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PROGRESS REPORT

BATTELLE MEMORIAL INSTITUTE

Oct 17 '52

THIRD MONTHLY PROGRESS REPORT

on

A STUDY AND EVALUATION OF LIQUID-LEVEL AND LIQUID-VOLUME CONTROLS FOR SHELL-, ROCKET-, AND BOMB-FILLING MACHINES

to

ARMY CHEMICAL CENTER

September 30, 1952

Contract No. DA 18-108-~~CHL~~ CmL-3965

by

Thomas M. Boland, William Hecox,
Roger L. Merrill, and Robert C. McMaster

BATTELLE MEMORIAL INSTITUTE
505 King Avenue
Columbus 1, Ohio

Battelle Memorial Institute

505 KING AVENUE COLUMBUS 1, OHIO

October 6, 1952

Mr. Alex Smallberg
Contracting Officer
Chemical Corps Procurement Agency
Army Chemical Center, Maryland

Dear Mr. Smallberg:

We are enclosing six copies of the Third Monthly Progress Report on "A Study and Evaluation of Liquid-Level and Liquid-Volume Controls for Shell-, Rocket-, and Bomb-Filling Machines" covering the period of September, 1952.

In this report, the results of the art-type patent search are disclosed, together with a description of several commercially manufactured components applicable to liquid-filling systems.

A filling system that weighs the desired amount of liquid in an intermediate chamber, and then deposits this liquid into a munition, has been selected as the system most suitable for accurate volume filling. Reasons for this choice, and a detailed description of the weigh-chamber-type system, are presented.

Yours very truly,

Thomas M. Boland

Thomas M. Boland
Electrical Engineering Division

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SUMMARY

An art-type search was conducted of the patent literature dealing with items that may be incorporated into a munitions-filling system. The results of this search are reviewed ~~in this report~~. A considerable number of patents on constant-volume filling machines and liquid-level indicators were discovered. Further technical information on system components was received also.

The selection of a system which appears most suitable for volume filling of shells, rockets, and bombs has been made. This system, which weighs the desired amount of liquid in an intermediate chamber, is described in detail in this report.

The "Components" section includes a description of four components, three of which are embodied in the selected weigh-type system.

INTRODUCTION

This is the Third Monthly Progress Report on "A Study and Evaluation of Liquid-Level and Liquid-Volume Controls for Shell-, Rocket-, and Bomb-Filling Machines", covering September, 1952.

A program to investigate various liquid filling methods and their possible application to the filling of munitions was begun during the first month of this project. Considerable information has been obtained since that time on filling machines of commercial manufacture, together with other items which may prove applicable in the design of a munition-filling device.

Several methods have been proposed for placing a given volume of liquid agent in a shell, rocket, or bomb. These methods have been depicted in block diagram form, and a discussion of their relative merits was included in the previous report.

WORK IN PROGRESS

Two phases comprise the present work:

1. Further collection of technical information on subjects relating to the filling of munitions.

2. The selection and description of a definite system to accomplish accurate volume filling of munitions.

Collection of Technical Information

Additional technical information relating to the filling of munitions has been collected during September. It consists of the results of the art-type patent search, and of further data compiled from manufacturers' bulletins.

Patent Search Results

The Battelle Patent Division was authorized at the start of this project to conduct an art-type patent search relating to liquid-filling devices. This search has now been completed, and copies of patents describing devices of this type have been received.

Constant-Volume Filling Machines. Most of the patent literature dealt with the development and modifications of constant-volume filling machines. Several different methods of obtaining these repeatable volumes are disclosed.

Piston Fillers. The first of these methods is known as "piston filling". This is accomplished by a piston-cylinder combination, wherein the cylinder is filled, and then the contents are discharged by the positive stroke of the piston.

The cylinder could be filled by vacuum as the piston is withdrawn, or by gravity.

Submersion Fill of Volume Chamber. The second method is as follows: A chamber (open at the top) of known volume is submerged below the level in the supply, and allowed to fill. Then this chamber is raised above the level in the tank. Then the desired volume is permitted to flow from the chamber into the container to be filled.

Gravity Fill of Volume Chamber. The third method employs a system in which an intermediate chamber of known volume is filled by gravity, and then this volume is deposited into a receptacle. This method is very similar to one of the suggested systems included in the Second Monthly Report.

Fill of Volume Chamber by Displacement Structure. Another method of filling an intermediate container of known volume is to position it with its open top slightly above the liquid level in a supply tank. A displacement structure is lowered into the liquid so that the level rises to flow into the measuring chamber until it is filled. The displacement structure is raised, leaving the measuring chamber brimful, as the supply tank level drops. Then the receptacle is filled.

Vacuum Filler. A container also may be filled to a given level by evacuating the container and the pipe from the supply tank. With the liquid supply open to the atmosphere, the liquid will flow into the container until the vacuum line intake is covered. This intake can be set at the desired fill level.

Liquid-Level Indicators. The patent search also disclosed a number of liquid-level indicators. These may be of special value in the consideration of a device that will fill a munition to a given level.

Float Devices. For the most part, the liquid-level indicators found in the patent literature were float devices. Detection of float position was, in most cases, optical. In some patents, the float movement actuated various types of gadgets to detect a given level. These gadgets included bells, whistles, and other similar devices.

Pressure Instruments. Other types of level indicators found were of the general class of pressure instruments. Some of these were operated by the restriction of air flow as a nozzle opening was approached. Another instrument of this kind incorporates a whistle device with the filling nozzle, so that, as the air in a container is displaced by a liquid during filling, it is forced through the whistle until the air-vent tube is covered by the liquid.

High-Frequency Level Detection. Another device for level inspection utilizes a high-frequency generator and a detector which detects the liquid level by measuring the state of resonance of the remaining cavity of the container being filled. This method requires accurate knowledge of the cavity dimensions, if the volume of deposited liquid is to be known.

Optical Indicators. Several optical systems similar to that described in the "Components" section of the First Monthly Progress Report were found also.

A list of patents reviewed (numbers and titles) appears at the end of this report.

Manufacturers' Literature

Further manufacturers' bulletins have revealed two important components which appear to be most suitable for use in a munition-filling device. These are: (1) a valve produced by the D. H. Annin Company, Los Angeles, California, and (2) a type of filling nozzle made by several manufacturers. Both of these products are described in the "Components" section of this report.

Information also was received dealing with a liquid-level detector which is comprised of a stainless steel probe and an accompanying electric control circuit. A combination of these, or similar probe devices, may prove useful for inspection of munitions after they have been filled to a given level.

Selection and Description of Filling System

Six possible systems for volumetric filling of munitions were outlined in block diagram form in the Second Monthly Progress Report. Of these six, the system that weighs the desired volume of agent in an intermediate container and then places this quantity of agent in the munition has been selected for development.

The reasons for this choice are:

1. No temperature correction is required. Identical amounts (by weight) are deposited at each filling operation.

2. This system can be designed so that the ratio of weigh-chamber weight to agent weight is small. This increases the accuracy of measurement of the liquid.

3. No compensation for variations of shell tare weight or variations of shell volume is necessary. This system is independent of the container into which the agent is deposited.

4. Proportional control of filling rate as scale balance is approached is incorporated in this system. This feature provides increased accuracy over a system which is "on-off", that is, fills to balance, then shuts off sharply.

5. This system lends itself to a range of liquid volumes. By changing the counterweight on the balance arm, any amount of agent within the dimensions of the weigh chamber can be placed into the munition undergoing filling.

A detailed drawing of this proposed system, as now conceived, appears in Figure 1.

The weigh chamber is attached, as shown, to the balance arm. The knife edge is attached to the chamber so that the chamber always will be in a vertical position. The counterweight pan also is held vertically at all times.

The valve which controls the flow of the agent into the weigh chamber is actuated through a gear box from the servo motor. This motor may be a two-phase motor, one phase of which is excited continuously from an alternating-current source. By controlling the second phase, motor speed, torque, and direction of rotation are controlled also.

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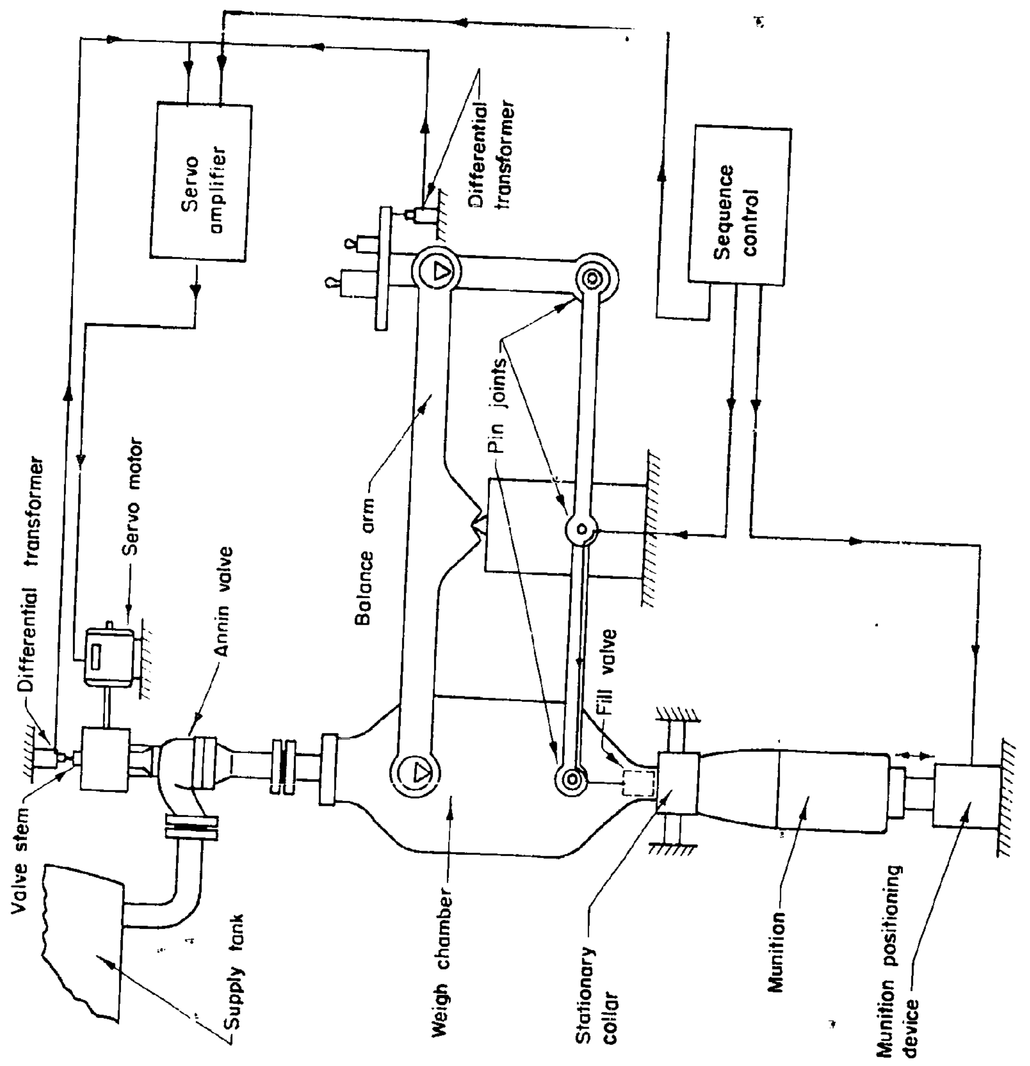

FIGURE 1. WEIGHT SYSTEM FOR FILLING MUNITIONS

Deflection of the balance arm, as well as the position of the valve plug with respect to the valve seat, may be detected through differential transformers. This device is explained in detail in the "Components" section of this report.

The differential transformer connected to the supply control valve stem is so mounted that its voltage output is zero when this valve is closed. As the valve opens, the voltage output increases.

The differential transformer attached to the scale balance is mounted in such a manner that, when the scale is balanced exactly, its output is zero. As the scale is unbalanced because of lack of liquid in the weigh chamber, this differential transformer's voltage output increases. This voltage is 180° out of phase with the voltage from the valve stem differential transformer.

The voltage output of these differential transformers is fed to a servo amplifier which controls the servo motor that drives the supply valve.

Operational Sequence

The conditions of this system at the start of a filling operation are as follows:

1. The valve controlling the flow out of the weigh chamber (fill valve) is closed.

2. Counterweights that will balance exactly the weight of the desired amount of agent are placed on the pan at the opposite end of the balance arm from the weigh chamber.

3. The valve that controls the flow from the supply tank is closed also.

When the sequence control notifies the servo amplifier to begin filling the weigh bucket, the servo amplifier detects the positions of the scale and the supply control valve. This is accomplished by the signal from the two differential transformers. The voltage output from the scale differential transformer is, at this instant, a maximum (scale at maximum balance). The voltage output from the valve differential transformer is zero (valve closed).

The servo amplifier drives the servo motor so that the supply control valve opens wide. The valve differential transformer output is now equal to the output of the scale differential transformer, but of opposite phase, as was stated previously. Therefore, the net output is zero voltage. This condition remains until the scale starts to balance.

As the desired amount of liquid is approached, the scale begins to balance. The output of its differential transformer thereby decreases, and the servo amplifier immediately detects the voltage input to it from the valve differential transformer. It (the servo amplifier) drives the servo motor so that the valve begins to close.

This begins to restrict the flow into the weigh chamber. The servo motor will continue to close the valve as long as the voltage input from the valve differential transformer to the servo amplifier exceeds that of the scale differential transformer.

Should the valve close too fast, and the scale differential transformer's output exceed that of the valve differential transformer, the motor will open the valve until there is zero input to the servo amplifier.

Flow is restricted increasingly as balance is approached. This system is designed to close the valve when scale balance is reached. At this condition, there is zero voltage output from both differential transformers.

When the scale is balanced, the desired quantity of liquid agent is in the weigh chamber.

While this operation was taking place, a munition (a shell, for example) could be fed onto a munition-positioning device. This might consist of a pneumatic or hydraulic cylinder that would force the shell against a collar surrounding the bottom of the weigh chamber. The purpose of raising the shell in this manner is to reduce the possibility of splash of the agent as the contents of the weigh chamber are released into the shell.

When the desired amount of liquid has been fed into the weigh chamber, the sequence control disconnects the servo amplifier from the two differential transformers, thereby keeping the supply control valve shut. Also at this time, the valve at the bottom of the weigh chamber is opened and the agent flows into the munition. A valve for this application is described in the "Components" section of this report.

When the weigh chamber is empty, the differential transformers are connected to the servo amplifier again, and the weigh chamber again begins to receive liquid agent from the supply tank.

It is noted again that positioning and removal of the shell can be accomplished while the weigh chamber is being filled, thereby increasing the number of munitions filled during a given time.

Components

In this section, four components will be described in detail which may be included in the filling system suggested above. The components are the

Annin valve, the differential transformer, the helical potentiometer, and a filling nozzle.

The Annin Valve

The D. H. Annin Valve Company, Los Angeles, California, manufactures a valve (Figure 2) which is suggested for controlling the liquid flow into the weighing chamber. It has one particularly desirable feature, namely, that it is available with three different shaped valve plugs. These plugs make available three different characteristics of per cent flow to per cent valve opening: linear, percentage, and semithrottle. These characteristics, together with the three plug shapes, are shown in Figures 3 and 4.

The linear valve plug is designed to vary fluid flow in direct proportion to the valve lift throughout the opening range. The percentage valve plug is designed to vary fluid flow in an equal percentage ratio with each increment of valve lift. With the semithrottle valve plug, the first quarter of the valve lift controls fluid flow in direct proportion, and the last three-quarters of the lift provide a wide open flow orifice.

The Differential Transformer

The differential transformer is an electrical device which consists of three coils wound on a hollow form in which a magnetic slug is inserted. These three coils are wound as shown in Figure 5.

The primary coil is excited by an alternating-voltage source, and the secondary coils are connected in series-bucking.

When the magnetic slug is positioned exactly in the middle of the three coils (Position O, Figure 6), the net secondary voltage output is zero. As the slug moves to the right of center (Position O), the inductive coupling increases between the right secondary coil and the primary coil. Therefore, the voltage output of the right secondary coil is greater than that of the left secondary coil, and the net secondary output increases as the slug moves outward to the right.

The net secondary voltage output increases in a like manner when the slug is displaced to the left of center (Position A, Figure 6). However, this voltage is 180° out of phase with the voltage output when the slug is moved to the right, since the two secondary coils are connected in series-bucking.

The Helical Potentiometer

Another means of detecting the displacement of a valve stem, or other shafts whose movement is caused by a rotating member, is the helical

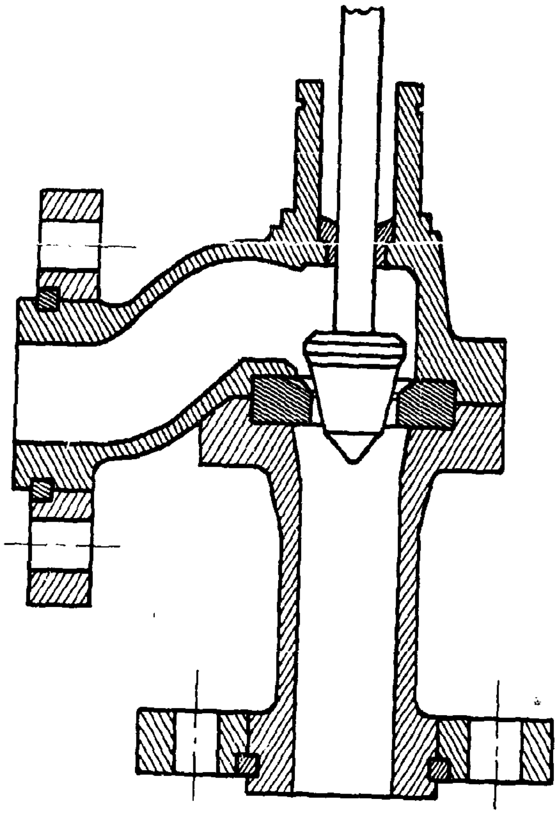

FIGURE 2. ANNIN VALVE

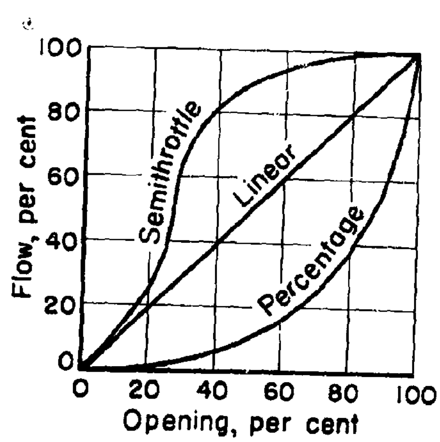

FIGURE 3. TYPICAL CHARACTERISTIC FLOW CURVES

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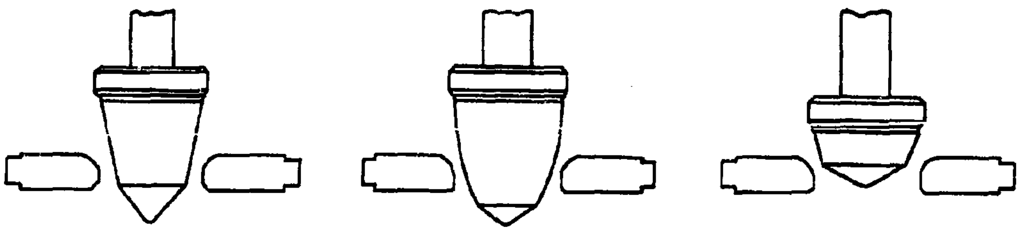

FIGURE 4. VALVE-PLUG DESIGNS

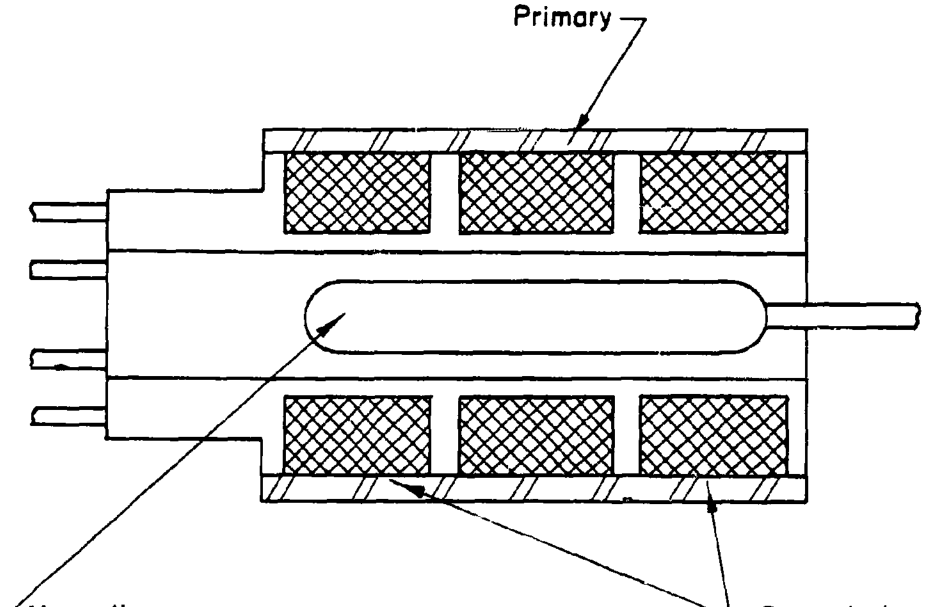

FIGURE 5. DIFFERENTIAL TRANSFORMER

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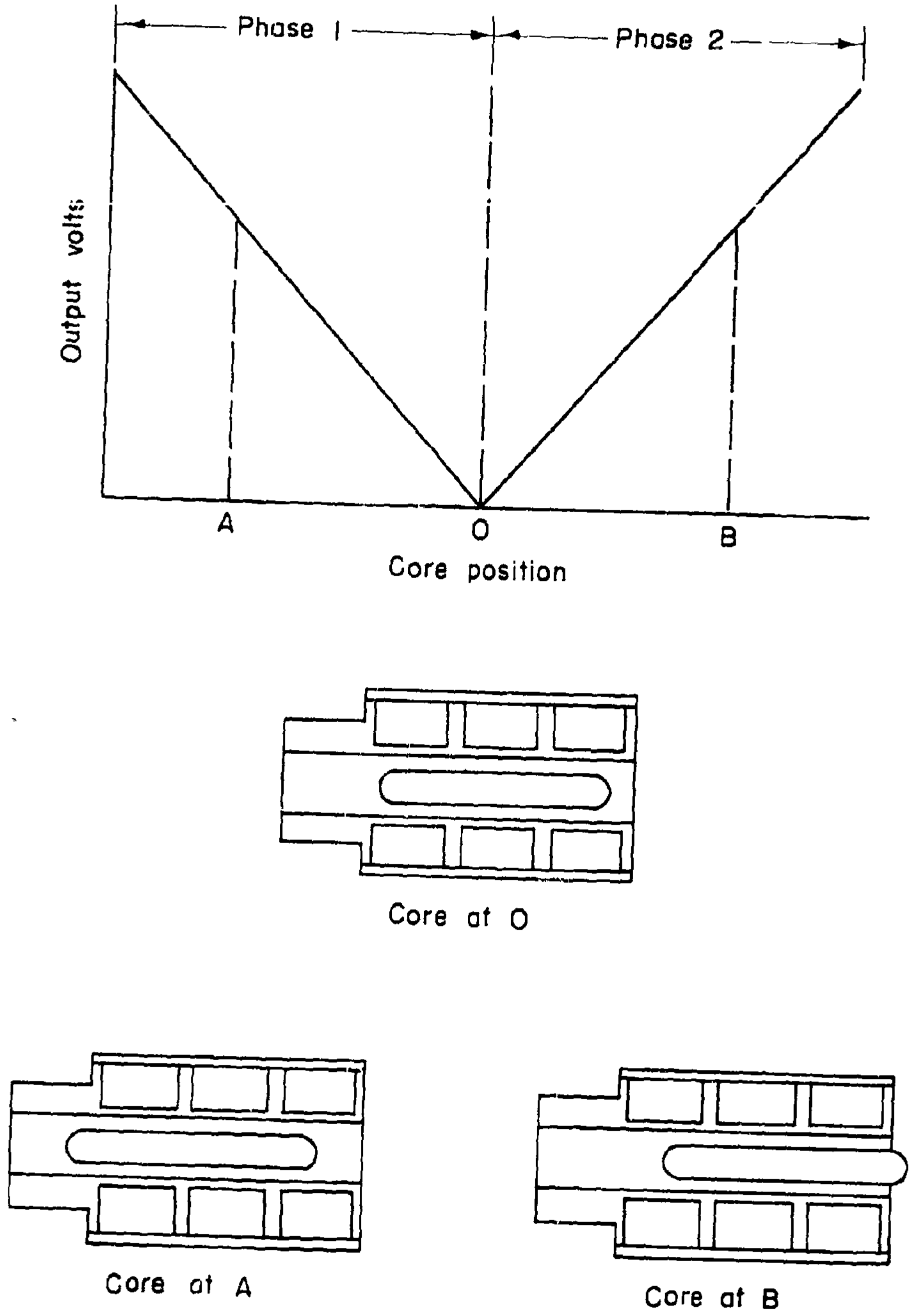

FIGURE 6. VOLTAGE CHARACTERISTIC OF DIFFERENTIAL TRANSFORMER

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potentiometer (Figure 7). It is applicable to gear trains, or other devices which cause linear movement, but themselves have only rotating motion.

The helical potentiometer consists simply of a precision-wound slide wire helically coiled in a small, compact case. Three terminals are provided, one at each end of the coil, and one to a slider which follows the slide wire as the slider shaft extension is rotated.

By connecting a helical potentiometer to a rotating member, the number of rotations of the member can be detected by noting the resistance between center tap and an end terminal. In the case of a motor-driven valve, the position of the valve stem can be determined by connecting a helical potentiometer to the gear shaft directly driving the valve stem, provided the gear ratio between driving shaft and stem is known.

Filling Nozzle

The filling nozzle shown in Figure 8 was found in the manufacturers' literature received at Battelle relevant to this project. This nozzle appears to be dripproof, and may be applicable for use as the valve at the bottom of the weigh chamber. It is suggested that, for compatibility with the rest of the system and for ease of control, this valve be electric solenoid operated.

FUTURE WORK

The future effort will be directed toward:

1. Arrangement of a meeting with representatives of the Army Chemical Center to discuss the filling system disclosed in this report.
2. Further collection of useful information relating especially to the components which comprise the weigh-type system. These might include gear boxes, servo motors, and scale balances.
3. Inquiries regarding the possible use of a pneumatic system for control of the filling of the intermediate chamber.
4. Placement of orders for some of the fundamental parts of the filling system.
5. Setting up the fundamental differential equation for the closed-loop system of weigh filling constant liquid volumes.

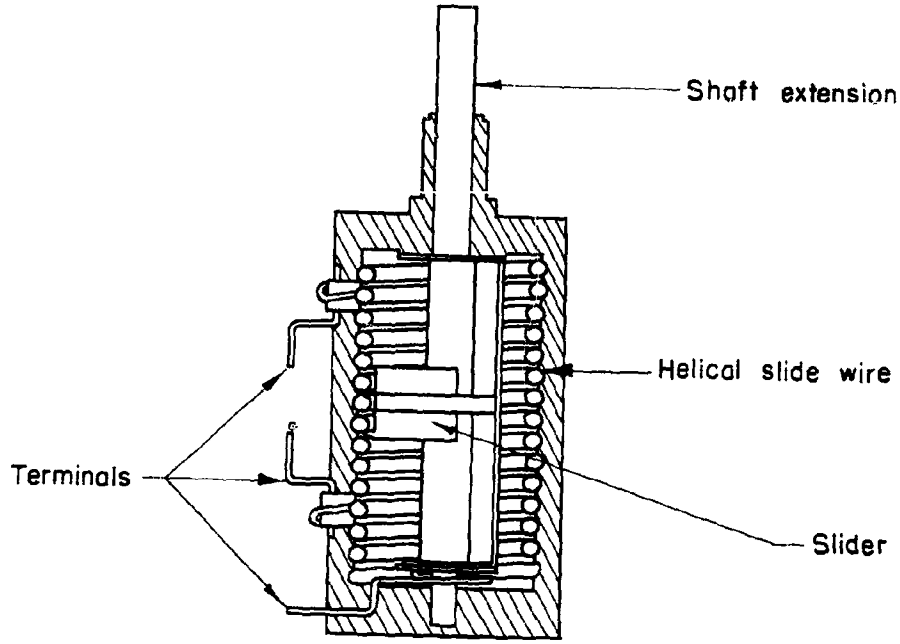

FIGURE 7. HELICAL POTENTIOMETER

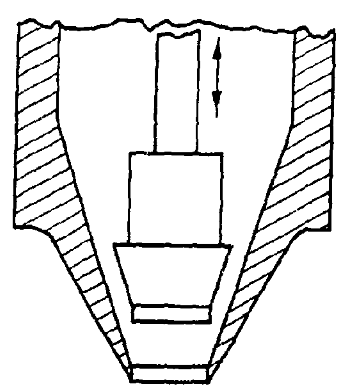

FIGURE 8. FILLING NOZZLE

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LIST OF UNITED STATES PATENTS

Constant-Volume Filling Methods

Piston Fillers

	Patent No.	Title
1.	693,921	"Can Filling Machine"
2.	721,850	"Measuring and Filling Apparatus"
3.	1,246,180	"Liquid Measuring and Container Charging Machine"
4.	1,307,898	"Bottle Filling and Corking Machine"
5.	1,393,276	"Filling Machine"
6.	1,565,686	"Dispensing Valve"
7.	1,690,067	"Filling Machine"
8.	1,932,976	"Metering-Filling Machine"
9.	1,993,367	"Filling Machine"
10.	2,043,578	"Pump for Filling Machines"
11.	2,150,760	"Ampoule Filler"
12.	2,180,702	"Device for Delivering Measured Quantities of Liquid"
13.	2,245,287	"Liquid Metering Machine"
14.	Re. 19,777	"Sirup Valve for Bottle Fillers"

Submersion Fill of Volume Chamber

	Patent No.	Title
1.	1,166,607	"Bottle Filling Mechanism"
2.	1,633,048	"Bottle Filling Device"
3.	1,731,465	"Filling Mechanism"
4.	1,955,441	"Liquid Filling and Measuring Apparatus"
5.	2,030,084	"Apparatus for Filling Receptacles"
6.	2,030,951	"Receptacle Filling Apparatus"
7.	2,155,317	"Measuring Cup"
8.	2,172,012	"Filling Machine"
9.	2,554,939	"Liquid Filler"

Gravity Fill of Volume Chamber

	Patent No.	Title
1.	744,048	"Can Filling Machine"
2.	813,761	"Device for Filling Bottles"
3.	1,852,308	"Liquid Filling Machine"
4.	2,150,913	"Shell Filling and Closing Machine"
5.	2,367,031	"Volumetric Measuring Machine"

Fill of Volume Chamber by Displacement Structure

	Patent No.	Title
1.	1,170,232	"Bottle Filling Machine"
2.	1,360,023	"Measuring Bottle Filling Machine"

Vacuum Filler

	Patent No.	Title
1.	1,262,274	"Bottle Filling Apparatus"

Liquid-Level Indicators

Float Devices

	Patent No.	Title
1.	28,637	"Gage for Filling Barrels"
2.	328,827	"Automatic Barrel Filler"
3.	1,506,324	"Oil Gauge"
4.	1,990,386	"Nozzle"
5.	2,107,952	"Signaling Device"
6.	2,146,211	"Gasoline Hose Nozzle Attachment"
7.	2,399,291	"Liquid Level Indicator"

Pressure Instruments

Patent No.	Title
1. 1,951,472	"Tank-Filling Nozzle With Gauge"
2. 2,073,360	"Liquid Level Indicator"
3. 2,114,705	"Filling Nozzle"
4. 2,269,737	"Measuring Device"
5. 2,398,958	"Level Indicator for Storage Bins or Hoppers"

High-Frequency Level Detection

Patent No.	Title
1. 2,491,418	"Automatic Inspection Device"

Optical Indicators

Patent No.	Title
1. 2,566,789	"Optical Sight Means for Indicating the Level of Liquids or Other Reflective Surfaces"

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October 2, 1952