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Description of a special logging truck built for the U.S. Geological Survey for borehole gravity survyes

by

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

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I. Introduction

The truck described in this report (figs. 1 and 2) was built for the U.S. Geological Survey (USGS) to be specifically used in well-logging operations employing borehole gravity meters (BHGM). The original logging system used with the BHGM by the USGS was laborious and slow (McCulloh and others, 1967; Beyer, 1971, p. 92-101). In 1974, after a new small diameter borehole gravity meter (SBGM) was conceived and contracted for, the Energy Research and Development Agency (ERDA), now a part of the Department of Energy, agreed to fund the building of a logging truck under interagency agreement EX-76-C-01-2287. Larry A. Beyer, of the USGS, set forth the original design and with the assistance of Quentin Gordon, also of the USGS, determined the specifications. SIE, Inc.[1/] of Fort Worth, Texas, built the truck to those specifications. Ron Paara, a structural engineer on their staff, designed the tower, the measure-head, and the spooling configuration details. SIE, under my direction, made several modifications and additions to the truck contract during the initial construction. After the truck was used in the field for about 6 months, and again after 18 months, more additions and modifications were made. Most of these changes were directly related to making the operation of the BHGM safer, smoother, and faster while obtaining more accurate data.

[1/] Use of brand names in this report is for descriptive purposes only and does not necessarily constitute endorsement by the U.S. Geological Survey.

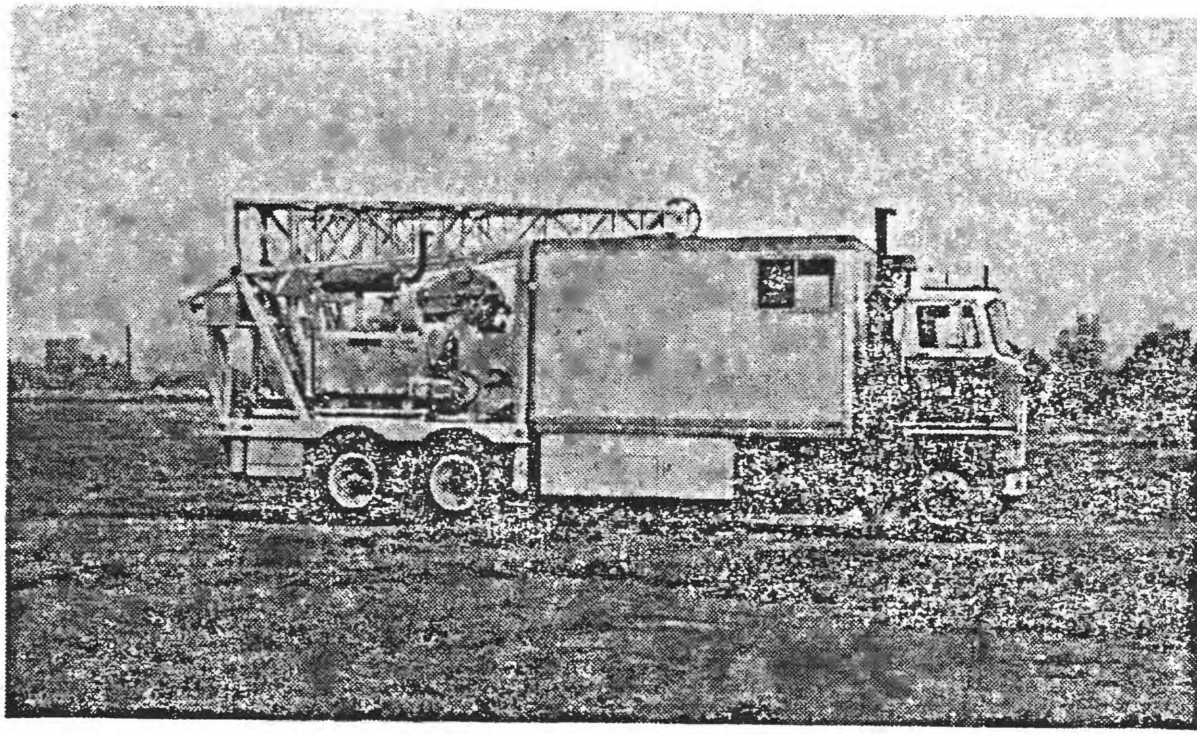


Figure 1. USGS BHGM logging truck with tower down.

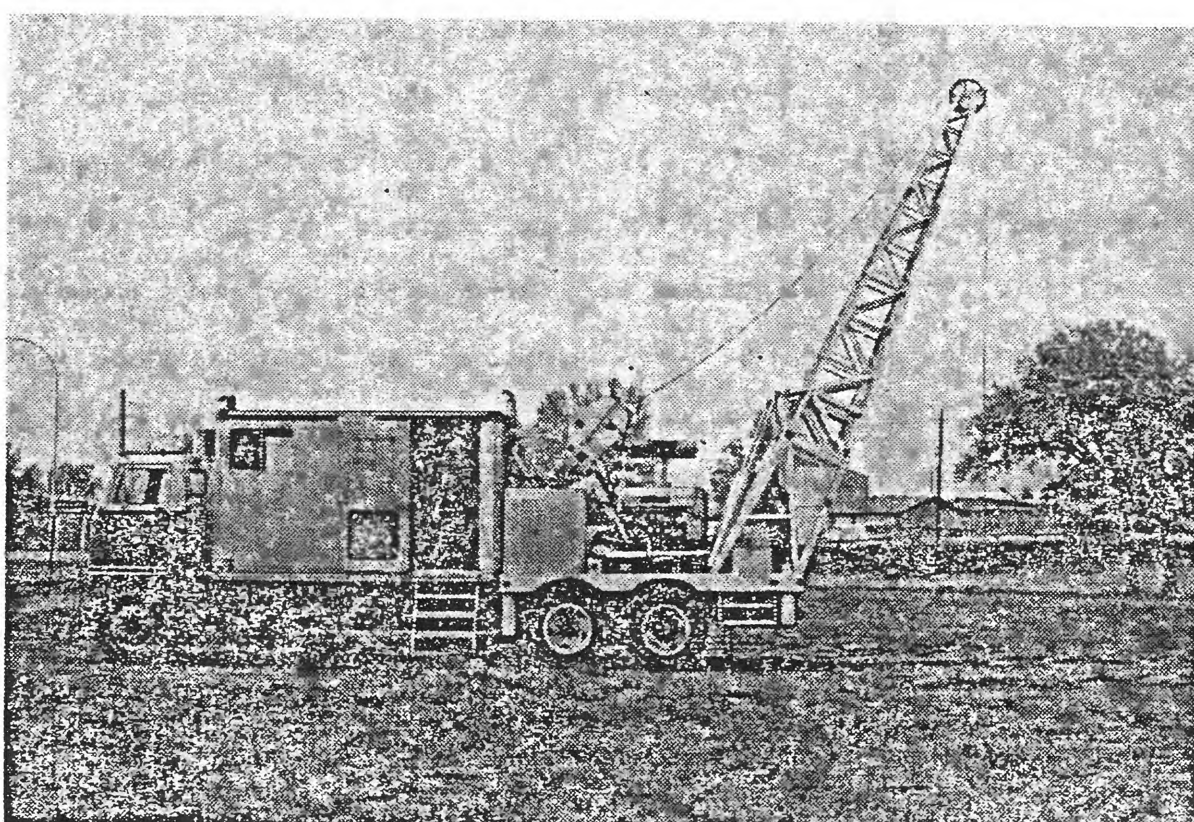


Figure 2. USGS BHGM logging truck with tower and measure-wheel system up.

The truck is self-contained for most operations. It is capable of sustained highway speeds for travel anywhere in the United States and has the following features: 1) a large work space inside the control van which also serves as a mobile electronics laboratory; 2) a hydraulically operated tower to support cable sheaves that extends to a height of 25 feet (fig. 2); 3) a hydraulically operated draw-works with about 12,000 feet of 15/32" seven-conductor cable which is capable of handling up to about 18,000 lbs. of pull; 4) four outrigger cylinders to stabilize the truck by isolating it from its suspension and rear wheels; 5) two 6-KW 110-volt AC generators; 6) two independent cable-depth measuring systems; 7) a magnetic cable-marker system; 8) a built-in cable-clamp or line-wiper control system operated from inside the control van; 9) built-in air-compressor and high-pressure liquid cleaning systems; 10) a special "damped" system for transporting the BHGM vertically in its pressure sonde on the highway, while "on temperature"; and 11) a large flat-bed trailer with loading ramps that can be towed for carrying a support vehicle (fig. 3).

In 1976, prior to the completion of this truck, several wells were logged using logging trucks provided by different commercial companies. Not only was this method of logging costly but there seemed to be major obstacles to deal with on each truck used. These included: 1) generator problems, 2) poor gamma-ray equipment, 3) difficulty in finding seven good conductors within the cable, 4) resistances too high for the BHGM in some cables, 5) providing or finding adaptors to match the cablehead to our tool, 6) instructing the truck operator in techniques needed for logging with our tool, 7) the logistics of finding a truck when and where it was

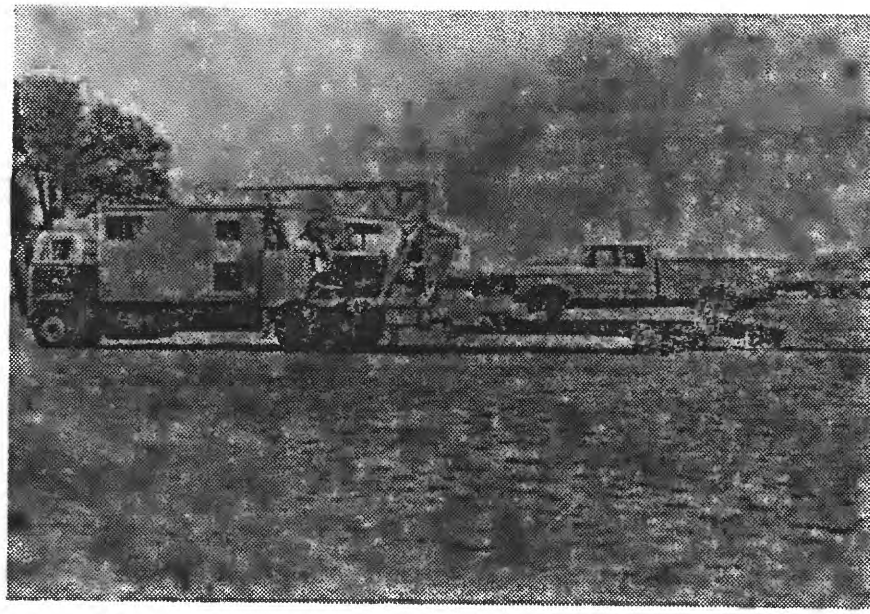


Figure 3. Overall view of the USGS BHGM logging truck ready for transit (includes trailer and support vehicle).

needed, 8) poor handling of our electronic consoles by the airline companies while enroute to and from a wellsite, and 9) the parting of a cable which almost caused the destruction of the BHGM (value of the downhole tool is $250,000 and a two year manufacturing time minimum) during the logging of the last well that was logged using a commercial truck.

II. Acknowledgements

I wish to thank Marion Hawthorne of SIE, Inc. for the time and interest he took in helping to solve many of the design problems. I also acknowledge the discussion and aid provided toward solving these problems by L. A. Beyer, F. G. Clutsom, R. J. Martinez, J. W. Schmoker, and D. L. Smith, all of the USGS.

III. Truck Descriptions

A.) Basic truck

The logging truck is built on a 1971 International-Harvester C4070A long wheel base (248 inches) chassis with the following specifications:

Power: 335 HP Cummins NTC 335 turbo-charged diesel engine.

Transmission: 10 speed RT-910 Fuller with a 5 speed compound range.

Rear-end: Tandem-axle 14-334 SQHD Rockwell differentials with posi-traction, power-lock between axles when required, and a Hendriks suspension.

Fuel system: 300 gallons of diesel which fuels the entire truck.

Braking: Air-brakes on 10 wheels plus a Jacob's engine brake.

Tires: Eight 10x22 tires on the rear and two 10X20 tires on the front.

Height: At high point with tower down (fig. 1), truck is 12 feet 11 inches.

Length: Overall length is 33 feet.
Length to pintle hitch is 31 1/4 feet.

Weight: Approximately 38,000 lbs with 28,000 lbs on rear-axles.

Turning circle: 96 feet Left.
83 feet Right.

Trailer capabilities: Any trailer with a pintle hook up to 24,000 lbs. GVW can be pulled. The truck has an air-activated electric brake connector.

Electrical system: A 12-volt DC system using four 6-volt batteries (two sets in parallel of two batteries each in series) and a 60-amp alternator. Through a switching system mounted in the front cab, the batteries mounted in the rear of the truck for the operation of the logging functions can be charged by the Cummins 60-amp alternator (fig. 22).

B). Logging operations--outside features

1) Generators: There are two 6-KW 110 volt AC electric generators. The controls for these units are discussed on page 32.

a) The Onan diesel unit, shown in figure 4, is used mainly: i) to operate the heavy electrical equipment which is only used at short intervals, ii) when power is needed but there is no logging in progress, and iii) as a backup unit. The main complaint with this generator is that it is noisy.

b) The hydraulically operated generator (see fig. 5) runs off the Waukesha engine through a Vickers pump. The generator is used primarily to supply power for the electronic equipment because transient spikes are caused by the turning on and off of the heavy electric motors. It has been found that the AC regulator used with the electronics equipment cannot always handle these spikes.

2) Tower and outrigger cylinders: The truck is equipped with a tower which when raised (figs. 1 and 2) places a sheave wheel 25 ft above the ground and 9 ft behind the truck. The tower is used to support and direct the logging tools and cable into the well, and can also be

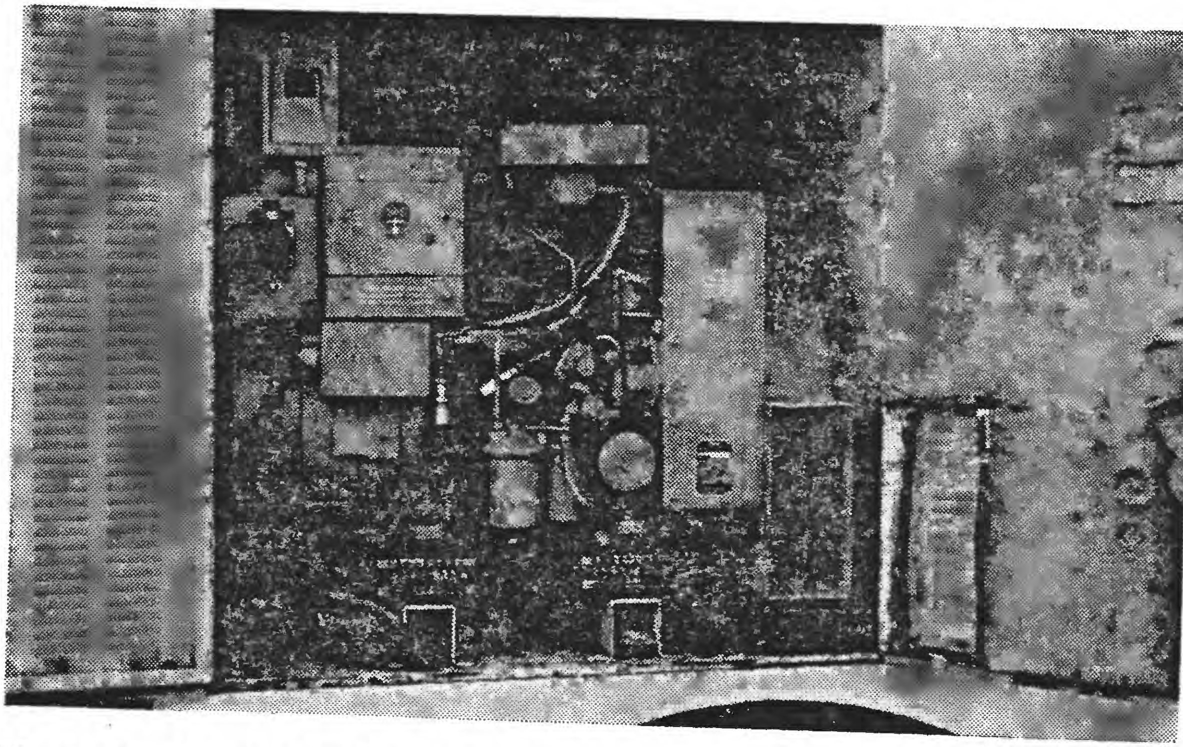


Figure 4. Onan 6-KW 110-volt AC diesel generator located on left side of BHGM logging truck.

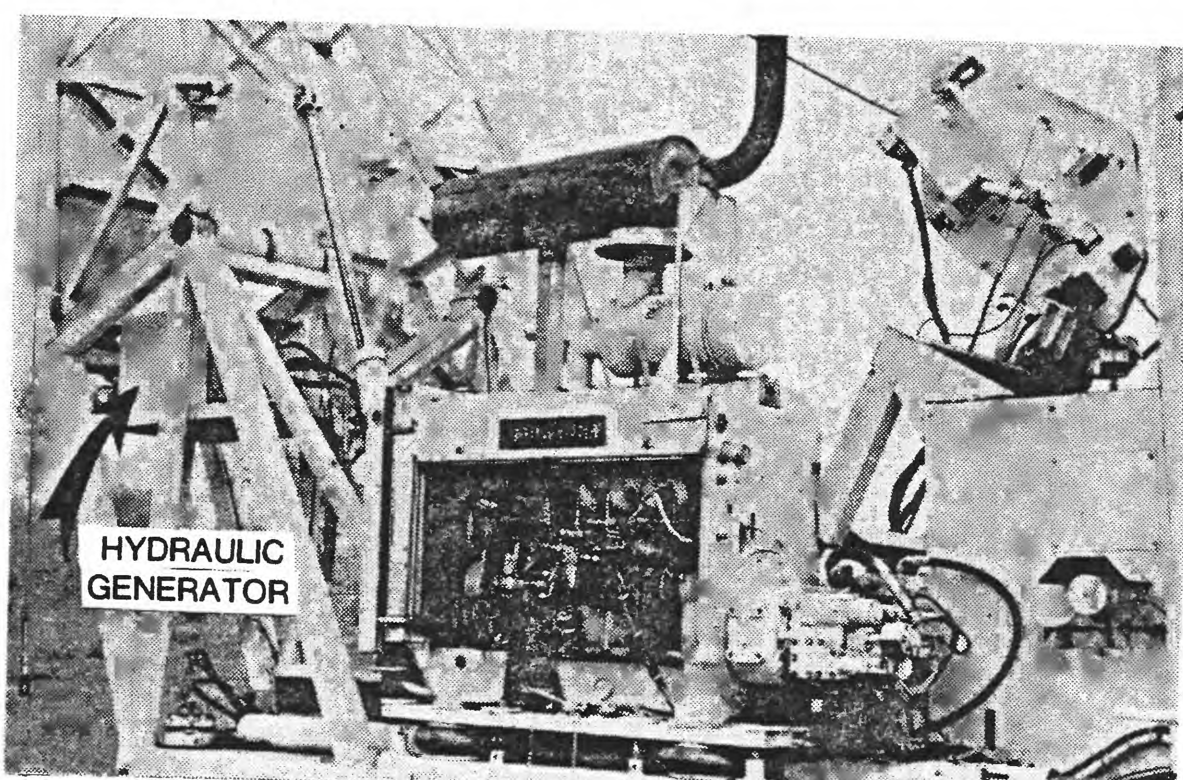


Figure 5. Waukesha VRD310 diesel engine and Vickers-Onan hydraulic 6-KW 110-volt AC generator located on right side of BHGM logging truck.

used for crane operations such as placing and removing heavy tools (e.g. sinker bars) on and from the tool rack and moving heavy objects (e.g. small buildings and well-head flanges) from over wells. The moving part of the tower weighs only 800 lbs (including sheave wheel) but is designed to handle up to 18,000 lbs vertical cable pull when the tower is fully extended. If a work-over rig is already present at a well, the truck can be operated without using the tower. The tower is not high enough to be used at most wells under pressure where the use of a lubricator is required.

There are four vertical hydraulic outrigger-cylinders (fig. 6) located at the four corners of the logging draw-works platform. These cylinders provide a stable platform and limit the transmission of truck movement down the cable to the BHGM. The meter is read at static positions and is very sensitive to all vibrations.

The cylinders and tower are operated hydraulically from an electrically-operated hydraulic pump (see fig. 8 for diagram of this system). The controls are located on the left side of the truck (fig. 7). There is a second control (in parallel) inside the control van for the tower (fig. 26).

3) System for operation of logging cable: The drum and logging cable (11,000 ft to 12,000 ft, seven-conductor, 15/32 in. diameter) are powered and controlled by a Sundstrand hydraulic pump and motor through a three-speed transmission and a gear-reduction box connected to the drum by a sprocket-driven chain. The pump is powered through a two-pump geared adaptor attached directly to a Waukesha VRD310 diesel engine which produces 79 HP at 1800 RPM (fig. 5). The Vickers

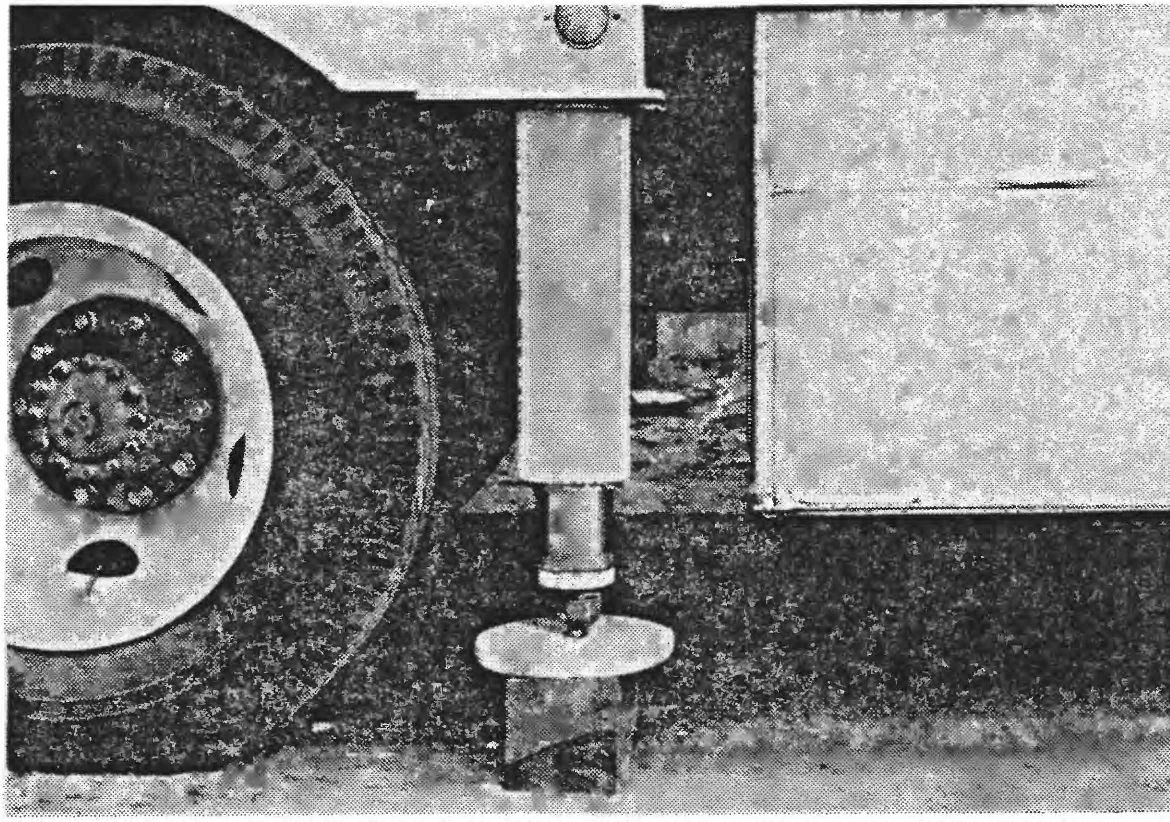


Figure 6. View of an extended hydraulic-outrigger cylinder on BHGM logging truck.

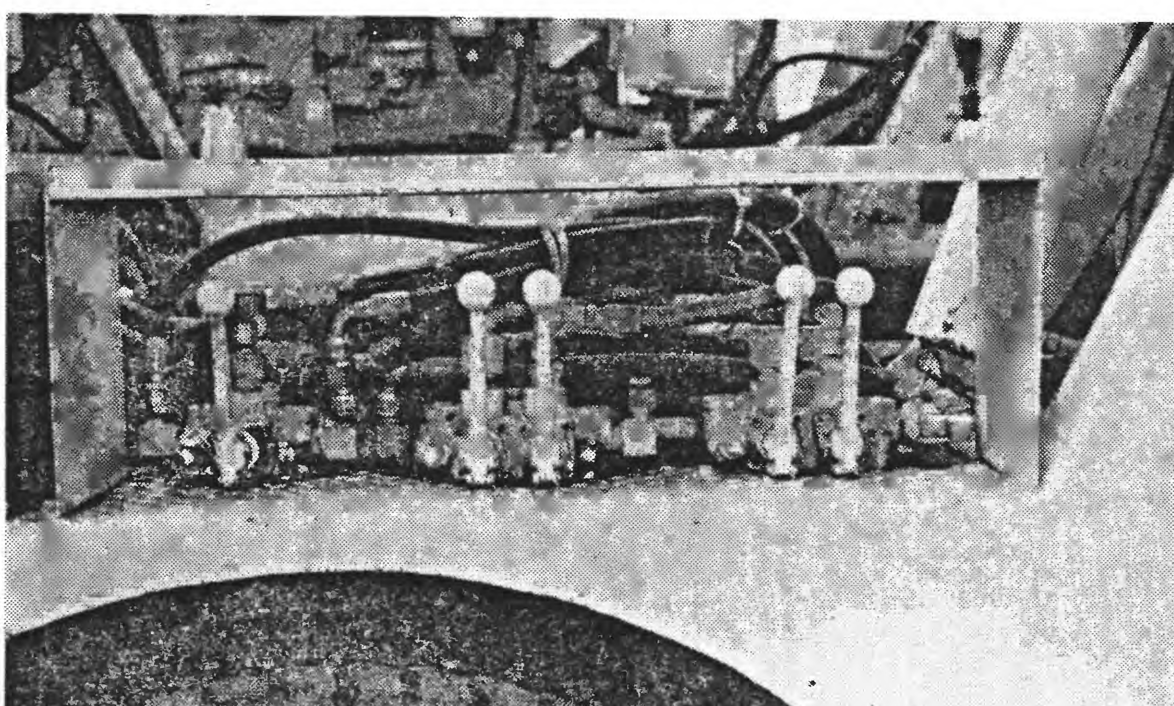


Figure 7. Control valves for tower and outrigger cylinders located on left side of BHGM logging truck.

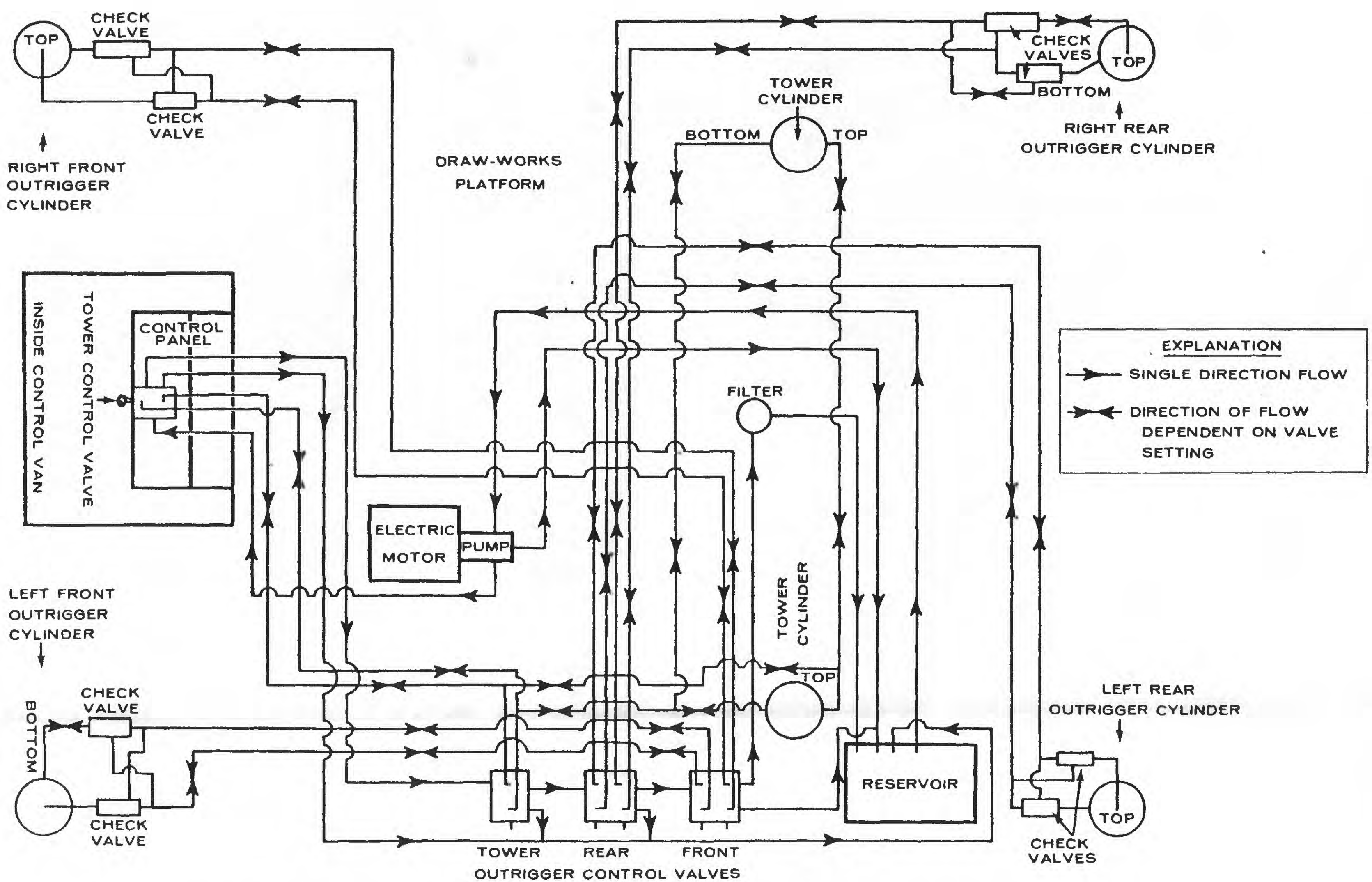


FIGURE 8. DIAGRAM OF ELECTRO-HYDRAULIC PUMP SYSTEM ON THE BGHM LOGGING TRUCK.

hydraulic pump which runs the above-mentioned generator is also attached to the geared adaptor.

The charge pressure from the Sundstrand pump keeps two large spring-loaded cylinders extended which, when the pressure is released, automatically brake the cable drum. The drum is braked under the following conditions:

a) The Waukesha engine is not running (cylinders close when engine stops).

b) Charge pressure is lost (break in a hydraulic hose, etc).

c) Dump-valve in control van is placed in the up position (see figure 9 for a diagram of the Sundstrand hydraulic system).

The charge presssure also operates the cylinders that raise the measure-head for use with the tower (fig. 11 and see next section).

The Waukesha engine rests on four 9-inch diameter air-cushions. In the clamped position (fig. 10), the engine rests directly on steel channel bars and is held in place by 1/2-inch-in-diameter threaded pins. When the engine is to be used, nuts are loosened, the pins are released and the air-bags inflated to about 12 PSI. The cushions do an excellent job of isolating engine vibrations from the truck. However, this was not the main reason for the air-cushion installation. Initially, four 4" X 6" X 4" rubber cushions were used. However, when the truck was in transit, the bolts used for holding the engine firmly in place frequently broke.

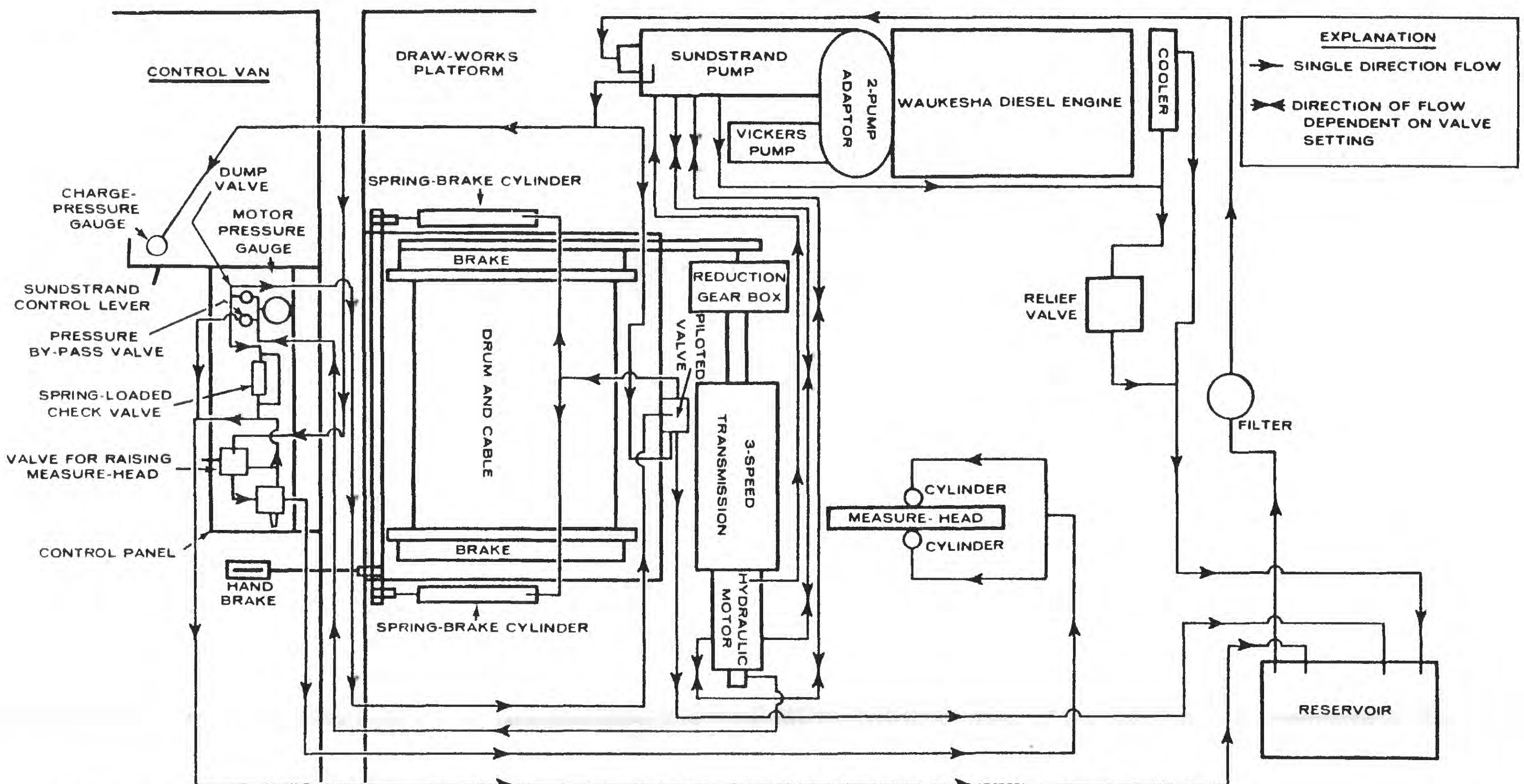


FIGURE 9. DIAGRAM OF THE SUNDSTRAND SYSTEM FOR OPERATION OF THE DRAW-WORK ON THE BHGM LOGGING TRUCK.

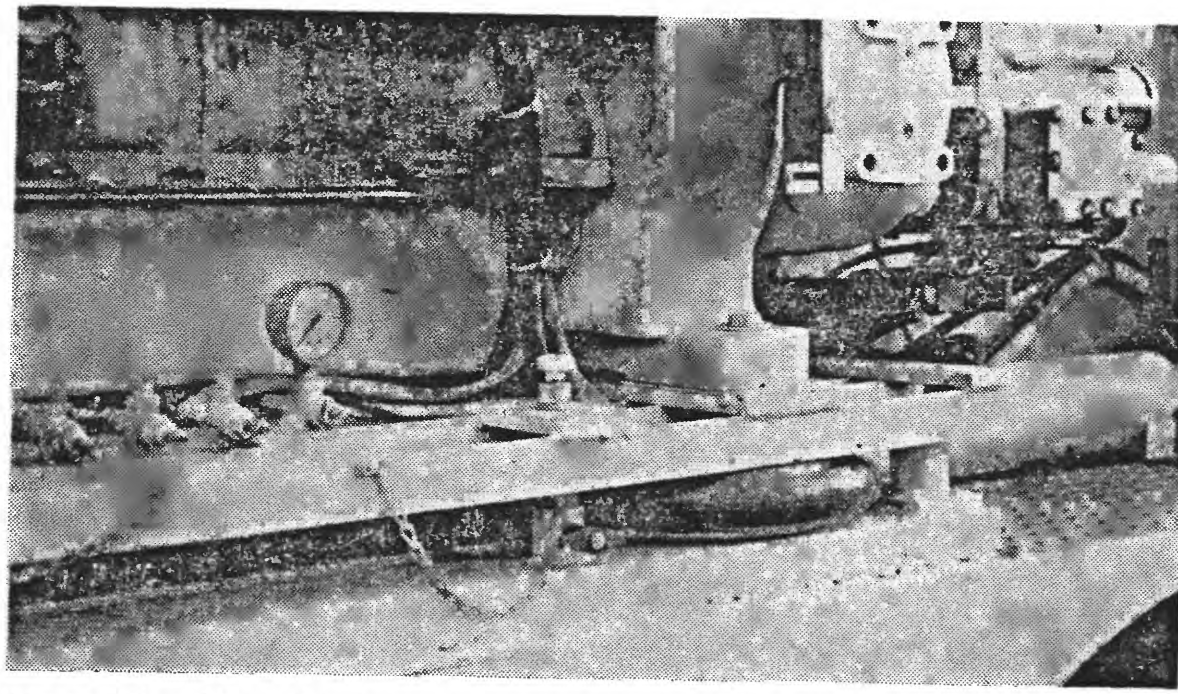


Figure 10. View of an air-cushion (in clamped position) used as an engine mount for the Waukesha.

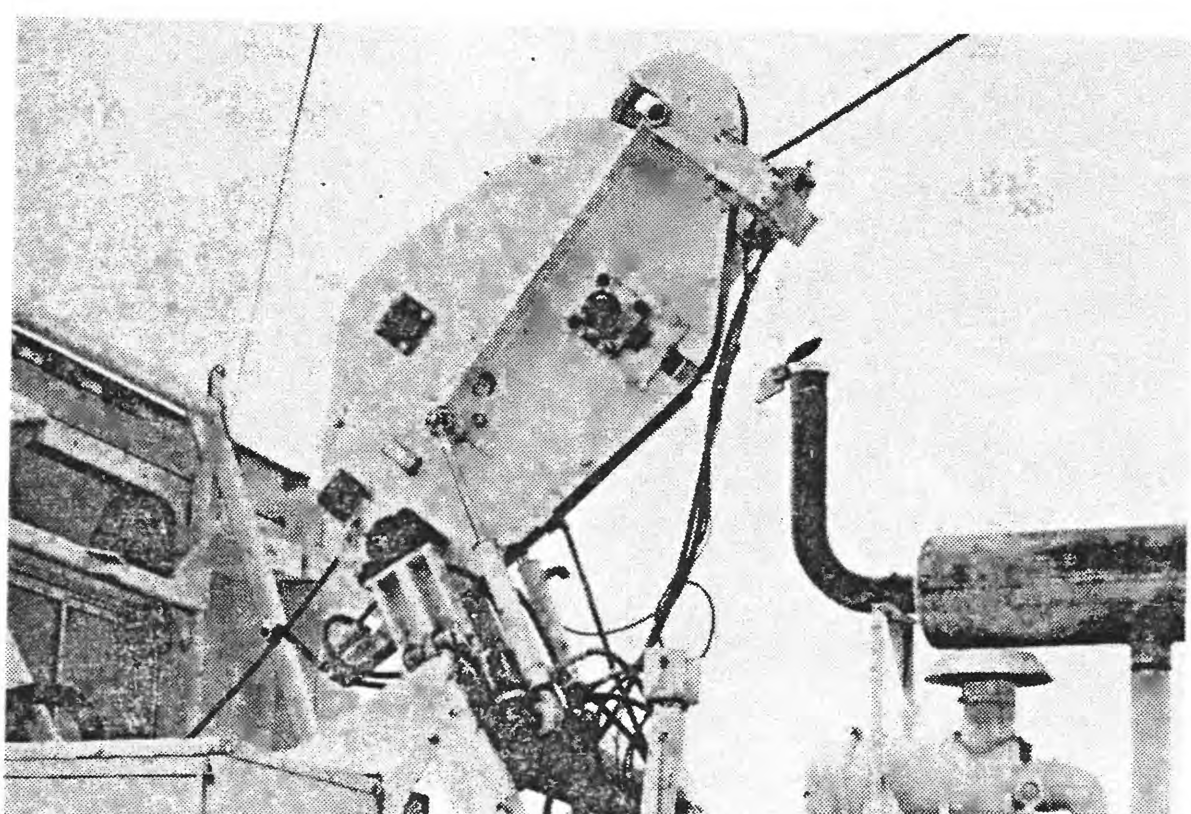


Figure 11. Measure-head system in up position.

4) <u>Measure-head system</u>: Figure 11 shows the measure-head in position for use with the tower. The head can also be operated in lower positions when the cable goes horizontally out to a work-over rig.

This measure-head is two heads reassembled into one housing. The first measure-wheel is a Gearhart-Owens Ind. conventional three-wheel system which drives a mechanical odometer and a selsyn transmitter. It also contains a Martin-Decker weight indicator transducer. The second measure-wheel is a SIE, Inc. straight-line system which drives a Dynamics Research Corp. encoder. There were some problems with this encoder (mainly moisture getting inside the unit), but after it was encased in foam, there has been no trouble. Because the encoder is not supposed to be operated at temperatures below 32°F (0°C), a small heater with a thermostat set at 35°-40°F has been installed in the outer encoder case.

A magnetic cable marking coil has also been attached in the measure-head system housing. (Its operation is discussed in Section IV-F.)

The carriage that holds the measure-head (fig. 11) moves back and forth along a large steel beam so that the cable is properly spooled onto the drum. This carriage is moved automatically by two vertical arms attached to a hydraulic four-way valve at the back of the head which activates a hydraulic motor that moves the carriage by a bicycle chain. The hydraulic system is powered by a power-steering pump that is run by a fan belt on the front of the Waukehsa engine (fig. 12). Figure 13 is a schematic of the system. There are 12-volt DC electric shut-off and override valves that are controlled

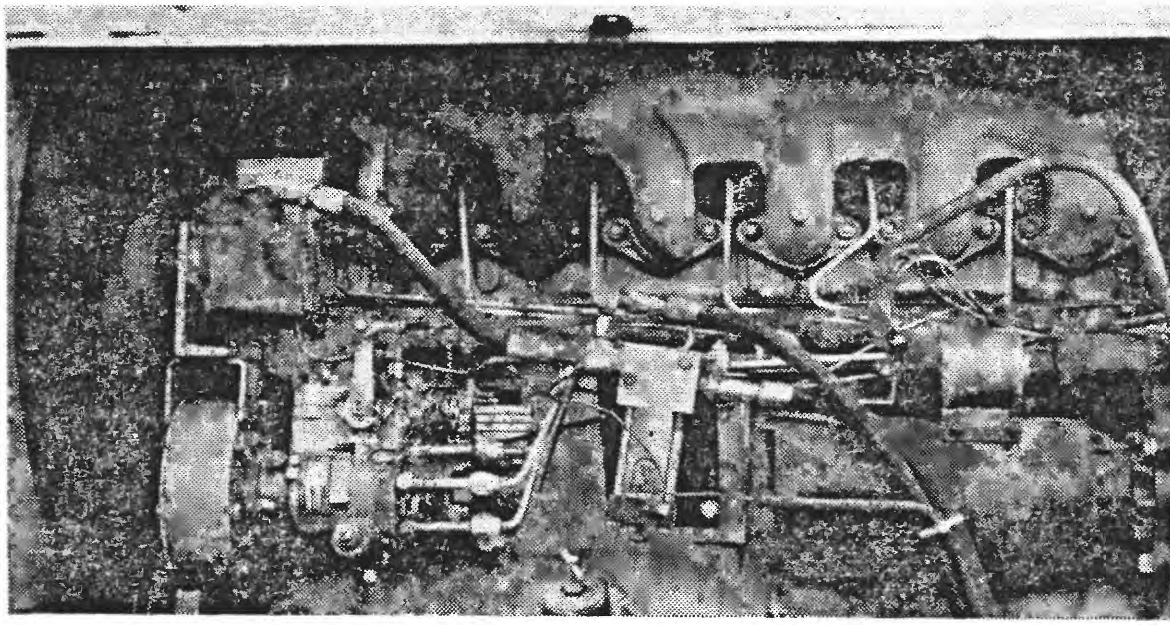


Figure 12. Close-up view of Waukesha engine showing power-steering pump system used to power spooling motor.

from inside the control van.

Originally, the measure-heads were attached to an 8-foot-long hydraulic-operated parallel-arm system that proved to be too cumbersome; i.e. the heads were very heavy, it was difficult to clamp and unclamp from its storage position making it a safety hazard for the worker, the spooling was manually controlled, and because of the arc made by the measure-head while spooling, an odometer accuracy of better than ±0.3 ft (+0.1 m) could not be maintained. The error in the odometer reading caused by the new spooling configurations on the steel beam is less than ±0.03 ft (0.01 m).

5) Cable-clamp/line-wiper provision: There is a female connector at the rear of the truck (fig. 14) into which a hydraulic hose can be inserted. Any low-volume high-pressure hydraulic system (up to 10,000 PSI) can be operated from inside the control van.

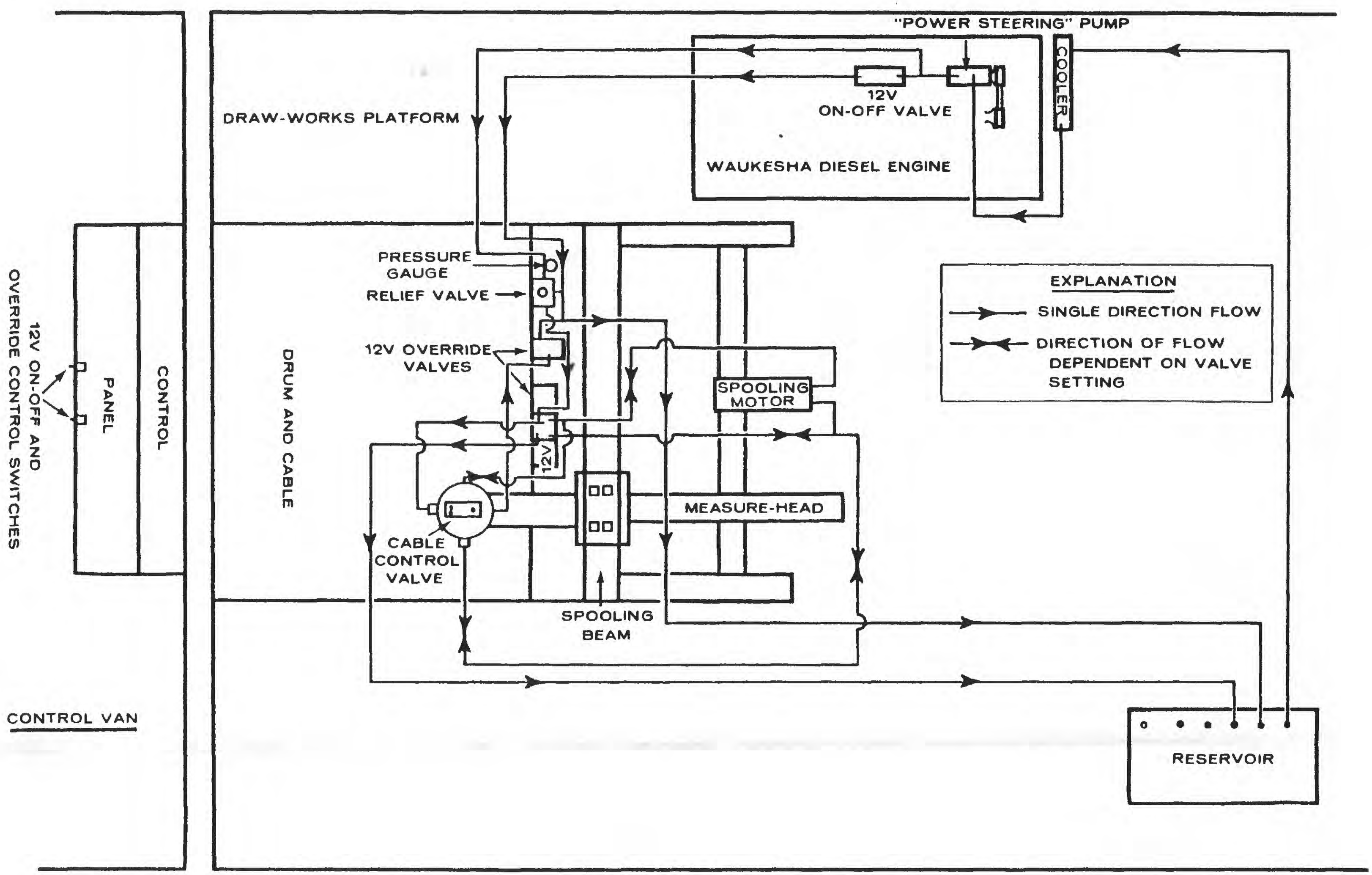


FIGURE 13. DIAGRAM OF SPOOLER HYDRAULIC SYSTEM.

A modified line-wiper with three hard-rubber inserts (fig. 15) is used as a cable clamp. Most lubricator line packers or wipers can also be operated off this hydraulic system.

6) <u>Special storage facilities</u>: The truck has two special storage facilities in addition to the usual storage compartments and racks for tools, equipment, and other miscellaneous supplies.

a) Radioactivity source compartment--Located near the back of the logging draw-works platform, beneath the tool racks, and within the frame-work of the truck is a compartment in which the neutron source is stored (figs. 16 and 17) (the compartment is large enough for three sources). The source is locked-up within the storage pig, which is welded to the truck, and the heavy compartment doors are also locked. A second pig is used when the source is stored in a permanent building. The shielding of the storage pig, the frame, and the thick steel doors is enough to reduce the radiation level at the edge of the truck to well below the level required for posting "Radioactive" signs on the truck.

b) Vertical BHGM storage cylinder--A special "damped" storage system to carry the BHGM on the road in a vertical position while still in the pressure housing is shown in figure 18. The bottom of the BHGM sonde rests in a shock-mounted receptacle within the truck frame system. The aluminum vertical cylinder that surrounds and holds the sonde is attached to the truck by three shock mounts. A foam cylinder is used between the sonde and the aluminum cylinder. A 110-volt AC line coming out at the top of the control van can be used to keep the BHGM "on temperature".

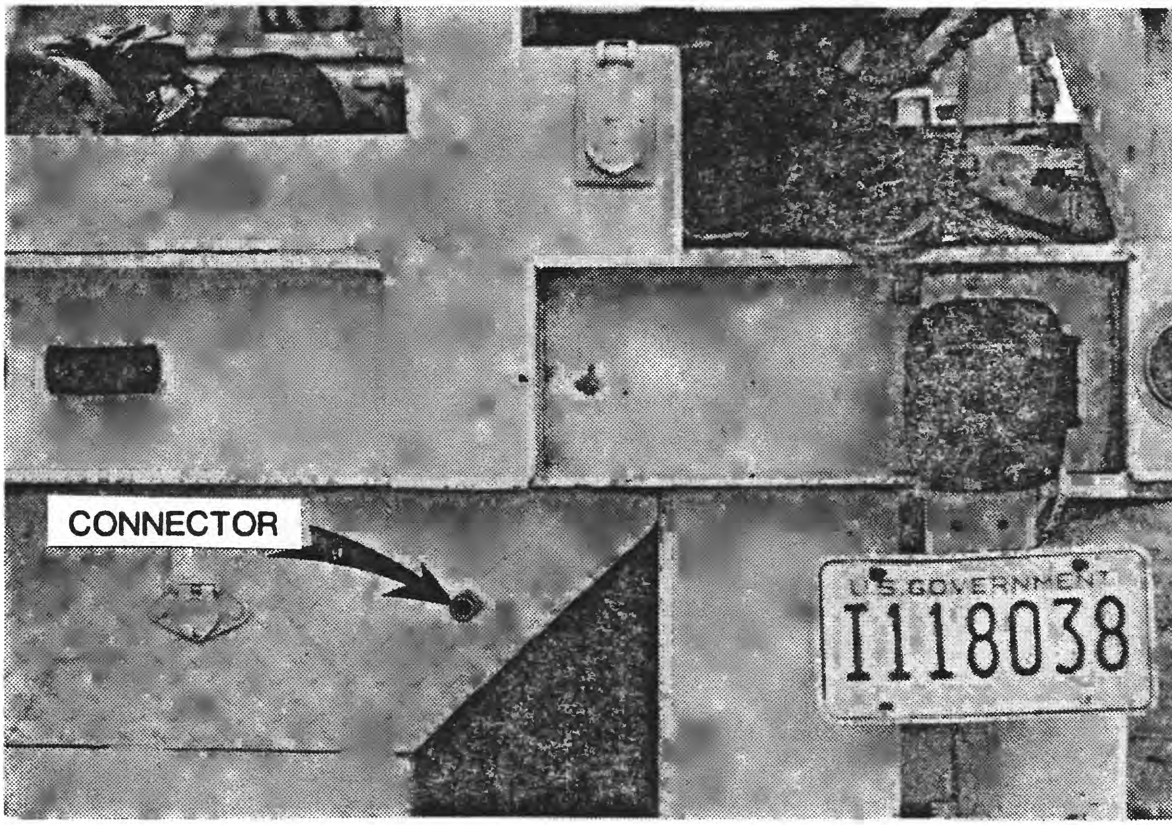


Figure 14. Cable-clamp/line-wiper connector located at the rear of the BHGM logging truck.

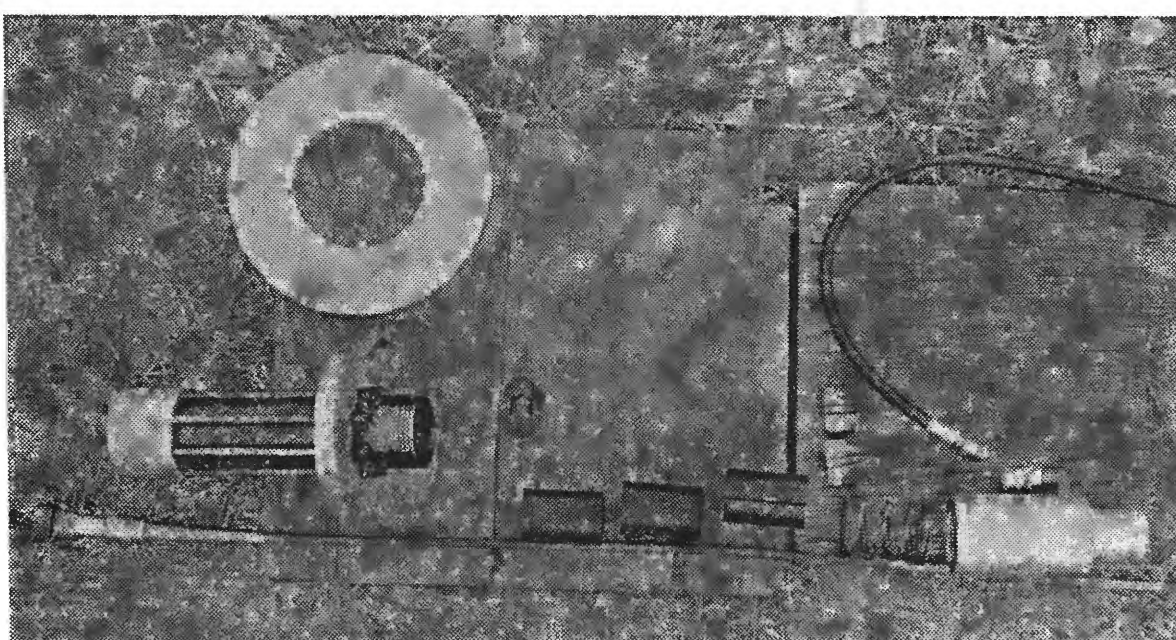


Figure 15. View of the cable-clamp system components.

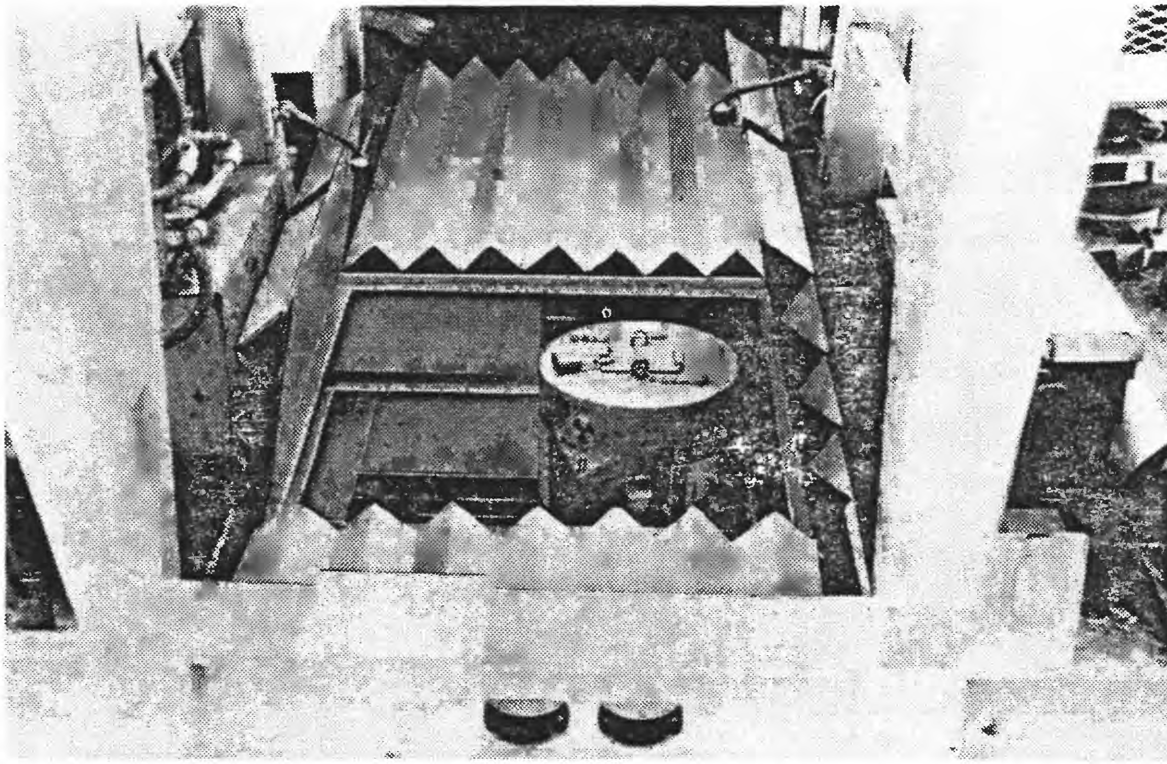


Figure 16. View showing location of Radioactivity source compartment near the rear of the BHGM logging truck

Figure 17. Close-up view of the Radioactivity source compartment. Pig is for 3 curie AmBe Neutron source.

This line can be switched either 1) to the AC current provided by one of the generators, or 2) to the 110-volt AC inverter system (discussed in Section IV-G) which draws current from the two 220-amp-hour storage batteries located on the logging draw-works platform.

The vertical winch system next to the vertical storage cylinder (fig. 19) is used to lift the BHGM sonde on and off the truck and to insert and remove the meter itself from the sonde. The operation is discussed in Section IV-C.

7) <u>High-pressure cleaning system</u>: This system is for washing down tools and the cable during and (or) after logging a well containing dirty or corrosive liquids. A two-compartment liquid storage tank is located at the rear of the truck on the left side within the tower base (fig. 20). Any liquid cleaning agent or water can be placed in either compartment. At the base of the tanks are hoses that go to a 500-PSI high-pressure pump, and faucets for gravity feed. The outlet from the pump is a hydraulic-type connector located on the left side of the truck. Water or any other cleaning agent must not be allowed to freeze because the high-pressure pump can very easily be cracked.

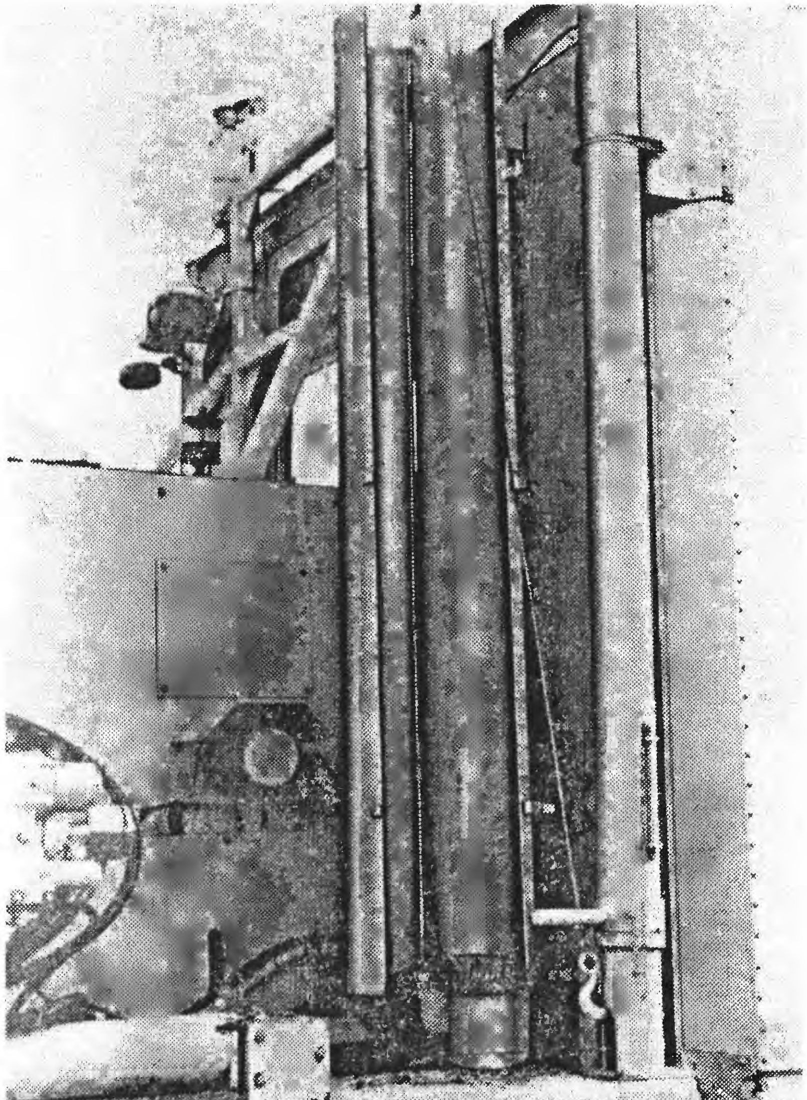


Figure 18. The BHGM's vertical storage cylinder located on the right side of the logging truck.

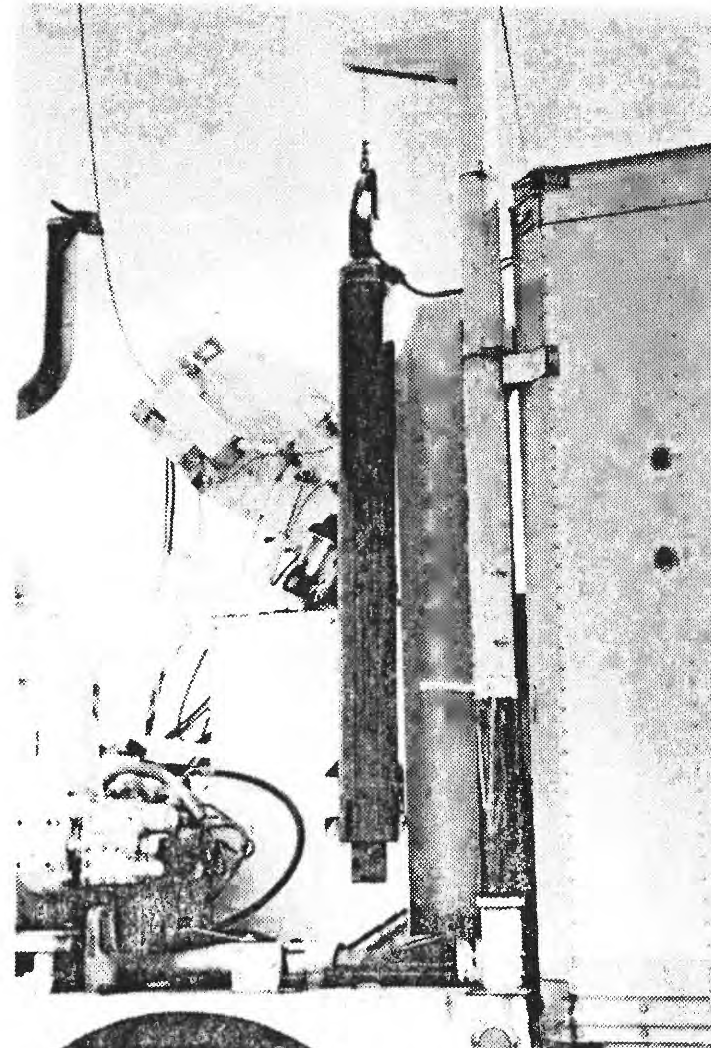


Figure 19. The BHGM hanging on the winch located near its vertical storage cylinder on the right side of the truck.

8) Air-compressor: An air-compressor and a 12-gallon air-tank are also located in the left tower base (fig. 21). A 3/4 HP motor powers the pump which has a 100 PSI maximum capability. A 25-foot air-hose is at the rear of the truck below the liquid cleaner tank and is on an automatic rewind reel. Additional lengths of hose can be added. The purposes of the air-compressor are to: a) inflate the air-cushions under the Waukesha engine, b) blow dirt from logging tools during installation, c) maintain tire pressures.

9) Batteries: There are two 220-amp-hr 12-volt DC batteries in parallel, located on the draw-works platform, that are used for starting the Waukesha and Onan engines and for keeping the BHGM "on temperature" through the use of an inverter when the truck is in transit (fig. 22).

C) Logging operations - control and instrument van features

1) Overall view of the van: A plan view of the inside of the control van is shown in figure 23. One feature is the large amount of work space. There is a large workbench at the front of the van for personnel to do data reduction or electronic repairs when needed. There is enough room for two or three people to work and move around. On the left side of the van is a cabinet (fig. 24) with compartments for storing parts for repairs and other miscellaneous supplies. There is a small tool rack on top of this cabinet. On the right side of the van are the tool instrument racks, and at the rear is the control console and small instrument rack for operation of the draw-works. Next to

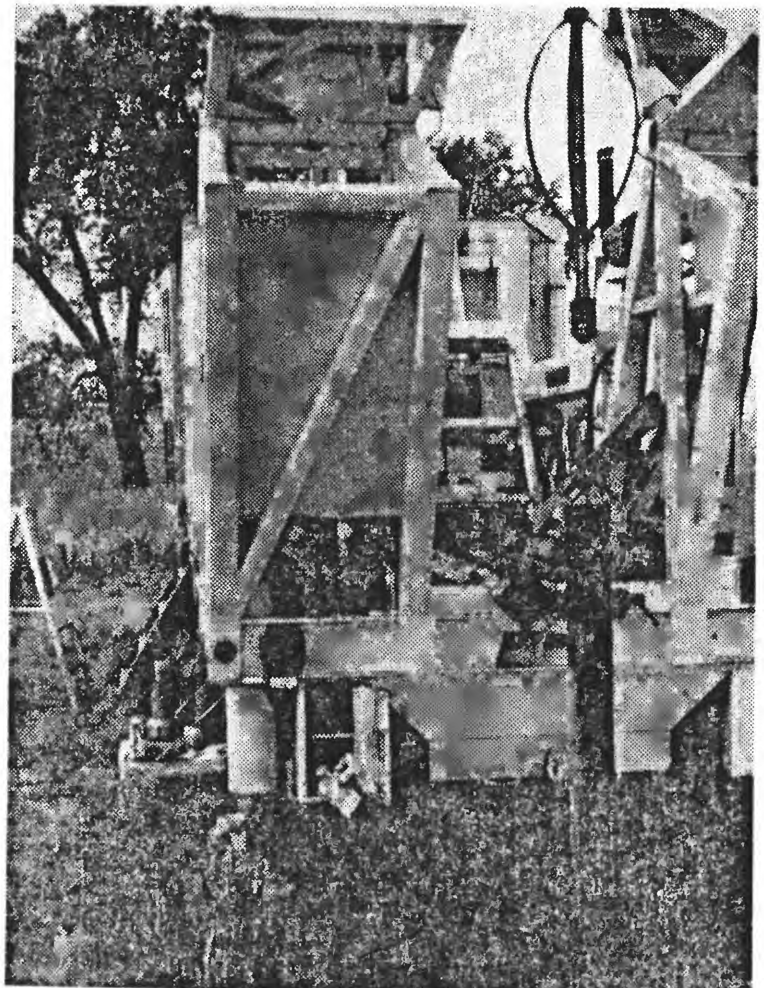


Figure 20. View of liquid solvent tanks, gravity feed faucets, and air-compressor self-winding hose located at the left rear of the BHGM logging truck.

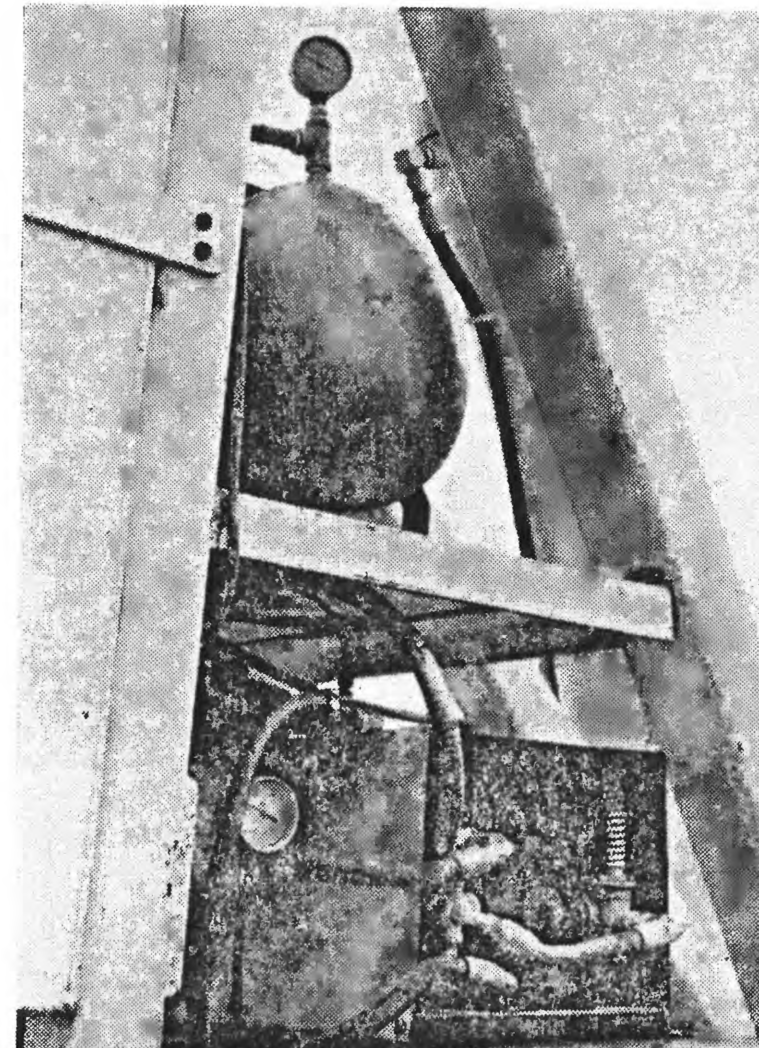


Figure 21. View of the air-compressor tank, air-regulator gauges, and high-pressure liquid pump.

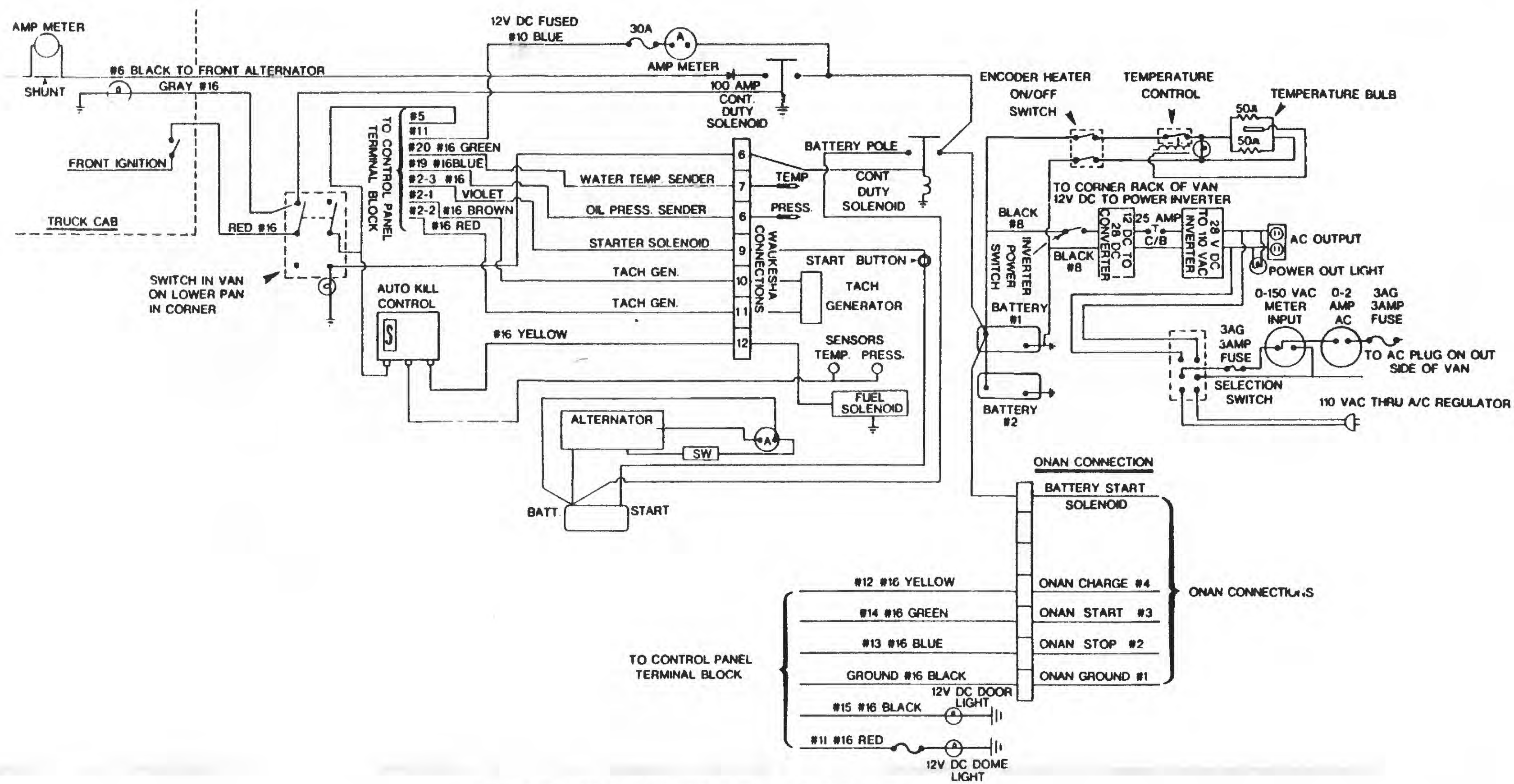


FIGURE 22 SCHEMATIC OF 12 VOLT DC LOGGING FUNCTIONS CIRCUIT

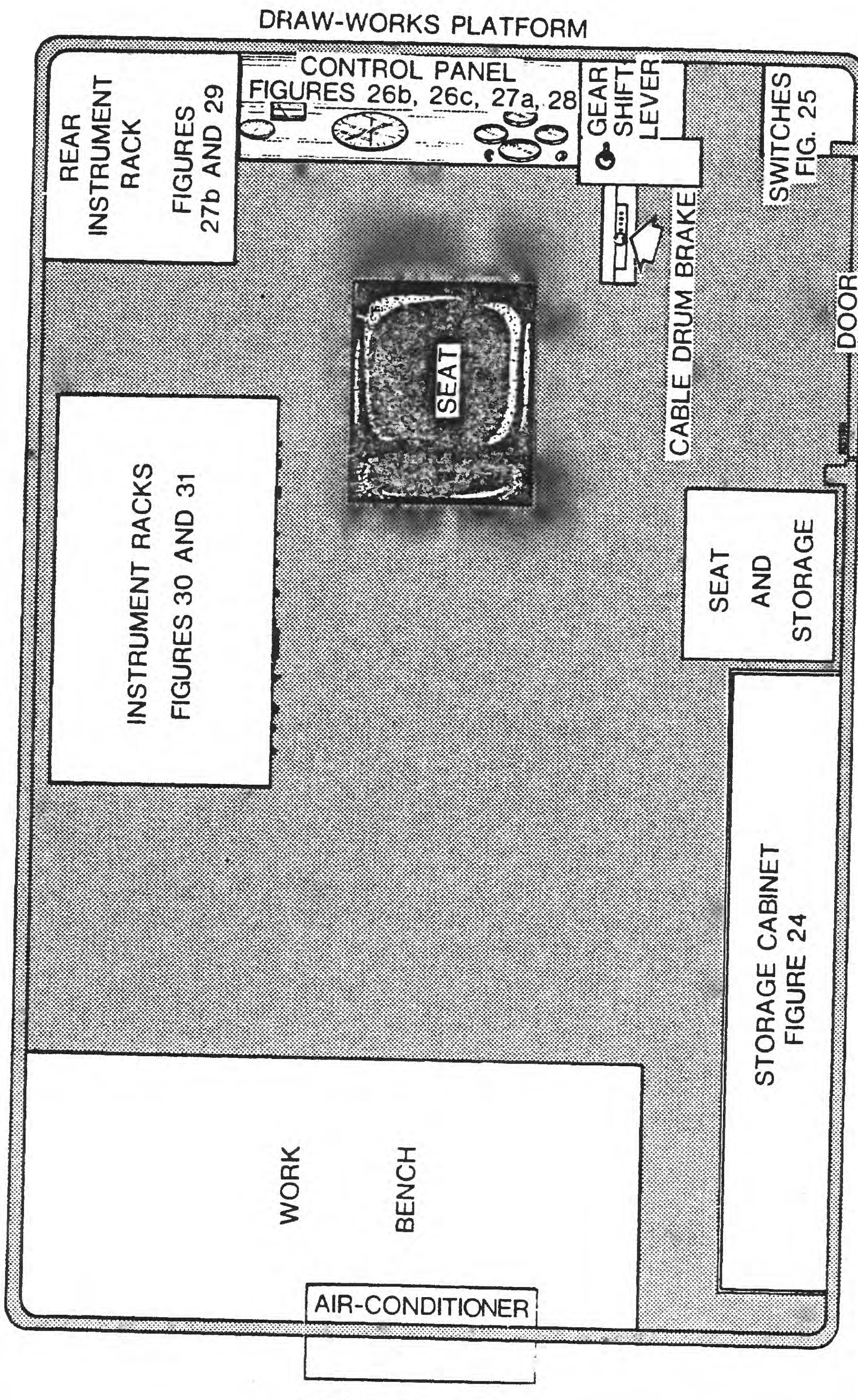


FIGURE 23.-LAYOUT OF CONTROL VAN

the rear window on the left side is a bracket and an antenna for a walkie-talkie for communication with people working outside. There is also a two-way intercom on the left wall for communication with the front cab for times when people are riding in the control van. Two of the seats in the van have seat belts for these occasions.

2) <u>Electrical system</u>: There are three possible 110-volt AC sources of electrical power for the truck: a) 6-KW from the generator driven hydraulically by the Waukesha engine, b) 6-KW from the Onan diesel generator, and c) shore power, i.e.- power plugged into the truck from an outside source. There are three separate electrical circuits on the truck as shown in figure 25: a) circuit with subcircuit breakers for most electrical and electronic needs within the control van (figs. 26a, 26b, and 26c), b) circuit for the electrically driven hydraulic pump for operation of the tower and outrigger cylinders, and c) circuit for the air compressor and the high-pressure fluid pump. Located at the rear of the van next to the door are three large switches for choosing which power source to use on what circuit. There are 27 possible combinations.

3) <u>Control panel</u>: The control panel (figs. 26b, 26c, and 27a) and the built-in instrument panel (fig. 27b) immediately adjacent, at the rear of the van, is where the logging operation is controlled from, except for the control and processing of the electronic signals to and from the logging tools (which will be

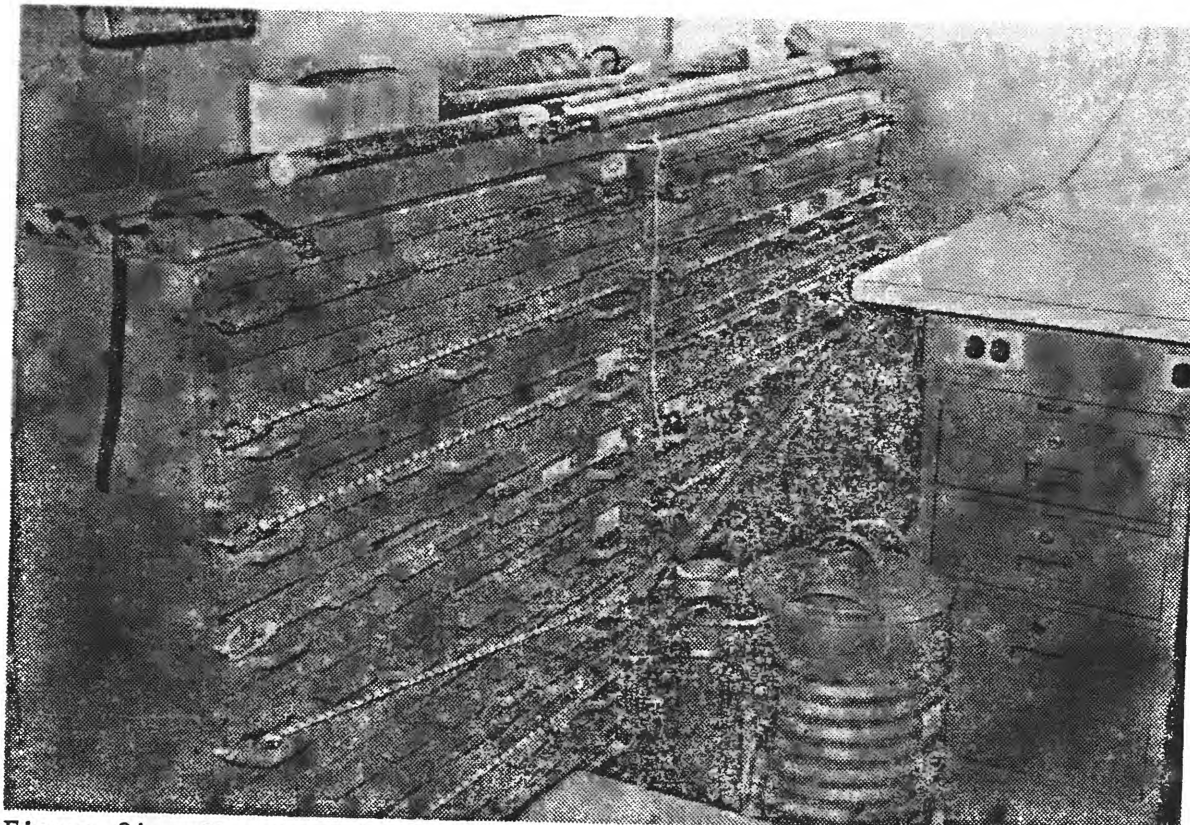


Figure 24. Storage cabinets located inside control van on left side of the BHGM logging truck.

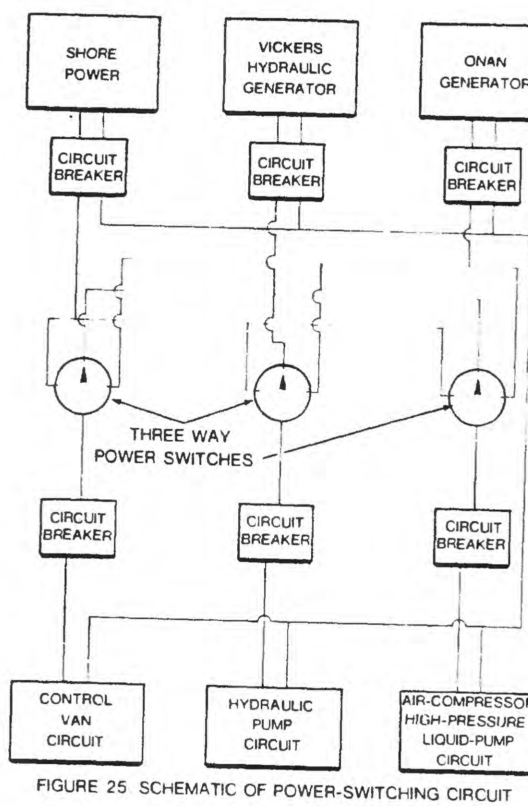


FIGURE 25 SCHEMATIC OF POWER-SWITCHING CIRCUIT

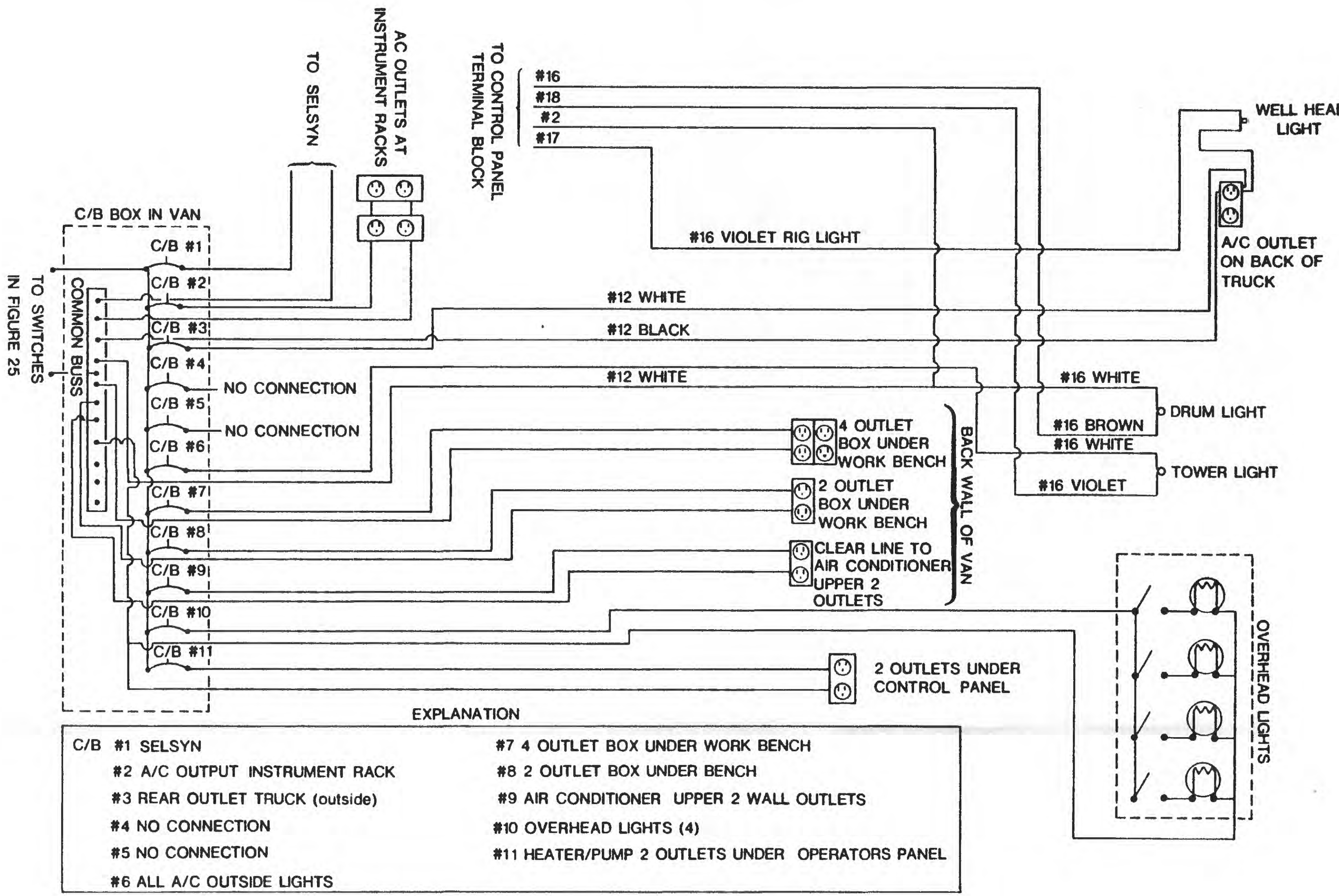


FIGURE 26a. SCHEMATIC OF 110 VOLT AC VAN CIRCUIT.

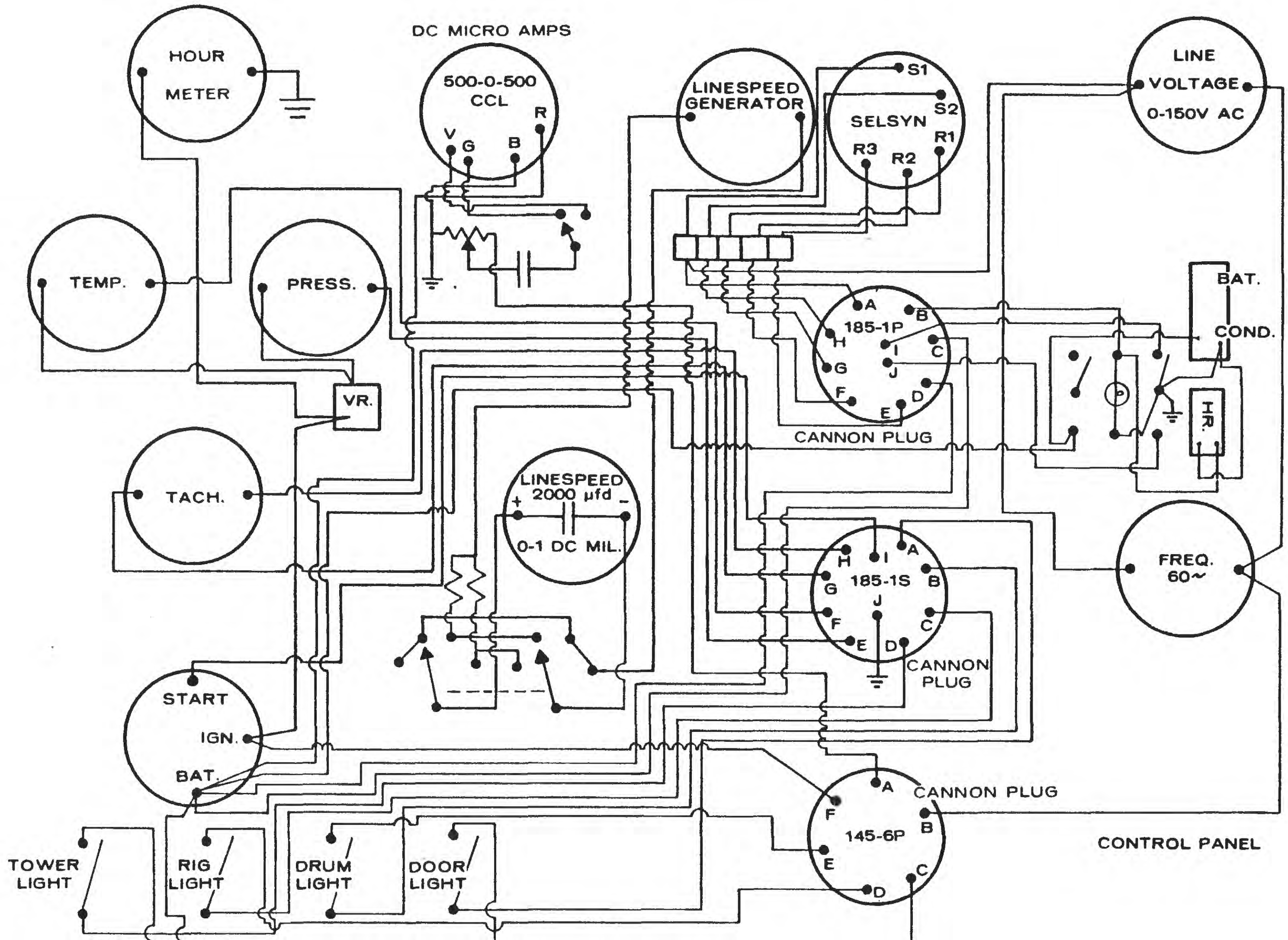


FIGURE 26b. SCHEMATIC OF CONTROL PANEL

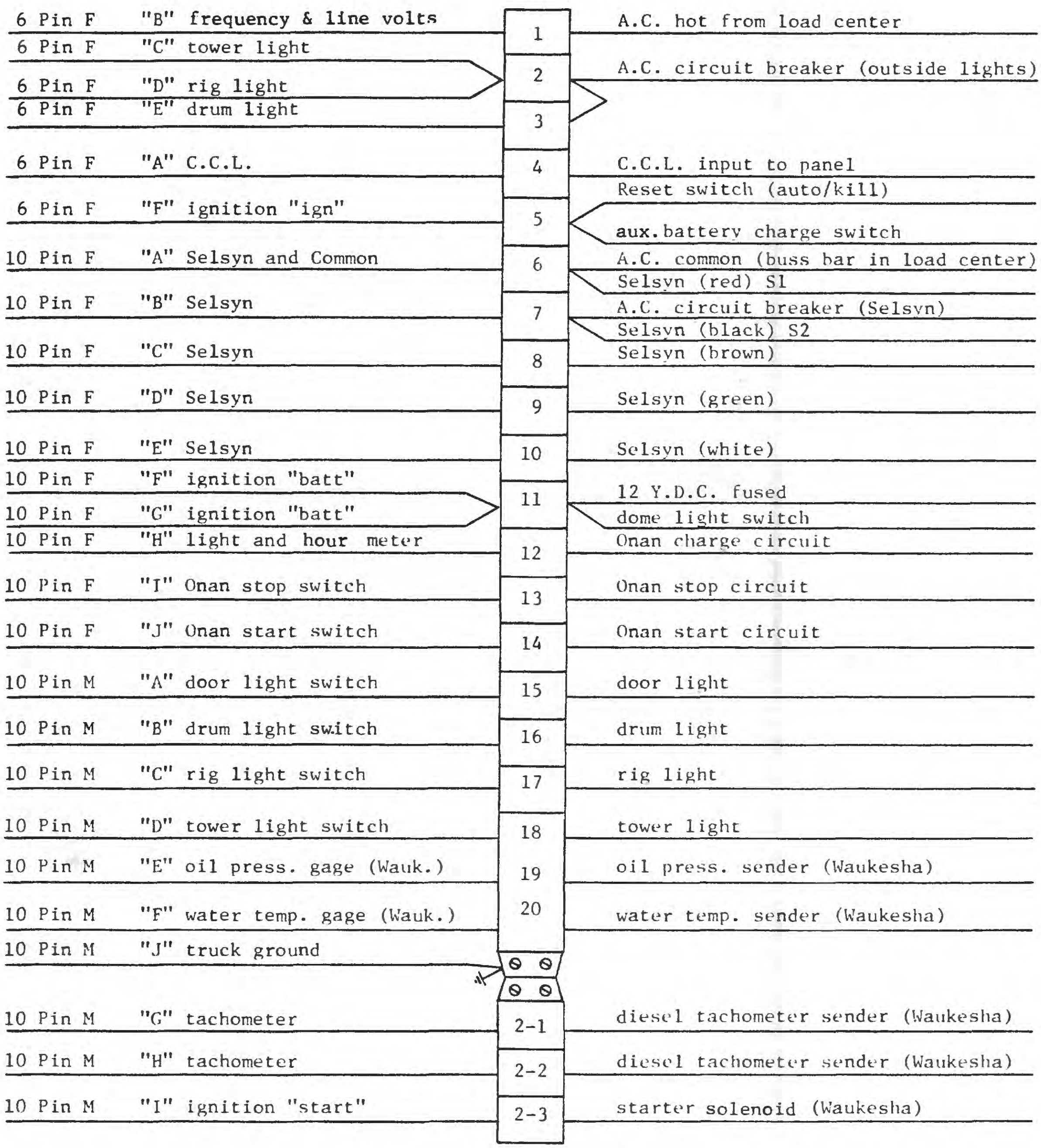


Figure 26c. Schematic of Behind Control Panel

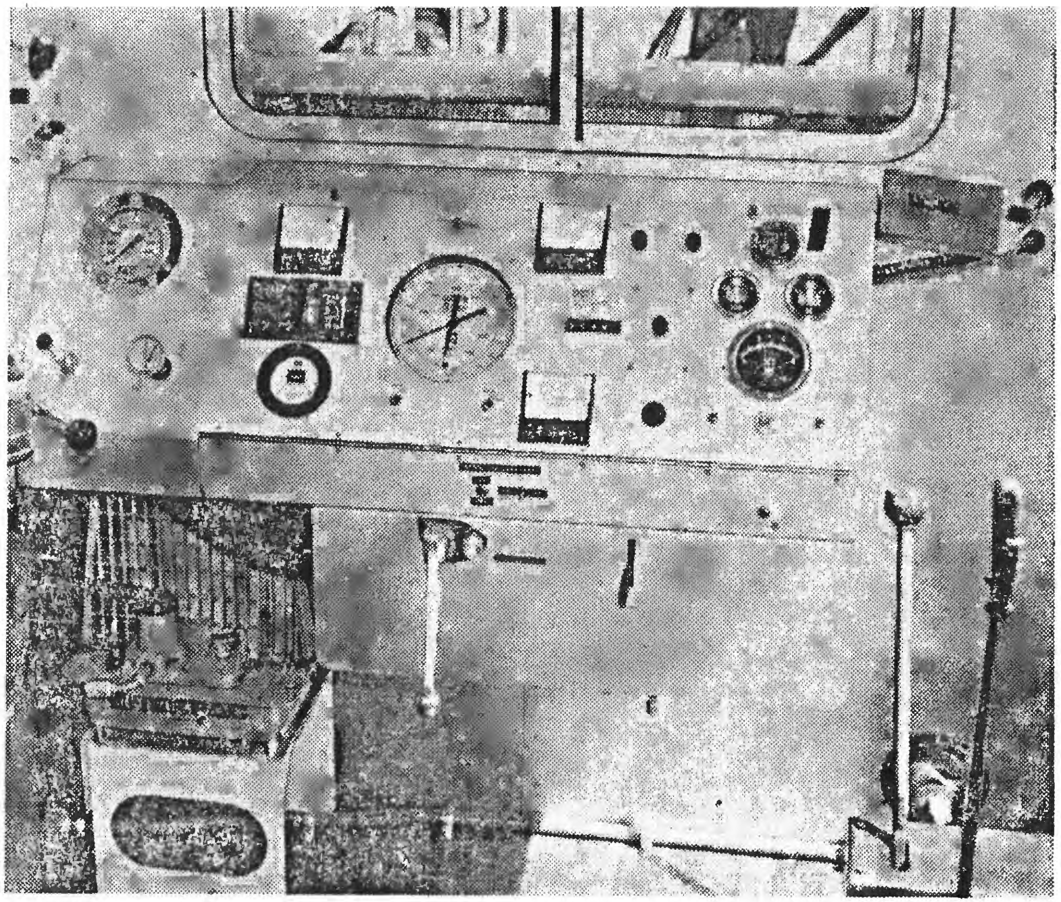


Figure 27a. Control panel located inside the control van at the back.

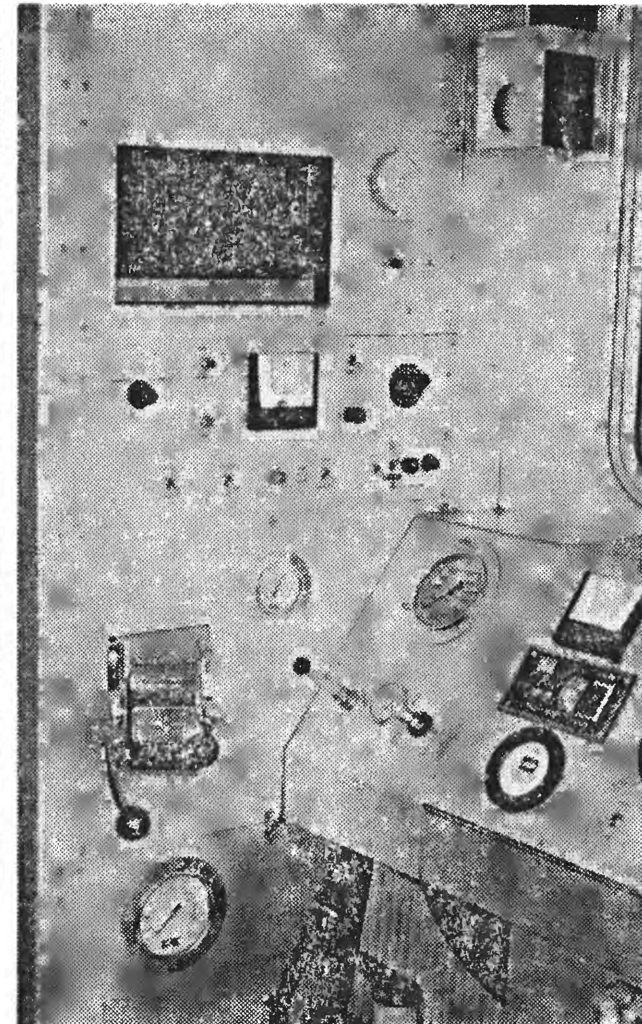


Figure 27b. Rear instrument panel located inside the control van next to the control panel on the right side of the BHGM logging truck.

discussed in the next section).

Figure 28 is a sketch of the control panel indicating what the various instruments and controls are. The panel includes instruments and controls for the operation of:

a) the Waukesha diesel engine (see section III-A for operation).

b) the Onan diesel generator,

c) the up and down movement of the tower,

d) the drum and cable (see section IV-D) for operation),

e) the measure-head system including the mechanical and selsyn odometers (see section IV-E for operation),

h) the cable-clamp/line-wiper hydraulic system,

i) the casing collar locator (CCL) system, and

j) the outside lights.

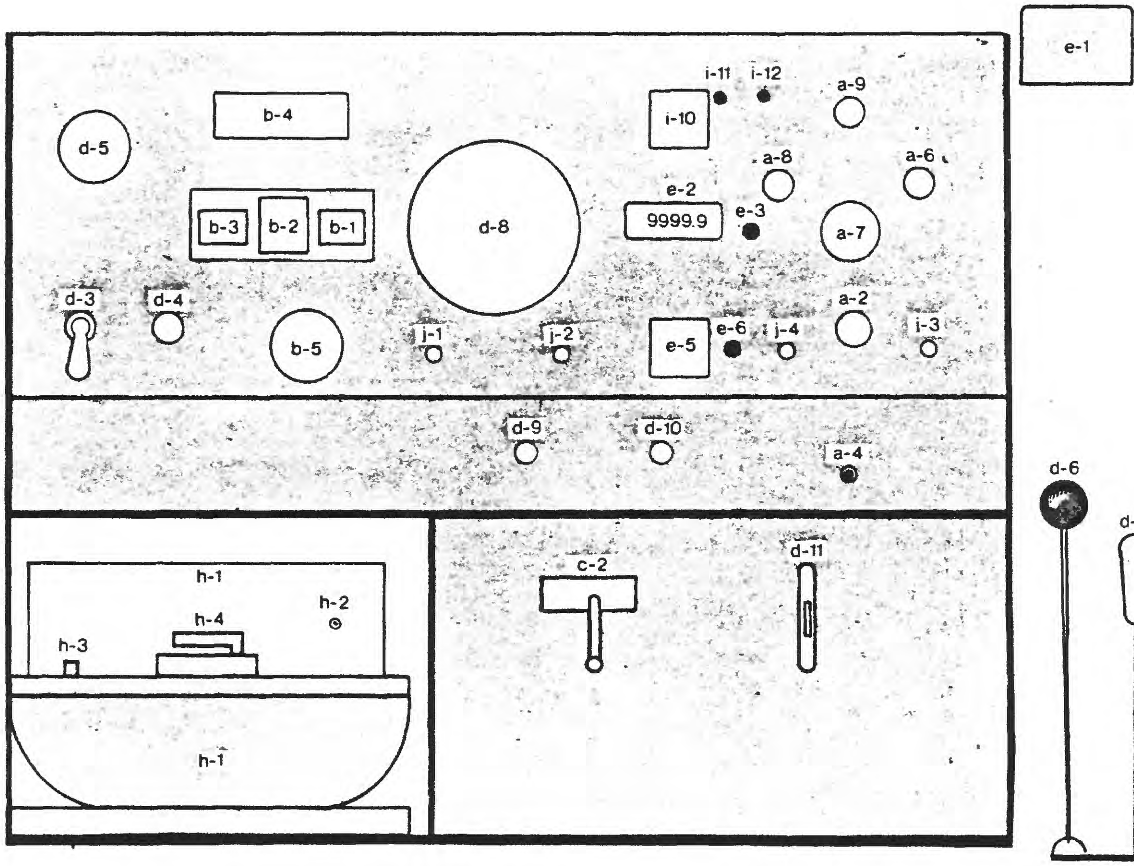
Figure 29 is a sketch of the adjacent built-in instrument panel. This panel includes instruments and controls for the operation of:

a) the Waukesha diesel engine (see section IV-A for operation),

c) the electrically operated hydraulic system,

d) the drum and cable (see section IV-D) for operation),

e) the encoder odometer (see section IV-E for operation),



EXPLANATION

Waukesha engine

a-2 Start-stop switch
a-4 Low oil-pressure by-pass switch
a-6 Oil-pressure gauge
a-7 Tachometer
a-8 Temperature gauge
a-9 Hour-meter

O'nan diesel generator
b-1 Start-stop switch
b-2 Battery-condition gauge
b-3 Hour-meter
b-4 Voltage meter
b-5 Cycles meter

c-2 Valve for tower

Drum and cable operation
d-2 Mechanical drum brakes lever
d-3 Dump-valve
d-4 Pressure-relief valve
d-5 Pressure gauge
d-6 Transmission gear-shift lever
d-8 Cable tension gauge
d-9 On-off switch to spooling system
d-10 Spooling system over-ride switch
d-11 Measure-head position valve

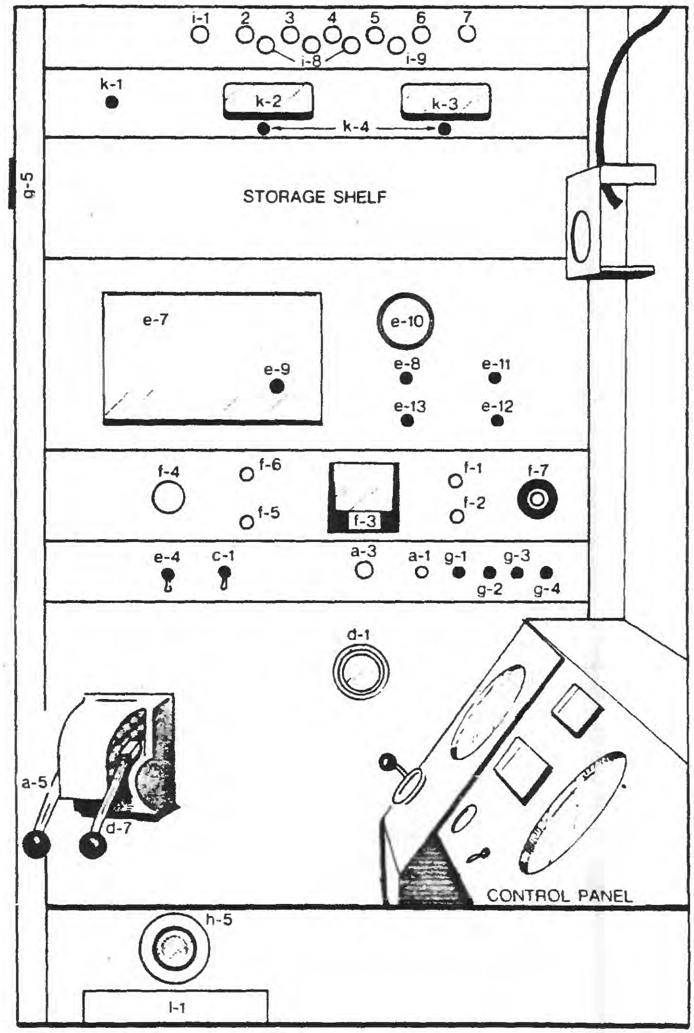
Measure-head system
e-1 Mechanical odometer
e-2 Selsyn odometer
e-3 Selsyn reset knob
e-5 Line-speed indicator
e-6 Control switch for L/S indicator

Cable-clamp/line-wiper system
h-1 Hydraulic pump and reservoir
h-2 Off, hold-on, continuous-on switch
h-3 Reservoir filler plug
h-4 Hydraulic-pressure valve

CCL system
i-10 CCL indicator
i-11 Direct signal or amplified mode
i-12 Amplifier sensitivity knob

Lights
j-1 Stair light switch
j-2 Drum light switch
j-3 Tower light switch
j-4 Well area light switch

Figure 28. Sketch of control panel



EXPLANATION

Waukesha engine
- a-1 Battery charging switch
- a-3 Battery "on" light
- a-5 Throttle
- c-1 On-off switch for electrically operated hydraulic system

Drum and cable operation
- d-1 Charge-pressure gauge
- d-7 Draw-works control lever

Measure-head (Encoder) system
- e-4 On-off switch for Selsyn odometer
- e-7 Encoder digital readout
- e-8 On-off switch for encoder
- e-9 Encoder "zero" button
- e-10 Encoder reset knob
- e-11 Readout position switch
- e-12 Encoder heater on-off switch
- e-13 Heater indicator light

Magnetic cable marker
- f-1 On-off switch
- f-2 Fuse
- f-3 Magnetic mark indicator
- f-4 3-way mode switch
- f-5 Sensitivity dial
- f-6 Magnetize button
- f-7 Demagnetize power dial

Inverter system
- g-1 Converter on-off switch
- g-2 Inverter on-off switch
- g-3 Pilot light
- g-4 Fuse
- g-5 2-plug outlet

- h-5 Pressure gauge for cable-clamp line-wiper system

Patch panel
- i-1 Through cable conductor
- i-7 Input plugs
- i-8 3 ground plugs
- i-9 CCL signal input plug

Heat source for [illegible]
- k-1 Electrical source switch
- k-2 Voltage meter
- k-3 Current meter
- k-4 Two 2-amp fuses

- l-1 Control van circuit breaker box

Figure 29. Sketch of rear instrument panel

f) the magnetic cable marker (see section IV-F for operation),

g) the inverter system (see section IV-G for operation),

h) the cable-clamp/line-wiper hydraulic system, and

i) the patch panel, and

k) the temperature control for BHGM while in storage cylinder.

4) Instrument racks: This dual rack (fig. 30) contains all the instruments that are needed to control and process the signals to and from all the wireline tools, including the BHGM. Following is a description for each console presently mounted in the rack and shown in figure 31. Additional equipment can be added if desired.

a) Power regulator--This unit is used to protect the electronic equipment in the rack from possible harm if stray spikes or voltage fluctuations occur. Maximum power this unit can handle is 2000 watts which is more than enough because not all of the instruments are used at the same time.

b) Scope--This unit is used for trouble-shooting the other equipment and for monitoring the wireline tools signal if desired.

c) Recorder for continuous logging--This unit, made by Gearhart-Owens Industries, Inc. (GOI), contains four-channels, a USGS-modified felt ink pen system, and a chart drive that is operated by the selsyn transmitter. Most continuous-

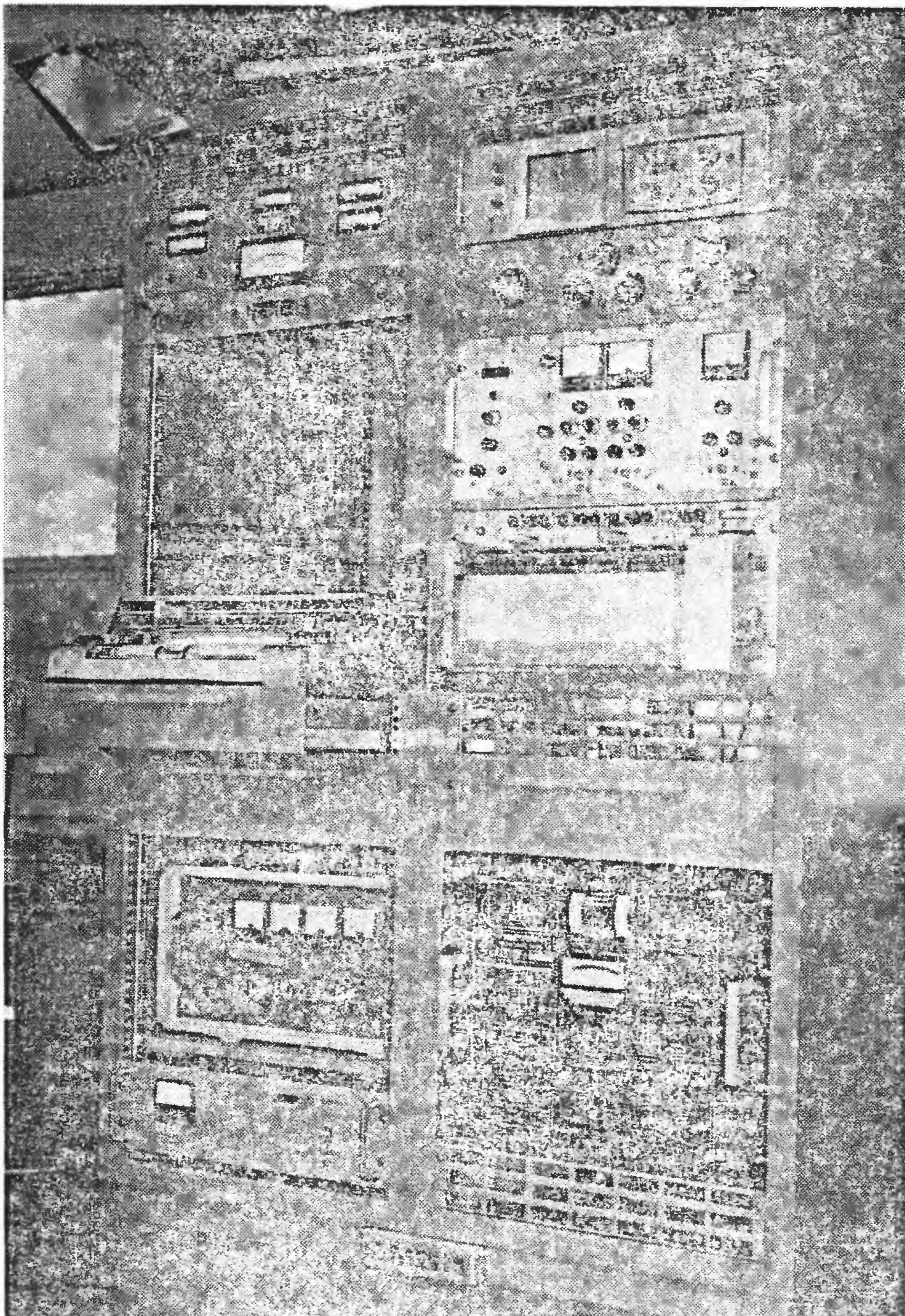


Figure 30. Photo of instrument racks located inside control van on right side of BHGM logging truck.

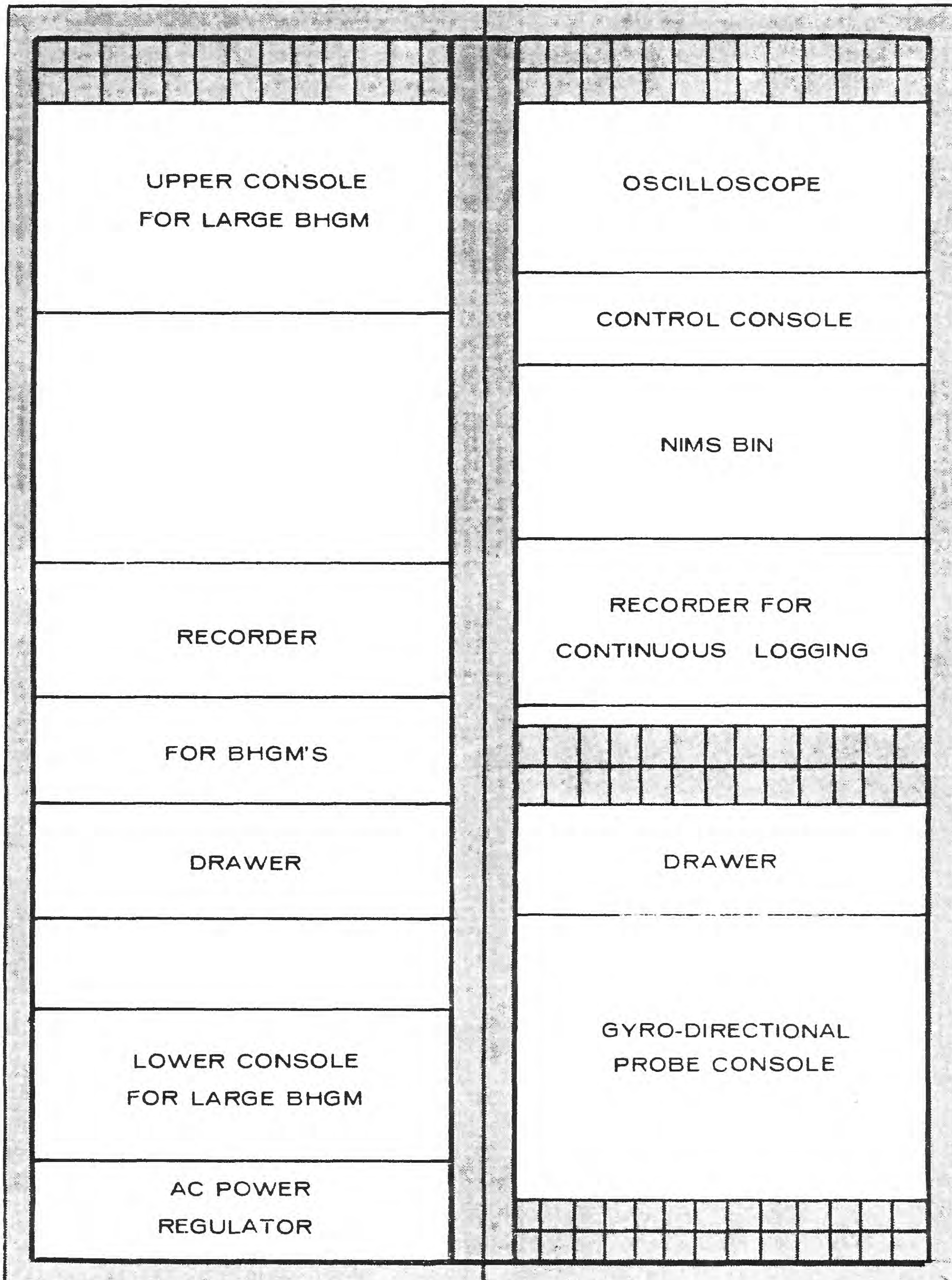


Figure 31. Sketch of instrument racks

operation wireline-tool signals can be recorded on this unit.

d) Nims Bin and logging modules--This unit contains the modules from which temperature, caliper, gamma-ray, neutron, and casing collar locator (CCL) tools are controlled. Other modules are available for operation of electrical or sonic tools. Figure 32 is a schematic for a USGS designed CCL amplifier module.

e) Gyro-directional probe console--This unit, made by Humphrey,Inc., contains everything that is needed to operate the probe including a digital readout of the slant angle and directional values. Input cables are connected directly to the patch-panel plugs (fig. 29). Signal outputs can be connected to the Control console (section IV-H) which will input these signals into the continuous logging recorder.

f) Control console--This unit, made by the USGS, is used to switch the various wireline tool signals to any of the four channels in the logging recorder. This includes signals from the Nims Bin and gyro-directional probe console that are connected in the back, or signals from other tool consoles that can be connected in the front. A 24-hour clock set to Coordinated Universal Time (CUT) is also part of this console. Figures 33, 34, and 35 are sketches and schematic of the console. Section IV-H describes its operation.

g) BHGM consoles--These units, designed and built by the USGS, consist of a power console and an instrument control console for the large 6-inch diameter BHGM, and only one console with

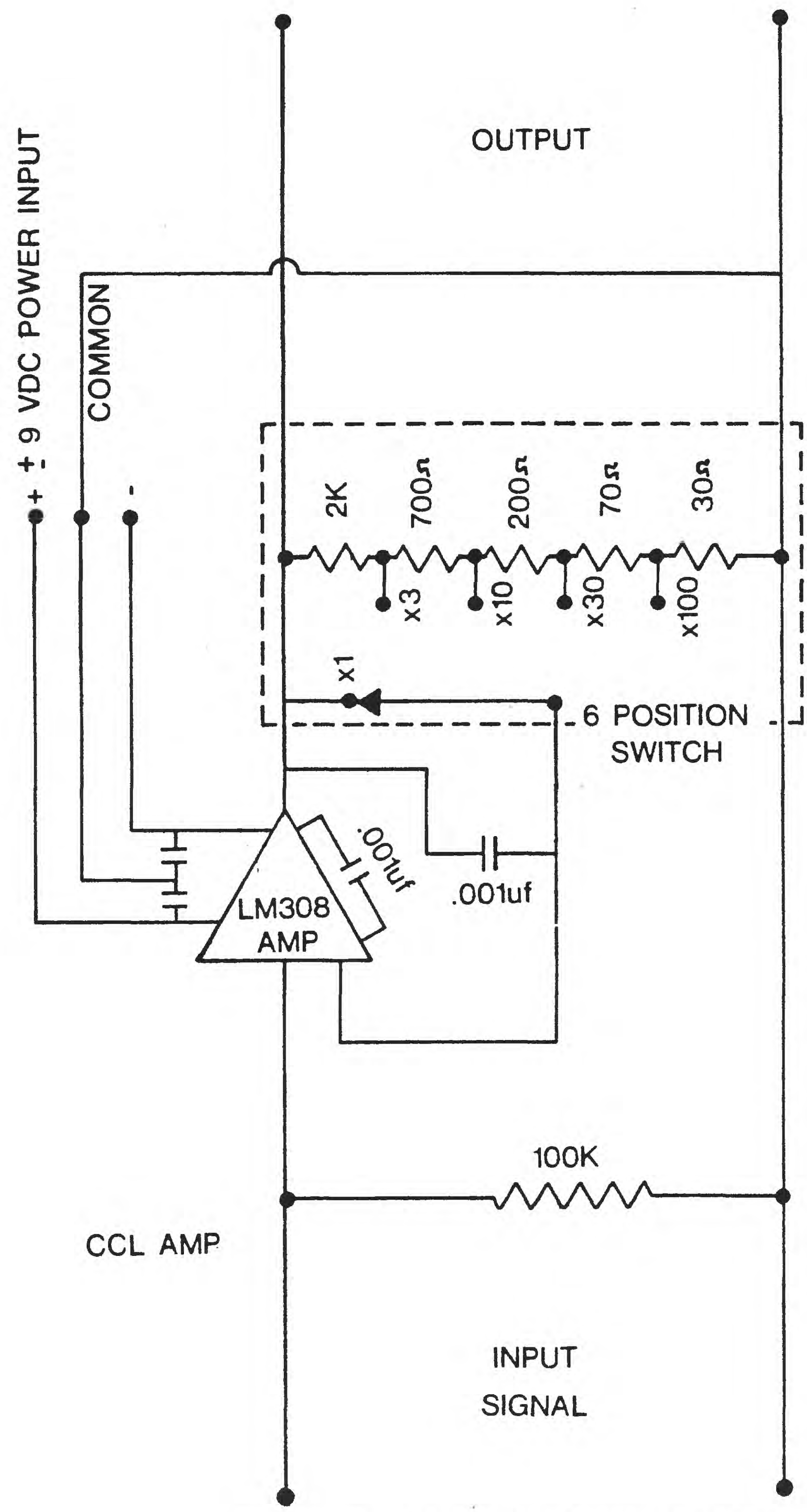
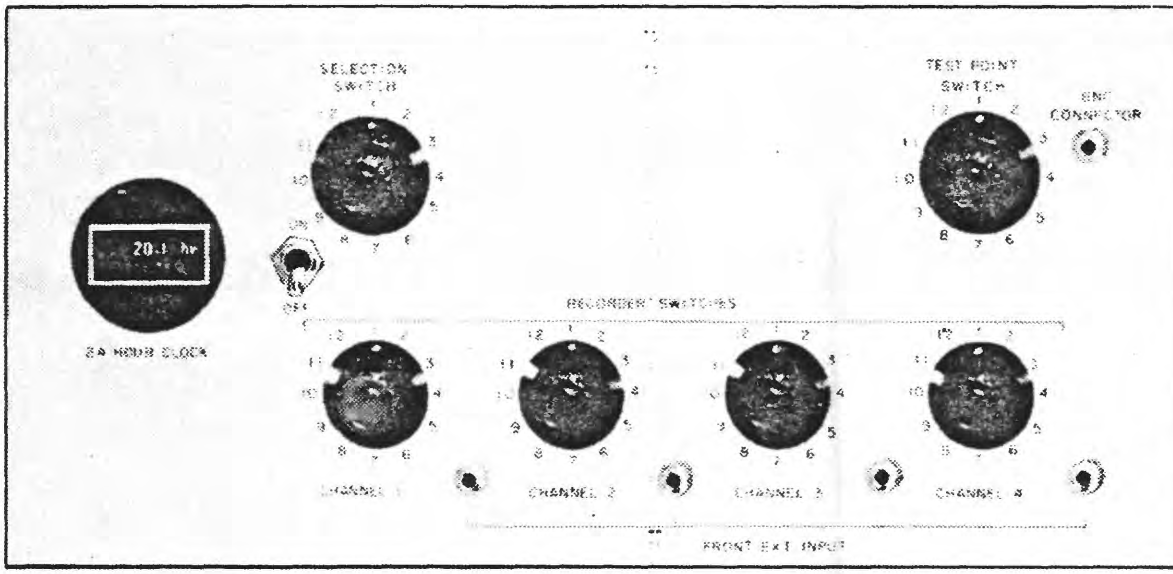


Figure 32. Schematic of CCL amplifier



Explanation

Positions for recorder knobs (channel 1, channel 2, channel 3, channel 4) and test switch knob.

Position 1: Rate meter module #1 (G-R, temp, caliper)
2: Rate meter module #2 (Neutron)
3: Power module or CCL module (CCL)
4: Temperature module (diff. temp.)
5: Directional Prope SA
6: Directional Prope SAB
7: Directioal Prope P.B.
8: Front Panel BNC input

Test switch knob only

Position 8: Position #8-channel 1
9: Position #8-channel 2
10. Position #8-channel 3
11. Position #8-channel 4

Selection switch

Position 1. G-R, Neutron, CCL
2. Temperature, Diff. Temp., CCL
3. CCL Module

Figure 33. Sketch of front of control console

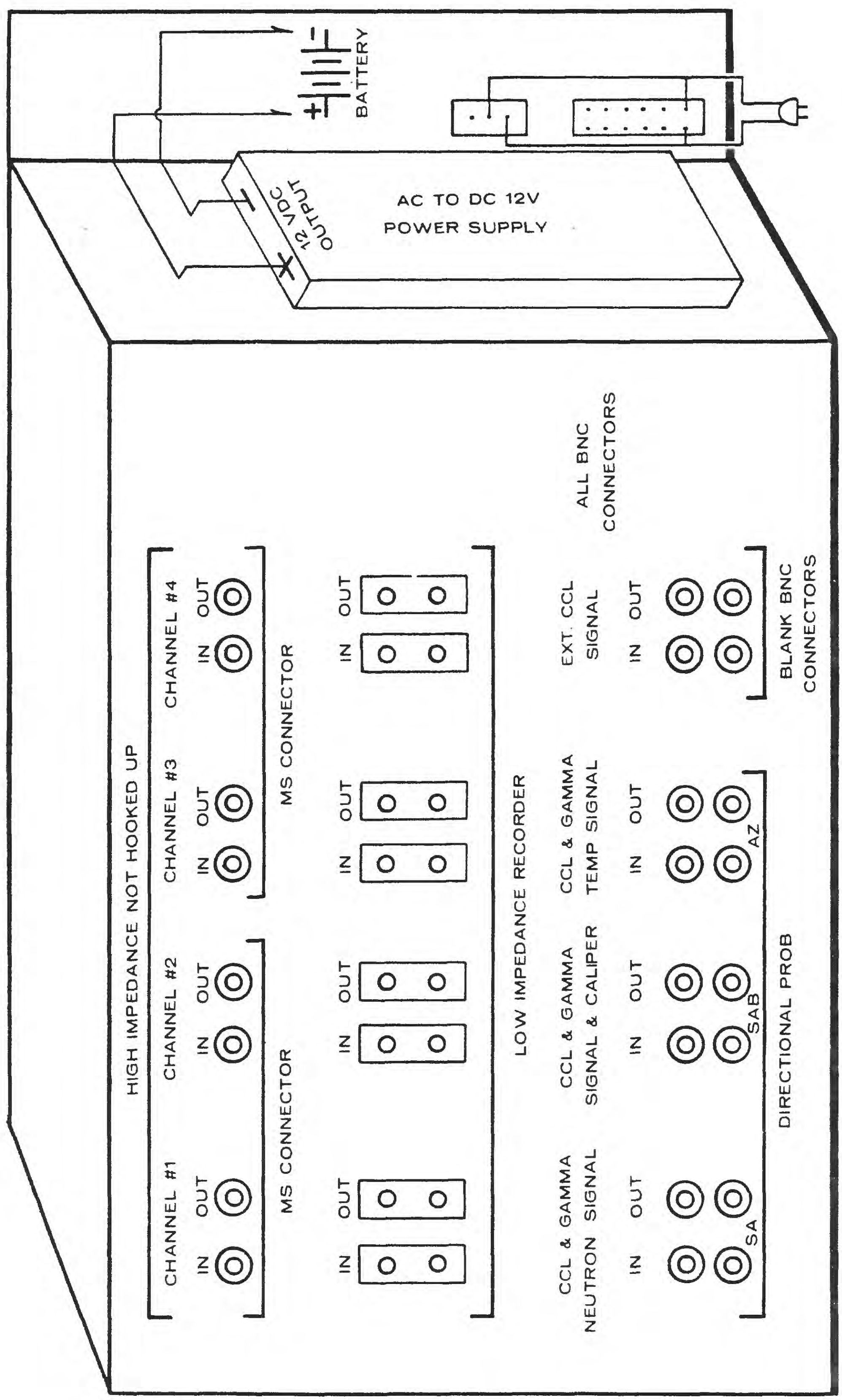


Figure 34. Sketch of rear of control console

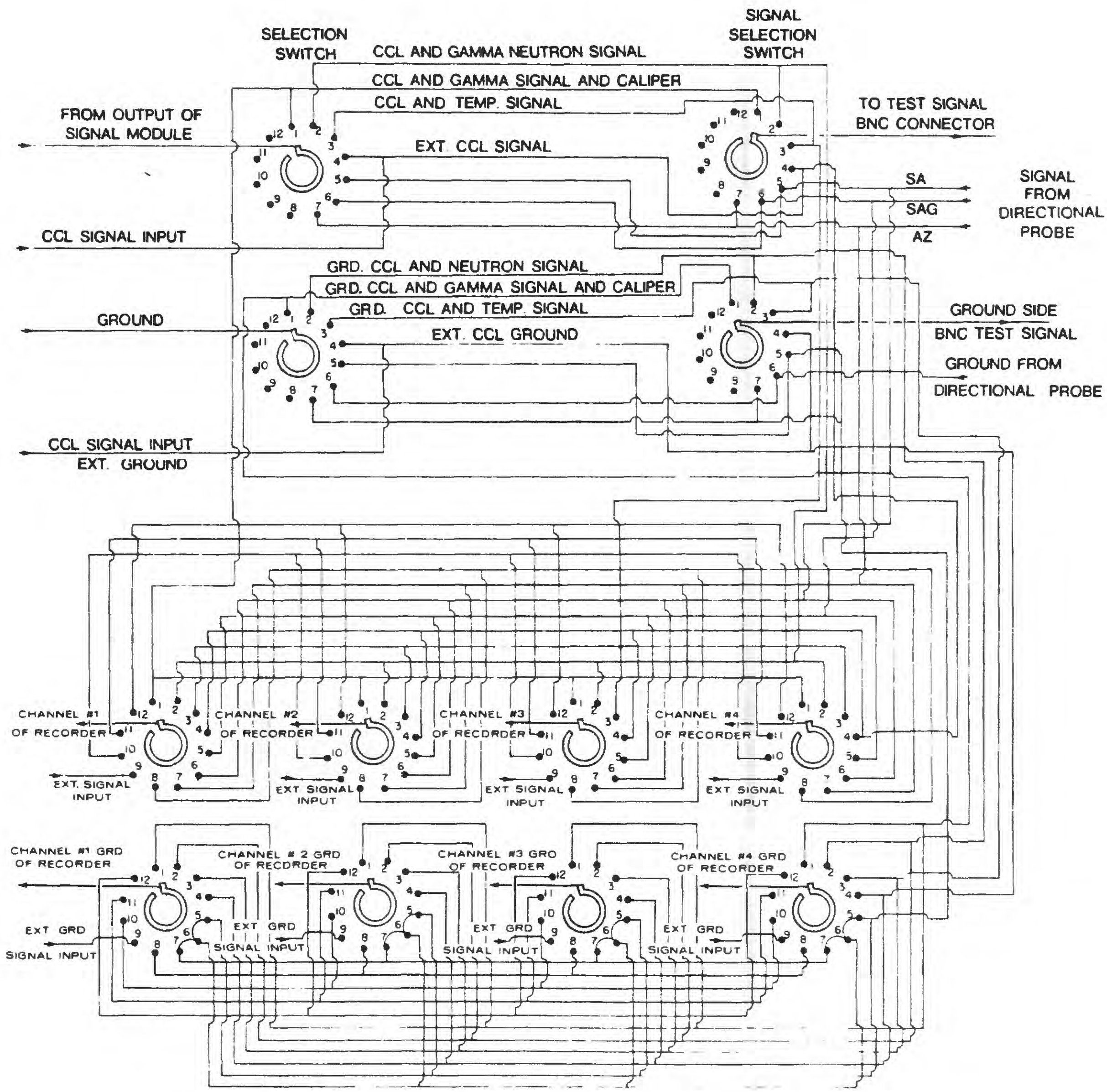


Figure 35. Schematic of control console.

both functions for the small 4 1/8-inch meter. The electronics for these consoles are still in the developmental stage and the diagrams have not been published (Fred Clutsom, written commun., 1979).

h) Recorder for BHGM's--This unit, made by Houston Instruments, is a standard one- or two-channel analog strip-chart recorder that uses 10-inch wide paper and felt ink pens. Because the BHGM is read at stationary locations within the well, the chart drive is the standard time-drive.

i) Drawers--There are two drawers in the racks for storage of chart paper and miscellaneous supplies.

j) Extra space and access--There is still space remaining for other instruments in both the main instrument racks and in the rear instrument panel. Access to these racks is relatively easy with a small space behind the racks for hands to reach into; the consoles can be removed easily. Because the patch-panel to the cable is mounted high on the rear instrument panel, connection of any console is easy.

IV Operating Procedures

A). <u>Operation of the Waukesha diesel</u>

1) Check oil in engine (fig. 5).

2) Put switch "a-1" (fig. 29) in "Waukesha" position. This switch determines whether the Waukesha or the Cummins engine will charge the back batteries, and the Waukesha engine can not be started with the switch in the "truck" position (fig. 22).

3) Press-in switch "a-4" (fig. 28)

4) Turn key switch "a-2" until engine starts (fig. 28). Light "a-3" (fig. 29) will come "on" when "a-2" is turned "on".

5) Release "a-4" after oil-pressure appears in gauge "a-6" (fig. 28).

6) Turn air-compressor circuit switch to hydraulic generator (left-rear corner of control van). Onan diesel generator can be used if desired.

7) Allow engine to idle at 800 RPM ("a-7", fig. 28) for a short time. Then increase RPM to 1200 which is the required minimum for full load usage of the generator. The hydraulic oil needs to warm up before the generator will put out 60 cycles.

8) Loosen nuts and remove engine tie-down pins (fig. 10).

9) Inflate air-cushions to about 12 PSI using air-compressor (fig. 21).

B). <u>Truck Setup</u>

1) Back truck to about 9 feet from well.

2) a) Remove cross bar that holds tower to headache bar.

   b) Remove pin from measure-head support cradle.

   c) Remove cable-head from support cylinder.

3) Check oil in hydraulic reservoir.

4) a) Start Waukesha engine. (see section IV-A).

   b) Turn electric hydraulic-pump circuit switch to hydraulic generator (Onan diesel generator can be used if desired).

   c) Turn hydraulic-pump switch "c-1" to "on" (fig. 29).

5) Raise tower (check for clearance, ie.-power lines, trees). Make sure cable is loose--otherwise damage may occur.

6) Raise meaure-head to desired position (fig. 11) using valve lever "d-11" (fig. 28).

7) Making sure dump-valve "d-3" (fig. 28) is in "down" position, release the mechanical brake "d-2" and lower cable (see section IV-D) so that cable-head is just above the well-head.

8) Move the truck so that the cable is in the desired position over the well.

9) a) Place wooden blocks beneath hydraulic-outrigger cylinders (fig. 6).

   b) Lower cylinders until logging platform is raised to desired height.

   c) Check that platform is level and cable is centered over the well.

10) Redo steps 9 and 10 if cable is not centered.

11) Turn Cummins engine "off".

12) Truck is ready for logging operations.

13) Tower can be used for removing heavy tools and sinker-bars from tool rack.

14) Remove desired tools and start logging with a conventional tool and(or) with the BHGM dummy.

15) At this point, the BHGM heater circuit can be removed from the inverter power source and placed onto the hydraulic generator source. The hydraulic generator should be producing 60 cycles by now. If the heater needs to be placed onto a generator source before this, the Onan diesel can be used. All later operations of the tower should be powered from the Onan diesel generator. The Onan diesel should also be used for keeping the BHGM on "heat" when logging operations have been shut down for the night.

C). <u>Placement of BHGM in pressure sonde</u>

1) The small mast and winch system next to the BHGM storage cylinder (fig. 18), on the right side of the truck, is turned out from the truck with the hook on the winch cable lowered to a convenient height so that the BHGM top-sub with special cap (cap has electrical fitting for heater circuit) can be attached.

2) Attach top-sub (figs. 36 and 37).

3) Attach BHGM to top-sub (figs. 38 and 39).

4) Place BHGM back on "heat" by attaching cord from special cap into the monitoring box, attaching the monitoring to an 110-volt AC outlet, and turning the on-off switch to "on". Figure 40 is the schematic for this box.

5) Make sure the BHGM is drawing the desired amount of current. If it is not, turn the switch off immediately and find the trouble.

6) Raise the BHGM high enough to clear the sonde.

7) Place sonde and dolly beneath BHGM.

8) Turn "off" heater circuit.

9) Lower BHGM into sonde (fig. 41).

10) Tighten top-sub into sonde (winch cable must be removed from top-sub of large BHGM for this step).

11) Turn heater circuit switch back to "on" again checking for desired amount of current.

12) At this point, the BHGM could be placed in the storage cylinder (fig. 19), or left in place until it is to be placed onto the logging cable.

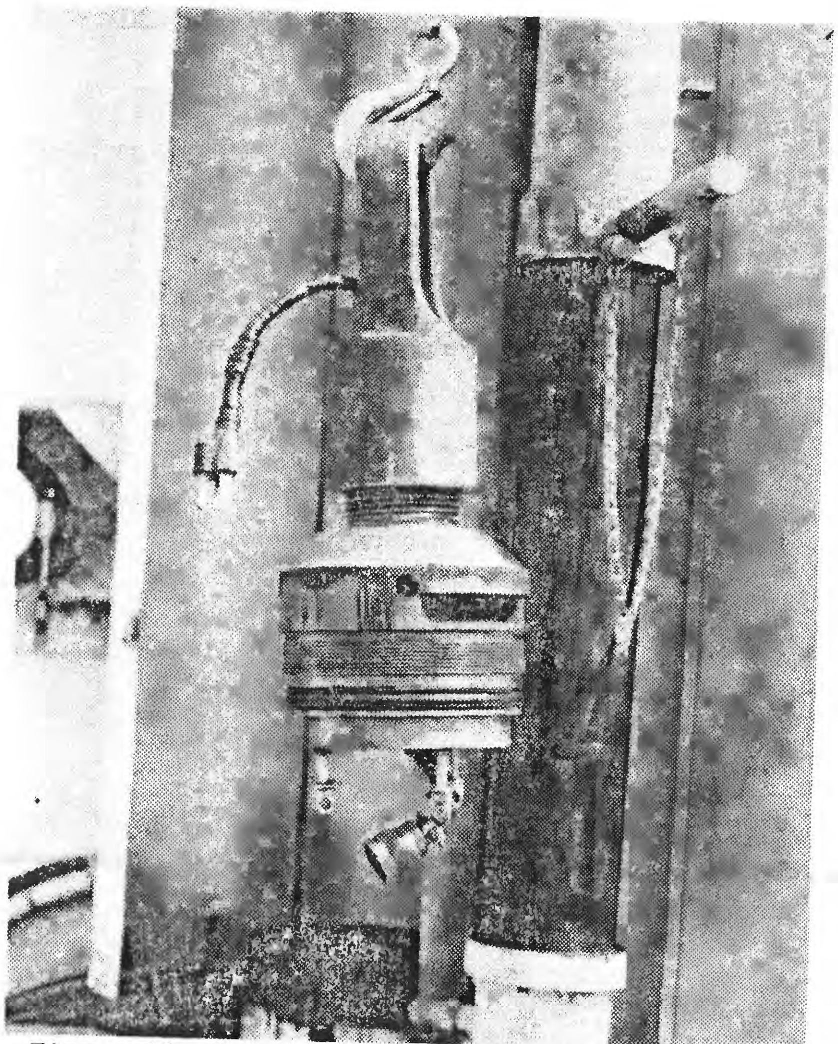


Figure 36. Large BHGM top-sub and special cap hanging from small winch located on the right side of the BHGM logging truck near the vertical cylinder.

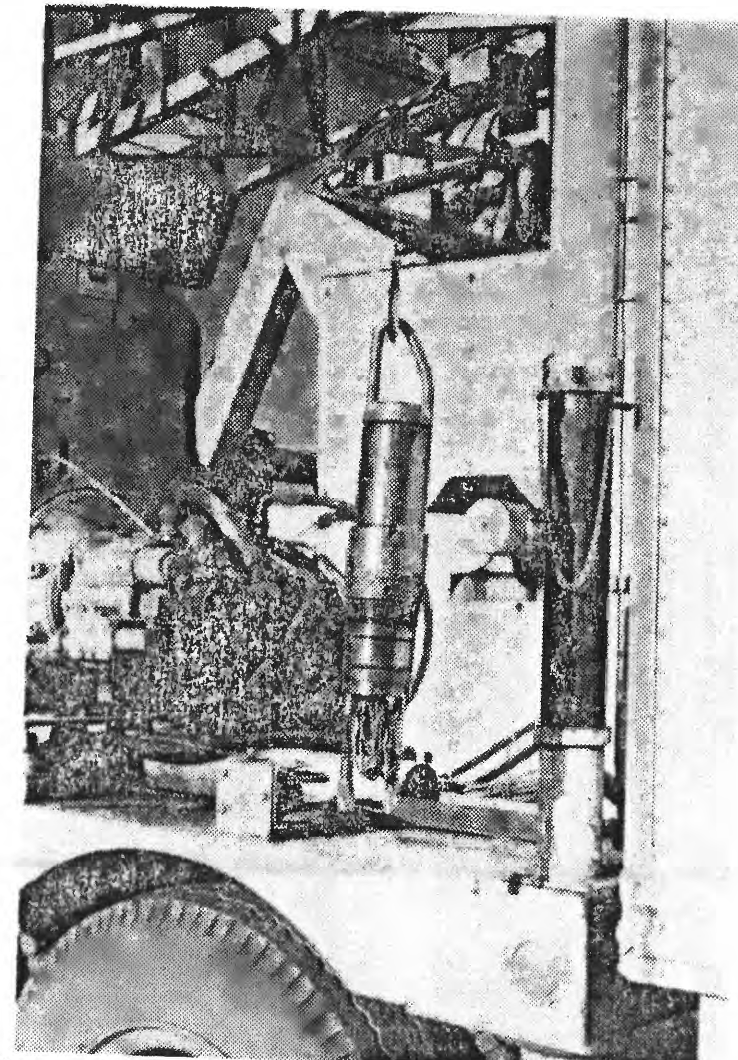


Figure 37. Small BHGM top-sub hanging from small winch located on the right side of the BHGM logging truck near the vertical storage cylinder.

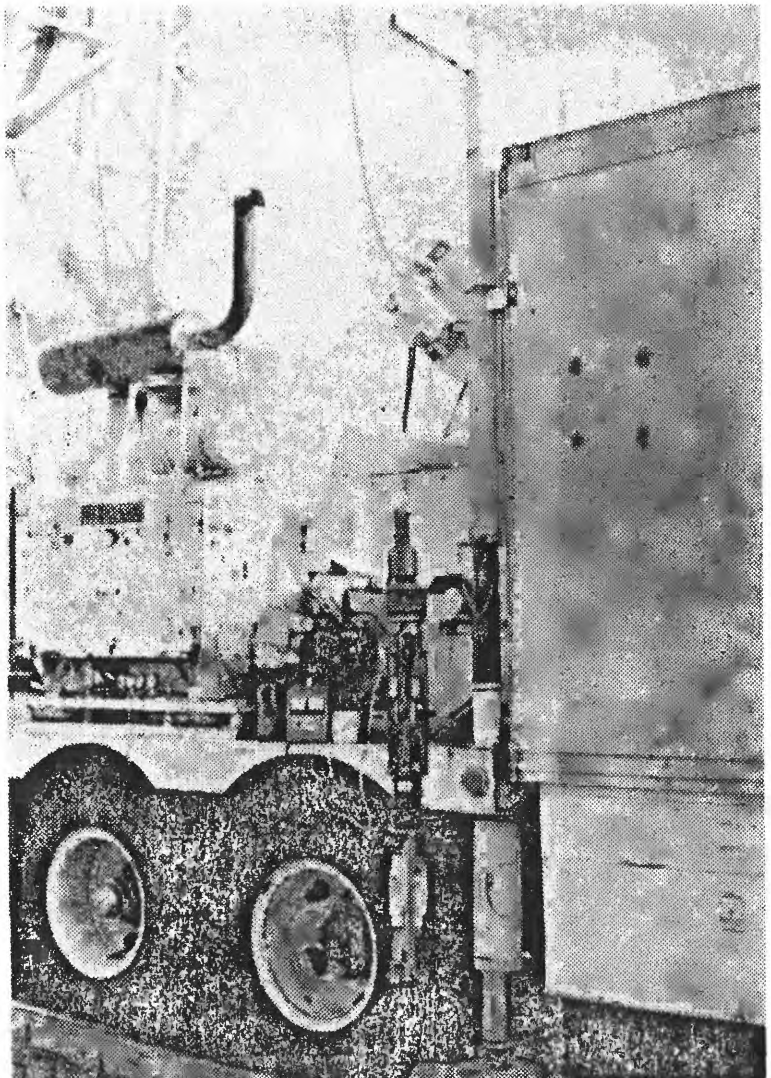


Figure 38. Exposed view of large BHGM attached to top-sub

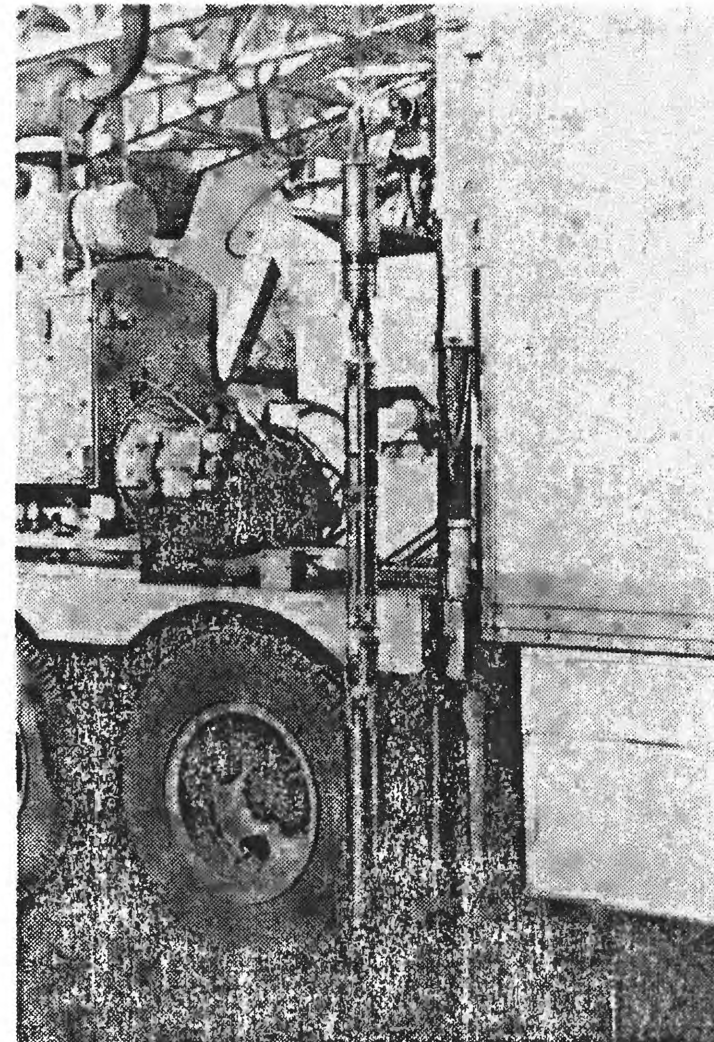


Figure 39. Exposed view of small BHGM attached to top-sub

ALL METER STANDARD CURRENT WILL ONLY SHOW WHEN LOAD IS ON OUTPUT VOLTAGE WILL SHOW INPUT

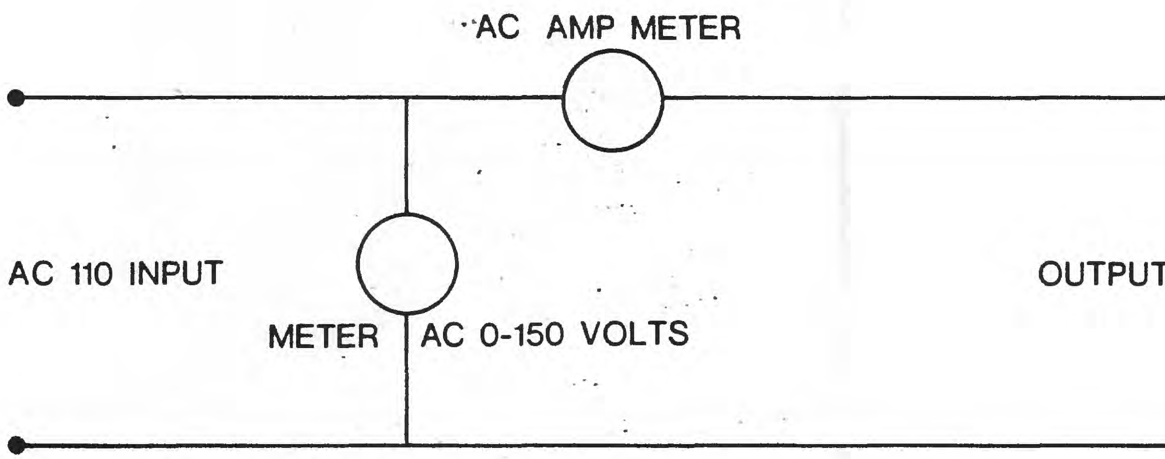


Figure 40. Schematic of BHGM heater monitoring box

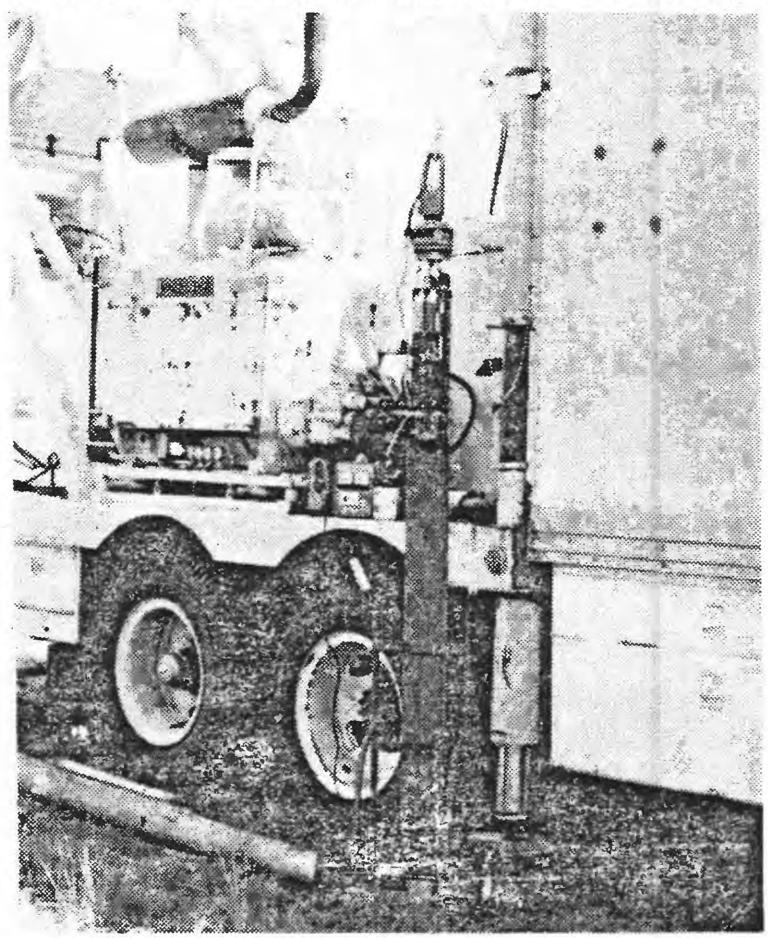


Figure 41. Large BHGM part way into pressure sonde

The placement of the BHGM in the pressure sonde can be accomplished most conveniently while a logging run with a conventional tool (such as gamma-ray) or with the BHGM dummy is in progress.

Power for maintaining "temperature" in the BHGM when the meter is in the storage cylinder is provided by a wire and plug at the top of the van above the cylinder. See Section IV-G for its operation.

D) Operation of the Draw-works

1) Start Waukesha engine (see section IV-A).

2) Check charge-pressure gauge "d-1" (fig. 29). Normal pressure, depending on engine RPM, is between 150 and 300 PSI.

3) Raise measure-head (fig. 11) to desired position using valve lever "d-11" (fig. 28).

4) Place dump-valve "d-3" (fig. 28) in the "down" position. This closes off the hydraulic by-pass between the Sundstrand pump and motor (fig. 9) and also allows the Sundstrand pump charge-pressure to release the drum brakes.

5) Place gear-shift level "d-6" (fig. 28) into gear desired. Gear selection will depend on logging speed desired and weight of the tool string.

6) Release mechanical brake lever "d-2" (fig. 28).

7) Turn "on" switch "d-9" (fig. 28) which activates the spooling system.

8) The cable can now be moved. Control lever "d-7" (fig. 29) is used. "Up" on the lever moves the cable up the hole and "down" on the lever moves the cable down the hole. The amount that the lever is moved up or down will determine the amount of hydraulic pressure (see gauge "d-5", fig. 28) available to the Sundstrand motor which will determine the amount of pull and (or) velocity for the cable. Higher Waukesha engine RPM's also makes available more hydraulic pressure.

9) When starting to move up a hole, the pressure-relief valve "d-4" (fig. 28) must be reset. The valve can be set anywhere between 0 and 3,000 PSI. Set the valve so that there is just enough pressure for the drum to turn at the desired speed. For moving in the down-direction, the

maximum hydraulic-pressure is preset inside the motor.

10) Anytime that there is hydraulic pressure to the Sundstrand motor, the tension gauge "d-8" (fig. 28) must be watched. A tension greater than 3,000-4,000 lbs on the cablehead will pull the head off the cable. The weight of the cable in the well must be added in to obtain maximum allowable tension.

The tension is measured by a transducer that is attached to the spring-loaded front wheel in the three-wheel footage measure system. The gauge is linearly accurate but is offset on the low side. Figure 42 is a chart showing the true versus the observed values for the gauge. The observed values must be checked periodically by attaching the cable to a dynometer.

11) If trouble arises in the cable spooling during the logging operation, the override switch "d-10" (fig. 28) can be used. This switch is also used when removing and returning the measure-head to its cradled position.

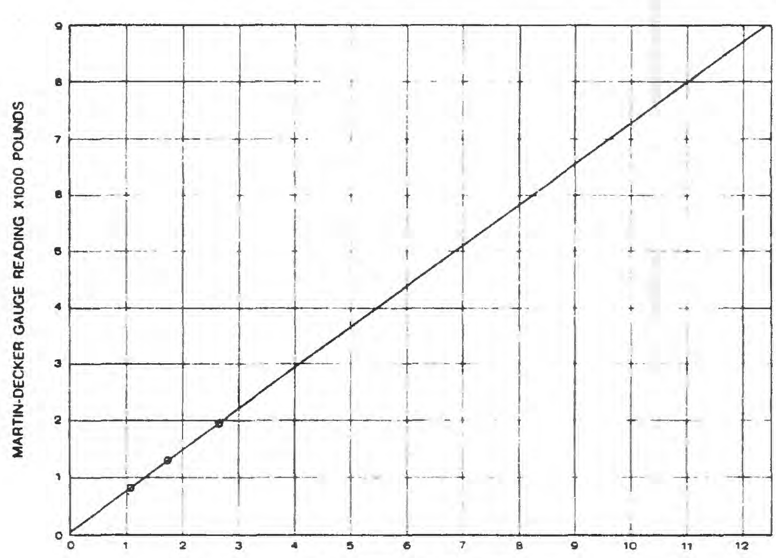


FIGURE 42 MARTIN-DECKER TENSION GAUGE CORRECTION CHART

E) Use of the Measure-head Systems

1) The measure-head must be in the desired position for accurate usage (see section IV-D for operation of the draw-works).

2) Position logging tool at desired reference point.

3) Set odometers to desired value (zero is usually used). There are three odometers, and discussion of their usage follows:

a) "e-1" (fig. 28) is a mechanical odometer which runs off a gear drive attached to the middle wheel in the three-wheel measure system. It measures in feet to the nearest foot. The meter's main function is as a back-up system in case of an electrical failure.

b) "e-2" (fig. 28) is a selsyn odometer which is also attached to the same measure wheel as "e-1". It measures in feet to the nearest tenth. The selsyn transmitter also powers a receiver located on the continuous logging chart recorder (section III-C-4-c). The odometer is preset by control "e-3" (fig. 28) before the on-off switch "e-4" (fig. 29) is turned "on". "e-4" turns "on" the selsyn transmitter which sometimes changes the counter "e-2" by ±0.1 to ±0.5 feet. The switch must be turned "off" before the counter can be reset.

c) "e-7" (fig. 29) is a digital readout for a encoder odometer which is attached to the straight-line measure wheel. It measures in feet to the nearest hundredth.

"e-8" is the on-off power switch.

"e-9" is a reset button which sets the readout to zero.

"e-10" is a knob for presetting or resetting the digital readout to other values. This knob is attached to a second encoder which can be removed and used as a backup if the outside encoder fails.

"e-11" is a switch for switching the readout "e-7" to either the outside encoder or to "e-10". The reading is not affected.

"e-12" is an on-off switch for a small heater located in the encoder outer case. The heater is needed because the encoder can not be operated at temperatures below $32^{o}F$ ($0^{o}C$).

"e-13" is a pilot light which, when "on", indicates that the heater is drawing current. The light will go "off" when the temperature at the encoder is at or above 35^{o}-40^{o} F. The cable should not be moved prior to this.

The question has been raised many times as to why two measure wheel systems are necessary, especially since it was quite expensive to incorporate the two into one housing. The reasons are:

i) the straight-line measure wheel is needed because it is more accurate than the three-wheel system. The better the accuracy of ΔZ (the vertical depth in a borehole between BHGM stations), the better the accuracy of the density determinations becomes, because

$$\rho_B = \frac{F - (\Delta G/\Delta Z)}{0.02556}$$

where ρ_B is the bulk density in g/cm^3, F is the free-air gradient in milligals/feet, and ΔG is the observed gravity difference between the BHGM stations (Robbins, in press).

ii) the three-wheel system is needed to operate the transducer for the tension gauge.

iii) the straight-line wheel might slip if more than one odometer system were attached to it.

4) The switch "e-6" (fig. 28) must be positioned so that the line-speed indicator "e-5" (fig. 28) will show the correct velocity. There are four positions: two for the cable coming up the hole and two for down the hole; one up and one down position are 0-50 ft/min each and the other two are 0-500 ft/min. "e-5" is powered from the selsyn odometer system.

5) When logging run has been completed, reposition tool at reference point and note difference due to cable stretch or slippage.

F) Use of the magnetic cable marker

The purpose of this system is to mark the cable so as to be able to return to the same location at a later time. The controls and indicator are shown in figure 29 and the schematic is shown in figure 43.

1) Turn power switch "f-1" on.

2) With the cable stationary, turn switch "f-4" to "magnetize".

3) Push in magnetize button "f-6" in for a few seconds, then release.

4) Turn switch "f-4" to "detect". Cable can now be moved.

5) For detecting and returning to the same location, watch the meter "f-3" as the cable moves slowly by the mark. Where the needle passes through null, as it swings from one side to the other, is the location of the magnetic mark. If the meter sensitivity needs to be changed, use dial "f-5".

6) The magnetic mark can be erased, if desired, by first turning switch "f-4" to "demagnetize" while the cable is stationary and located at the mark. Turn power dial "f-7" full "on" for a few seconds, then turn full "off".

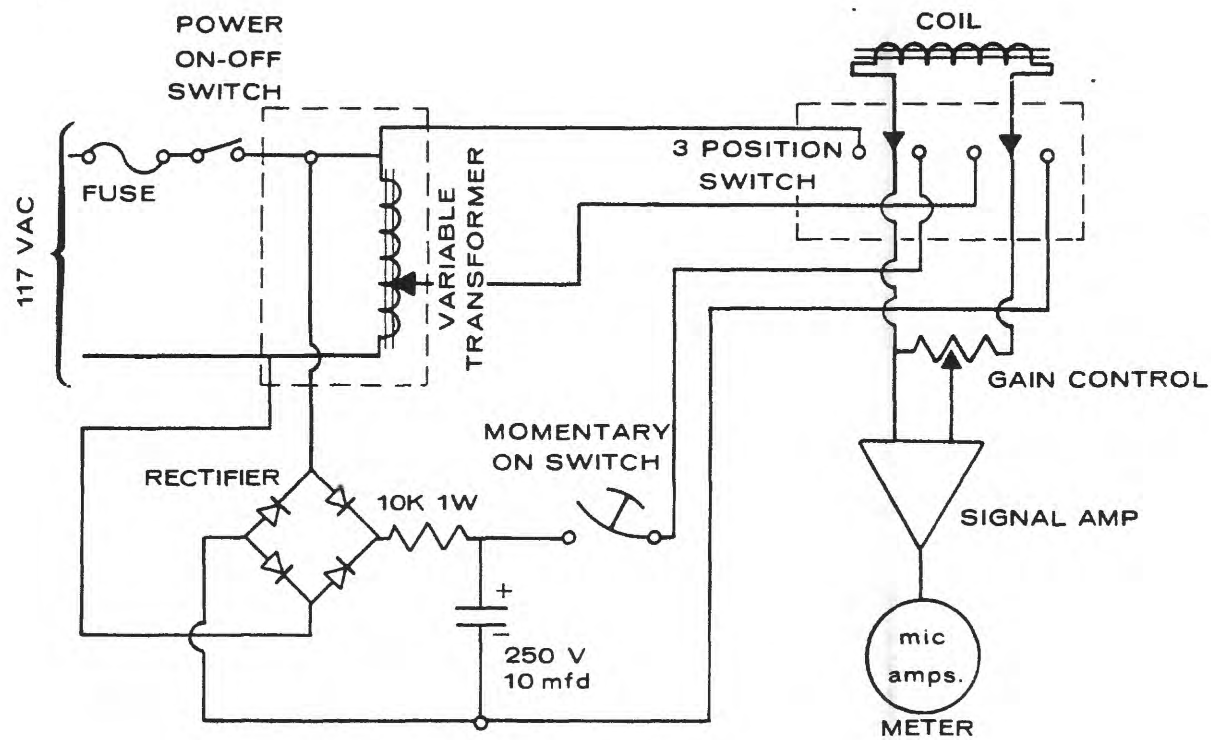


Figure 43. Schematic of magnetic cable marker

G) Operation of Inverter System

This system is powered by the two 220-ampere-hour 12-volt batteries located on the draw-works platform (the batteries are in parallel) (fig. 22). These batteries can be charged by any one of the following three engines on the truck: (1) The 60-amp alternator on the Cummins. Switch "a-1" (fig. 29) must be in the "truck" position, and the switch in the cab must be "on"; (2) The 60-amp alternator on the Waukesha. Switch "a-1" must be in the "Waukesha" position; (3) The 5-amp generator on the Onan.

The main purpose of the inverter is to provide power for keeping the BHGM "on temperature" when the AC generators are not "on" (e.g., when in transit or parked at night). The maximum time that a meter can be kept "on heat" before the batteries need recharging depends somewhat on the outside temperature, but should be limited to about 20 hours. The inverter can be used for any other need that requires a maximum power of 250 watts or less. If overloaded, the inverter will automatically shut-down without damage.

Inverter power can be obtained from inside the control van at outlet "g-5" (fig. 29) or outside at the plug located above the BHGM vertical storage cylinder (section II-B-6-b).

1. To obtain 110-volt AC power at outlet "g-5":

    a) Turn "on" switch "g-1" (fig. 29);

    b) Turn "on" switch "g-2" (fig. 29). Pilot light "g-3" should now be lit with power available at "g-5".

2. To obtain power at the outside plug:

a) Turn switch "k-1" (fig. 29) fro "off" to desired pow r source after outside plug has be n plugged into the BHG . The power source can be either the inverter system or the .C generator.

b) Meter "k-2" should show 110 vol s. Meter "k-3" shou d indicate desired current. If not, immediately turn off "k-1" and find source of trouble.

H) Use of the Control Console

This unit was designed so that the various wireline tools that are used (or maybe used in the future) can be accomodated with a minimum of wire switching at the back of the instrument modules. Besides the 24-hour clock, the console provides the following three independent functions:

i) to switch the various output signals from the Nims Bin modules, the gyro-directional probe, or any other tools to the four channels on the continuous-logging chart recording.

ii) to switch between several Nims Bin configurations, and

iii) to provide a convenient outlet for the checking of all signals into the chart recorder.

To use console:

1) Determine which recorder channels are desired (refer to the GOI recorder operator's manual), and switch the channel knobs to the desired tool signal position (fig. 33).

2) If a signal from the Nims Bin is needed, the Nims Bin selection switch must be positioned for the particular tool being used. Use GOI's operator's manual. As new modules are acquired, more positions can be added to this switch.

3) Tools not connected to the back of the console can have their signals inputted directly to a recorder channel by connecting a channel BNC connector on the front of the panel and turning the channel knob to position #8.

4) Turn "on" the recorder power and each channel amplifier (fig. 31).

5) After the wireline tool consoles (see appropriate manuals for operation) have been set and the amplifier controls set on the recorder, logging can begin.
6) Signals into the recorder channels can be monitored or tested by turning the test switch knob to the appropriate position (fig. 33).

IV. References

Beyer, L. A., 1971, Vertical gradient of gravity in vertical and near vertical boreholes: U.S. Geological Survey Open-File Report 71-42, 217 p.

McCulloh, T. H., LaCoste, L. J. B., Schoellhamer, J. E., and Pampeyan, E. H., 1967, The U.S. Geological Survey--La Coste and Romberg precise borehole gravimeter system - instrumentation and support equipment, in Geological Survey research, 1967: U.S. Geological Survey Professional Paper 575-D, p. D92 - D100.

Robbins, S. L., in press, Reexamination of the values used as constants in calculating rock density from borehole gravity data: Geophysics.