Hydraulic Automatic Lift-Gate Mechanism for Controlled Release of Walleye into Lake Winnipegosis

K.R.Scott and H.J. Ballon

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

July 1983

Canadian Manuscript Report of Fisheries & Aquatic Sciences No.1704

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Manuscript Report of Fisheries and Aquatic Sciences

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. They differ from Technical Reports in terms of subject scope and potential audience: Manuscript Reports deal primarily with national or regional problems and distribution is generally restricted to institutions or individuals located in particular regions of Canada. 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 management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

Manuscript Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted by *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Details on the availability of Manuscript Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Ils se distinguent des Rapports techniques par la portée du sujet et le lecteur visé; en effet, ils s'attachent principalement à des problèmes d'ordre national ou régional et la distribution en est généralement limitée aux organismes et aux personnes de régions particulières du Canada. 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, notamment gestion des pêches; techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Manuscrits peuvent être considérés comme des publications complètes. Le titre exact paraît au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figuera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros de 1 à 900 de cette série ont été publiés à titre de manuscrits (Série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés en tant que manuscrits (Série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros allant de 901 à 1425 ont été publiés à titre de manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 ont été publiés à titre de Rapport manuscrits du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été changé à partir du rapport numéro 1551.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

ERRATA

SCOTT, K.R. & H.J. BALLON 1983 Hydraulic automatic lift-gate mechanism for controlled release of walleye into Lake Winnipegosis. Can. Manuscr. Rep. Fish. Aquat. Sci. 1704.

Page 3 - replace the table in column 1 with the version below.

Hydraulic pressure -	600 lb/in^2
Motor current -	54 A
Gate rise time -	1.3 min
Gate lowering time -	1.5 min

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 1704

July 1983

HYDRAULIC AUTOMATIC LIFT-GATE MECHANISM FOR CONTROLLED RELEASE OF WALLEYE INTO LAKE WINNIPEGOSIS

by

K. R. Scott and H. J. Ballon

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

This is the 39th Manuscript Report
from the Western Region, Winnipeg

Cat no. FS 97-4/1704 ISSN 0706-6473

Correct citation for this publication is:

Scott, K.R., and H.J. Ballon. 1983. Hydraulic automatic lift-gate mechanism for controlled release of walleye into Lake Winnipegosis. Can Manuscr. Rep. Fish. Aquat. Sci. 1704: iv + 11 p.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Scott, K.R., and H.J. Ballon. 1983. Hydraulic automatic lift-gate mechanism for controlled release of walleye into Lake Winnipegosis. Can. Manuscr. Rep. Fish. Aquat. Sci. 1704: iv + 11 p.

A walleye (Stizostedion vitreum) rearing and stocking program on Lake Winnipegosis, Manitoba, involved the use of manual culvert lift-gates to facilitate fish releases. Fingerling walleye were planted in several natural or artificial impoundments in the spring, reared over the summer in a predator-free environment and released into Lake Winnipegosis in the autumn, after attaining a viable size. In order to allow unattended automatic operation at remote sites, a mechanical worm-gear driven unit was designed and successfully operated at Pacheta Lake in 1977.

This unit had several disadvantages including custom-machined stainless steel threaded drive shaft, specially modified time clock, special reversible direct-current motor, and a somewhat unwieldy control compartment housing.

To avoid these problems the system was redesigned to incorporate a standard 24 Vdc hydraulic power unit operating a 4.5 in diameter double-acting cylinder. Timing was controlled by a liquid crystal display (LCD) digital alarm clock and power was supplied by four heavy duty tractor batteries buried in a waterproof container. The unit was fabricated and installed on a 30 in diameter gate mechanism, attached to the impoundment culvert and operated successfully for two accelerated laboratory trials, each equivalent in duration to a full season's use, plus a nine-day field test.

Key words: dams, automated; culvert; aquaculture, ponds; rearing; fingerlings; hydraulic power.

RESUME

Scott, K.R., and H.J. Ballon. 1983. Hydraulic automatic lift-gate mechanism for controlled release of walleye into Lake Winnipegosis. Can. Manuscr. Rep. Fish. Aquat. Sci. 1704: iv + 11 p.

Des vannes manuelles permettant de relâcher plus facilement le poisson ont été utilisées dans le cadre d'un programme d'élevage et d'empoissonnement de dorés (Stizostedion vitreum) dans le lac Winnipegosis, au Manitoba. Au printemps, des alevins de dorés ont été placés dans plusieurs réservoirs naturels et artificiels, élevés durant l'été à l'abri des prédateurs puis relâchés à l'automne dans le lac Winnipegosis, ayant atteint une taille convenable. Afin de faire fonctionner automatiquement les installations situées dans des endroits isolés, un dispositif mécanique avec engrenage à vis sans fin a été mis au point et utilisé avec succés au lac Pacheta en 1977.

Ce dispositif comportait plusieurs désavantages, notamment un arbre de transmission fileté en acier inoxydable fait sur mesure, un mécanisme d'horlogerie spécialement modifié, un moteur réversible à courant continu de fabrication spéciale, et un compartiment de commande peu maniable.

Afin de remédier à ces inconvénients, l'installation a fait l'objet d'une nouvelle conception comportant un mécanisme d'entrainement hydraulique ordinaire de 24 Vcc actionnant un cylindre à double effet de 4,5 po. d'alésage. La minuterie était commandée par une horloge à affichage numérique par cristaux liquides et le courant fourni par une batterie de quatre accumulateurs de tracteur (modéle résistant) enterrée dans un coffret étanche. L'ensemble a été monté sur une vanne de 30 po. de diamétre, réuni au ponceau de retenue et éprouvé avec succès lors de deux essais accélérés en laboratoire, chacun représentant l'équivalent d'une saison complète de fonctionnement, auxquels se sont ajoutés neuf jours d'essais à pied d'oeuvre.

Mots-clés: barrages, automatiques; ponceau; aquiculture en réservoir; élevage; alevins; force hydraulique.

INTRODUCTION

The Province of Manitoba is engaged in a walleye rearing and stocking program on Lake Winnipegosis. Fingerlings are planted early in the spring in eleven natural or artificial impoundments at various locations around Lake Winnipegosis and released later the same autumn after reaching a survivable size.

EARLIER TECHNIQUES

Using the original method, the outlets from the impoundments are dammed with earthen dikes until release time. This serves two purposes: first, the fingerlings are protected from predators during their growth period and second, water levels are maintained sufficiently high to permit successful migration into Lake Winnipegosis. Since the ponds are only about seven feet deep, winterkill eliminates overwintering predators which would have otherwise remained in the rearing impoundments. To release the fish in the autumn, the earthen dike is removed, and the fish are free to migrate into Lake Winnipegosis in search of better food supplies.

Since most of the impoundments were located in remote areas and many accessible only by boat, winter roads or aircraft, seven of the eleven locations were fitted with channel culverts. The size of the culverts ranged from 24 to 48 inches diameter and each was fitted with a manually operated lift-gate mechanism (Fig. 1). This method greatly facilitated fish releases but, due to the difficulty of reaching the sites, the gates would often be left open once releases started. This often resulted in water levels becoming too low to permit natural migration, necessitating manual transfer of the stranded fish.

In order to allow automatic, unattended operation of the lift-gates, a worm-gear driven unit was designed, attached to a 24 inch culvert and successfully operated at Pacheta Lake in the autumn of 1977 (Scott 1982). This system took advantage of the fact that previous studies (T. Smith, personal communication) indicated that walleye had a decided preference to migrate only during a few hours of each day (Fig. 2). The lift-gate operating regime was therefore controlled by a time clock which automatically opened the gate at 4:00 pm and closed it at midnight. The unit was completely self-contained and was powered by two tractor batteries placed in a waterproof container buried in the ground. Although the worm-gear driven unit operated successfully, it had several disadvantages. These included custom-machined stainless steel threaded drive shaft, specially modified time clock assembly, nonstandard reversible direct-current motor, a somewhat unwieldy control compartment cover and rather complicated electronic reversing and overload circuitry. To overcome these problems, it was decided to design, test and install an alternate lift-gate unit incorporating a hydraulic instead of the original mechanical power train.

DESIGN CONSIDERATIONS

HYDRAULIC DESIGN

Since most of the culvert sizes were either 24 or 30 in diameter, a 30 in manual lift-gate was chosen for modification to adequately test the system. This was supplied to us by the Province of Manitoba. A major criterion of the new system was to eliminate most of the custom-designed components of the previous mechanical system (Scott 1982) and replace them with standard, commercially available components. The power unit (Fig. 3) (Webster Electric 1974) consisted of a positive displacement hydraulic gear pump (A) with an externally adjustable relief valve and an integrally mounted 24 Vdc automotive motor (B) and a hydraulic oil reservoir (C). For reliability, the standard motor operating solenoid was replaced by a 75 A silicon controlled rectifier (SCR) (RCA 1978) mounted on a large heat sink (D). The motor voltage was specified as 24 Vdc to reduce battery current and allow the use of smaller cable and an inexpensive, readily obtainable SCR. Control circuit components (Fig. 4) were mounted on a plug-in card (A), timing was controlled by a digital alarm clock (B) and a four-way, solenoid operated valve (C) switched the flow of hydraulic fluid to either end of the 4 1/2 in diameter double-acting hydraulic cylinder (Fig. 5, A) by means of flexible hoses (B). The piston rod of this cylinder (C) was connected to the bottom of the 30 in diameter gate (D) in order to minimize the overall height. Power for the unit was supplied by four 12 V tractor batteries mounted in a waterproof box (E) and connected in series-parallel to give a total electrical storage capacity of 220 Ah at 24 Vdc. Current flowed through a waterproof cable running to the bottom of the gate, through a protective pipe welded to the gate frame and then to the top control compartment. All electrical components and the hydraulic power unit were mounted above the gate on a 3/8 in thick steel plate and protected from the weather and vandalism by a seven-inch-high steel control component cover (F). Figure 6 shows the general layout and overall dimension of the lift-gate unit.

DESIGN CALCULATIONS

In order to keep the hydraulic unit size and battery pack requirements within reasonable limits, it was decided to base the design on a gate rise time of 1.5 min. While this was quite long compared to usual hydraulic operating mechanisms, it was not an undue constraint on our system since speed was not a requirement.

The hydraulic pump was the smallest unit commercially available. Assuming an operating pressure of 1300 lb/in^2, a Webster model OH6B pump was selected with a pumping capacity of 0.9 US gal/min and a corresponding motor current at 24 Vdc of 60 A. The hydraulic cylinder size required was then calculated from the relationship:

Volume of cylinder = Pumping rate x rise time, or in equation form

$$\frac{\pi}{4} \times (D_2^2 - D_1^2) \times L = K \times Q \times t \qquad (1)$$

where D_1 = cylinder inside diameter (in)
D_2 = piston rod outside diameter (in)
L = cylinder stroke length (in)
K = conversion factor (231 in^3/US gal)
Q = pumping rate (US gal/min)
t = time (min)

Assuming a piston rod outside diameter of two inches and substituting design values we get

$$\frac{\pi}{4} \times (D_2^2 - 2^2) \times 30 = 231 \times 0.9 \times 1.5$$

Solving for D_2 yields D_2 = 4.2 in. The cylinder selected therefore had a 4 1/2 in bore with a 2 in piston rod.

To calculate the ampere-hours required from the batteries based on three minutes operating time per day for 42 days

$$\text{Ah (total)} = \text{Ah(motor)} + \text{Ah(control card)} \qquad (2)$$
$$= \text{A(motor)} \times \text{h/season} + \text{A(card)} \times \text{h/season}$$
$$= 60 \times \frac{3}{60} \times 42 + 0.02 \times 24 \times 42$$
$$= 126 + 20 = 146 \text{ Ah}$$

therefore four batteries having a total rating of 220 Ah at 24 Vdc were selected.

CONTROL SYSTEM

To initiate the raising and lowering of the gate, a small LCD alarm clock (Fig. 7, A) which runs for one year on one "AAA" cell was used. Leads to the gate control board were: a) clock alarm output; b-b) across the alarm-disable switch; c-c) AM-PM display-switching output; d) power ground.

By proper signal conditioning and gating, this enabled the clock to give two alarm outputs at the required operating times, at 4:00 PM to raise the gate and at 12:00 midnight to lower it.

The sequence of systems operation is as follows:

When the alarm output of clock (A) is enabled, it is inverted and level-shifted by transistor (B). The amplified pulses are passed to both NOR gate (C) and IC inverter (D). NOR gate (C) is enabled, completing the clock alarm-disable circuit b-b, thus conserving battery power. The initial alarm pulse through the inverter (D) will trigger both the motor SCR circuit (E) and 'up' solenoid circuit (F). The motor SCR (E) completes the grounding circuits of both the pump motor (M) and the 'up' solenoid (F) of the fourway valve, and the hydraulic piston will raise the gate.

At midnight, the AM-PM display outputs c-c become out of phase, producing a pulse at the output of IC comparator circuit (G) which is applied to IC inverter (H). This inverter will trigger both the motor SCR circuit (E) and the 'down' solenoid circuit (I). The pump motor (M) and the 'down' solenoid (I) will be energized and the gate lowered.

When the piston reaches either end of its travel, hydraulic pressure will exceed the 850 lb/in^2 set point of the pressure limit switch (J), whose normally closed contacts will then open. This will trigger the pressure limit IC (K) and apply a momentary pulse to the turn-off transistor driver circuit (L) and the time-delay circuit (N). This delay circuit will apply a second pulse, 1/2 s later, to (L). Both pulses are passed to turn-off SCR (O) which does not latch because of its 470Ω load resistor (P). The negative-going pulse at the anode of (O) is coupled through capacitor (Q) to the anode of motor SCR (E). This de-energizes motor SCR (E) which turns off both the motor (M) and the directional valve solenoid. The motor, drive transistors and SCRs are operated from the 24 Vdc battery pack (R) which also powers a 5 Vdc voltage regulator for logic circuitry.

SAFETY AND OVERLOAD FEATURES

To test the lift gate control system at other than normal operating times, external 'up' and 'down' push-button test switches (T) and (U) are connected to the inputs of inverters (D) and (H). They will initiate the same signal sequences as the clock alarm outputs. Inadvertent operation of the wrong test switch will turn on the motor and drive the piston against its mechanical stop. The rise in hydraulic pressure will open pressure switch (J) to initiate the normal turn-off sequence. If the coupling capacitor (Q) had been previously discharged and had not been sufficiently recharged at this time, turn-off SCR (O) will not pass a negative pulse through it to unlatch motor SCR (E) and turn off the motor. Since capacitor (Q) charges to operating level in less than 1/2 s, the delayed pulse through time delay circuit (N) arriving 1/2 s after the primary pulse ensures reliable turn off of motor SCR (E).

Control circuit power switch (S-a,b) is an external DPST toggle switch, pole S-a applying 24 V to the power devices and to the 5 V control board voltage regulator. If, during a test or emergency situation, one desires to stop the gate between the upper and lower limits, merely turning off the control circuit power switch (S-a) will not work. Switching off the power to the control board would disable the turn-off circuit while the motor SCR (E) would remain latched. This problem was overcome by simultaneously opening the contacts of switch (S-b), which is in series with pressure switch (J), thus duplicating its action. A 1000 μF capacitor across the control board's 5 V supply maintains power to the turn-off circuit for sufficient time to allow completion of the sequence and stop the motor. The control system and motor draw about 54 A under normal operation. If any component of the control system turn-off circuitry should fail, the motor will remain running at an end stop and, with the pressure relief valve set at 1100 lb/in^2, will draw 70 A. A 35 A "SLO-BLO" fuse (V) in the main power line will blow within eight seconds thus preventing overheating of the motor and draining of the batteries.

TEST PROCEDURES

To test the gate under simulated operating conditions, a calculation was made of the force acting on the face of gate due to the water pressure, using the equation

$$F = K \times H \times \frac{\pi}{4} \times D^2 \qquad (3)$$

where F = force on face of gate (lb)
K = pressure developed per inch of water ($0.036\ lb/in^3$)
H = height of water above gate centre (in)
D = open diameter of the culvert (in)

Substituting the open diameter of the culvert (29 in) and the estimated maximum height of water above the gate centre (40 in) we get:

$$F = 0.036 \times 40 \times \frac{\pi}{4} \times 29^2 = 951\ \text{lb}$$

The modified gate assembly was connected to the power supply and placed in a horizontal position to allow weight to be added to the gate during the test. Pressure in the cylinder was measured by a hydraulic gauge temporarily teed into the line, and motor current was measured by a clamp-on ammeter clamped around the power cable. Time was measured with a digital watch.

The force to simulate the water pressure was achieved by five persons, total weight 925 lb., standing on the gate while the system was operated. Several tests were performed with average values as follows:

Hydraulic pressure lb/in^2 600.
Motor current A 54.
Gate rise time min. 1.3.
Gate lowering time min. 1.5.

The slower lowering time occurred because of the method of attachment of the piston rod to the gate. On the downstroke, the entire cylinder volume must be pumped, whereas on the upstroke a portion of the volume is displaced by the rising piston rod.

The results of the tests showed that the gate rise time was faster and the hydraulic pressure and motor current were less than calculated thus the selected equipment exceeded design criteria.

Following the design proof tests, the system successfully passed two accelerated pilot plant trials each equivalent in total duration to a full season's operation. For these tests, the gate was cycled up and down by the clock seven times a day for six days, the batteries being recharged between the two trials.

FIELD INSTALLATION

The entire assembly was transported to Salt Point on Lake Winnipegosis. The batteries, in their waterproof container, were buried in the ground, the gate was attached to the culvert and the interconnecting power cable installed. After checking for proper operation, the steel control compartment box was bolted over the hydraulic power pack and controls. Figure 8 shows the installed gate unit when looking toward the impoundment. The culvert can be seen just below the water's surface.

The unit was turned off for four months to await the starting time for fish releases. The system was then activated and ran successfully for 14 days at which time the batteries were found to be almost completely drained. Tests were discontinued at this time as water levels were too low for adequate water flows. The premature battery failure was diagnosed by an battery consultants as due to charge loss of the batteries during the four-month interval between installation and usage.

COMPARISON AND EVALUATION

Total material cost of the installation was $1,350.00 (not including the gate itself which was supplied by the Province of Manitoba). This compares with $1,108.00 for an earlier system (Scott 1982) which used a mechanical worm-gear drive and a stainless steel threaded rod. The hydraulic unit was much more compact, particularly the control compartment which was only seven inches high compared to 32 in for the mechanical system. Furthermore, most of the components for the hydraulic system were commercially available whereas the mechanical system was largely custom fabricated. The hydraulic system required four batteries compared to two for the mechanical system and this comprised the majority of the extra cost. An overall comparison would tend to favor the hydraulic system.

The flawless operation of the unit during the accelerated laboratory tests showed that the system could easily meet design criteria.

It is strongly recommended that future installations incorporate maintenance-free lead-calcium battery packs to give adequate ensurance against charge loss during extended standby periods. An alternative solution is to install freshly-charged standard tractor batteries just prior to the start of the gate operating regime, thus avoiding the problem of charge loss during the six-week period of fish releases.

ACKNOWLEDGMENTS

We thank Trevor Smith, Hugh Valiant and Gerry Edwards of the Department of Renewable Resources, Province of Manitoba who provided the original gate and did the site preparation for, and installation of, the modified automated lift-gate unit.

REFERENCES

SCOTT, K.R. 1982. Mechanical automatic lift-gate mechanism for controlled release of walleye into Lake Winnipegosis. Can. Manuscr. Rep. Fish. Aquat. Sci. 1675: iv + 10 p.

WEBSTER ELECTRIC CO. INC. 1974. Bulletin FP 133.2 June 74.

RCA. 1978. RCA Solid State Power Devices Data-book SSD-220B.

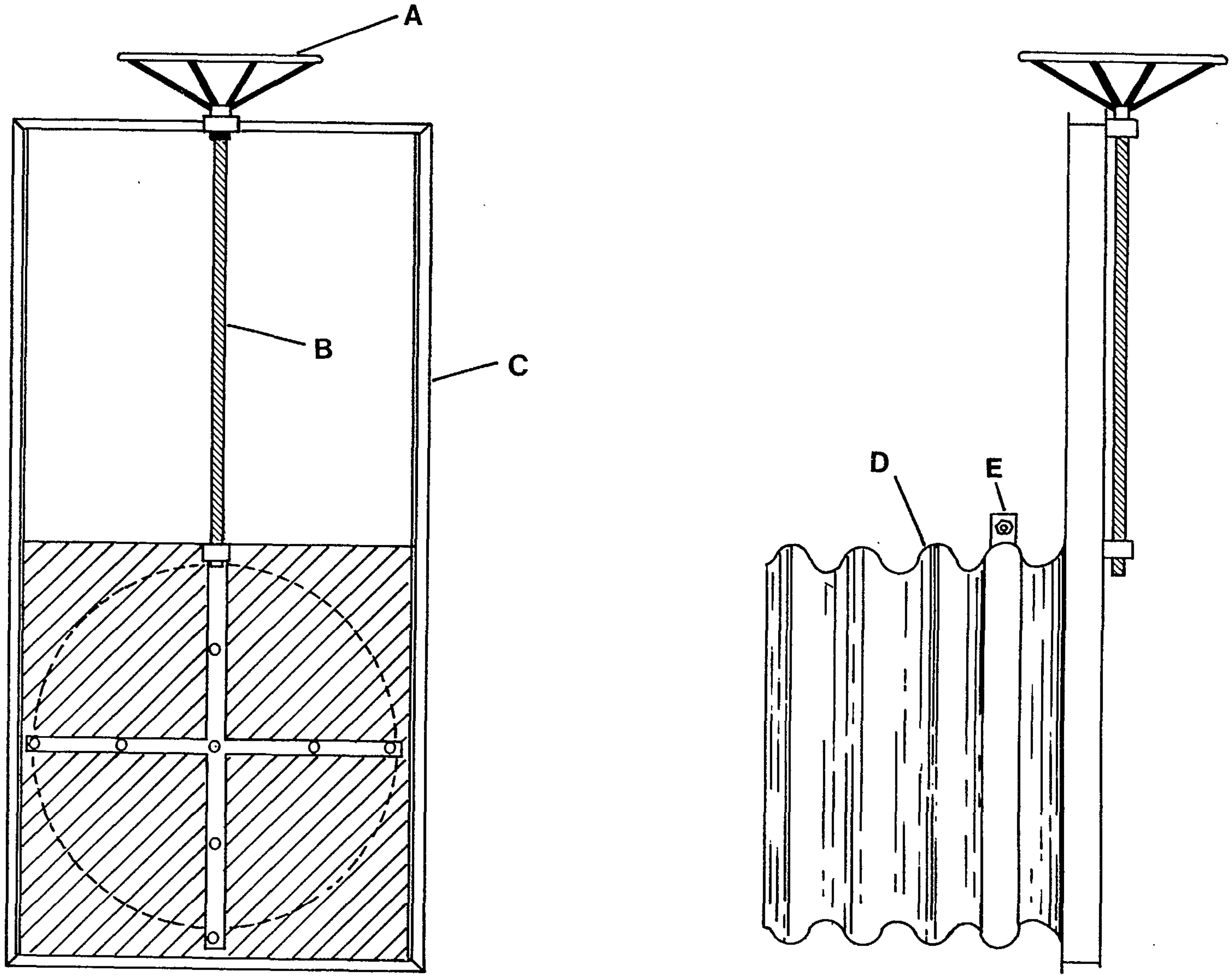

Figure 1. Manually operated control gate
A, hand wheel; B, threaded shaft; C, gate upright supports;
D, channel culvert; E, liftgate culvert coupler.

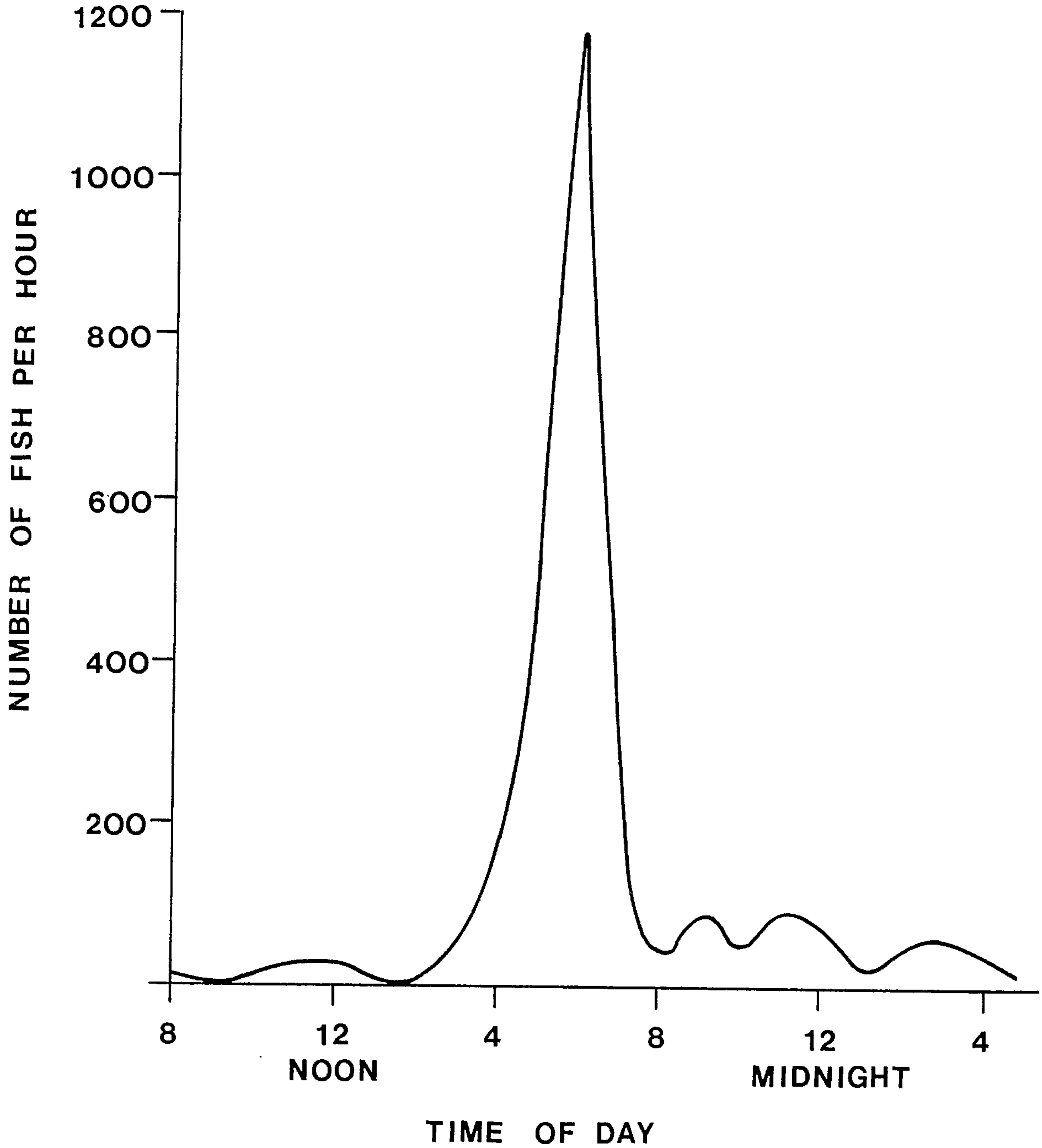

Figure 2. Walleye migration pattern.

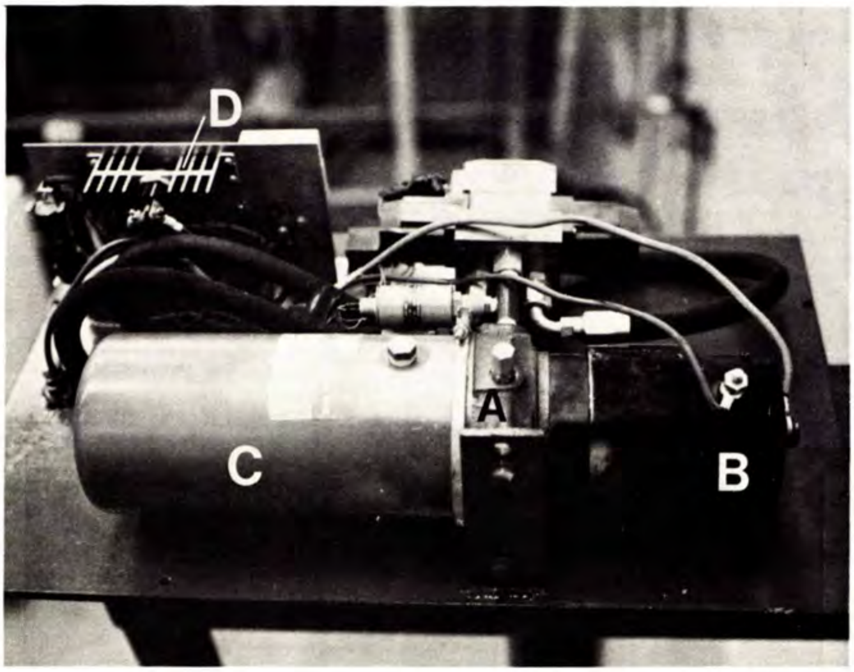

Figure 3. Hydraulic power unit
A, hydraulic gear pump; B, 24 Vdc automotive motor;
C, hydraulic oil reservoir; D, 75 A SCR mounted on heat sink.

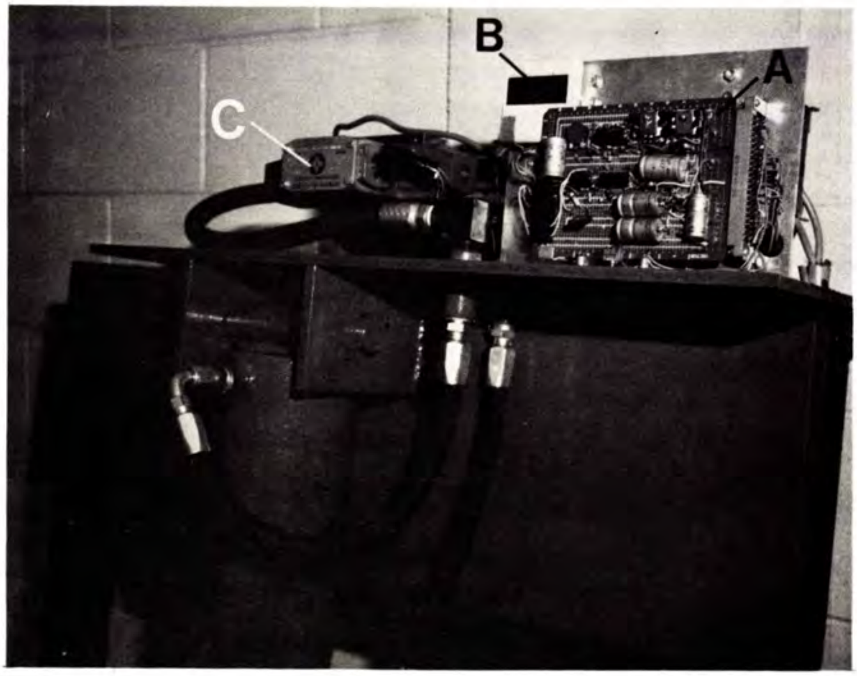

Figure 4. Control components
A, plug-in circuit card; B, digital alarm clock;
C, four-way solenoid operated hydraulic valve.

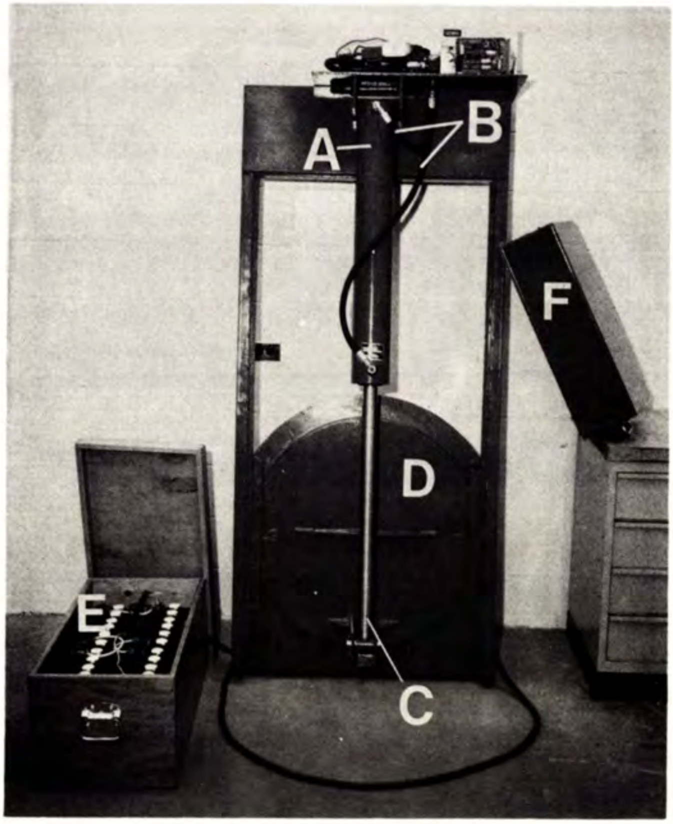

Figure 5. Gate assembly components
A, double acting hydraulic cylinder; B, flexible hydraulic hoses, C, cylinder piston rod; D, 30 inch diam gate; E, batteries in waterproof box; F, control compartment box.

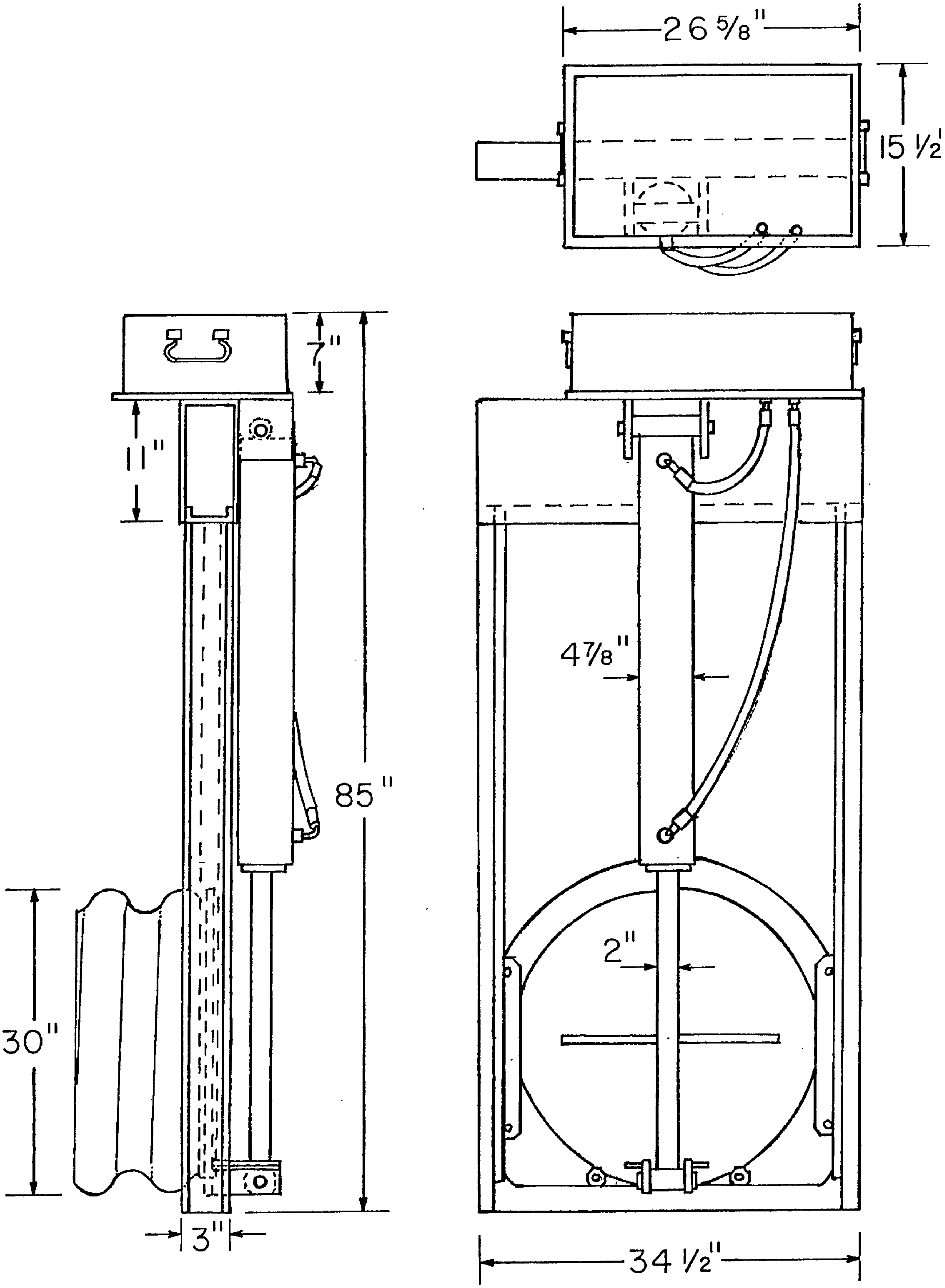

Figure 6. General layout and overall dimensions of lift-gate unit.

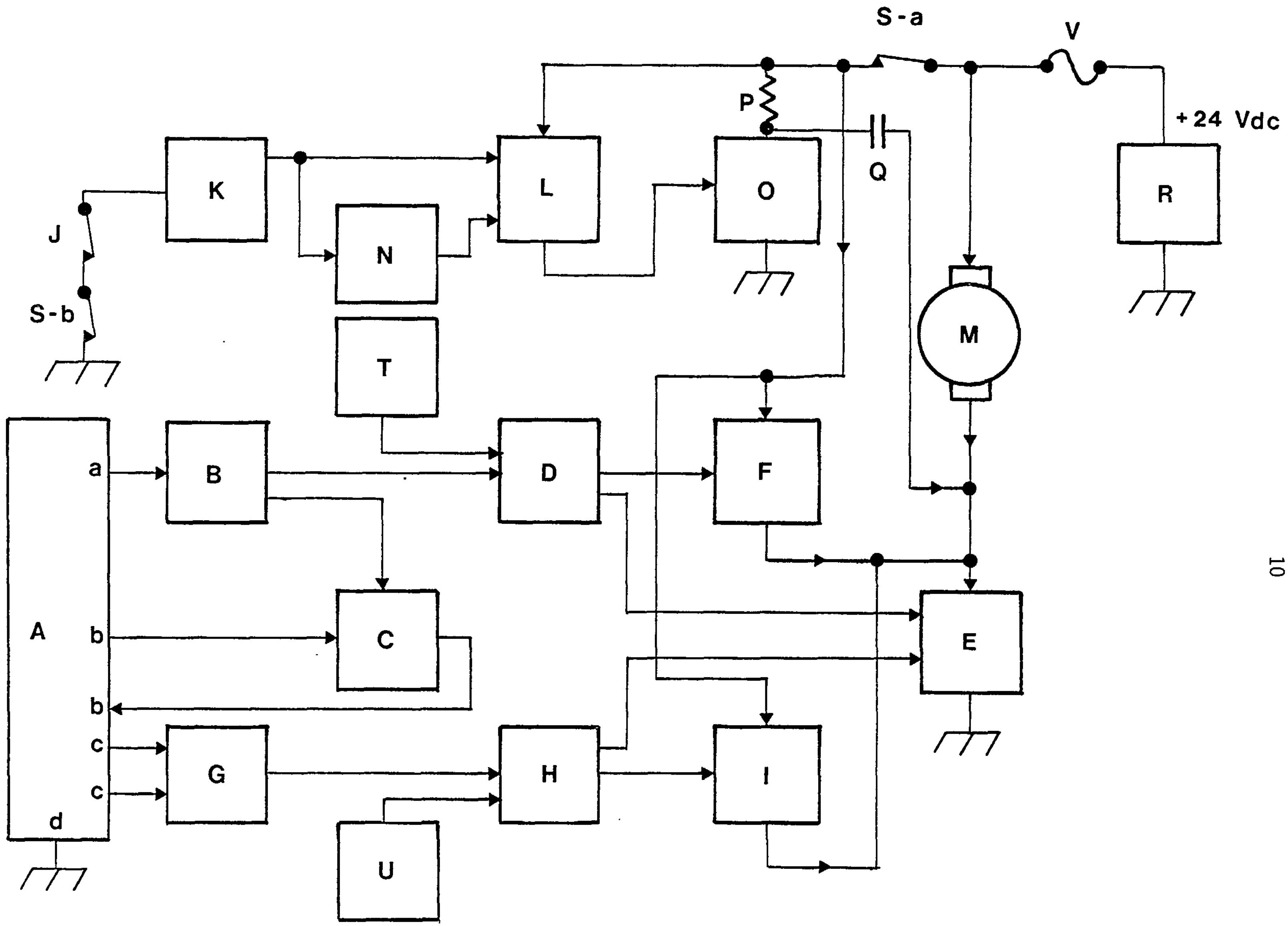

Figure 7. Control system block diagram - A, LCD alarm clock; B, transistor inverter; C, NOR gate; D, H, 'up' and 'down' IC inverters; F, I, 'up' and 'down' solenoid circuits; E, 75A motor SCR; G, IC comparator circuit; J, hydraulic pressure limit switch; K, pressure limit IC; L, turn-off transistor driver circuit; M, pump motor; N, time-delay circuit; O, turn-off SCR; P, 470Ω load resistor; Q, coupling capacitor; R, 24 Vdc battery pack; S-a, S-b, DPST control circuit power switch; T, U, 'up' and 'down' switches.

Figure 8. Hydraulic gate unit installed at Salt Point impoundment.

Printed in Canada by
Supply and Services Canada
Printing Office
for exclusive distribution by
Fisheries and Oceans
Freshwater Institute
Winnipeg, Manitoba
Canada