98257

Solenoid-Activated Metering Device for the Continuous Dispensing of Liquid Growth Medium

L.L. Hendzel

Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

November 1986

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1489

Fisheries and Oceans Pêches et Océans

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457–714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715–924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of

Fisheries and Aquatic Sciences 1489

November 1986

SOLENOID-ACTIVATED METERING DEVICE

FOR THE CONTINUOUS DISPENSING OF LIQUID GROWTH MEDIUM

by

L.L. Hendzel

Central and Arctic Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

This is the 2nd Technical Report

from the Central and Arctic Region, Winnipeg

Cat. no. Fs 97-6/1489E ISSN 0706-6457

Correct citation for this publication is:

Hendzel, L.L. 1986. Solenoid-activated metering device for the continuous dispensing of liquid growth medium. Can. Tech. Rep. Fish. Aquat. Sci. 1489: iv + 8 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Hendzel, L.L. 1986. Solenoid-activated metering device for the continuous dispensing of liquid growth medium. Can. Tech. Rep. Fish. Aquat. Sci. 1489: iv + 8 p.

The construction of an electronically controlled, electro-magnetic metering device for the timed delivery of liquid growth medium is presented. The apparatus consists of two parts, each assembled from readily available components. These are a timing module and a solenoid activated gate. Silicone tubing, passing through the gate; connects the pressurized medium reservoirs to the culture vessels. Performance data is presented for one particular application.

Key words: solenoid; interval timer-relay; metering; liquid growth medium; semi-continuous cultures; algae.

RÉSUMÉ

Hendzel, L.L. 1986. Solenoid-activated metering device for the continuous dispensing of liquid growth medium. Can. Tech. Rep. Fish. Aquat. Sci. 1489: iv + 8 p.

On décrit la construction d'un appareil électromagnétique électronique servant à mesurer le débit d'un milieu de culture liquide. L'appareil est constitué de deux parties, soit un chronomètre et une vanne actionée par un solénoide, qu'on peut assembler à l'aide de pièces faciles à trouver. Une canalisation en silicone qui traverse la vanne joint les réservoirs pressurisés de milieux de culture et les récipients de culture. On présente des données sur le rendement d'une expérience menée à l'aide de cet appareil.

Mots-clés: solénoide; relais pour chronomètre; mesure; milieu de culture liquide; cultures semi-continues; algue.

INTRODUCTION

The need for an inexpensive and reliable way of controlling the flow of liquid medium to a number of semi-continuous algal cultures resulted in the development of a device which would repetitively and accurately control the aseptic delivery of medium from pressurized reservoirs, through silicone tubing to algal cultures. The relatively low cost of this device made practical the use of many such cultures for growth-related experiments. Commercially-avialable peristaltic pumps would provide the controlled flow needed but were too expensive for the number of cultures required. Less costly methods of medium delivery to semi-continuous cultures were explored.

Initially, manually-controlled, semi-continuous cultures were used. In this procedure, a volume of culture is aseptically removed by pipette daily and an equal volume of sterile medium added. This single daily addition of fresh medium results in large fluctuations in the concentration of limiting nutrient, which can have an effect on the outcome of the competition experiment (Turpin and Harrison 1979). The use of gravity flow from flasks and Mariotte bottles, controlled by metering valves was unsuccessful. At the low flow rates needed (10 mL per 24 h), uniform control of these devices was very difficult. Finally, a gate valve activated by a solenoid was developed where the flow of liquid medium through silicone tubing from pressurized reservoirs was controlled by periodic opening of the gate for short intervals.

METHODS-APPARATUS

The dispensing controller consists of two parts (Fig. 1), the timing module and the solenoid-activated gate, connected by a length of two-conductor wire. The timing module provides a range of "off" times with one set "on" interval. A rotary switch is used to select one of 10 "off" intervals ranging from 10 to 300 s. This "off" interval is the length of time that the solenoid is non-energized, with the gate being firmly pressed against the silicone tubing preventing any flow of medium. After the elapse of the selected "off" time interval, the solenoid is energized for a fraction of a second (<0.1 s), retracting the gate, allowing a pulse of medium to flow through the silicone tubing.

The timing module has three separate relays (Fig. 2): a timing relay (RL-1) which controls the length of time the solenoid gate remains non-energized, an intermediate DC relay circuit (RL-2) which lengthens the time of the "on" cycle of the solenoid gate, and a solid-state (opto-isolated) relay (RL-3) to switch the high inductive load of the solenoid. Control voltages to relays RL-1 and RL-3 is 120VAC, and 110VDC to RL-2, while all relays switch 120VAC. Figure 2 illustrates the timing and switching circuit. Line current (120VAC) passes through a 2.5-amp slow-blow fuse and branches into two routes, one directly to terminal 1 on the output side of RL-3 (Crydom A1210, International Rectifier) and the other through the normally closed contacts of relay RL-2 (KRP-5DG, AMF-Potter and Brumfield) to the input of the time delay relay RL-1 (R15A-300A-15-X4E1, AMF-Potter and Brumfield). The time delay function is controlled by 11 resistors (R3-R13). These are arranged in series around a 10-position rotary switch, SW-1, (Centralab PA2001), and controls the length of time the output contacts of relay RL-1 remain open. When the selected time interval has elapsed, the contacts of timing relay RL-1 close, energizing the intermediate relay (RL-2) circuit through a full-wave bridge rectifier (W-1) charging capacitor C-1 (8 μF, 250VAC electrolytic) and closing the contacts of relay RL-2 which energizes the input side of RL-3 through terminal 4, resulting in activation of the solenoid. The contacts of the timing relay RL-1 open and capacitor C-1 discharges. After discharge, the contacts of the intermediate relay RL-2 return to their normally closed position, removing power to the solenoid, which in turn switches power back to the timing relay RL-1, restarting the cycle. The length of this "on" cycle is determined by the value of capacitor C-1; a higher capacitance will result in the solenoid being energized for a longer period. Resistor R-1 (1.2 KΩ, 1/2 watt) protects the bridge rectifier (W-1) while resistor R-2 (4.7 KΩ, 1 watt) protects the intermediate relay RL-2. Resistors R3 to R13 (see parts list for resistance values) are selected in accordance with the specifications of the timing relay RL-1. Component specifications may vary depending on the application.

All components were wired using point-to-point connections within a suitable metal enclosure. The timing relay RL-1 and the intermediate relay RL-2 were mounted in the appropriate sockets while the solid-state relay RL-3 was mounted directly to the enclosure. Two three-lug terminal strips were used to simplify mounting of the rectifier W-1 and associated resistors R-1, R-2 and capacitor C-1. Output from the solid-state relay was connected to an enclosure-mounted, two-pin Jones socket (S-302-AB).

The design of the timing module circuit was altered slightly in order to simplify construction. The changes involved (Fig. 2a) replacing the P&B timer relay (R15A-300A, 115VAC X4E1) and the rotary switch with its array of resistors with an Agastat solid-state time-delay relay (Amerace Ltd., Markham, ON; model SSC 22AGA). Also the intermediate switching relay (RL-2) was replaced with a 110VDC double pole, double throw relay (P&G KRP 11DG) to energize RL-3 and secondly, to provide the necessary feedback to reset the timer in RL-1. This modification offered the same range of "off" times, without affecting reliability or the cost.

The solenoid-powered gate was constructed of easily obtainable materials and simply bolted together. The base was constructed of a piece of "U-shaped" channel iron (18 cm long x 12 cm high). Bolted to the base were two "L-shaped:" side brackets, (20 cm long x 5 cm wide with a 90° bend approximately 4 cm from one end) spaced 7.5 cm apart. The solenoid (Guardian pull type 18 intermittent duty, 120VAC) was mounted at the top, equidistant between the two L-brackets. A block of plastic on one side of the solenoid was necessary for proper spacing. A steel rod (80 mm long x 8 mm diameter) passed through a hole in an aluminum block and connected the solenoid plunger to the centre of a steel bar (70 mm long x 13 mm wide x 6 mm thick) perpendicular to the steel rod. The bottom edge of the bar was ground to the shape of a blunted vee. The length of the rod must allow for approximately 5 mm of travel when the solenoid is energized. The aluminum guide block (78 mm long x 38 mm wide x 25 mm thick), mounted directly beneath the solenoid acts to center the rod. This keeps the gate mechanism perpendicular to the base and acts as a bearing point for one end of a compression spring which holds the gate firmly against the base when the solenoid is not energized. The spring chosen was 25 mm long x 10 mm diameter and required 5-7 kg of pressure for 50% compression. The spring must be able to exert enough force to keep the silicone tubing pinched closed but not too stiff to prevent the solenoid from raising the vee bar clear of the tubing when energized. The solenoid powered gate can be semi-enclosed with an aluminum box. When left uncovered, it was easy to raise the gate manually in order to position the silicone tubes between the vee-bar and the base. A piece of thin rubber (1.0 mm thick) on the base cushioned the impact of the vee bar when the solenoid cycled on and off. Silicone tubes were held in place on either side of the gate by a two-piece plexiglass block, each half having semi-circular notches in which the tubes were placed. The corresponding top half was placed over the lower half and held in place with screws. When the silicone tubing shows signs of wear, another section can be drawn into place.

Each semi-continuous culture consisted of a sealed, pressurized medium reservoir connected to a non-sealed culture flask by a length of silicone tubing (Fig. 3). The medium reservoirs were 500 mL Erlenmeyer flasks, filled with 400 mL of sterile inorganic medium. The top of each medium reservoir was sealed with a #7 green neoprene stopper through which passed one long glass tube extending to the bottom of the flask, and one short length of glass tubing extending just below the bottom of the stopper. A suitable length of silicone tubing was fastened to the long glass tube and routed through the solenoid-activated gate to the appropriate culture flask. The other glass fitting allowed for pressurization with sterile air at a constant pressure of 0.035 $kg \cdot cm^{-2}$. The silicone tubing used between the medium reservoir and the culture flask was a thin-walled type (Cole-Parmer 6411-62, Cole-Parmer Instrument Co., 7425 North Park Avenue, Chicago, Illinois) which allowed for positive sealing by the vee bar but also afforded good elastic memory. The culture vessels were 125 mL Erlenmeyer flasks stoppered with gauze-wrapped sterile cotton, through which passed the silicone tubing from the medium reservoir to a point just below the stopper. A length of glass tubing, extending to the bottom of the culture flask, was connected by silicone tubing to a serum stoppered test tube, allowing for daily sampling.

DISCUSSION

Performance was monitored over a 16 day period (Table 1), at one "off" time interval setting; that is, one dilution rate. The average volume dispensed per 24 h was 16.14 mL with the range being 15.1-17.8 mL per 24 h. Long term experiments (up to 30 days) requiring the delivery of small volumes of medium (10 mL per 24 h) have been repeated many times, proving the device to be reliable and durable. At a constant reservoir pressure of 0.035 $kg \cdot cm^{-2}$, the volume dispensed can be varied from 0.65 $mL \cdot h^{-1}$ to 24 $mL \cdot h^{-1}$. Additional flexibility in selecting the length of time cycles and regimes can be easily attained by plugging the unit into an inexpensive programmable timer.

ACKNOWLEDGEMENTS

I would like to thank B. Van der Veen of the Electronics Lab for his technical assistance in designing and assembling the electronics, and W. Burton of the Workshop for his help in the design and construction of the solenoid-activated gate. In addition, I would like to thank Pat Healey for his comments on this manuscript, Mike Pidlubny for drawing the figures and Donna Laroque for typing the manuscript.

REFERENCES

TURPIN, D.H., and P.J. HARRISON. 1979. Limiting nutrient patchiness and its role in phytoplankton ecology. J. Exp. Mar. Biol. Ecol. 39: 151-166.

Table 1. Volume of distilled water dispensed per 24 hours over 16 days at 20° C with a reservoir pressure of 0.035 $kg \cdot cm^{-2}$.

Day	$mL \cdot 24\ h^{-1}$	Day	$mL \cdot 24\ h^{-1}$
1	16.1	9	16.8
2	17.3	10	16.3
3	17.0	11	15.3
4	15.1	12	15.5
5	17.8	13	15.4
6	16.2	14	15.2
7	16.0	15	15.3
8	16.5	16	16.5

Table 2. List of parts.

Resistors	Intermediate Switching Relay
R-1 - 1.2 KΩ 1/2 watt R-2 - 4.7 KΩ 1 watt R-3 - 47 KΩ 1/2 watt R-4 - 56 KΩ 1/2 watt R-5 - 100 KΩ 1/2 watt R-6 - 180 KΩ 1/2 watt R-7 - 220 KΩ 1/2 watt R-8 - 220 KΩ 1/2 watt R-9 - 220 KΩ 1/2 watt R-10 - 150 KΩ 1/2 watt R-11 - 120 KΩ 1/2 watt R-12 - 120 KΩ 1/2 watt R-13 - 100 KΩ 1/2 watt	P&B KRP-5DG 120VCD input 120 VAC output Solid State Relay Crydom A1210 International Rectifier 120VAC input and output Rotary Switch Centralab #PA2001 Ten position rotary switch
Capacitor	Solenoid
C-1 - 8uF250 VDC	Guardian pull type #18 intermittent duty 120VAC
Rectifier	Misc. Hardware
Full-wave bridged 1.5 A, P.I.V. = 200 Fuse Holder Littlefuse Fuse Littlefuse 2.5 A Slow Blow	Wire Spade lugs Terminal strips Jones plug and socket Metal enclosure Power cord Knob for rotary switch Misc. screws, nuts, washers, etc. (As per modification)
Timer-Relay	
P&B R15A-300A 115VAC X4E1	Agastat relay SSC 22AGA P&B KRP 11DG 110VDC input 120VAC output

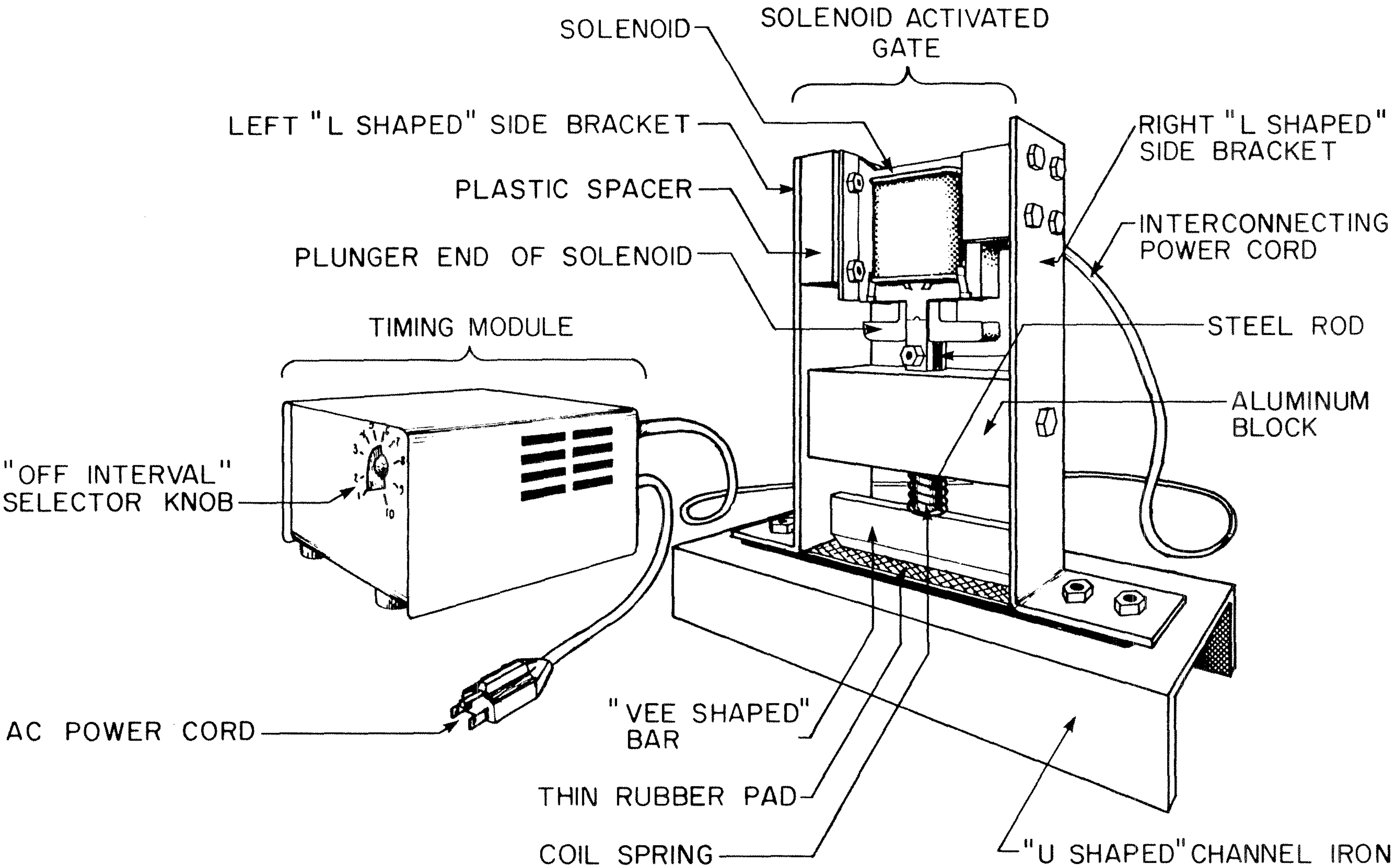

Figure 1. Diagram of the two components of the dispenser: the timing module and the solenoid activated gate

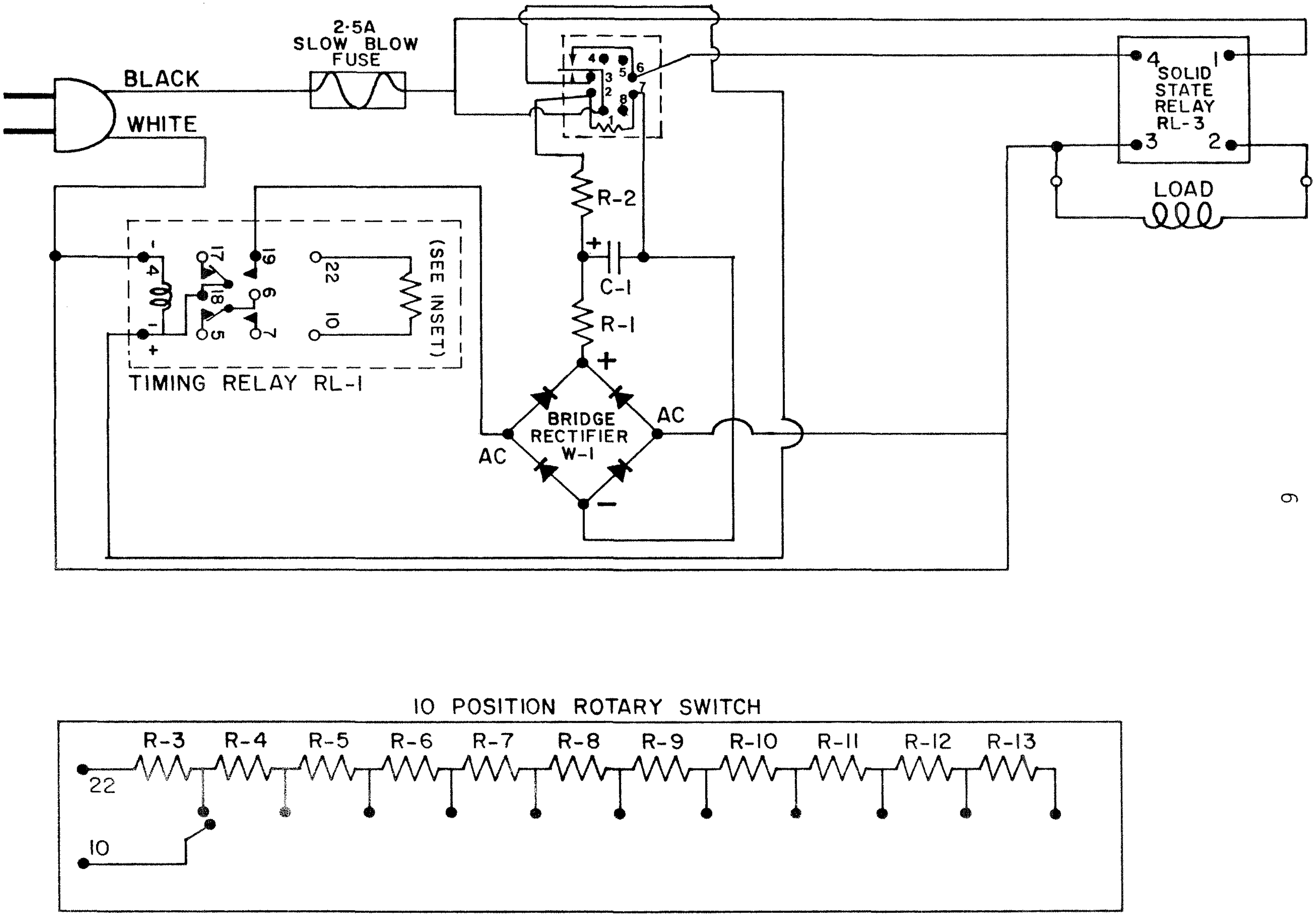

Figure 2. Schematic diagram of the timing module circuit.

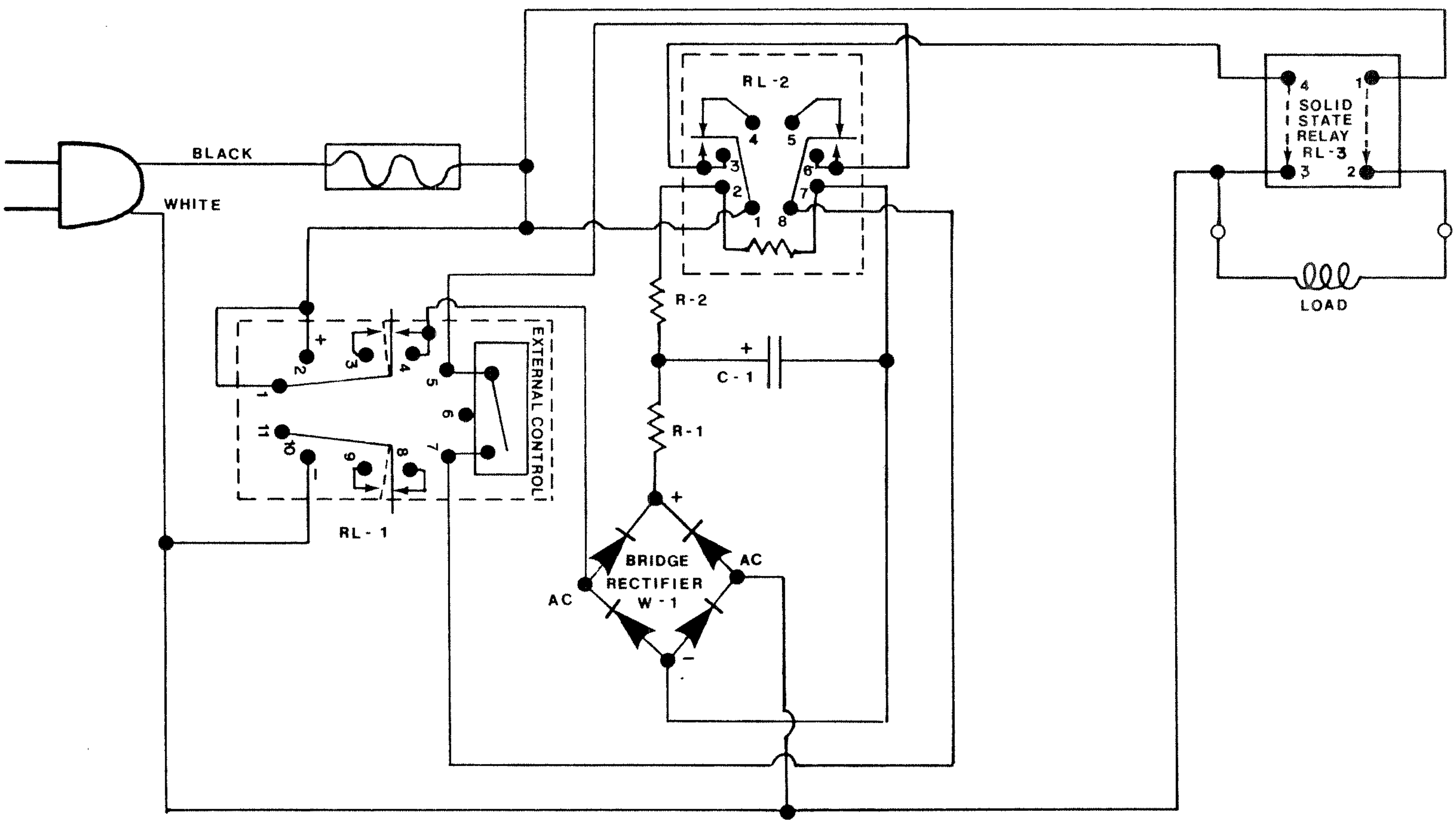

Figure 2a. Schematic diagram of the modified timing module circuit.

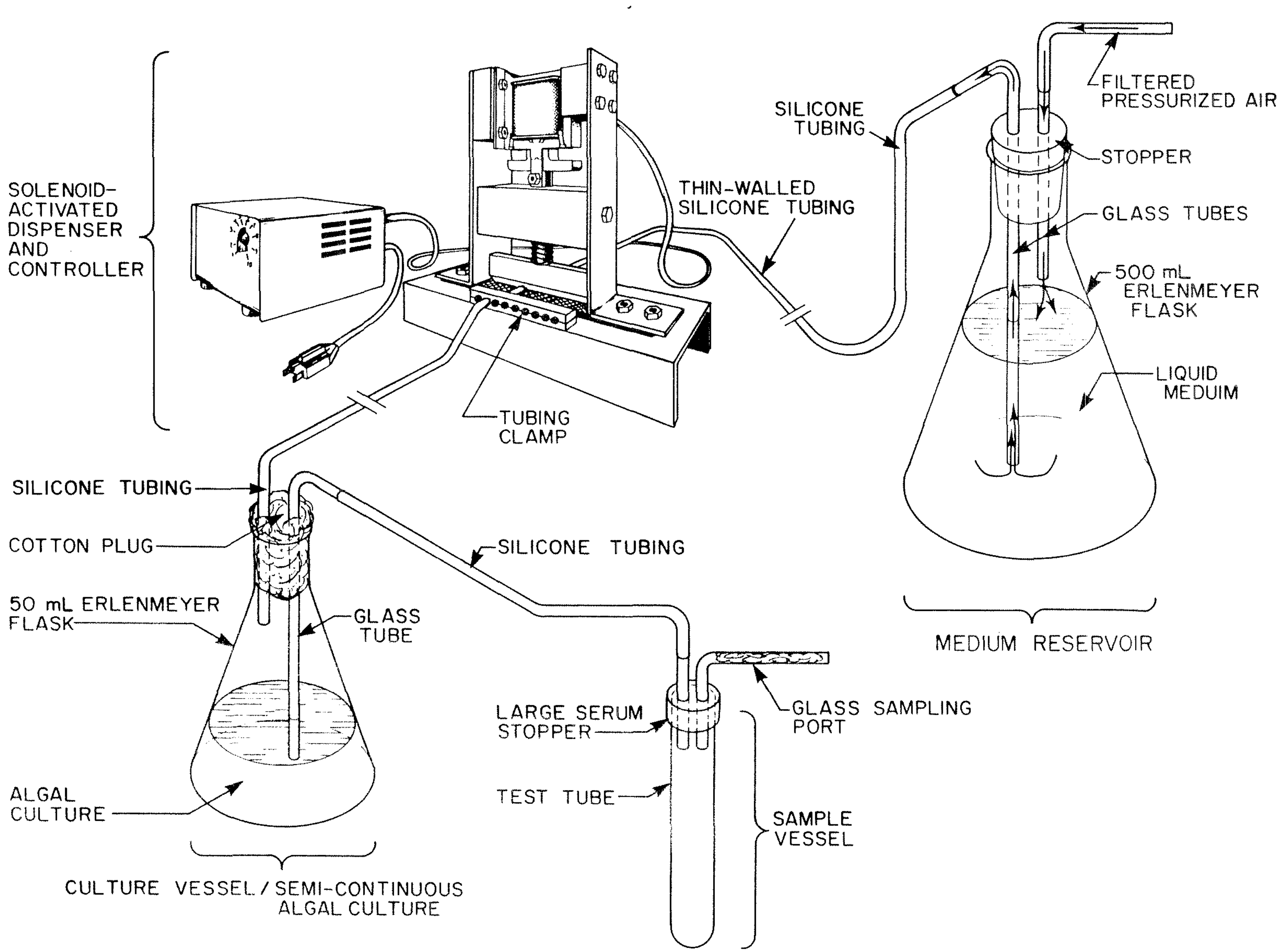

Figure 3. Diagram of the assembled components.