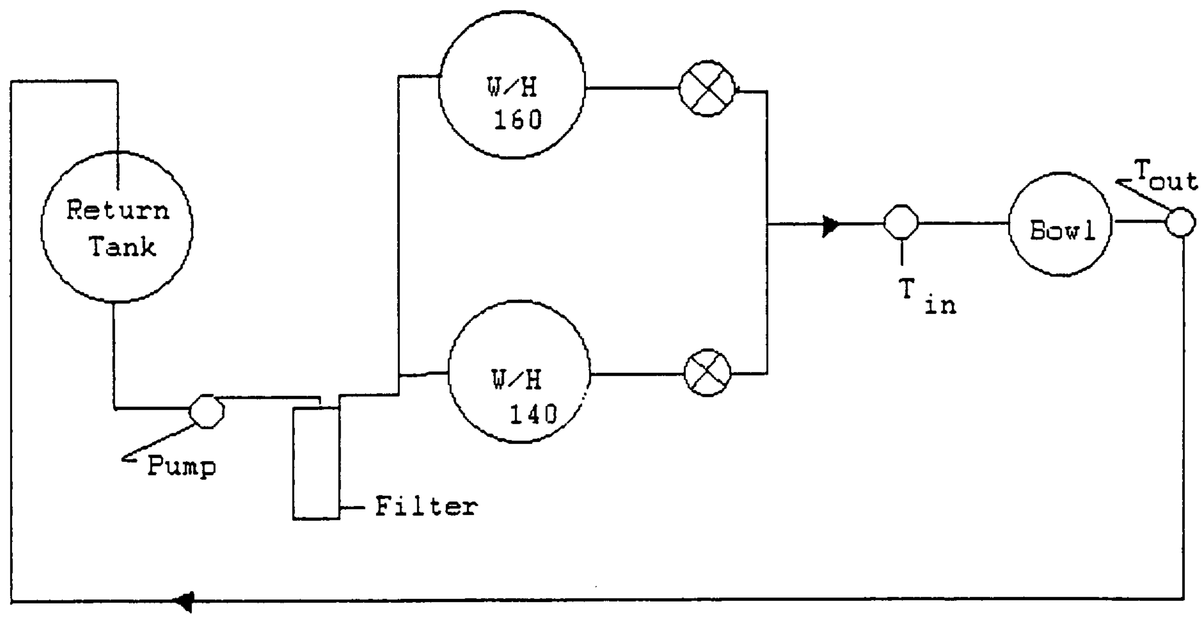

Figure 1.1. The heating system.

One approach, therefore, is to use a personal computer to control the introduction and mixing of the composite propellant ingredients to the mixer (making sure that temperature is constant on the walls of the bowl, detecting local "hot spots" within the mixture, and taking in-situ measurements of the viscosity of the mixture to check if it is within an acceptable range). Then, pump the mixture, via computer programs, into a cast which will be placed in an oven for curing and then stored for future use.

<u>Results to Date</u>

The major results to date are as follows:

1. A used Baker-Perkins PX-2 mixer was acquired; this introduces a factor of 6 cost reduction (see Fig. 1.2 for the complete mixer setup). A heating system was required for its operation.
2. In September 1988, Schallhorn designed the heating system to be used for the mixer (see Fig. 1.1). It was determined that the minimum volumetric flow rate for the heating system for a 1-degree temperature drop acrosss the mixer

operating at steady state was 2.5 gallons per minute. Therefore, we selected a pump with a volumetric flow rate of 4.4 gallons per minute to ensure a negligible temperature drop across the mixer bowl. Since only two temperatures are needed, it was logical to have two separate reservoirs, each at one of the required temperatures. We chose to have both reservoirs be hot water heaters. Because we only had 120-volt a/c power available, we had to choose the most efficient heater size on the market. As we began to search for heaters for the project, it was discovered that the same heating element was commonly used in different-sized 120-volt water heaters. This made it clear that for maximum water heating, the smaller the water heater, the more advantageous. That was the basis for the selection of two 10-gallon water heaters (see Fig. 1.3). The system uses distilled water to eliminate the possibility of scale buildup in the system. To further ensure the cleanliness of the water in the system, a filter is placed in the system immediately following the pump (see Fig. 1.4).

3. Acquisition of the components of the heating system was begun in October 1988. By the middle of November, all of the components were in and the heating system was assembled.
4. Initial verification of the temperature profile of the heating system was begun in December 1988. Verification of the heating system continued through March 1989, including verification of flow rate and the time required to heat the system from a cold start.
5. In August 1988, research was begun to determine which personal computer to purchase for this project. By the end of September, an IBM PS/2, Model 80 was selected, with an Intel 80386 microprocessor operating at 20 MHz, a 115-megabyte hard disk drive, and 2 megabytes of RAM. The computer was ordered at the end of September, along with the following peripherals: a 14-inch monitor, a 80387 math coprocessor, a modem, a 5.25-inch external diskette drive, additional memory, a mouse, and a Hewlett Packard Laserjet II printer. Due to shipping problems from IBM, the computer did not arrive until late in January, and the peripherals did not arrive until early February. By the middle of February, the computer system was operational. This computer system will be used on various other NASA Center projects, also.

Summary and Future Work

In summary, this task strongly suggests that there is a need for automated production of propellants for space-based propellant production. We have also seen

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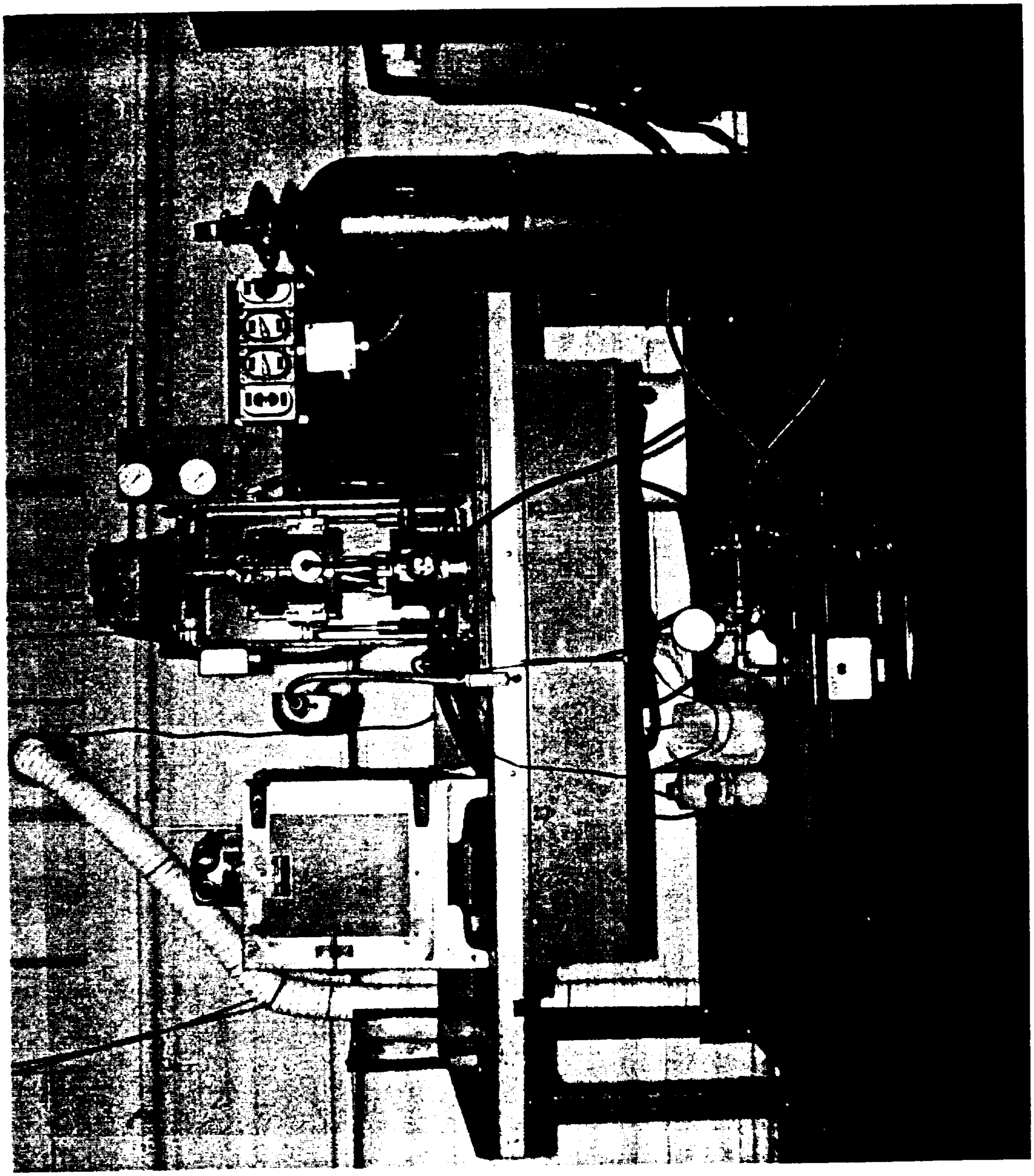

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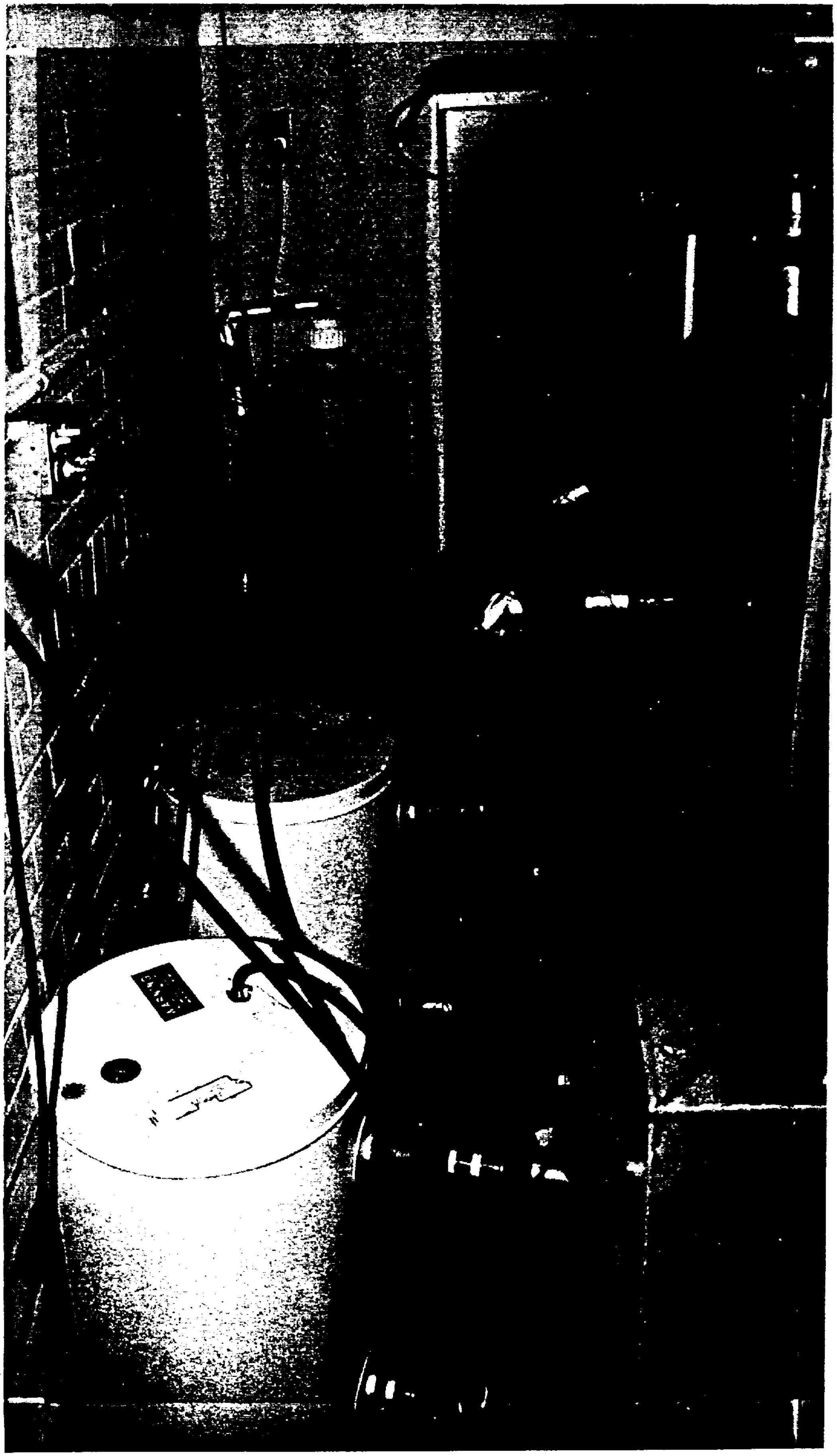

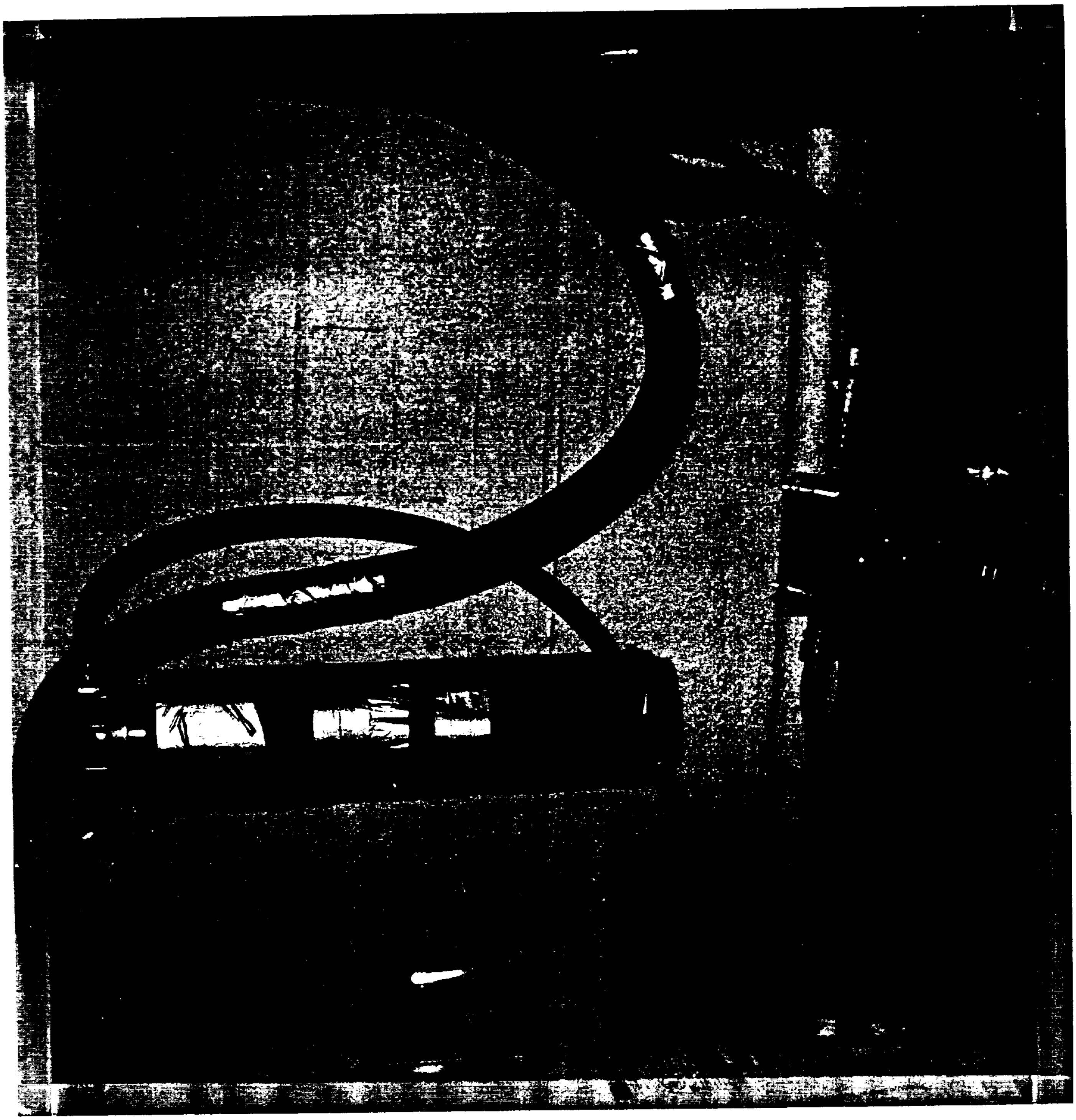

that there is no current system to produce composite propellants without human intervention. A mixer has been acquired to help perform this task. We have designed and built a heating system to be used in conjunction with the mixer to maintain constant mixing temperature. The heating system has been, and is continuing to be, tested under operational conditions for design verification. We have acquired an IBM PS/2 personal computer for the computer portion of the automation.

For the 1989-90 academic year, the student plans to begin his Ph.D. research, which will consist of the actual automated propellant production. During the year, we will begin to automate the mixing process itself. It is hoped to have the computer control the addition of each ingredient from a "hopper" (yet to be built) to the mixer at required times and have the computer control the mixing of the ingredients for the required amount of time. We also plan on building and installing the in-situ viscosity measuring device for future integration into the automation system.

Acknowledgments

We would like to take this opportunity to thank University of Arizona technician Gary Hopkins for his help in assembling the heating system. We would also like to acknowledge Richard Wilson, who is doing the automatic controls portion of the heating system.