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ENGINEERING AND TEST REPORT UNITED STATES NAVAL APPLIED SCIENCE--ETC(U)

1971   N140(62462)77644B

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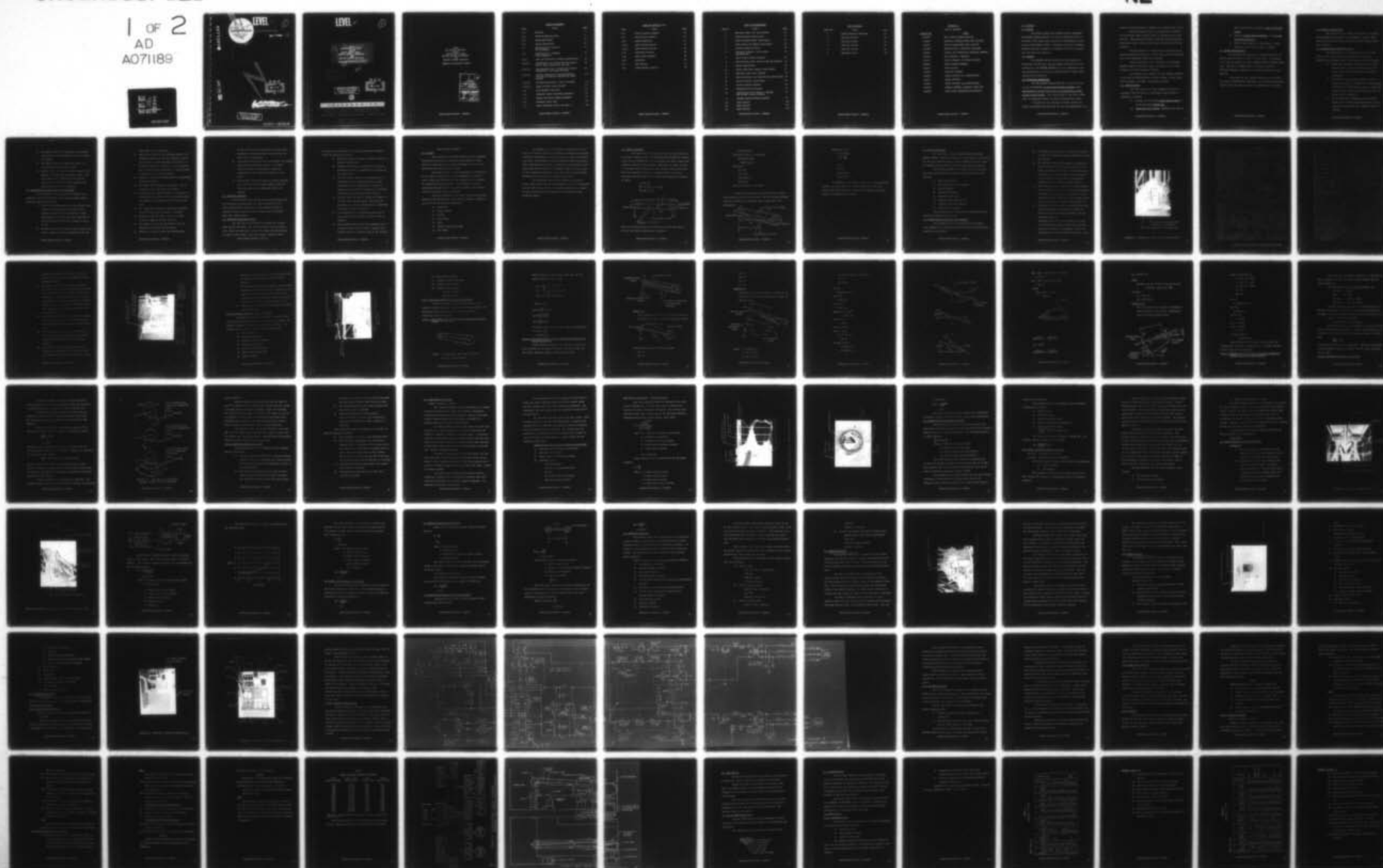

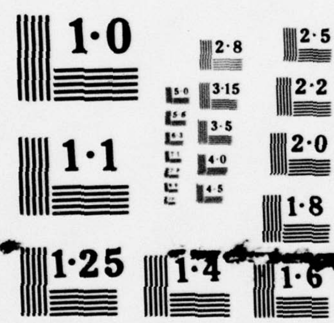

NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

LEVEL II

(1)

Telephonics CORPORATION

MOST Project -4

HUNTINGTON, L.I., N.Y.

NSSC-1622E

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UNITED STATES NAVAL
APPLIED SCIENCE LABORATORY
VDS
TOWLINE FLEXING FACILITY

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APPLICATIONS AND SERVICE FOR GOVERNMENT AND INDUSTRY

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FINAL
ENGINEERING AND TEST
REPORT
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VDS
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CONTRACT N140(62462) 77644B

Instrument Systems Corporation • Telephonics

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1.0 ABSTRACT

1.1 GENERAL

The UNITED STATES NAVAL APPLIED SCIENCE LABORATORY VDS TOWLINE FLEXING FACILITY was built by ISC/Telephonics in accordance with design plans prepared by ISC/Telephonics under contract N140-(62462) 77644B. Government owned and furnished AN/SQA-8 VDS Hoist equipment was modified by ISC and incorporated into this test facility.

1.2 PURPOSE

The TOWLINE FLEXING FACILITY has been designed to demonstrate the VDS cable bending fatigue characteristics and reliability. ~~The FLEXING FACILITY~~ This facility will also demonstrate working repeatability of faired and unfaired VDS tow cables under simulated tow conditions.

1.3 FUNCTIONAL DESCRIPTION

The VDS TOWLINE FLEXING FACILITY is capable of subjecting VDS TOWLINES to controlled variable tensions while simultaneously driving this cable in a reciprocating motion around a driven sheave. The linear travel of the cable, under test, is adjustable within controlled and specified limits.

To enable the test facility to handle various size cables, provisions have been made for the interchangeability of

(over)

sheaves of various diameters, adapted to a standard type of hub.

Cable cycling direction is automatically controlled by cam operated limit switches which are actuated by the drum rotation. These switches energize solenoid operated hydraulic directional control valves which control the direction of drum rotation.

The Cable Tension is controlled and regulated by the hydraulic pressure setting of a relief valve and the "head end" area of the hydraulic Tensioning Cylinders.

Several protective safety devices are provided to prevent system and personnel damage in the event of critical component or control mechanism failure.

An enclosed area, separate from the FLEXING FACILITY, is provided by ISC/Telephonics for the storage of space parts, cable specimens, fairings, instruments and tools.

1.4 SPECIFICATIONS

The test facility has been designed and built in accordance with the contract requirements which provides a capability as follows:

a) Varying and maintaining cable tension loads up to and including 100,000 lbs.

b) Adjustable cable stroke, depending upon size of cable and diameter of sheaves, from 5 to 20 foot stroke.

c) Handling various sheave diameters, from 3 to 10 feet pitch diameters.

d) Subject cable samples to reciprocate at linear speeds up to 60 feet per minute, maximum.

1.5 FUTURE CONSIDERATIONS

The existing test facility is located adjacent to an outdoor pool 25 feet by 15 feet by 12 feet deep. An overhead 6 ton crane is provided to handle TOWLING FLEXING FACILITY equipment. The pool is equipped with the necessary pump and filtering equipment required for the proper operation of such facility.

To provide for such possible future use of the pool in testing of VDS Towlines underwater, the driving drum has been located within the test facility at a point close to the pool.

2.0 CONTRACT SPECIFICATION

The Contractor shall modify the presently Government owned AN/SQA-8 test equipment to accommodate a constant depth simulator for the test and evaluation of faired variable depth sonar towlines.

2.1 CONSTANT DEPTH MACHINE SIMULATOR

The modifications and construction of the constant depth machine simulator and installation in the present AN/SQA-8 test equipment shall consist chiefly of the following:

a) Modify and recondition and AN/SQA-8 cable drum, hydraulic drive mechanism, associated pump and control for constant depth machine simulator application.

b) The constant depth simulator machine shall be capable of applying a variable and maximum tension of 100,000 (50 tons) pounds in the test cable when mounted in the machine in a closed loop over two sheaves (cable and idler).

c) The machine shall continuously subject faired cables with a reciprocating motion with a travel that can be varied from approximately 5 feet to 20 feet.

d) The machine shall be constructed to accommodate cable sheaves of approximately 3 feet to 10 feet in diameter.

e) The machine must also subject the cable to a linear speed of 60 feet per minute.

f) Supply a cable sheave of a diameter equal to the AN/SQA-10 outboard wire rope idler sheave. The cable sheave shall differ from the outboard sheave in that the deep flanges necessary for ship maneuvering are not necessary.

2.2 MODIFICATION TO THE AN/SQA-8 TEST EQUIPMENT

The modification and construction of AN/SQA-8 test equipment, for the installation of the Constant Depth Machine Simulator, shall be as follows:

a) Modify the existing platform in the AN/SQA-8 test equipment to accommodate the constant depth machine simulator which is estimated to weigh approximately 15,000 lbs. and have dimensions of about 40 feet by 10 feet with a height of about 14 feet.

b) Provide space for the hydraulic pump equipment and control console in close proximitely to the constant depth machine simulator.

c) Install the machine on the existing AN/SQA-8 test equipment platform and provide sufficient access on all sides to permit handling of sheaves up to 10 feet in diameter, as well as to permit adjustment, inspection and observation of various faired towlines under test in the machine.

d) Provide an operations working area of approximately 50 feet by 20 feet.

e) For Winter time operation, a temporary means of closing the work area shall be provided.

f) Provide adequate rigging facilities including an overhead six ton crane to lift and position parts, test specimens and sheaves over the entire work area.

g) For night time operation, appropriate lighting for the entire work area shall be provided.

h) Provide an electric power source of at least 50 KVA at 3 phase, 220 VAC, 60 cycle.

i) The general area of the installation shall be provided with 24 hour security guard.

j) Provide an enclosed locked area approximately

20 feet by 20 feet for the storage of spare parts, instruments, fairing specimens and miscellaneous small tools and equipment.

k) The enclosed locked area shall be provided with a bench heavy vise and 110V power outlets. The bench shall be suitable for disection, repair and examination of test lengths of faired tow line cable.

l) The enclosed locked area shall be located adjacent to or near the constant depth machine simulator work area and shall be adequately heated and lighted.

2.3 TECHNICAL PERSONNEL

The contractor shall provide experienced personnel for the evaluation of experimental two cables submitted by U.S. Naval Applied Science Laboratory. These personnel shall be experienced with design and tests on cables used in Variable Depth Sonar (VDS) Systems.

2.4 TEST AND EVALUATION SERVICES

One test shall be performed to evaluate the constant depth machine simulator. The test will begin with installing a cable sheave and experimental length of faired electromechanical tow cable on the machine, adjusting tension, length of throw and make test connections to electrical conductors contained within the towline as follows:

a) Make observations of initial conditions and performance during test.

b) Provide surveillance as required to assess the performance during a succession of continuous 24 hour daily runs.

c) Stop the machine either at the conclusion of a specified number of operating cycles or upon observing an effect indicative of failure as judged by the contractor's experience in developing previous Variable Depth Sonar Systems.

d) Analyze, determine mode of failure and report to the U.S. Naval Applied Science Laboratory for decisions as to design modifications or otherwise the further course of the test.

e) It is expected that initially the test will be restricted to sheaves no greater than 5 feet in diameter.

f) Since modifications to the test equipment may be necessary during the test work, a machine shop facility shall be available close to the constant depth machine simulator.

2.5 REPORTS

Upon completion of AN/SQA-8 system and test equipment modification and test the contractor shall furnish a formal report in triplicate on the machine developed, as well as the facilities with which it will be used.

This Report shall include photographs and descriptions of the sizes of sheaves that can be accommodated, ranges of speed, throw, cable tensions and other details as will indicate the capabilities of the machine. The capabilities of the ancilliary equipment in the area such as cranes, tanks and instrument room shall also be described.

During the progress of the test, the contractor shall provide verbal notification of significant changes or damage to any or all of the following components:

a) conductors

b) tensil members

c) fairing

d) nose pieces

e) yokes

f) lateral restraining rings

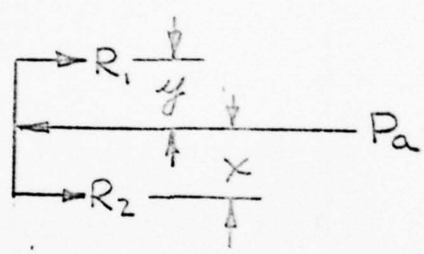
g) end sockets

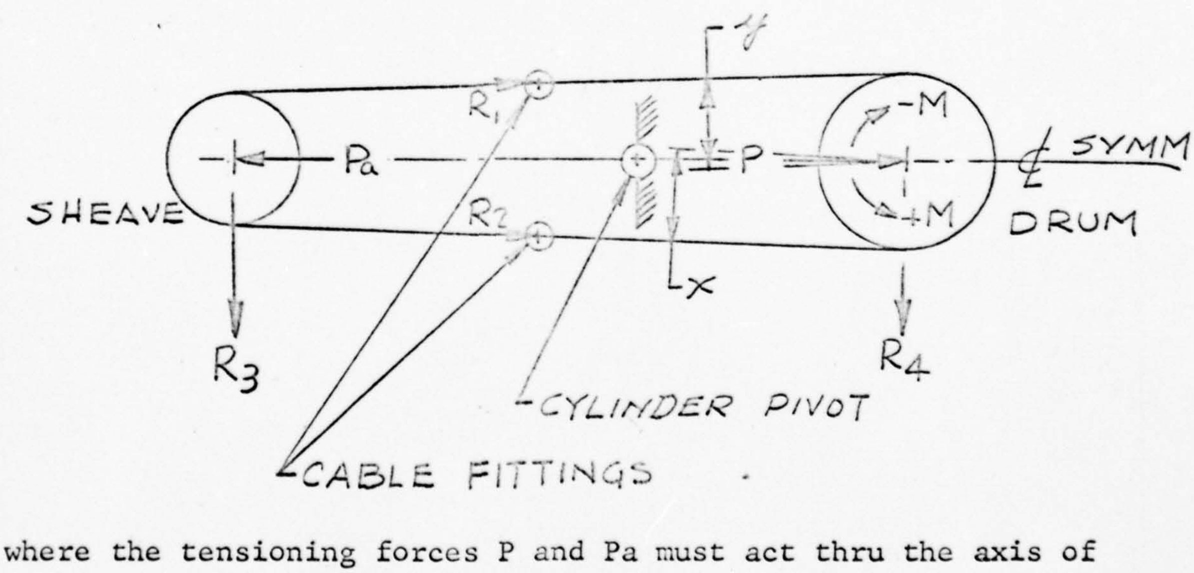
In addition, at the conclusion of each phase of test, data in the form of written description of conditions, of damaged components, measurements, number of cycles at which observations were made, and any other pertinent conditions shall be provided. Where continuation of testing is conducted, the contractor shall again make similar reports of subsequent stages of wear, damage or other impairment specified by the U.S. Naval Applied Science Laboratory at the time of restarting of the tests.

The contractor shall not be required to provide a formal final report, but the data obtained shall be in triplicate and all such data as well as all drawings developed as a result of this contract.shall be furnished to the Government with unlimited rights.

3.0 DESIGN PHILOSOPHY

The basic design philosophy of the Flexing Facility was to provide a machine capable of subjecting VDS TOWLINES to tensile loads of up to 100,000 lbs. and to maintain all loads, motions and reactions internal to the machine. Therefore, no loads, motions or reactions will be induced into the already existing structure. The basic principle of design necessitated that the drum be seperated from the driven sheave by the load tensioning cylinders as shown:





where the tensioning forces P and Pa must act thru the axis of the drum and sheave respectively, therefore:

$P = Pa = (R_1) + (R_2)$

Neglecting weight of components.

$\Sigma_M = (\Sigma_{-M}) - (\Sigma_{+M}) = 0$

$= (R_1 y) - (R_{2x}) = 0$

therefore:

(x) - (y)

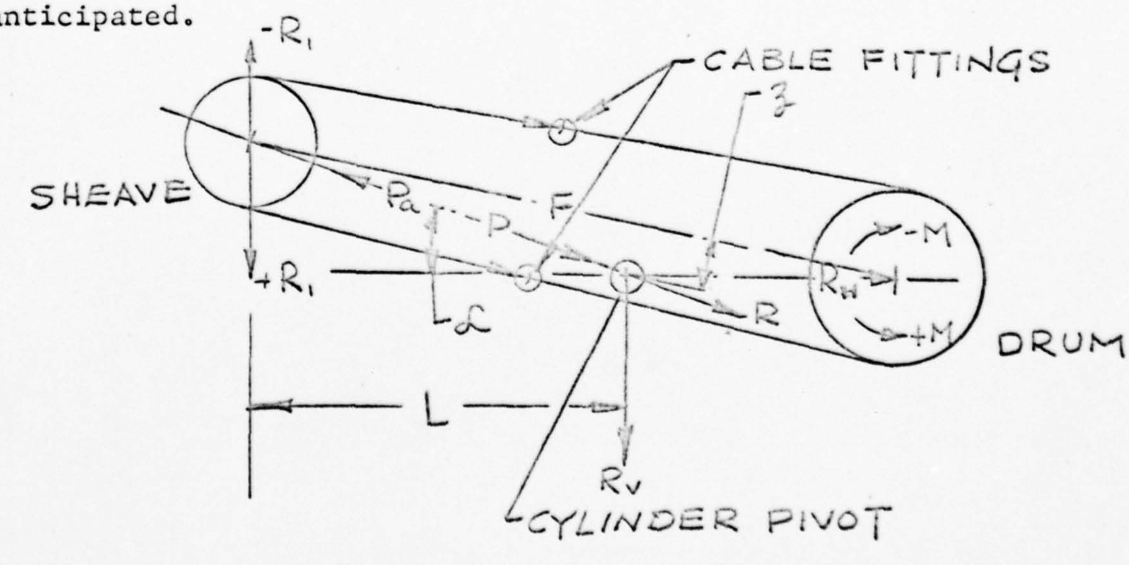
(P) - (Pa)

(-M) - (+M) and

$(R_1) - (R_2)$

must all be equal to (0) zero.

In order to accommodate the required maximum cable reciprocating travel of 20 feet, and to use the existing AN/SQA-8 hydraulic cylinders the following space diagram had to be anticipated.



Moment due to α:

$$\pm M = (F)(\pm z)$$

$$\pm R_1 = \frac{\pm M}{L}$$

$$R = P$$

$$P = Pa$$

$$R_H = R \cos \alpha$$

$$R_V = R \sin \alpha$$

In addition to the weight of the cable flexing facility machine, the small angle (α) and the force due to (F) will induce small loads R_V and R_1 into the test equipment structure which was considered and resolved.

4.0 DETAIL DESCRIPTION

The U.S. NAVAL APPLIED SCIENCE LABORATORY TOWLINE FLEXING FACILITY consists of components both designed specifically for this test facility machine and the AN/SQA-8 equipment which was modified for use with the above Towling Flexing Facility.

The following AN/SQA-8 components were received from U.S. Naval Applied Science Laboratory for use into this test facility.

a) Cable Drum Assembly

b) Hydraulic Drive Motor Assembly

c) Control Station

d) Hydraulic Cylinders

e) Hydraulic Power Unit

f) Magnetic Controller Size #2

g) Magnetic Controller Size #4

h) Junction Box Assembly

Other miscellaneous items that were received were not required therefore were not used.

4.1 MODIFICATION TO AN/SQA-8 TEST EQUIPMENT

The modification and construction of the AN/SQA-8 test equipment, for installation of the Towline Flexing Facility machine was as follows:

a) The AN/SQA-8 test equipment platform was modified as shown on Telephonics drawings 211J000 (2 sheets) and 211J008.

b) The hydraulic power pump equipment is located in close proximity of the cable drive drum so as to reduce the pressure line loss. This pumping unit is anchored to a frame which in turn is anchored to the concrete floor as shown on Telephonics drawings 211H000, 211D019 and photo figure 1.

c) The control station is located in close proximity with the driven sheave and is raised approximately 19 inches so as to provide the operator with an unobstructed view of the cable test specimen under test and evaluation as shown in photo figure 2.

d) The Towline Flexing Machine is installed onto the modified AN/SQA-8 test equipment platform as shown on Telephonics drawing 211H000 (2 sheets) and photo figure 3.

Sufficient space has been provided on all sides of the machine components which readily permits access for inspection, adjustments, repair and observation of various Towlines under test. This

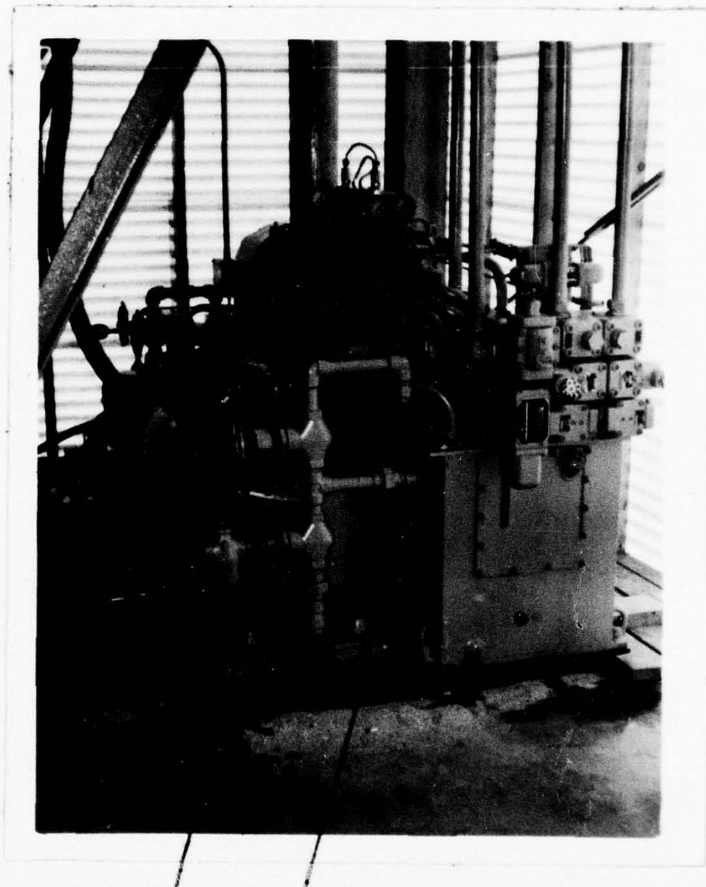


FIGURE 1 HYDRAULIC POWER UNIT INSTALLATION

FIGURE 2 CONTROL STATION INSTALLATION

FIGURE 3 CABLE FLEXING MACHINE INSTALLATION

machine also provides for sheaves of various diameter as can be seen on Telephonics drawing 211H000 (2 sheets).

e) For winter time and foul weather operation, a stud frame with corrugated fiber glass enclosure has been provided. The enclosure working area dimensions are approximately 50 feet by 25 feet. In addition, to the fiber glass enclosure, adequate lighting has been provided for night time operation, ventilation for summertime and heat for wintertime operation.

f) A six ton overhead crane with associated rigging has been provided to lift and position parts, test specimens and sheaves over the entire work area.

g) An electric 220 VAC 3 ϕ 60 ~ and 115 VAC 1 ϕ 60 ~ power source is provided for the Towling Flexing Facility Machine as shown in photo figure 4.

h) An enclosed heated, ventilated, lighted and locked area, approximately 20 feet by 20 feet for storage of space parts instruments, fairing

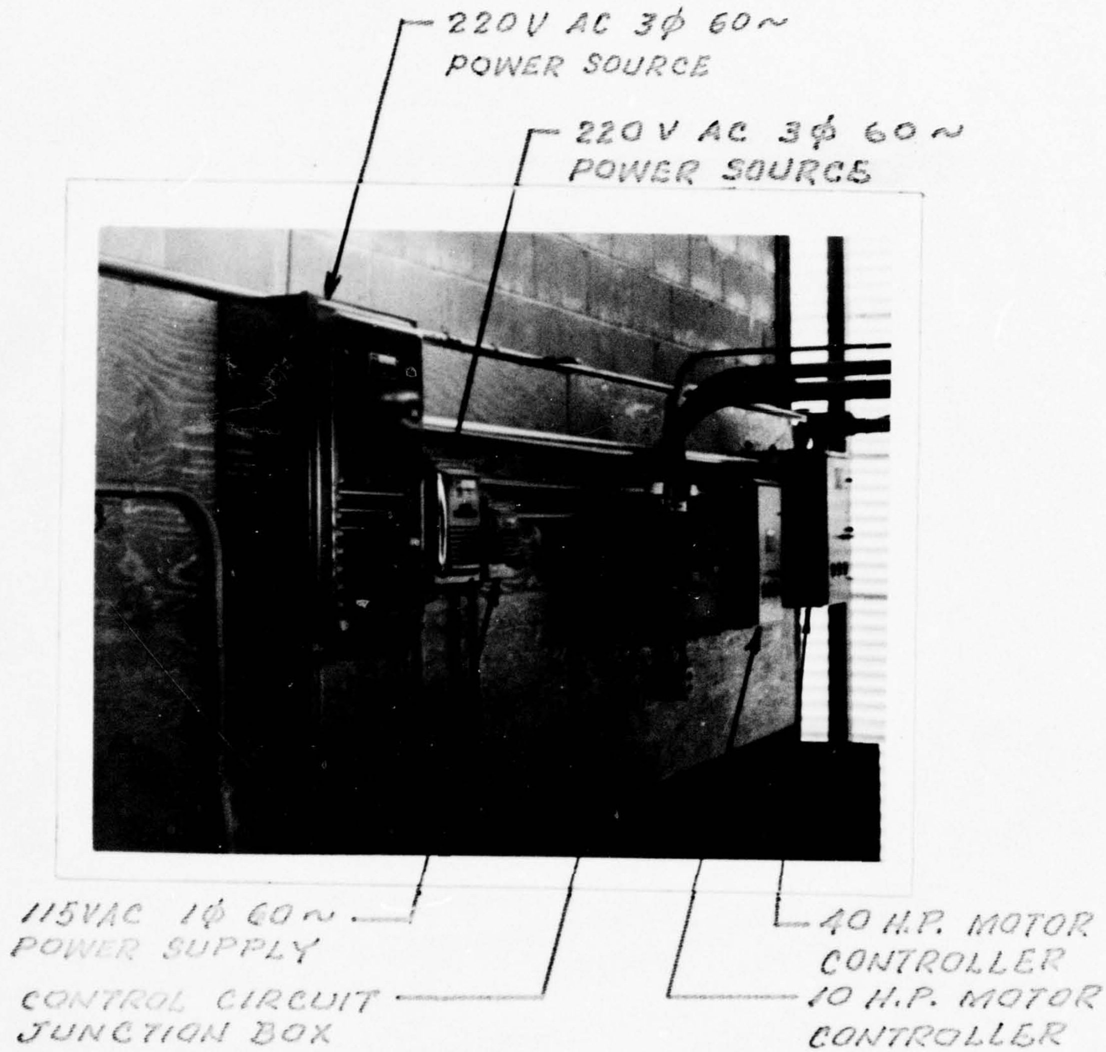


FIGURE 4 POWER SOURCE AND SUPPLY INSTALLATION

specimens, cable specimens and miscellaneous tools and equipment is provided as shown in photo figure 5.

The enclosed locked area is adjacent to the Towline Flexing Facility work area and is provided with a heavy vise, 115 VAC power outlets and benches which are suitable for disection, repair and examination of test lengths of faired towline cables.

i) The general area of the test facility is provided with ADT Security.

4.2 MODIFICATION OF AN/SQA-8 HOIST EQUIPMENT

The USN/ASL TOWLINE FLEXING MACHINE consists of components both designed specifically for the flexing machine and AN/SQA-8 equipment modified for use with this machine. The machine consists chiefly of the following major items:

a) Drum Assembly

b) Hydraulic Cylinders

c) Sheave and Sheave Supports

d) Hydraulic Power Unit

e) Size #2 Motor Controller

f) Size #4 Motor Controller

g) Control Station

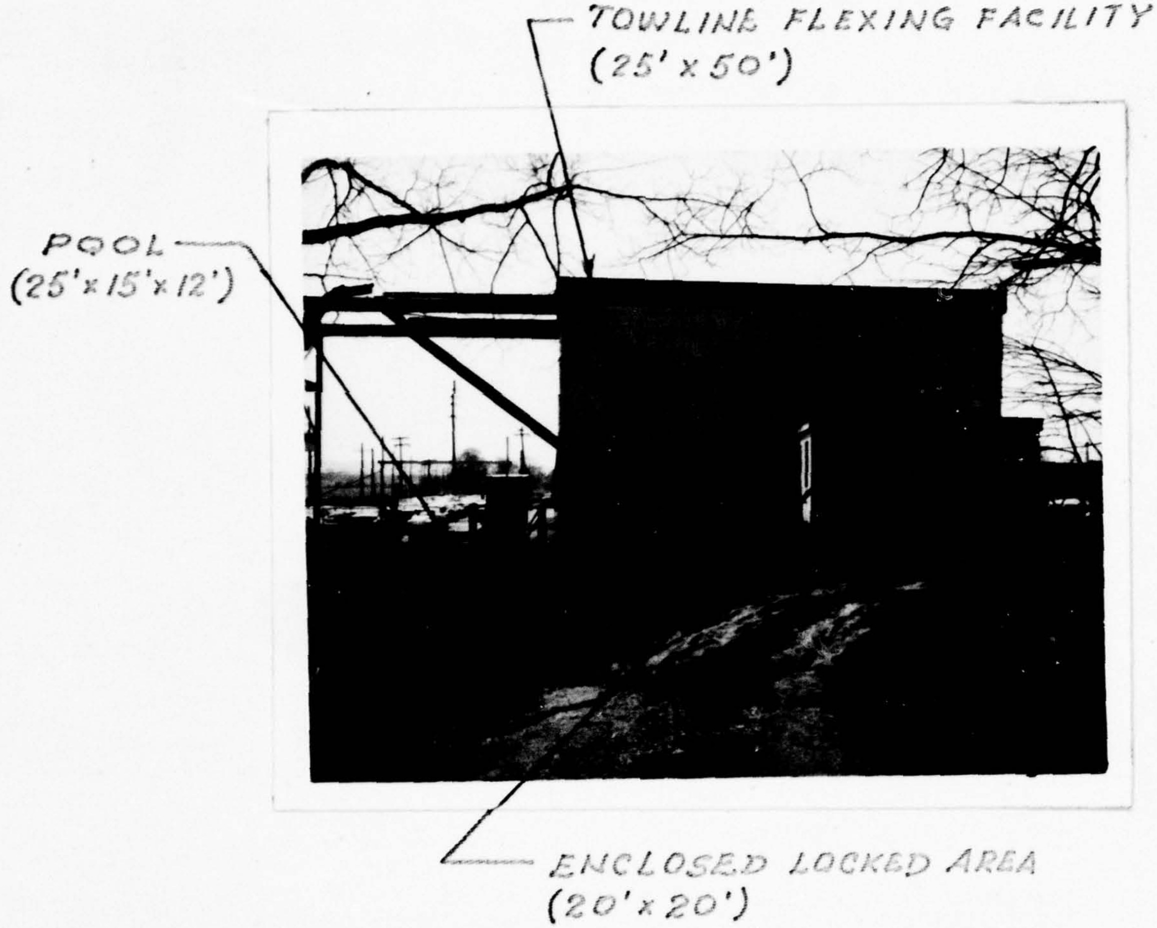


FIGURE 5 TOWLINE FLEXING FACILITY

h) Drive Cable Assembly

i) Component Support Assembly

j) Junction Box Assembly

k) Electric Power Supply

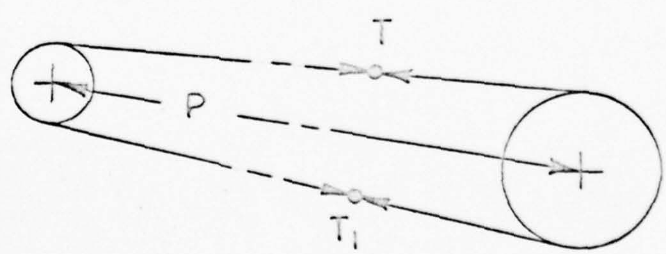
115 VAC 1 ϕ 60~

220 VAC 3 ϕ 60~

4.2.1 LOAD AND PERFORMANCE DESIGN CONSIDERATIONS

In order to comply with the specification a preliminary analysis was made to determine the design criteria for performance and stress analysis, which is as follows: (neglecting component weight)

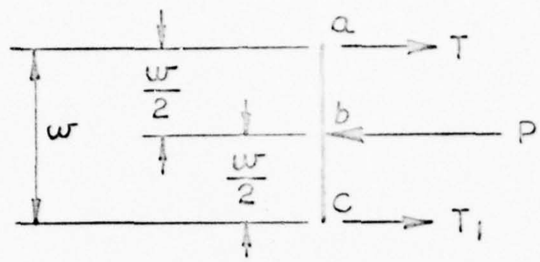
4.2.1.1 *COMPRESSION LOAD BETWEEN DRUM AND SHEAVE DUE TO CABLE* TENSION (T) and (T_1)



where: P = Compressive force due to T and T_1

T and T_1 = Cable Tension

Since T and T_1 are symmetrical about line of compressive force $P = (T) + (T_1)$



$$P=(T) + (T_1)$$

$$\Sigma_{Ma}=0= \frac{(Pw)}{2} - (T_{1w})$$

$$\Sigma_{Mb}=0=\left(\frac{Tw}{2}\right)-\left(\frac{T_{1w}}{2}\right)$$

$$\Sigma_{Mc}=0=\left(\frac{Pw}{2}\right)-(Tw)$$

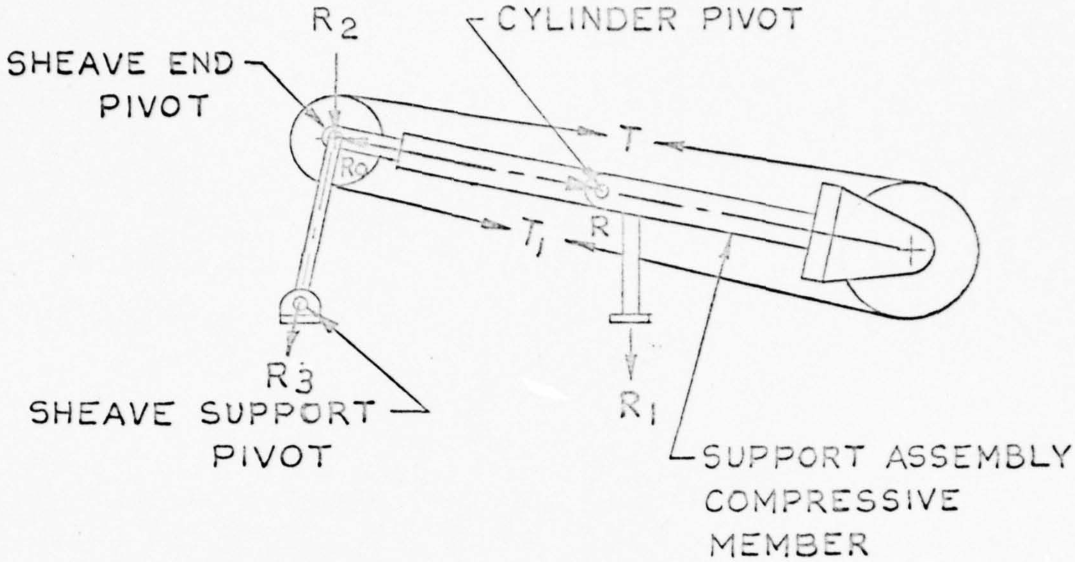
therefore, when cable tension T and T_1 = 100,000 lbs.

$$P = (T) + (T_1)$$

$$= 200,000 \text{ lbs.}$$

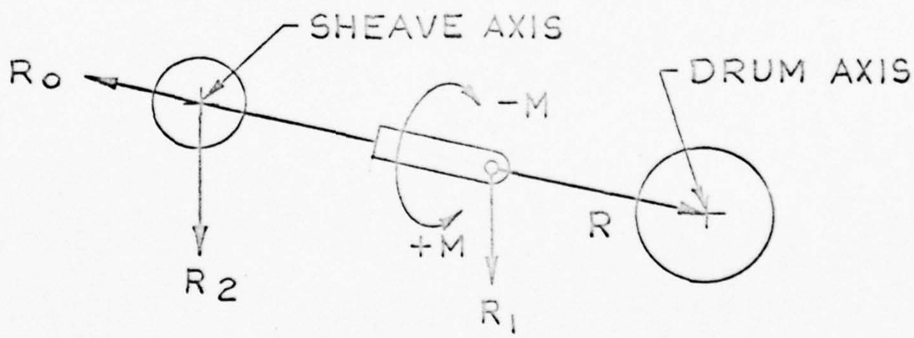
4.2.1.2 DECK REACTIONS DUE TO CABLE TEST TENSION 100,000 LBS. AND SHEAVE POSITION

Normal design condition of the machine, as shown on above drawing, is to maintain the cable load (P) in line with the sheave, drum and cylinder centerlines and axes.



Condition I

When compressive force P is in line with Tension cylinder and support assembly compressive members.



-M and +M then equals "0" zero, therefore:

$R_1 = 0$

$R_2 = 0$

$R_3 = 0$

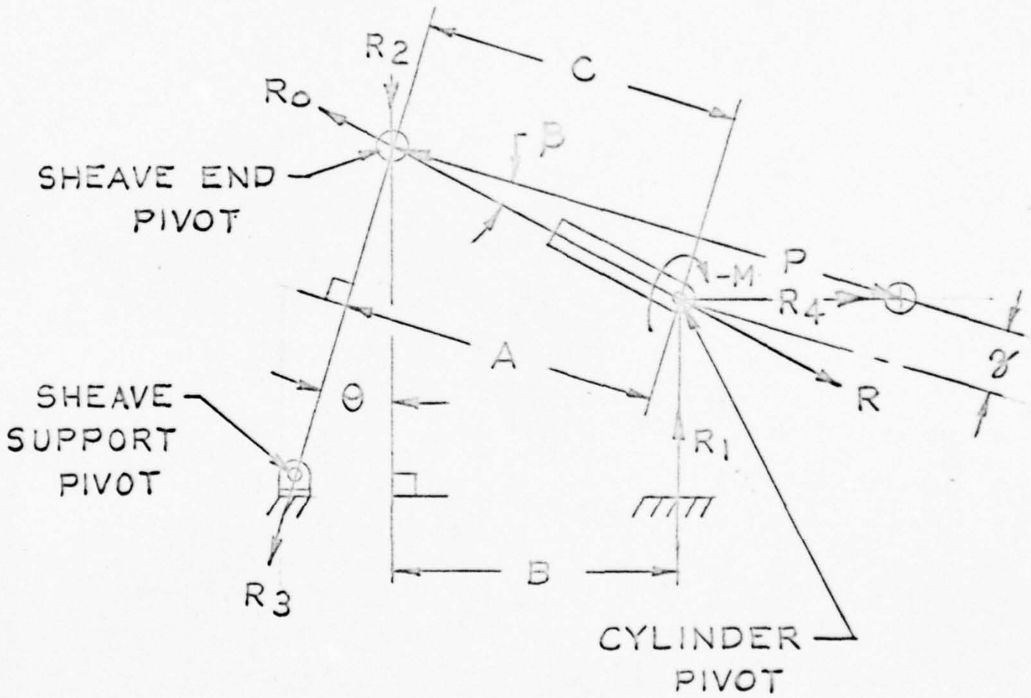
$Ro = P$

$Ro = R$

$R = P$

Condition II

When cable Tensioning cylinder is tangent to arc of sheave axis, compression force P is above the cylinder pivot.



where: P = 200,000 lbs.

A = 16' 5" =197"

B = 16' 4" =196"

$C = 16' \ 5''$ approx $= 197''$ approx

$z = 3''$

$\theta = 5^\circ \ 40'$

$-M = Pz$

$= 600{,}000$ in lb.

$R_2 = -M/B$

$= 3060$ lbs.

$R_3 = -M/A$

$= 3045$ lbs.

CHECK $R_3 = R_2 \cos \theta$

$= 3045$ lbs.

$\tan \beta = z/c$

$= .0152$

$\cos \beta = .99989$

$\sin \beta = .0152$

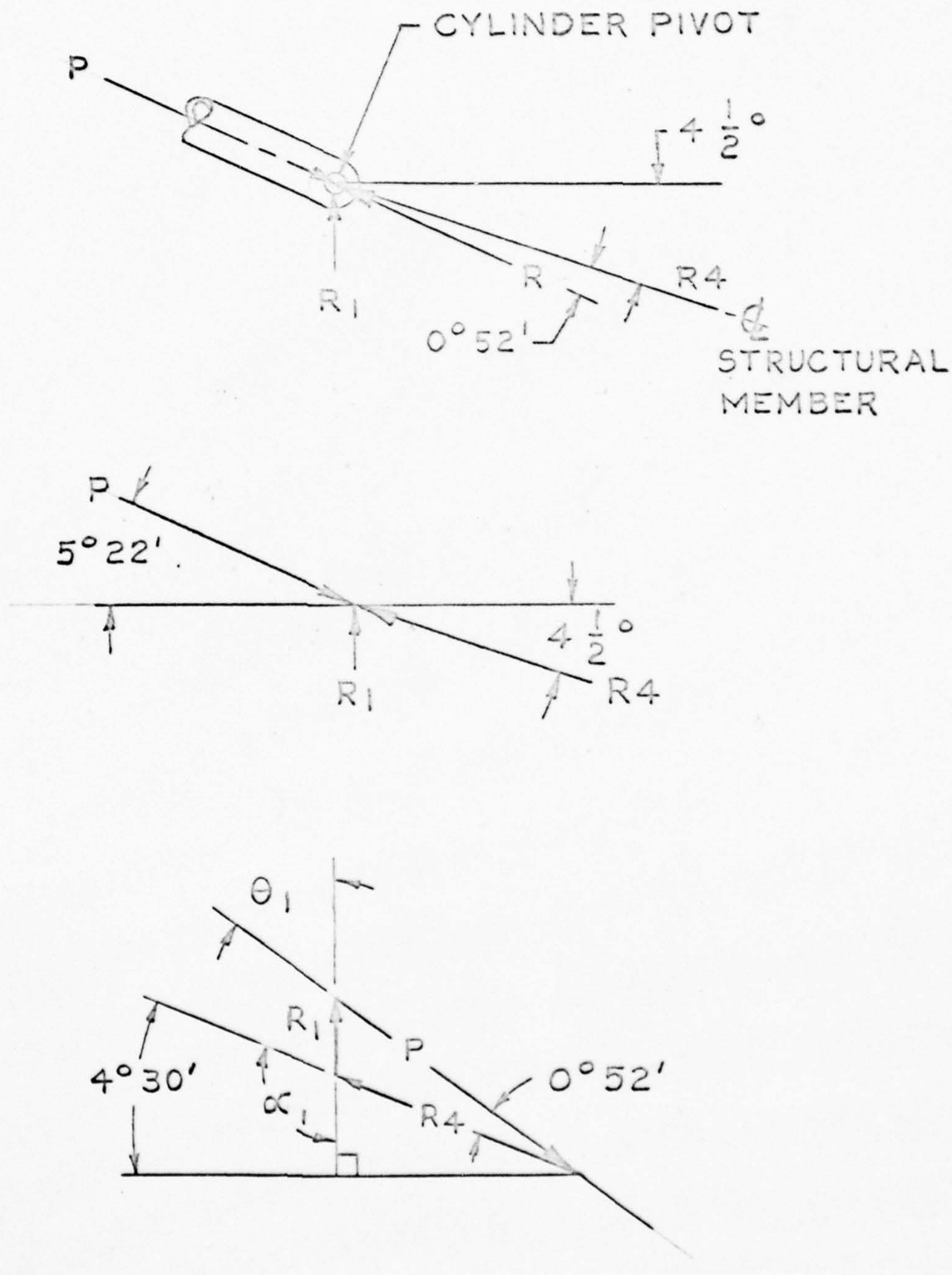
$\beta = 0^\circ \ 52' \ 15''$

$= 0^\circ \ 52'$

$R = R_o = P/\cos \beta$

$= 200{,}022$ lbs.

$= 200{,}000$ lbs.

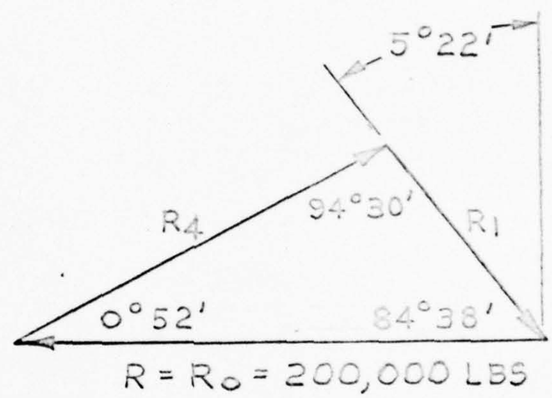


CYLINDER PIVOT
P
$4\frac{1}{2}°$
R_1
R
R4
0°52'
STRUCTURAL MEMBER
P
5°22'
$4\frac{1}{2}°$
R_1
R4
θ_1
R_1
P
4°30'
α_1
R4
0°52'

$$\Theta_1 = 180^\circ - (90^\circ + 4^\circ\ 30' + 0^\circ\ 52')$$
$$= 84^\circ\ 38'$$
$$\alpha_1 = 180^\circ - (84^\circ\ 38' + 0^\circ\ 52')$$
$$= 94^\circ\ 30'$$

CHECK:

$$\alpha_1 = 90^\circ + 4^\circ\ 30'$$
$$= 94^\circ\ 30'$$



$$\frac{R_1}{\text{Sin } 0^\circ\ 52'} = \frac{200,000}{\text{Sin } 94^\circ\ 30'}$$

$R_1 = 3035\#$

$$\frac{R_4}{\text{Sin } 84^\circ\ 38'} = \frac{200,000}{\text{Sin } 94^\circ\ 30}$$

R_4 = 199,739 lbs.

CHECK:

$200,000 = (R_4 \text{ Cos } 0^{o}\ 52') + (R_1 \text{ Sin } 5^{o}\ 22')$

$= 200,000 - (199,\ 716 + 284)$

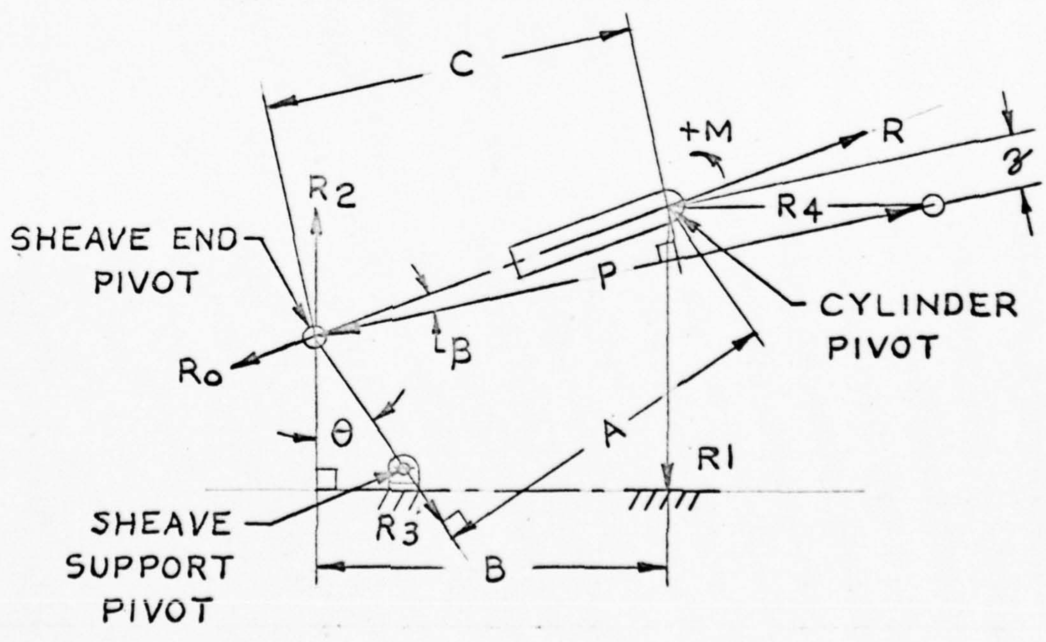
therefore:

R_1 = 3035 lbs.

R_4 = 199,739 lbs.

<u>Condition III</u>

When cable Tensioning cylinder is extended to sheave maximum extend position, compressive force P is below cylinder pivot.



where $P = 200,000$ lbs.

$A = 16' \ 11'' = 202''$

$B = 20' \ 9'' = 249''$

$C = 20' \ 9'' = 249''$

$z = 5''$

$\theta = 34^\circ$

$+M = Pz$

$= 1,000,000$ in lb.

$R_2 = M/A$

$= 4,950$ lbs.

$\text{Tan } \beta = z/c$

$= .02008$

$\text{Cos } \beta = .99980$

$\text{Sin } \beta = .02008$

$\beta = 1^\circ \ 9'$

$R = R_o = P/\text{Cos } \beta$

$= 200,000$ lbs.

Since Condition III R_1 and $R = R_o$ are small and approximately the same as condition II, no further analysis at this time need be considered.

4.2.1.3 PRESSURE REQUIRED ON CABLE TENSIONING CYLINDERS TO MAINTAIN 100,000 LBS. CABLE TENSION

Since load (P) on hydraulic cylinders is = 200,000 lbs. and 2 cylinders are used, the force on each cylinder then becomes 100,000 lbs.

The configuration of the Tension cylinders are:

Rod Dia = 5 inches

Bore = 9 inches

Rod Area = 19.6 sq. inches

Bore Area = 63.6 sq. inches

Hydraulic pressure required, at cylinder head end, to maintain cable Tension 100,000 lbs. when replenishing pressure is equal to 175 psi becomes (Rod end area =63.6-19.6=44 Sq. in.)

$$63.6\ p = (175 \times 44) + 100,000$$

$$p = 1694 \text{ psi at } 100\% \text{ efficiency}$$

The hydraulic system and components are rated for 2,500 psi to 3,000 psi working pressure. Assume a working pressure of 2,250 psi, the system efficiency then must be equal to or better than

$$\frac{1694}{2250} = 75\%$$

which appears to be more than sufficient. Therefore the USN/ASL furnished AN/SQA-8 hydraulic cylinder used for cable Tensioning will be used.

4.2.1.4 RECIPROCATING MOTION 5 TO 20 FEET

In order to provide a smooth reciprocating motion, it becomes necessary to start, stop and/or change the direction of reciprocation when the pump is on zero or minimum flow.

It therefore becomes essential that three cams and switches be used to sense the expended direction and stroke. The cams then must also be integral and geared with the drum rotation.

Since one revolution of the drum is equal to 18.32 feet (refer to para 4.2.1.5) a travel of 20 feet will require

$$\frac{20}{18.32}\ (360^{\circ})$$

$$\text{or}\quad 393^{\circ}$$

therefore a gear reduction between the drum output shaft and the cam switch assembly will be required. Assume a 2:1 reduction, the cam travel then becomes

$$\frac{393}{2} = 196.5^{\circ} \text{ for cable travel 20 feet}$$

and the timing will be from the pump neutral start to pump neutral stop. ∴ pump minimum stroke start and stop, which directly relates to the hydraulic flow change in direction controlling direction of cable motion.

Figure 6 depicts the cam sequence of operation. The assembly shown is with the cams and cable in the mid, on half (1/2),

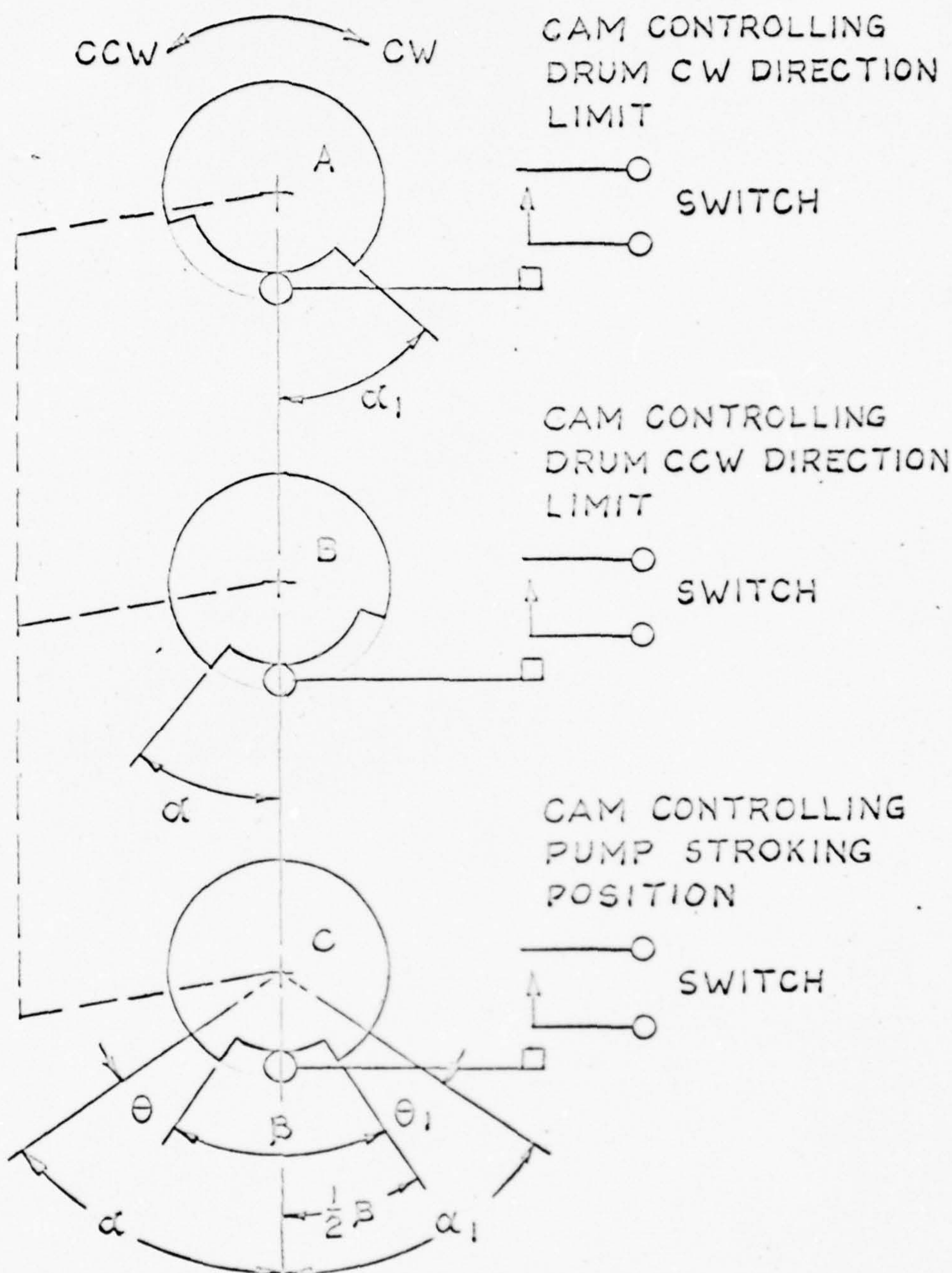


FIGURE 6 SCHEMATIC DIAGRAM
CABLE TRAVEL CAM OPERATION

travel position.

When the drum has rotated CW such that the angle of cam "C" is equal to 1/2 β, the pump will return from full stroke to minimum stroke during time angle θ_1,: Angle 1/2 β plus θ_1, (on can "C") is equal to α_1 of cam "A". When switch on cam "A" is emergized, it will pulse a electrically interlocked relay, energizing the solenoid of the hydraulic directional control valve to reverse the hydraulic flow to the CCW direction.

The pump will remain on minimum flow thru time angle θ, travel at maximum speed (60 FPM) thru angle β, return from full stroke thru time angle θ until angle α of Cam "B" energizes relay to reverse direction of flow and cable.

4.2.1.5 SPEED OF CABLE TRAVEL 60 FPM

The characteristics of the USN/ASL furnished AN/SQA-8 Drum are as follows:

a) The gear reduction consists of a primary planetary system of 50.1 and a secondary gear reducer system of 9.2.1 therefore the total reduction is equal to 9.2 x 50 or 460:1.

b) The basic drum consisted of 27.7 lays of cable which is equal to 490 feet of cable, therefore the length of cable per lay on the drum is equal to 490/27.7 or 17.69 ft. per lay and the drum RPM for cable speed 60 FPM is 60/17.69 or 3.39 RPM.

c) The required hydraulic motor input therefore becomes 460 x 3.39 or 1560 RPM.

d) Since the displacement of the hydraulic motor is 5.98 cu in per rev, the displacement required for 60 FPM then is 1560 x 5.98/231 or 40.38 GPM

Since the basic AN/SQA-8 equipment is to be used, it must be modified as follows:

a) Gear reduction, no change, total reduction 460:1

b) For structural requirements the drum surface diameter will be increased to 67.71 inches and a test drive cable 2.25 inches in diameter will be used. The cable length per lay then becomes 69.96 π/12 or 18.32 feet and the RPM of the drum for 60 FPM is then equal to 60/18.32 or 3.275 RPM.

c) The modified hydraulic motor input then becomes 460 x 3.275 or 1507 RPM.

d) Displacement of hydraulic oil is then 1507 x 5.98/231 or 39 GPM.

4.3 DRUM ASSEMBLY AND DRIVE

(Refer to figures 7 and 8)

The original AN/SQA-8 drum was constructed of a welded corrosion resistant steel shell with internal longitudinal stiffeners and externally welded grooves. Because of the high stresses induced during cable tensioning of 100,000 lbs., modifications in the drum were necessitated.

To reduce bending moments, which causes the drum shell to deflect in a manner similar to a beam, the drum width was reduced by removing a portion of the drum center. In addition, a rolled one inch thick apron was welded integral with the drum outer shell to assure that it would not collapse when subjected to continuous radial pressure due to cable Tensions of 100,000 lbs. (refer to drawing 211J010).

To prevent lateral creep of the drive cable, two (2) lead lined cable clamp are provided 180 degrees apart and are welded to the reinforced drum shell. Each clamp assembly consists of a removeable upper clamp and a fixed base clamp. (refer to drawing 211D020).

All carbon steel weldments were magnetic particle (Magnaflux) inspected and all corrosion resistant steel weldments were fluorescent dye penetrant (Zyglo) inspected. All weldments have proven satisfactory.

The modified drum shell is supported at both ends by large ball type of bearings which carries the imposed radial and axial thrust loads into their respective stanchions. The stanchions. are cast aluminum and are assembled at each end of the drum shell.

The starboard stanchion houses the cable travel limit switches and cams. The port stanchion houses a compound gear assembly 9.2 to 1 reduction and supports an external planetary gear box assembly 50 to 1 reduction. The external gear box supports on its input shaft end an emergency drive system for use in the event of power failure, a torque limiter and the hydraulic drive motor.

Specifications of the drum and drive are as follows:

a) Distance between flanges 25-5/8 inches

b) Drum O.D. 67.71 inches

c) Torque limiter 50 foot lbs. maximum

d) Hydraulic motor

1600 RPM maximum

5.98 cu. in. Displacement/rev.

40 H.P.

953 in lb. Torque at 1000 psi

2500 psi maximum pressure

DRUM SHELL CALCULATIONS - ELASTIC STABILITY

Due to the radial pressure (S) induced by the cable tension 100,000 lbs., the drum shell will be subjected to failure by elastic instability (collapse). The critical compressive stress (Sc) is determined by the following equation: (Hoisting Drum Design, Machine Design, April 1953).

$$Sc = \frac{2.6E\sqrt{\left(\frac{t}{D}\right)^5}}{\left(\frac{L}{D}\right) - .45\sqrt{\left(\frac{t}{D}\right)}}$$

where: Sc = critical compressive stress (psi)

E = modulus of elasticity

t = thickness of shell (inches)

D = Drum Outside Diameter (inches)

L = Drum length (inches)

Sc = 45,000 psi

Radial pressure (S) is determined by the following equation:

$$S = \frac{2T}{Rd}$$

where: S = Radial pressure (psi)

T = Cable tension (lbs.)

R = Drum Radius (inches)

d = Cable Dia or pitch (inches)

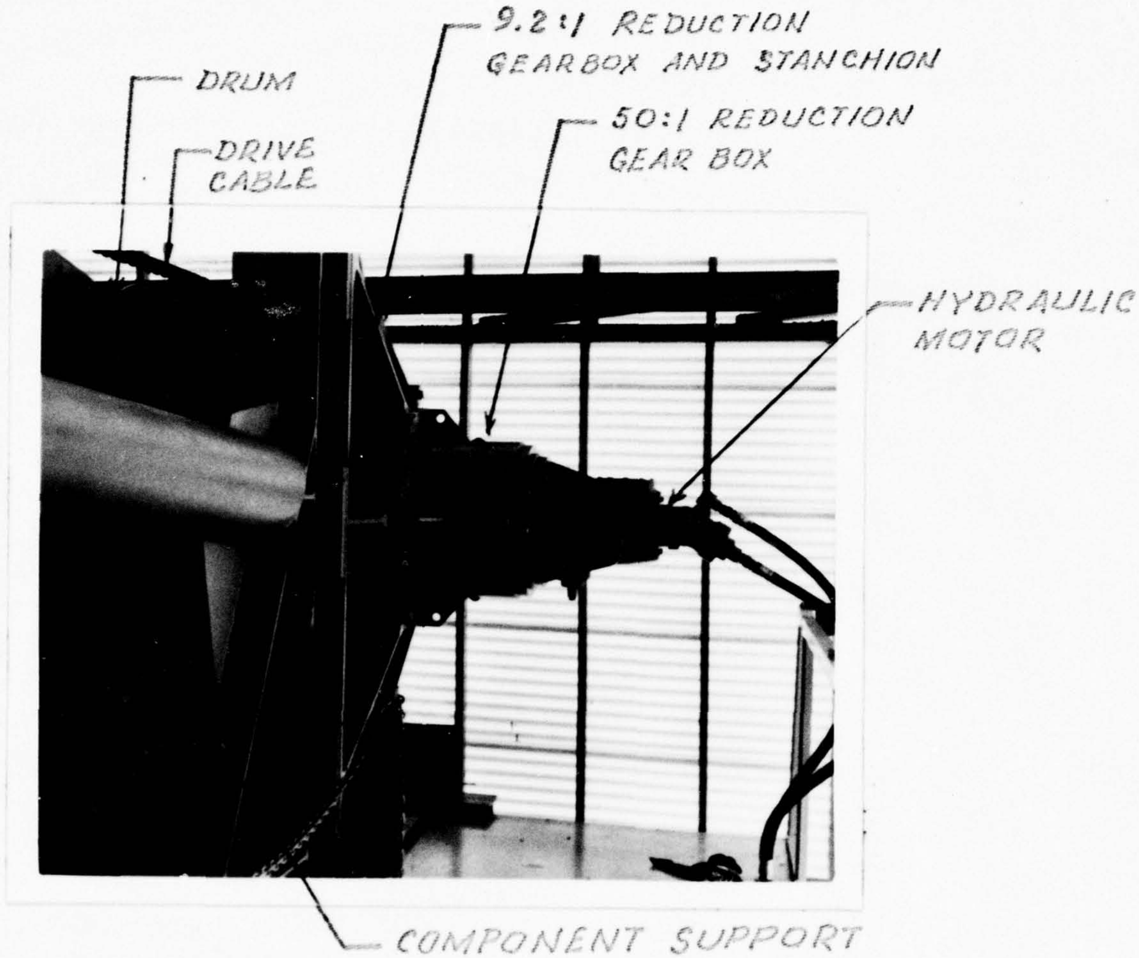


FIGURE 7 CABLE DRUM AND DRIVE ASSEMBLY

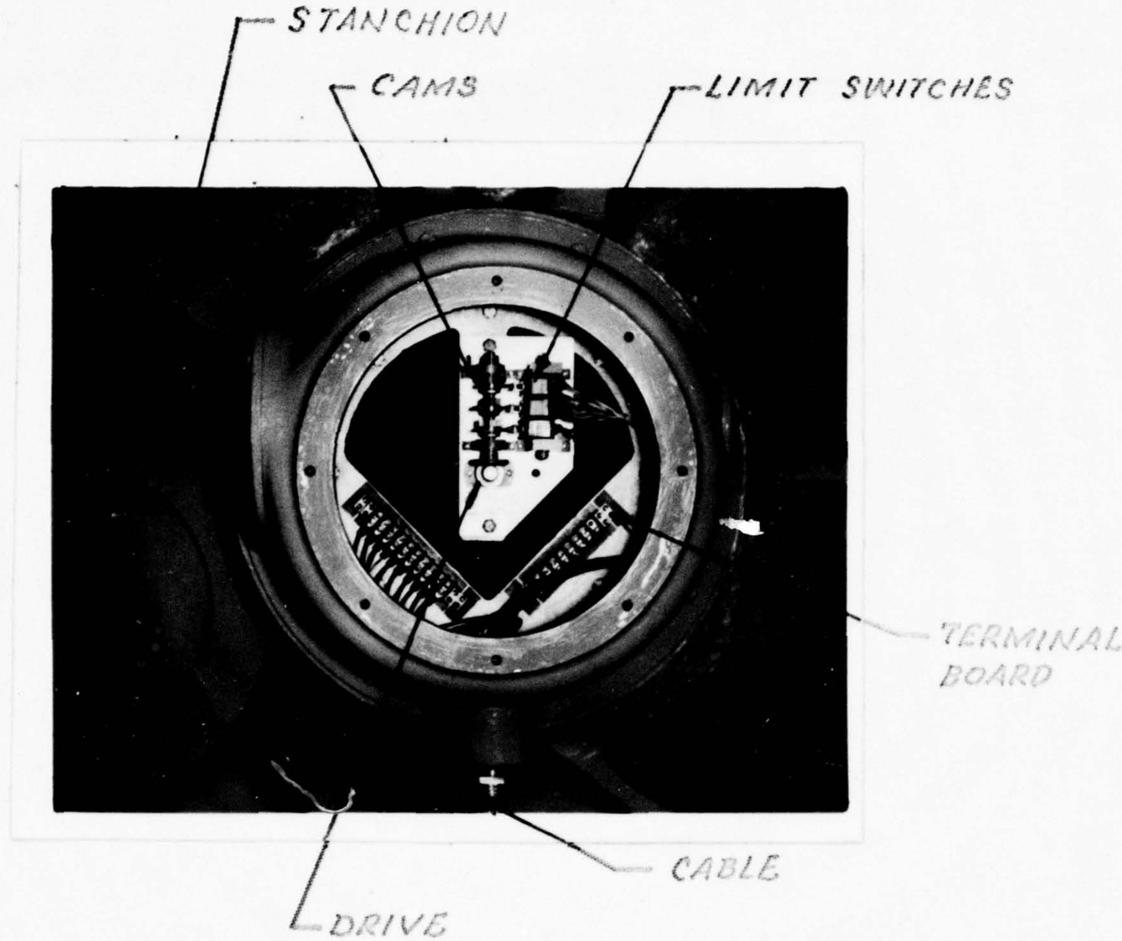


FIGURE 8 CABLE CYCLING LIMIT SWITCHES AND CAM ASSEMBLY

$S = 2620$ psi

$$M.S. = \frac{45{,}000}{2620} - 1$$

$$= 16+$$

The above calculations do not consider the longitudinal stiffeners, therefore the above (M.S.) is more than conservative.

4.4 HYDRAULIC CABLE TENSIONING CYLINDER

Tension loads are applied to the test cables by the application of hydraulic pressure to the head end of the cylinders. Applied loads are in direct proportion to the following equation at 100% efficiency.

$$\left[(P\,A) - (P_1 A_1)\right]$$

where P = Pressure at head end (psi)

P_1 = Pressure at Rod end (psi)

A = Area of piston, head end (inches)

A_1 = Area of piston, Rod end (inches)

The cable tension can be variable by adjusting the pressure (P) setting of hydraulic relief valves (B) and or (DD). Back pressure (P_1) can be varied by adjusting the valve (R) as shown on hydraulic schematic, drawing 211E002.

To accommodate any racking affect that may occur during operation, or may exist due to installation, the two (2) hydraulic cable tensioning cylinders are pinned at both ends to universal type fittings.

The specification for the hydraulic cable tensioning cylinders are as follows:

a) Bore=9 inches

b) Rod Dia=5 inches

c) maximum stroke=98 inches

d) maximum working pressure=3000 psi

e) nominal compressive load

$$\left[\pi\left(\frac{9}{2}\right)^2\right] 3000 = 189{,}000 \text{ lbs.}$$

The maximum load on the cylinder is 100,000 lbs., the allowable nominal working load is 189,000.

$$MS = \frac{189{,}000}{100{,}000} - 1 = 89\%$$

4.5 SHEAVE AND SHEAVE SUPPORT ASSEMBLIES

(Refer to figures 9 and 10.)

(Refer drawings 211J011 and 211E012.)

The sheave assembly consists of two basic sub assemblies;

a) Sheave Assembly

b) Hub Assembly

This approach, whereby one hub assembly may be used with various size sheaves, is advantageous from the economical viewpoint.

The Hub Assembly is an annular shaped weldment formed from hot rolled steel plate and mechanical tubing. A bronze bushing one inch thick by 24 inches long is press fitted into the center portion. Six machined pads are provided along the outer longitudinal surface of the weldment which mate with similar pads on the inner surface of the sheave weldment. The machined pads are provided with through holes allowing for bolting of the sheave to the hub.

The sheave weldment is formed by an outer and inner ring secured to each other by means of a stiffener. The machined pads are welded to the inner surface of the inner ring. A groove machined into the outer ring along the full circumference, provides good support for the wire rope and results in less abrasive wear on the rope. Two flanges which are flared outward, 5^{o}, are welded around the circumference providing lateral support for the cable. The groove is slightly oversized in order to avoid pinching or binding of the cable wire strands, and to permit the rope to adjust to the radius of curvature.

The specifications for the sheave provided, are as follows:

a) 50 inch pitch diameter

b) 1-9/16 inch groove diameter

c) Groove flange height of 4 inches

The Sheave Support Assembly is constructed in two parts; the lower portion is fixed to the deck and serves as the primary support, whereas, the upper portion containing the sheave shaft bearing is free to swivel about the vertical axis so as to accommodate any racking that may occur while maintaining cable tension. Therefore, in the event that racking does occur, tensional stresses in the sheave support are eliminated.

All welds have been magnetic particle inspected and have been found to be satisfactory.

Calculations

A) ELASTIC STABILITY OF SHEAVE STIFFENER

Assumptions:

a) Sheave stiffener is considered as being clamped at inner and outer diameters by the sheave hub and outer ring respectively.

b) Equation case number 20, of Formulas for Stress and Strain, Roark, 1st edition 5th impression, for a circular plate with a concentric hole under uniform radial compression on outer edge is assumed to be valid for the case on hand.

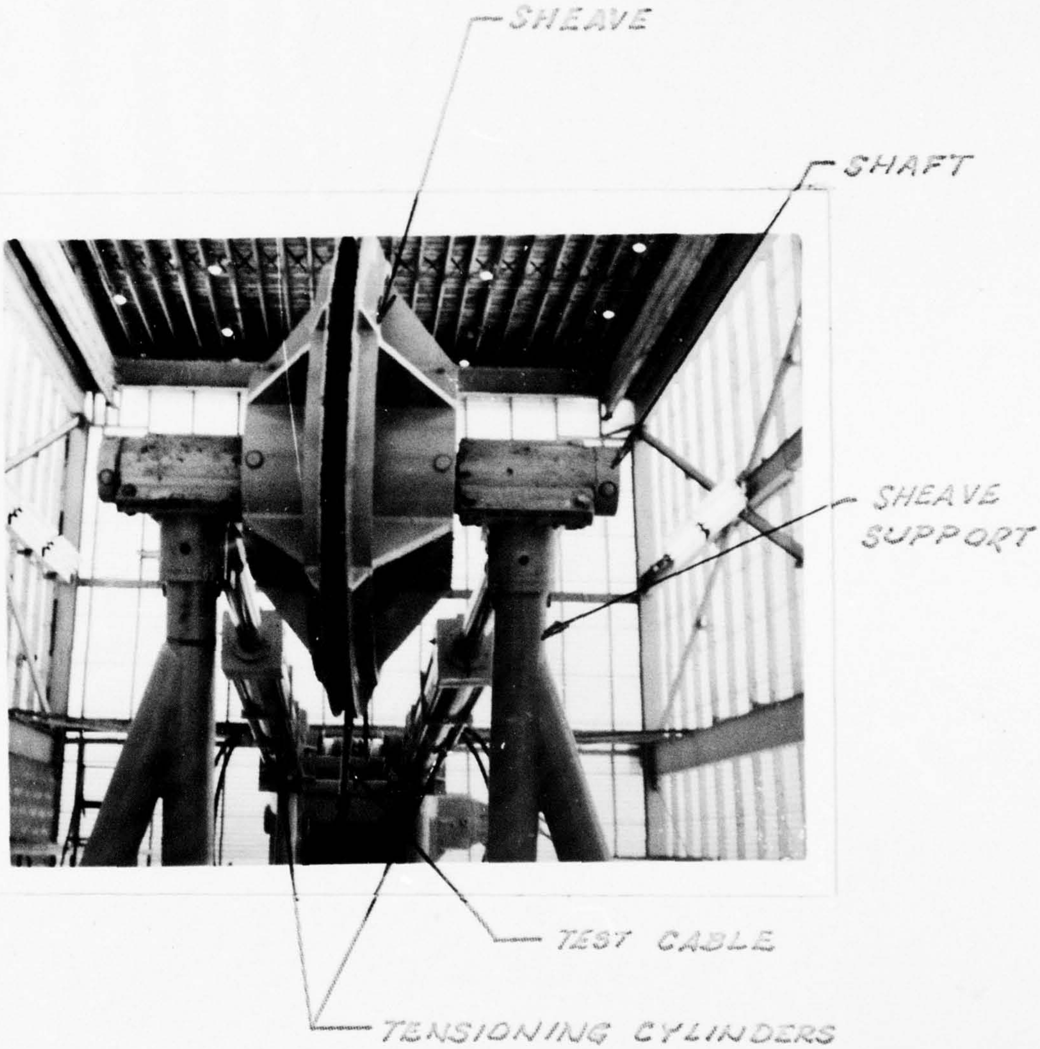


FIGURE 9 SHEAVE INSTALLATION

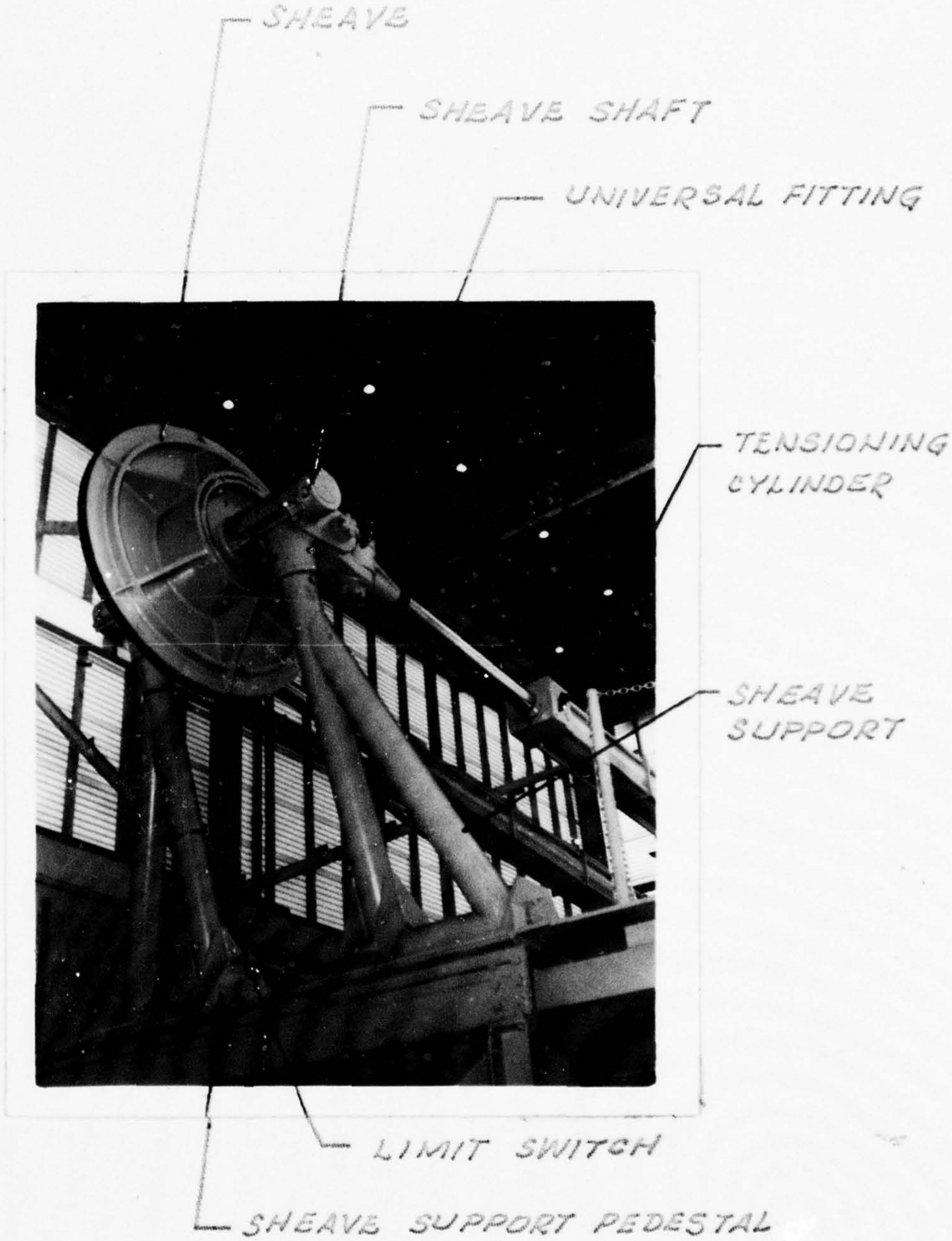
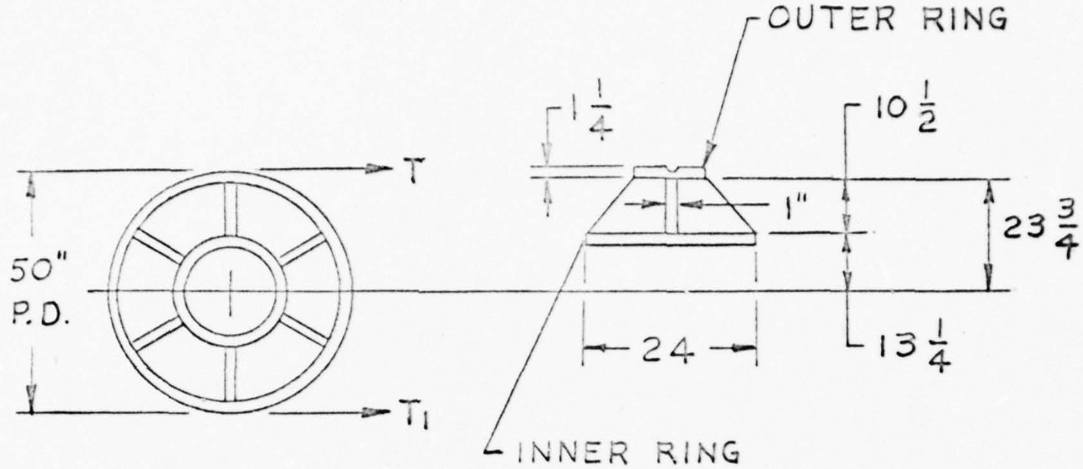


FIGURE 10 SHEAVE AND SHEAVE SUPPORT INSTALLATION



Cable Tension (T) and (T_1) will induce radial compressive stress in the sheave. This radial load may result in elastic buckling. The critical compressive stress (S') is determined by the following equation.

$$S' = K\left(\frac{E}{1-\nu^2}\right)\left(\frac{t}{a}\right)^2$$

$$= 134{,}350 \text{ psi}$$

where: S' = critical unit compressive stress (psi)

K = constant $\frac{a}{b}$

a = larger radii (23.75 inches)

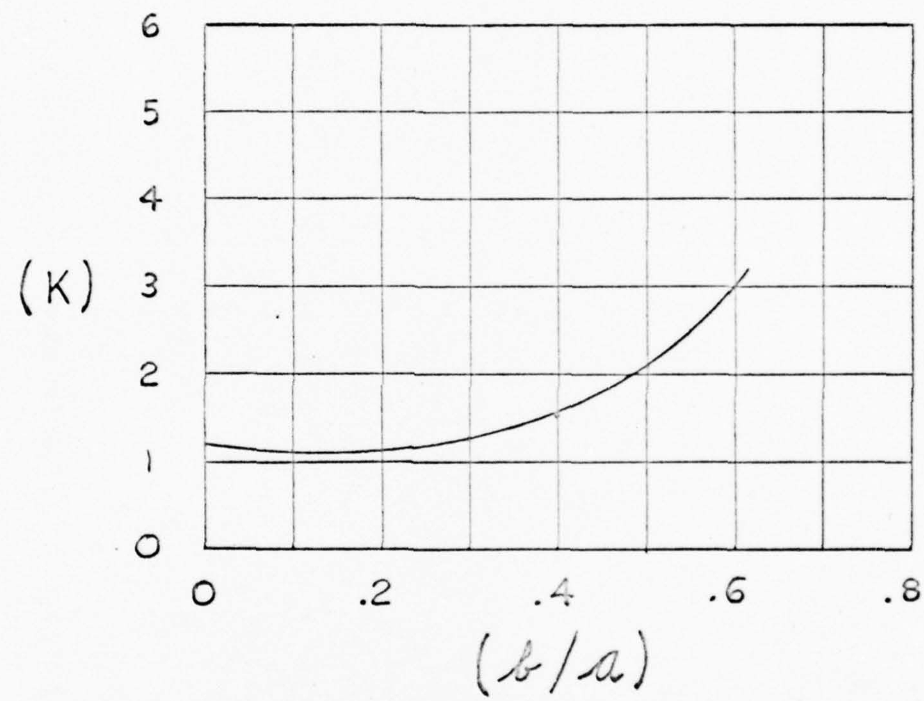
b = smaller radii (13.25 inches)

E = Modulus of Elasticity

ν = Poissons ratio

t = thickness

(K) depends upon (b/a) as is given approximately by the following graph.



The radial pressure on the sheave is directly proportional to the cable tension and inversely proportional to the diameter of cable and the pitch diameter of the sheave. This is expressed as:

$$S = \frac{2T}{Rd}$$

$$= 6160 \text{ psi}$$

where: S = Radial pressure (psi)

T = Cable Tension (lbs.)

R = Sheave Radius (inches)

d = cable diameter (inches)

where AN/SQA-10 cable

d = 1.3 inches

$$MS = \frac{134,350}{6160} - 1$$

$$= 21$$

B) BEARING LOAD ON SHEAVE CABLE GROOVE

The radial bearing stress induced by cable tension as previously calculated is 6160 psi. The allowable bearing, or compressive, stress for material used is 1.6 F_{cy} or 52,800 psi, therefore the Margin of Safety is:

$$MS = \frac{52,800}{6160} - 1$$

$$= 7.5$$

C) STRESS ON BRONZE SHEAVE BEARINGS

Stress on the sleeve type bronze bearings is determined by

$$S = \frac{2T}{A}$$

$$= \frac{P}{A}$$

where S = bearing stress

T = cable tension

P = Compressive load due to cable tension

A = projected Area

The sheave shaft is 6 inches diameter and the bearing length is 24 inches, therefore the projected bearing area is 144 Square inches.

S = therefore is 1390 psi

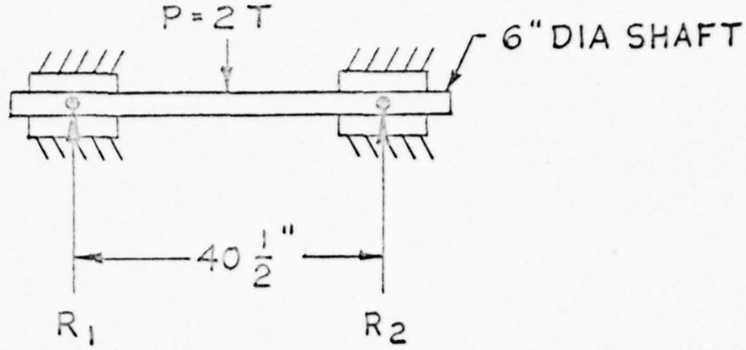
The allowable compressive stress, (psi) to produce compression of .001 inches is then equal to 15,000 psi,

$$MS = \frac{15,000}{1390} - 1$$

$$= 9.8$$

D) SHEAVE SHAFT DEFLECTION AND SHEAVE STRESS

Assuming that the shaft is simply supported with a concentrated load at center.



$$\delta \max = \frac{2TL^3}{48EI}$$

$$= .1445 \text{ inches}$$

where: δ max = maximum deflection (inches)

T = Cable Tension (lbs)

L = Length of shaft between supports (inches)

E = modulus of Elasticity

I = moment of inertia

$$\frac{\pi d^4}{64} = 64$$

Since the sheave inner hub and bronze bearing have not been considered and the assumption was that the load is concentrated at the center of a simply supported beam, the above deflection is very conservative.

Sheave stress $S_s = \frac{2T}{2A}$

$$= 3,520 \text{ psi}$$

$$MS = \frac{35000}{3520} - 1$$

$$= \text{approx } 9$$

4.6 HYDRAULIC POWER UNIT

The hydraulic power unit contains all of the hydraulic valves, solenoids, pump, motors and safety devices to provide hydraulic power to the drum and cable tensioning cylinders. It houses a self contained 150 gallon reservoir for the hydraulic system. The hydraulic power unit consists of the following major components:

Refer to figure 11 and drawings 211E002 and 102R501).

a) 150 gallon oil reservoir

b) Tension cylinder manifold

c) Drum drive monifold

d) Auxiliary device manifold

e) 10 H.P. motor and pump for control and replenishing pressure

f) Junction Box for electrical interconnection

g) 40 H.P. motor and pump for drum drive and tension cylinder pressure

h) Pump stroking control

i) Hydraulic piping

j) Electrical circuitry

The two variable displacement pumps are driven by the 40 H.P. electric motor. These pumps supply hydraulic fluid to the drum drive and cable tensioning cylinders. Pump delivery can be varied from zero flow to maximum flow by stroking the control stem of either pump, changing the internal pump piston displacement.

The stroking of the pumps are remotely controlled from the Control Station and form part of the automatic control system governing the cable tension and cycling.

The specifications of components of the hydraulic power unit are as follows:

a) 40 H.P. Pumps

 9.48 cu. in/rev. displacement

 1150 RPM

 3000 psi maximum

 41 GPM at 1500 psi

b) 40 H.P. Electric Motor

 Squirrel cage, induction

 1150 RPM

 220/440 V AC 3Ø 60~

c) 10 H.P. Electric Motor

 Squirrel cage, induction

1150 RPM

220/440 V AC 3Ø 60~

d) 10 H.P. Replenishing and Control Pressure Pump

Double tandem design fixed displacement

Vane type

1000 psi maximum pressure

20 GPM at 1000 psi

4.7 MOTOR CONTROLLERS
(refer to figures 4 and 11)

Two Magnetic Controllers are used; the size 2 motor controller is used for starting, stopping and protection of the 10 HP electric motor, and the size 4 motor controller is used for the starting, stopping, and protection of the 40 HP electric motor.

The Size 2 (15/25hp) motor controller is an AC magnetic across the line starting device used for energizing and deenergizing the 10 HP electric motor on the Hydraulic Power Unit. This controller is activated by means of a pushbutton switch on the Control Station. The Size 2 motor controller is designed for three phase, 60 cycle, 220 or 440 volts AC operation.

The Size 4 (50/100hp) motor controller is an AC magnetic across the line starter used to energize and de-energize the 40 HP electric motor on the Hydraulic Power Unit. This con-

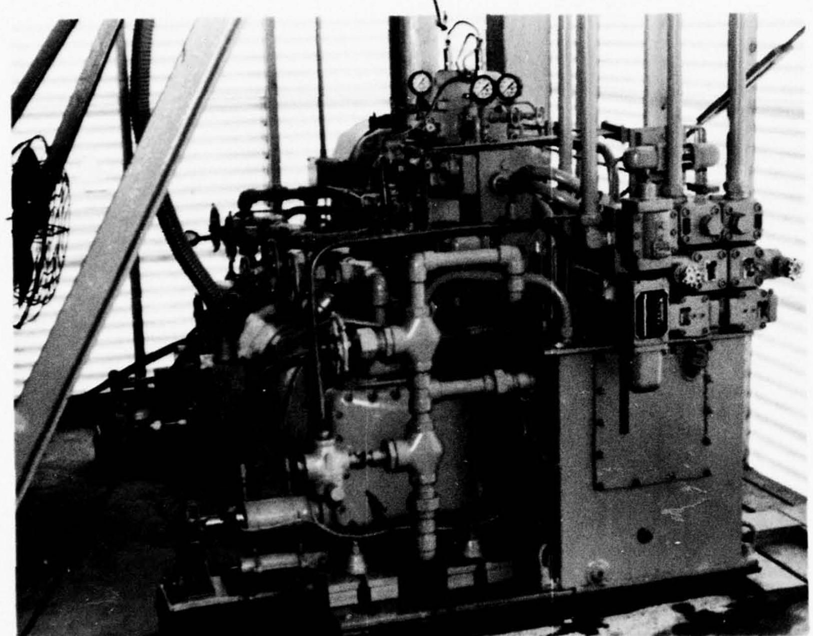


FIGURE 11 HYDRAULIC POWER UNIT ASSEMBLY

troller is activated by means of a pushbutton switch located on the Control Station. The Size 4 motor controller is designed for three phase, 60 cycle, 220 or 440 volts AC operation.

The Motor Controllers consist of a welded steel drip-proof housing which encloses contactors, overload relays and reset buttons. The magnetic contactors are electrically and mechanically interlocked to prevent accidental closing of the contactors under conditions of shock, vibration or tilt.

The overload relays used in the motor controllers are inherently compensated so that the tripping and resetting times are not affected by variations in the ambient temperature. The motor controller relays are remotely operated from the Control Station by 110 volt AC single phase 60 cycle power. When the contactors are energized they apply 220 volts AC three phase 60 cycle power to the 10 HP and 40 HP electric motors on the Hydraulic Power Unit.

An interlock device is provided in the Size 4 motor controller to prevent accidental starting of the 40 HP electric motor prior to the starting of the 10 HP electric motor. Further, this interlock circuit insures that the 40 HP electric motor is stopped before stopping the 10 HP electric motor thus assuring air free hydraulics and adequate hydraulic pressure.

The controllers provide low voltage protection to the motors. The motor is started by momentarily depressing the START button. This causes the line contactor to close, maintaining itself closed through its interlock device, and connecting the motor directly across the line. The motor is stopped manually by momentarily depressing the STOP button. This action causes the line contactor to open and disconnects the motor from the line.

4.8 CONTROL STATION

(Refer to figures 13 and 14)

The AN/SQA-8 control station has been modified and provided so as to START, STOP and OPERATE the TOWLINE FLEXING FACILITY in either the MANUAL MODE or AUTOMATIC MODE operation. Within the control station itself, the necessary automation relays and devices are assembled.

The console provides for the following:

(refer to figure 14)

a) Accurate hydraulic pressure gage which is maintaining cable tension

b) Hand control lever to manually operate the Cable Tension and flow of oil to the head end of the Tension Cylinders

c) Hand control lever to oscillate the drum and test

FIGURE 12 MOTOR CONTROLLER & JUNCTION BOX INSTALLATION

cable

d) OFF-ON-OFF Master power switch

e) Mode Selector Switch.

AUTOMATIC-OFF-MANUAL operation

f) Sequence Switch - AUTOMATIC-OFF

g) 40 and 10 H.P. START-STOP-EMERGENCY RUN switches

h) 40 and 10 H.P. START BY-PASS switches

i) MAINTAIN CABLE TENSION (H_1) solenoid ON-OFF switch

j) WARNING BUZZER indicating that cable tension is not being maintained

k) Pressure gages:

   1) Replenishing pressure

   2) Control pressure

   3) Cable Pay Out pressure

   4) Cable Haul In pressure

   5) Tension Cylinder extend pressure

   6) Tension Cylinder retract pressure

l) 115V AC 1Ø 60~ power fuses

m) Indicator lights

   1) DRUM PAY OUT direction

2) DRUM HAUL IN direction

3) POWER ON

4) TENSION CYLINDER EXTENDING

5) TENSION CYLINDER MAINTAINING CABLE TENSION

6) LOW OR LOSS OF HYDRAULIC PRESSURE

n) Cycle Indicator

o) Power fuses

p) Temperature

q) Cable tension Strain Guage indicator

r) 12 channel electrical conductor event recorder

s) Buzzer silencing switch

4.9 JUNCTION BOX ASSEMBLY
(Refer to figure 12)

The AN/SQA-8 Junction Box provided by the U.S. Naval Applied Science Laboratory was used as is without modification.

4.10 CONTROL MECHANISM

4.10.1 TOWLINE CYCLING CONTROL

(refer to figure 6, 8, 15 and drawings 211E002 and 211J003)

The drum is cycled by means of the hydraulic power. A means for automatic reversing of the drum and towline has been incorporated into the design. Fundamentally, the reversing or

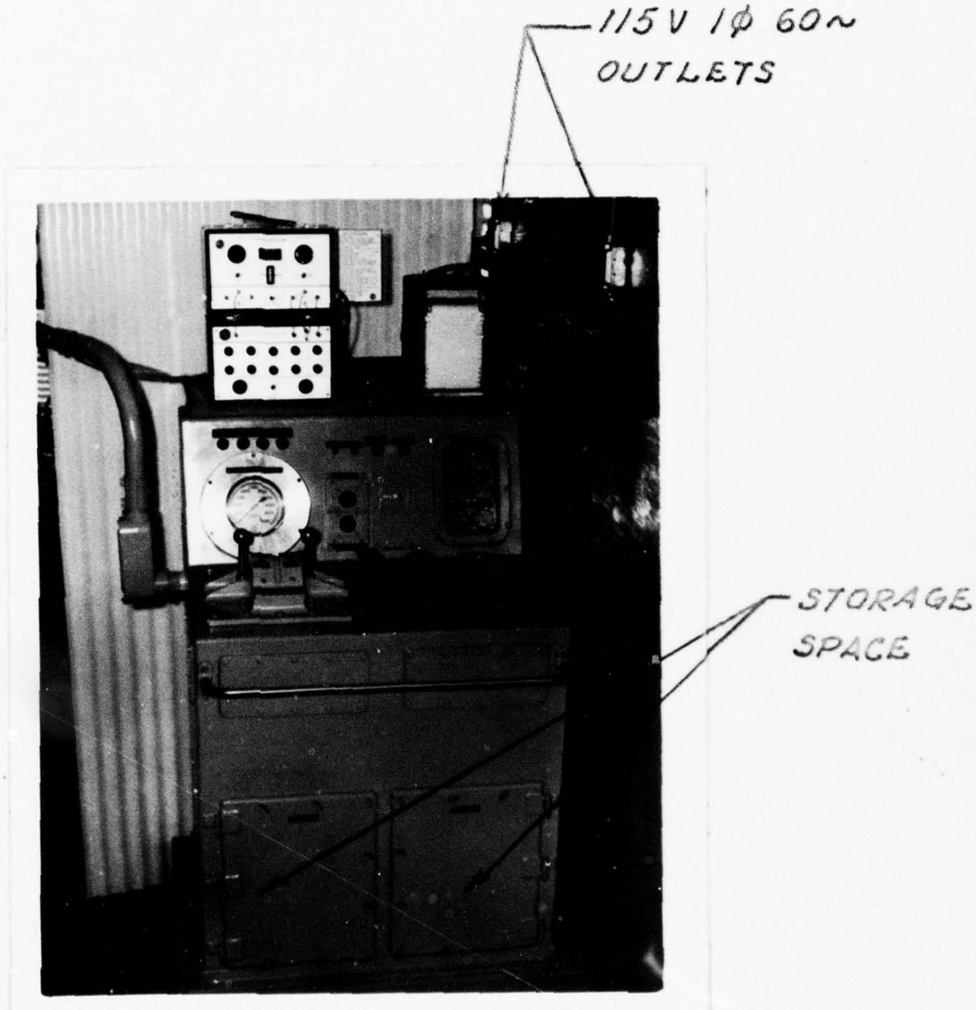


FIGURE 13 CONTROL STATION INSTALLATION

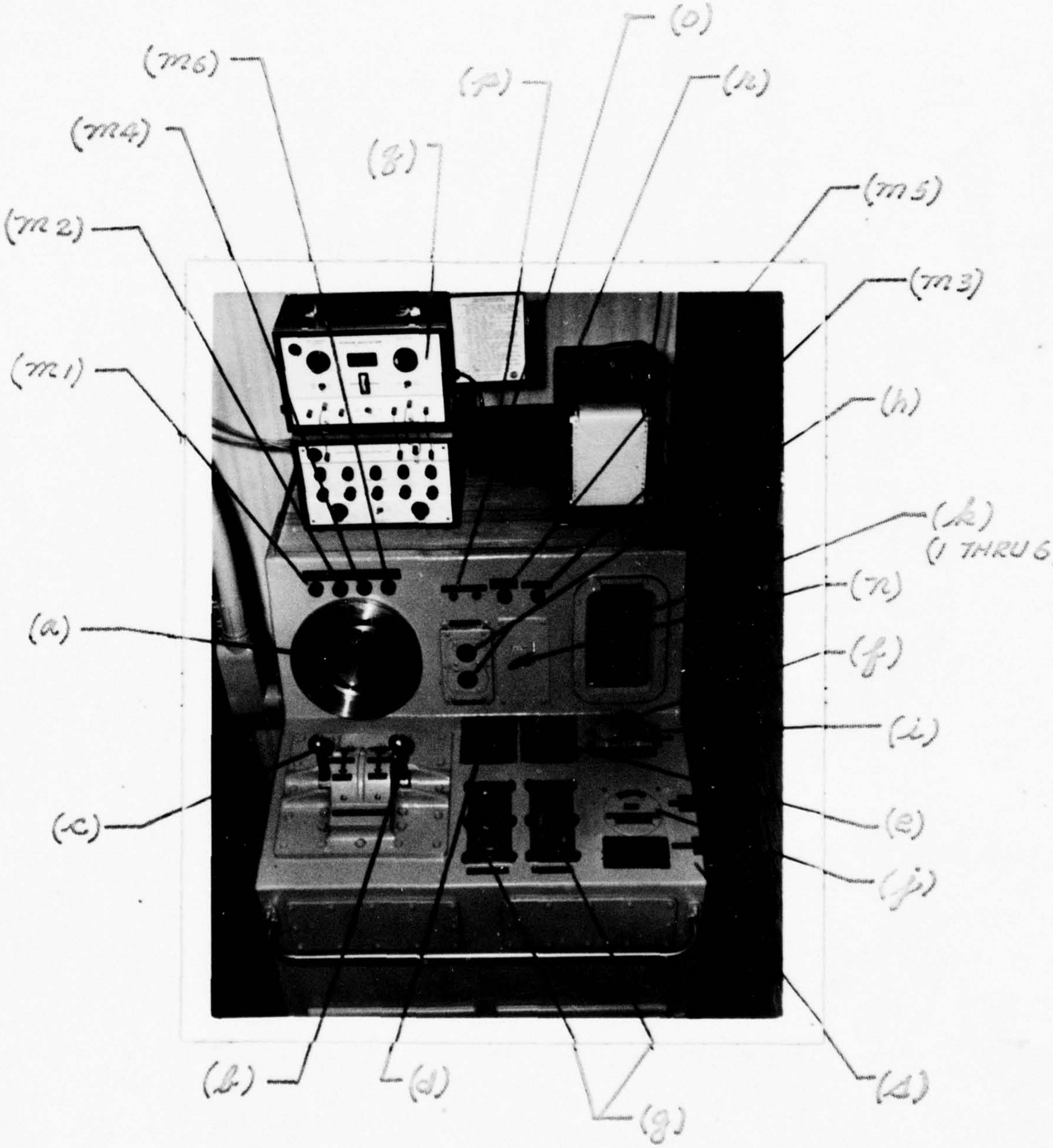


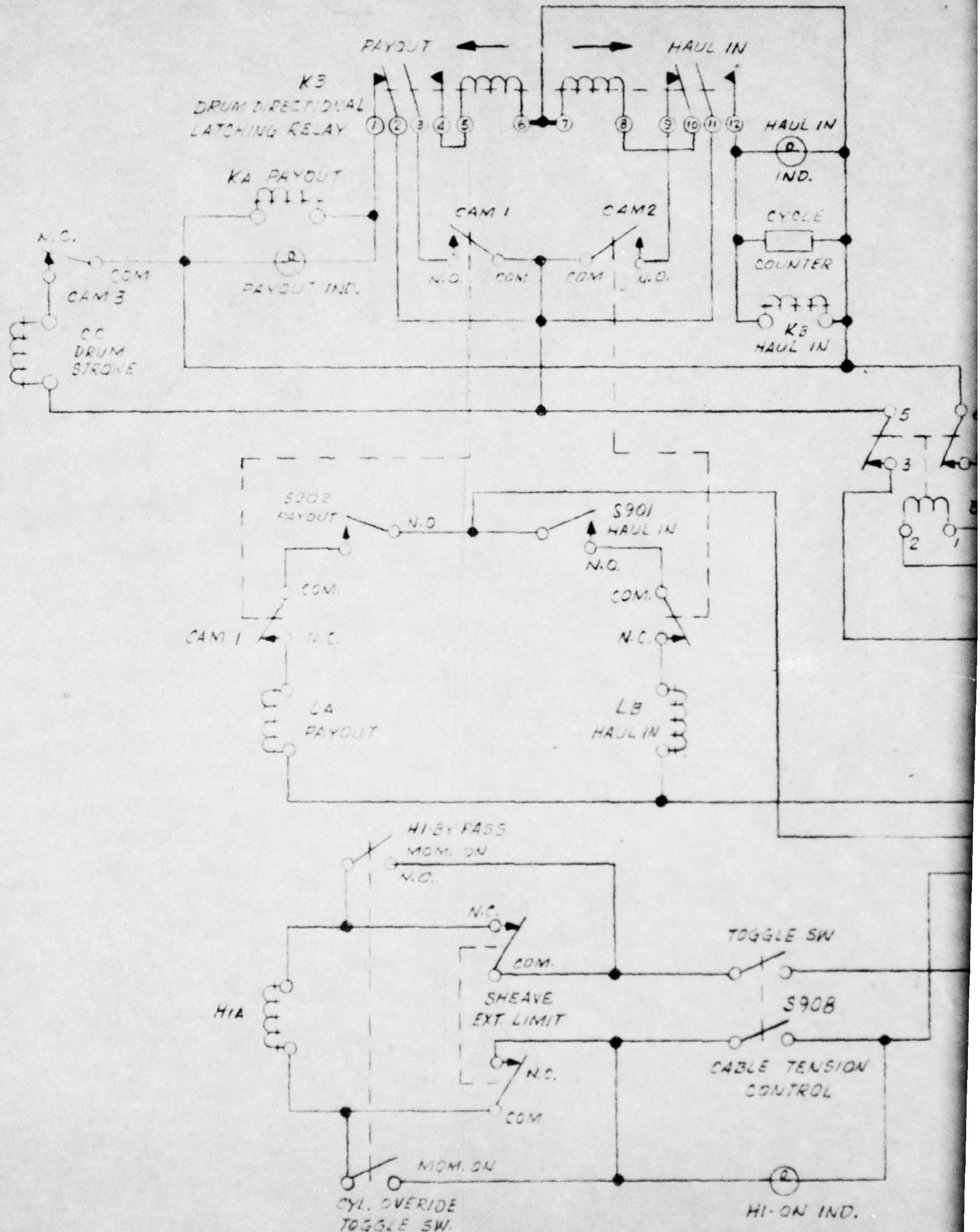
FIGURE 14 CONTROL STATION ASSEMBLY

cycling system consists of cam operated limit switches, refer to figure 6 and paragraph 4.2.1.4.

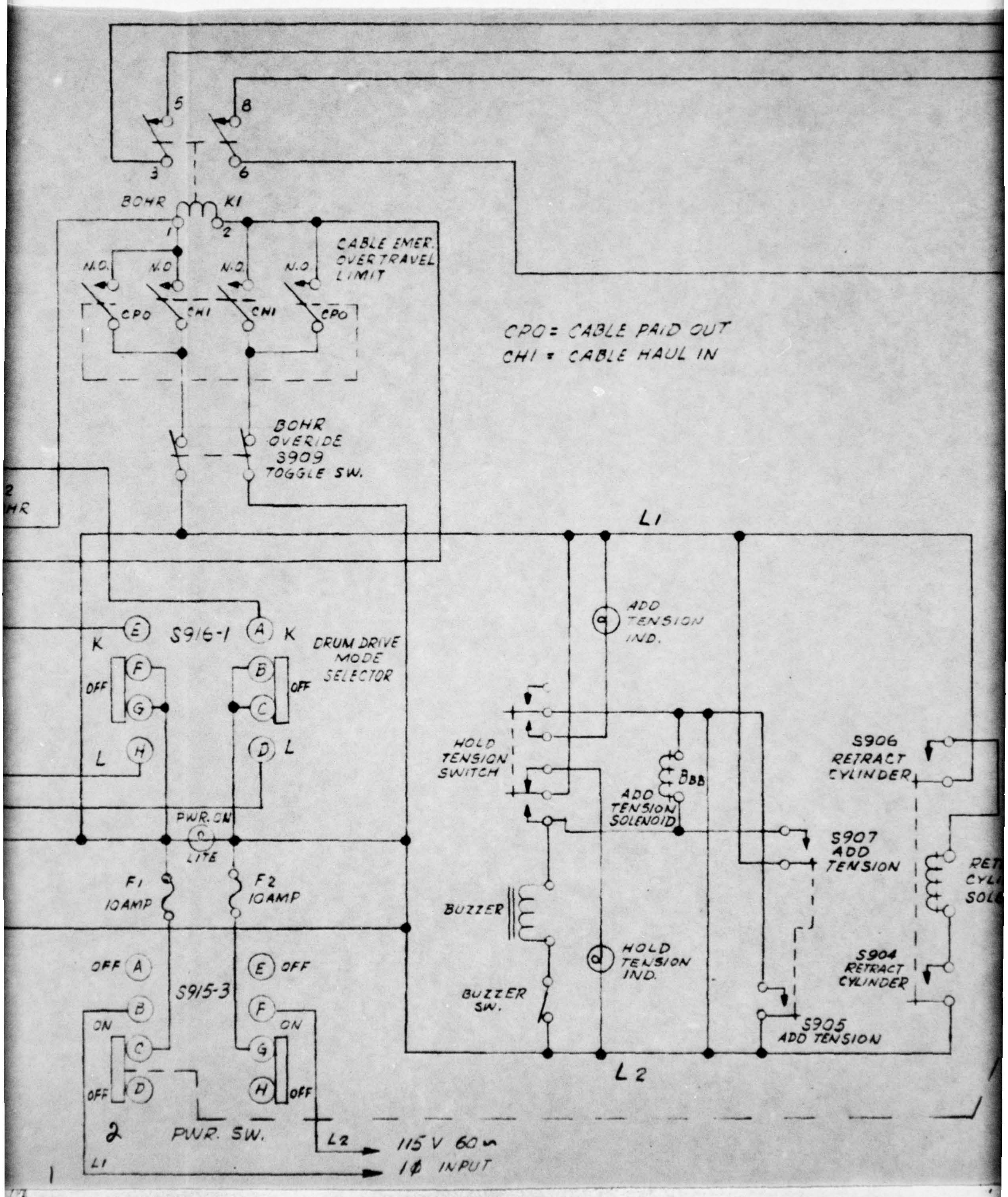
When the drum is rotating, and the towline speed is 60 FPM, any attempt to stop the towline or reverse the direction of rotation of the massive drum and drive cable, with its inherent high inertia, will impose a severe mechanical shock to the system. A simple means for eliminating this mechanical shock is provided. The control consists of a cam/switch energizing directional control valve CC, returning the pump to zero or minimum flow position. When the hydraulic flow is at a minimum, the second switch will energize the latching relay, energizing proper solenoid (A) or (B) of directional control Valve (K) thereby reversing the flow and direction of rotation without shock.

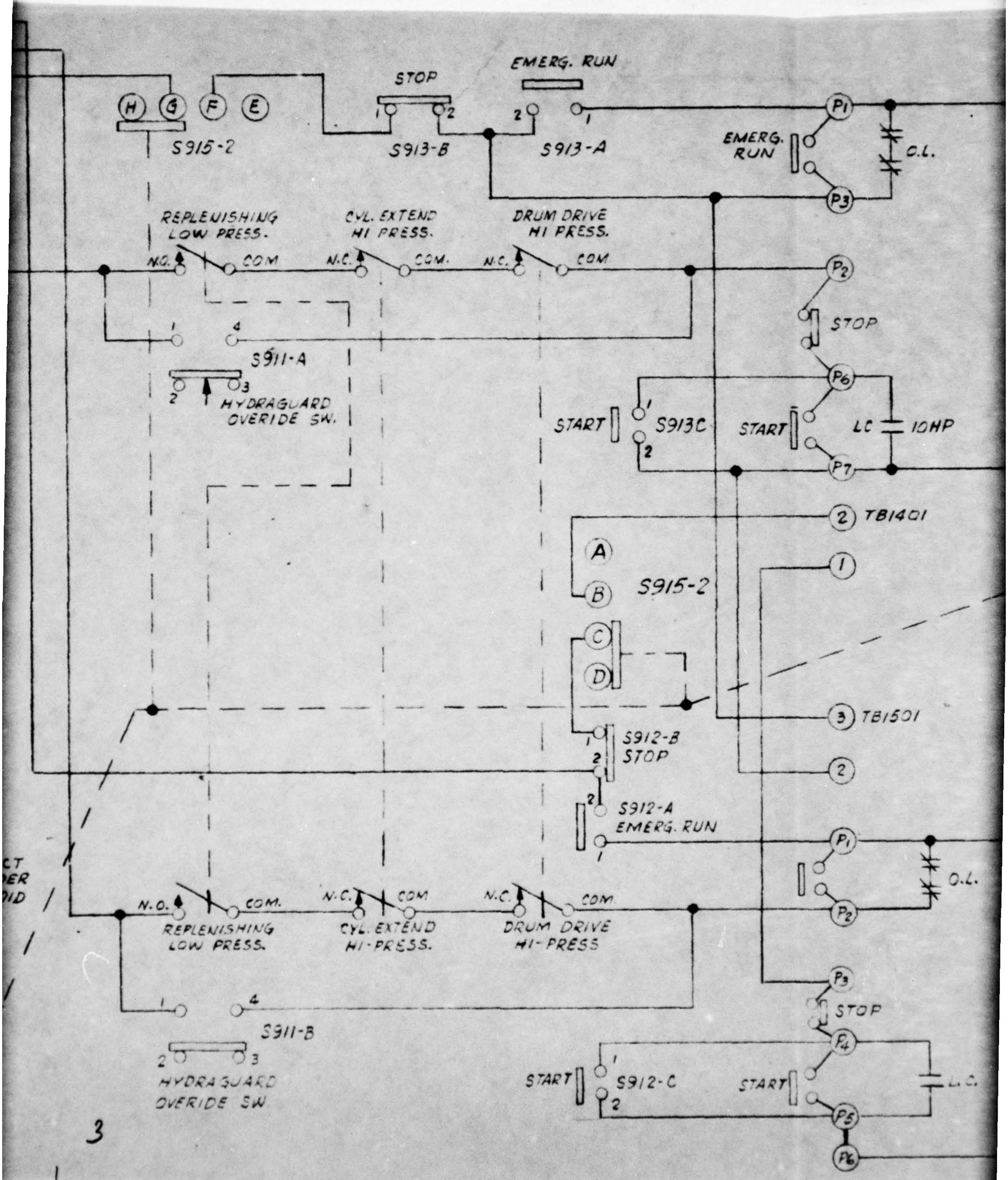
4.10.2 TOWLINE TENSION CONTROL

Towline tension is obtained by the application and maintaining hydraulic pressure on the head end of the Tensioning cylinders. Because of the static nature of the load, it would appear that once the cylinders were extended, further flow requirements would not be required. In actuality, due to attendent leakage under high system operating pressures, a small flow will be required to compensate for this leakage, thus maintain cable tension.



PAYOUT
HAUL IN
K3
DRUM DIRECTIONAL
LATCHING RELAY
HAUL IN
IND.
KA PAYOUT
CAM 1
CAM 2
CYCLE
COUNTER
N.C.
COM
CAM 3
PAYOUT IND.
N.O.
COM
COM
N.O.
K3
HAUL IN
D.C.
DRUM
STROKE
S902
PAYOUT
N.O
S901
HAUL IN
N.O.
COM.
COM.
CAM 1
N.C.
N.C.
LA
PAYOUT
LB
HAUL IN
HI-BY PASS
MOM. ON
N.O.
N.C.
COM.
TOGGLE SW
HIA
SHEAVE
EXT. LIMIT
S908
N.C.
CABLE TENSION
CONTROL
COM.
MOM. ON
CYL. OVERIDE
TOGGLE SW.
HI-ON IND.


5
8
3
6
BOHR
K1
1
2
CABLE EMER.
OVERTRAVEL
LIMIT
N.O
CPO
CHI
CPO = CABLE PAID OUT
CHI = CABLE HAUL IN
BOHR
OVERIDE
S909
TOGGLE SW.
L1
K
S916-1
E
A
F
B
G
C
H
D
OFF
L
DRUM DRIVE
MODE
SELECTOR
ADD
TENSION
IND.
HOLD
TENSION
SWITCH
BBB
ADD
TENSION
SOLENOID
S906
RETRACT
CYLINDER
PWR. ON
LITE
S907
ADD
TENSION
F1
10 AMP
F2
10 AMP
BUZZER
HOLD
TENSION
IND.
S904
RETRACT
CYLINDER
S915-3
ON
BUZZER
SW.
S905
ADD TENSION
L2
2
PWR. SW.
115 V 60 ~
1Ø INPUT
L1


H
G
F
E
S915-2
STOP
S913-B
EMERG. RUN
S913-A
P1
EMERG. RUN
O.L.
P3
REPLENISHING LOW PRESS.
N.O.
COM
CYL. EXTEND HI PRESS.
N.C.
COM.
DRUM DRIVE HI PRESS.
N.C.
COM
P2
STOP
S911-A
HYDRAGUARD OVERIDE SW.
P6
START
S913C
START
LC
10HP
P7
2 TB1401
A
B
S915-2
C
D
1
3 TB1501
2
S912-B STOP
S912-A EMERG. RUN
P1
O.L.
P2
REPLENISHING LOW PRESS.
N.O.
COM.
CYL. EXTEND HI-PRESS.
N.C.
COM
DRUM DRIVE HI-PRESS
N.C.
COM.
S911-B
HYDRAGUARD OVERIDE SW.
P3
STOP
P4
START
S912-C
START
L.C.
P5
P6

3

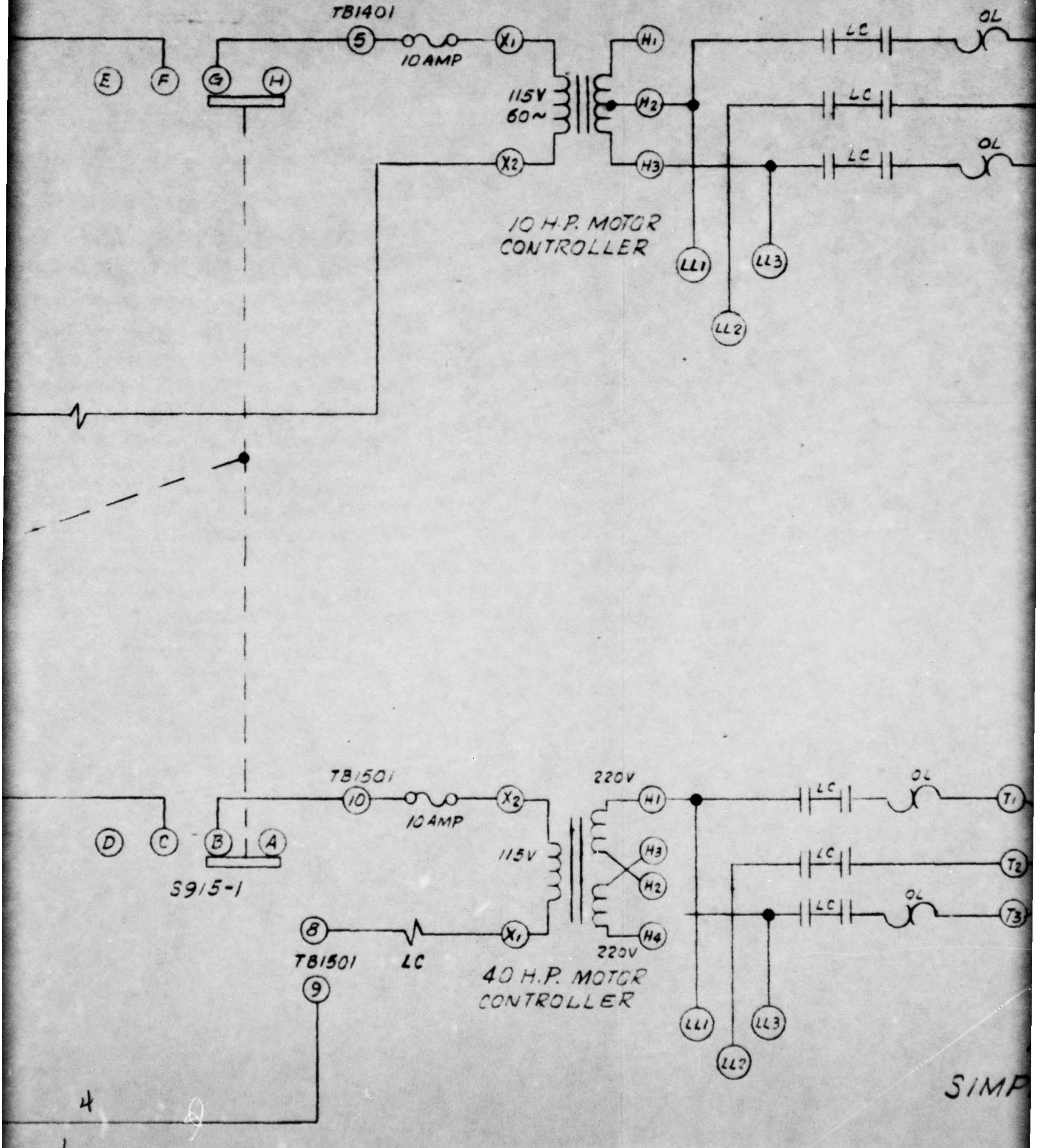

TB1401
5
10 AMP
X1
X2
H1
H2
H3
115V
60~
LC
OL
E
F
G
H
10 H.P. MOTOR
CONTROLLER
LL1
LL2
LL3
TB1501
10
10 AMP
X2
X1
220V
H1
H3
H2
H4
115V
D
C
B
A
S915-1
8
LC
TB1501
9
40 H.P. MOTOR
CONTROLLER
T1
T2
T3
SIMP
4

FIGURE 15

MPLIFIED WIRING DIAGRAM

S

Cable tension flow control is automatically accomplished by a switch and cam that is located on the flow control stem of the cylinder pump. Should the pump go off stroke, the sensing switch will sound the buzzer and energize the solenoid of directional control valve BB and return the pump to proper stroke, maintaining desired Cable Tension.

Cable Tension is maintained by adjusting balanced piston type relief valves D-D and B. Cable tension of 5000 to 100,000 lbs. can be attained by the adjustment of these relief valves.

4.11 PROTECTIVE DEVICES

Due to the automatic operation of the Towline Flexing Machine and the high loads imposed on the equipment and test cable, protective devices, which detect malfunctions or departure from normal operation, are required and are provided.

Two (2) basic types of motions are involved in the Towline Flexing Machine:

a) Towline tensioning cylinder extension and retraction.

b) Reciprocating motion of the cable (under Tension) and the rotary motion of the drum.

In the event of towline cable failure, a cage will be provided above the test cable to absorb and disipate the energy stored in the cable due to tension. In addition, should the cylinders continue to extend, a limit switch has been provided at the sheave support to automatically shut down the complete hydraulic power system and supply.

A hydraguard indicator and switch has also been provided into the cable tensioning hydraulic pressure circuit to shut down the hydraulic power system and supply in the event of pressure relied valve (B) and (D-D) failure or hydraulic shock above the relief valve setting.

To assure that the pressure required to drive the drum and to reciprocate the cable is not excessive, a second hydraguard indicator and switch has been provided. Should a malfunction exist in the hydraulic system, the hydraguard will sense the excessive pressure and automatically shut down the hydraulic system and supply.

In the event of hydraulic line failure, or excessive leak, a third hydroguard is provided to sense the pressure loss and again to automatically shut down the complete hydraulic power system and supply

Should the test cable exceed its linear reciprocating travel, a switch arrangement will provide a warning to the operator for corrective action.

In the event that the cable tensioning pump goes off stroke, in either direction, a direction sensing switch will return the pump onto proper stroke. If a malfunction should exist, and the pump does not return to proper stroke, a buzzer type alarm will warn the operator to take necessary corrective action.

4.12 DRIVE CABLE ASSEMBLY

The drive cable assembly consists of a closed loop formed by the test cable assembly and a wire rope assembly linked by means of cable fittings. The wire rope assembly is permanently secured to the drum by means of the lead lined cable clamp assembly. To prevent cable slippage, the wire rope is wrapped around the drum approximately 5 1/2 wraps.

The wire rope assembly consists of 2 1/4 diameter, 6 x 19 galvanized monitor steel, regular lay, wire rope, with open wire rope sockets and links at each end. The cable, socket, and socketing joint develop a minimum tensile strength of 390,000 lbs. (195 tons).

4.13 OPERATION

The operating controls for the Towling Flexing Facility Machine are located on the control station as shown in figures 13 and 14. The main power control switches are located elsewhere as shown in figure 4.

Adjustment of cable tension may be obtained by varying the pressure setting of relief valve (D-D). Relief valve (B) should not be adjusted for cable tension control, it must remain at maximum setting just below the hydroguard setting.

The cable reciprocating speed can be varied by adjusting the pump stroking cylinder, located just below the pump stroking stem. The speed of stroking can be varied by adjusting the flow control valves which are integral with the pump stroking cylinder.

CAUTION

BEFORE ENERGIZING THE MAIN POWER, ASSURE THAT:

a) All controls are in neutral position and all control station switches are in the off position.

b) Hydraulic oil reservoir is at proper level.

c) All safety guards are properly in place and secured.

d) Entire area is clear of unauthorized personnel and other obstructions.

4.13.1 STARTING PROCEDURE

(Refer to figures 4 and 14)

GENERAL: - Before energizing the equipment, and again soon after starting, make a visual inspection of all units, instruments, gauges and piping. A conscientious visual check will often disclose symptoms of incipient damage or failure before the results are serious and before emergency measures may be necessary.

(1) Turn 220V 40 H.P., 220V 10 H.P., and 115V POWER SWITCHES to the "ON" position.

(2) Rotate the control station POWER SWITCH (d) to the "ON" position, observe that "POWER ON" light (m3) is lighted.

(3) Depress and hold the 10 H.P. override switch (h) and simultaneously depress the 10 H.P. "START" pushbutton (g) until the 10 H.P. motor is running - release both pushbuttons.

NOTE

To purge the system of all air and to completely refill all voids with oil - allow the 10 H.P. motor to run for 10 seconds before starting the 40 H.P. motor.

(4) Depress the 40 H.P. "START" pushbotton (g) until the motor starts running - release the pushbutton.

(5) Rotate Mode of Operation Switch (e) to MANUAL.

(6) Place Drum Override Switch (f) to the "ON" position.

(7) Place Cable Tension Control Switch (i) to the "ON" position, observe "Cable Tension Maintained" light

(m5) to be lighted.

(8) Place buzzer control switch (s) to "ON" position

(9) Observe the cycles recorded on the counter (n), return to zero if necessary after recording the reading.

(10) Observe that the replenishing pressure gage (h) reading is 175 psi - adjust valve as necessary t attain reading.

(11) Assure that the control pressure (k) reading is 800-850 psi, adjust as necessary.

(12) Stroke the Manual Control handle (b) to extend position until Cable Tension is attained. Obse pressure on Gage (a).

NOTE

Cable Tension "ADD" light (m4) should be lighted during this operation and the buzzer (j) should sound

When Cable Tension has been Attained

(13) Stroke the Manual Control Handle (b) toward the retract position until the buzzer (j) stops and the Cable Tension "HOLD" light (m6) becomes lit Release control handle (b) to Neutral position.

NOTE

Cable Tension HOLD light (m6) must be lit and the buzzer (j) must be off.

(14) Stroke the Manual Control Handle (c) to reciprocate the cable and drum thru a few complete cycles in both directions.

(15) Return Manual Control Handle (c) to Neutral position at the end of either stroke Pay Out Cable or Haul In Cable.

IF FURTHER OPERATION IS NOT DESIRED,

a) Return Mode Selector Switch (e) to OFF position.

b) Return all other switches to OFF position.

c) Secure all Electrical power.

IF AUTOMATIC OPERATION IS DESIRED,

(16) Adjust and reduce the Control pressure to 300 psi, adjust as necessary.

(17) Rotate Mode of Operation Switch (e) to AUTOMATIC.

CAUTION

ASSURE THAT THE RECIPROCATING CABLE IS AT THE END OF ITS TRAVEL BEFORE SELECTING AUTOMATIC MODE OF OPERATION.

If further operation is not desired,

CAUTION

ASSURE THAT THE RECIPROCATING CABLE IS AT THE END OF ITS TRAVEL BEFORE OBSERVING NEXT OPERATION.

(18) Rotate Mode Of Operation switch to the OFF Position and secure all further operations shown after (15) above.

NOTE

Mode Selector switch (e) should not be placed in or taken out of "Automatic" or "Manual" position while the Cable is reciprocating. Only after the cable has come to the end of its travel should the Mode Selector Switch (e) be placed in any other position or sequence of operation.

TABLE 1

NORMAL OPERATING HYDRAULIC PRESSURES

(PSI) Extend Cylinder	(LBS. CALC.) Cable Tension	(PSI) Payout Cable	(PSI) Haul In Cable
400	17,740	1000	850
500	24,100	1000	850
600	30,460	1000	850
700	36,820	1000	850
800	43,180	1050	900
900	49,540	1050	900
1000	55,900	1075	925
1100	62,260	1100	950
1200	68,620	1150	1000
1300	74,980	1175	1025
1400	81,340	1200	1050
1500	87,700	1225	1075
1600	94,060	1250	1100
1700	100,420	1275	1125
1800	106,780	1300	1150

additional 100 PSI Hydraulic pressure is equal to 6,360 lbs. cable tension

Replenishing pressure 175 psi constant, Control Pressure 300 psi constant, except when in manual mode of operation.

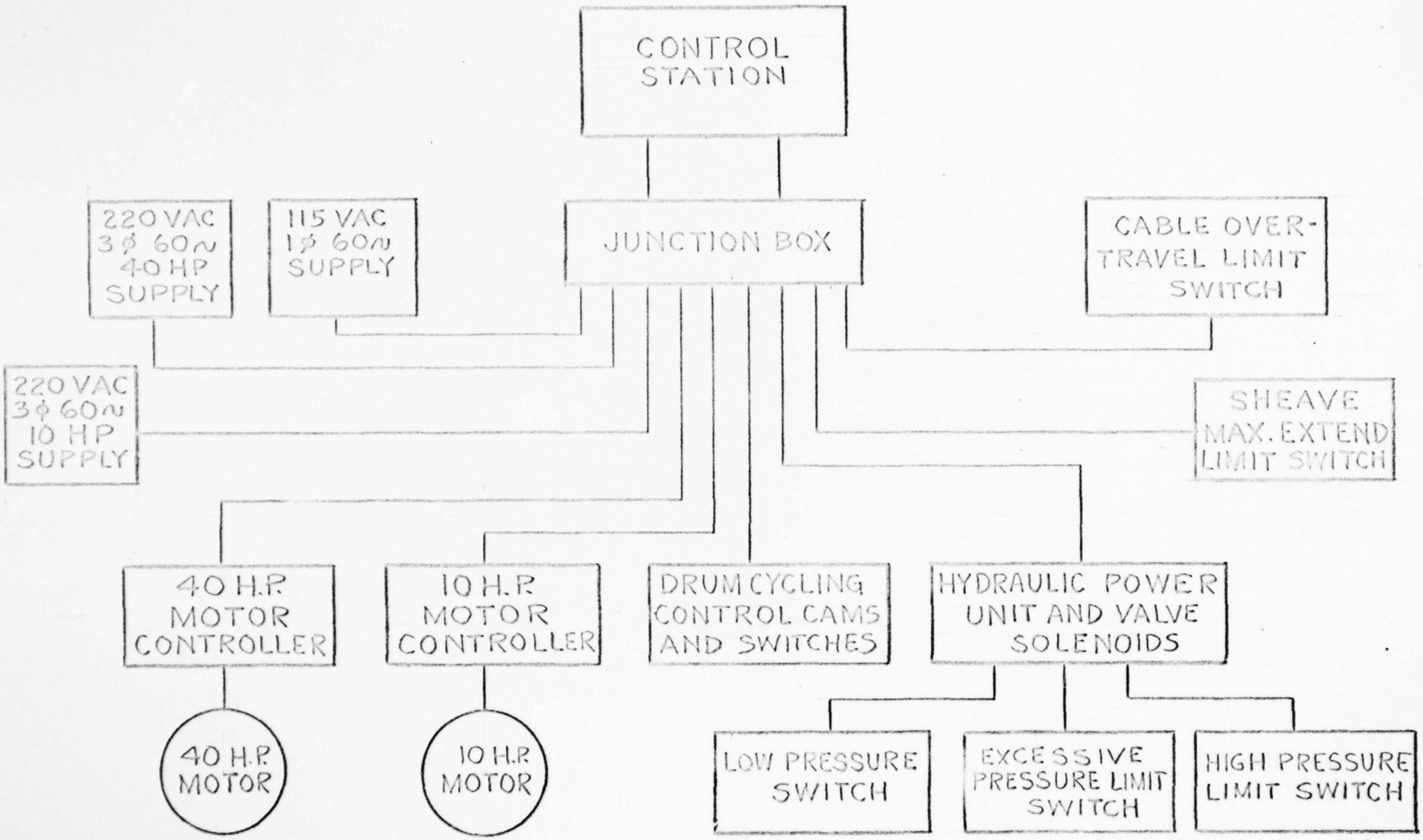


FIGURE 16 - INTERCABLING BLOCK DIAGRAM
USN/ASL VDS TOWLINE FLEXING FACILITY

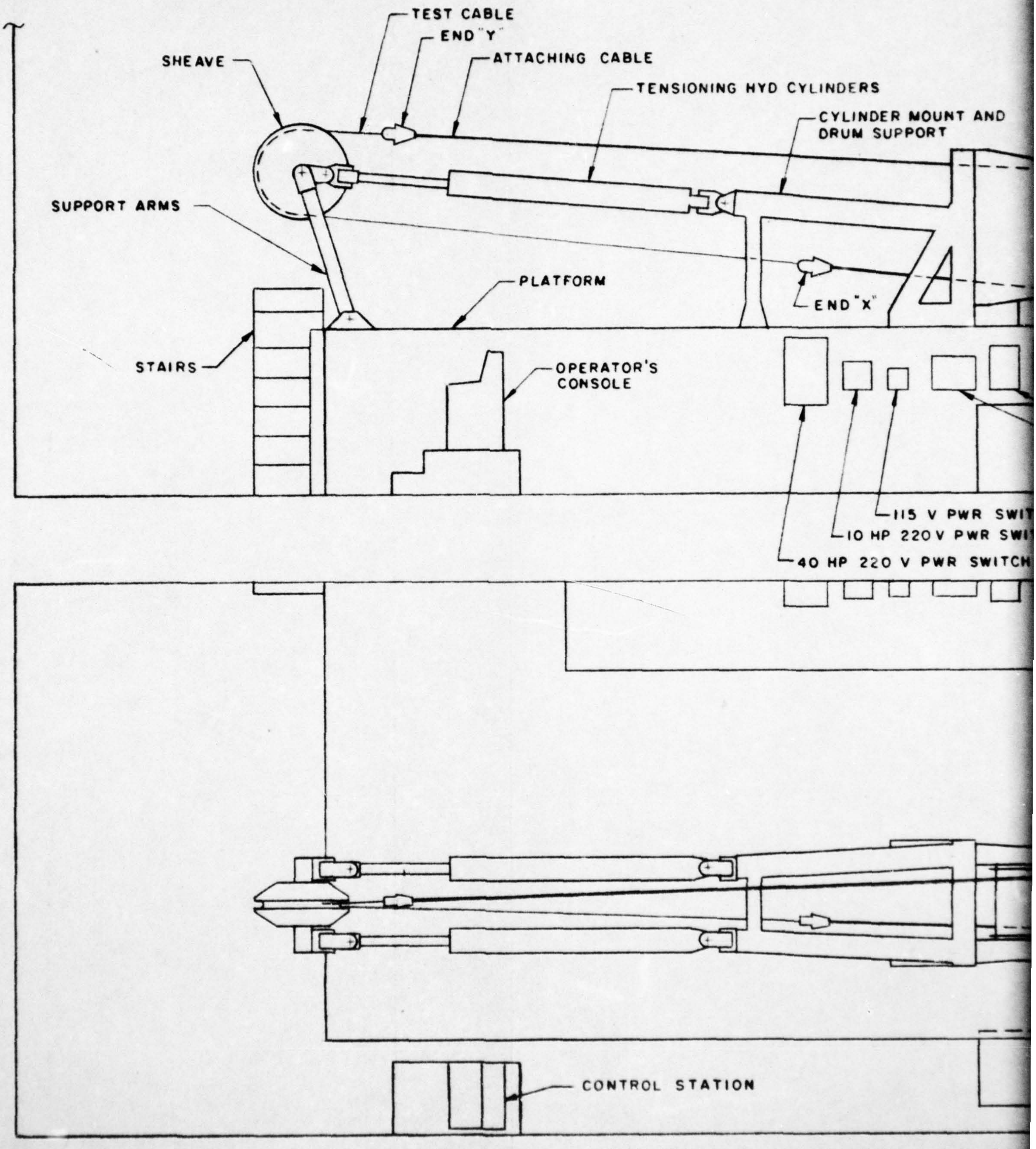
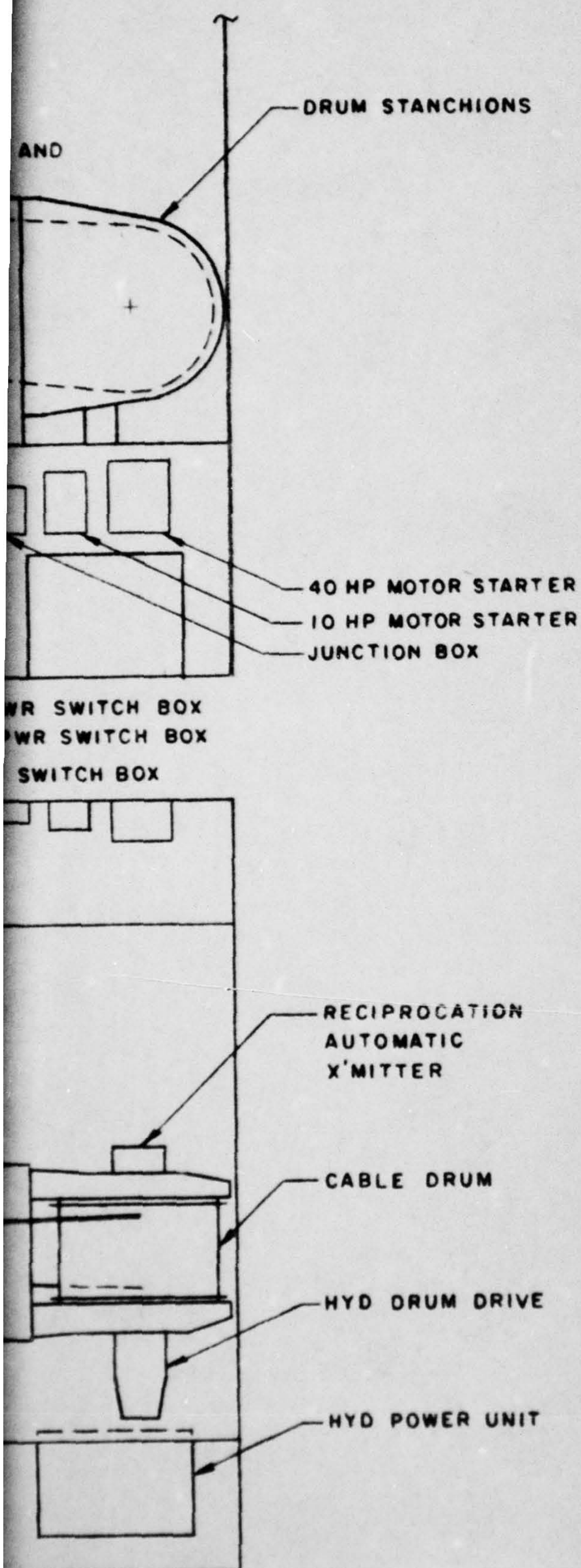


FIGURE 17 NASL TOWLINE FLE



E FLEXING FACILITY

5.0 TEST RESULTS

The Towline Flexing Facility and Machine was completed on March 4th, 1966, at which time preliminary tests began.

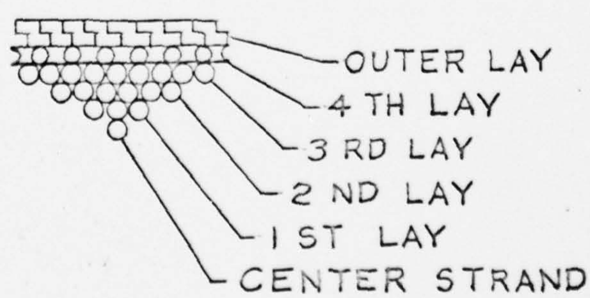
During the period between March 4th and March 18th, 1966, the Towline Flexing Facility Machine was adjusted and debugged so as to perform and comply with the specification of this contract.

The entire design and manufacturing is such that the Towline Flexing Machine will withstand usage with a minimum of maintenance and will operate smoothly and efficiently with maximum safety to the operator.

5.1 CABLE CONSTRUCTION (TEST)

The U.S. NAVAL APPLIED SCIENCE LABORATORY furnished Test Cable was installed onto the machine for qualification and acceptance.

The construction of the cable was as shown below:



5.2 PRELIMINARY RUN

The U.S. Naval Applied Science Laboratory furnished cable was installed onto the Towline Flexing Machine and the hydraulic pressure was adjusted to 400 psi. The machine was run for one half (1/2) and gradually increased in steps of 100 psi increments and operated for 1/2 hour at each increment until pressure of 1800 psi was attained.

During the above tests, the machine was operated both in the MANUAL and AUTOMATIC modes of operation. Necessary adjustments were made, all sequence of operation were observed, modification for smooth operation were made.

5.3 TEST RESULTS

5.3.1 TEMPERATURE RISE:

The initial tests conducted were to observe overheating of any major contributing component.

a) Drum drive motor

b) Sheave Support bearing

c) hydraulic power unit

The maximum permissable temperature of the hydraulic power unit was quickly exceeded. For continuous operation, some means of heat exchanging had to be provided, which were as follows:

a) Encapsulate both lines to the drum drive hydraulic motor with a water type cooling jacket.

b) Provide sufficient air circulation around the hydraulic power unit.

Results of the water cooling Jackets and Fan installation are recorded in tables 2, 3, 4 and 5.

TABLE 2

TEST RUN - 3-28-66

TEMP. RISE (^{o}C)

Running Time Hrs.	Drum Motor	STBD Sheave BRG	Port Sheave BRG	10 HP Electric Motor	K Valve	Pump Head	Globe Valve	Pipe 1 Hyd. Motor	Pipe 2 Hyd. Motor	Oil Reservoir	Remarks
1/4	52	8.2	10.8	34.5	51	43	53	51	51	34	(3)
1/2	56		11.3	35.5	58	49	59.5	57.5	59	38	
3/4	61		12.2	37	60	53	61	58	60	41	
1	61	11	12.5	38	62	56	63	60	62.5	45.5	
1 1/4	63	12	13.7	38	64	58	65	62	64	50	
1 1/2	66			38	64	60	66	63	66	51.5	
1 3/4	67			39	67	61.5	68	65	67	55	
2	69		16.4	41	68	63	69	66	68	58	
2 1/4	70		16.6	42	70	65	70.5	67	69.5	60	
2 1/2	71		16.8	42	72	66.5	72.5	69	71	62.5	
2 3/4	74.5		17.8	42	74	68	74	70	73	64.8	
3	74		18	41	74	68.5	73.5	70	72	65	(1)
3 1/2	72.5	19	20	39	74	68.5	73.5	70	72	65	(2)
4	66		21.2	36	65.5	50	61.5	62	66	64	
4 1/4	66		22		64.5	50	61	62	65	63	

REMARKS (TABLE 2)

(1) Control pressure was decreased from 600 psi to 300 psi.

(2) Fan was turned "ON" to blow on pump head.

(3) Cold water flowing thru cooling jackets.

(4) Cable Tension pressure gage indication 380 psi.

(5) Cable Haul in pressure 800 psi.

(6) Cable Pay out pressure 900 psi.

(7) Control pressure 600 psi (see remark #1 above and in table).

(8) Replenishing pressure 150 psi.

(9) One (1) complete cycle, with 12 foot stroke, 33 seconds per cycle.

TABLE 3

TEST RUN - 3-29-66

TEMP. RISE (^{o}C)

Running Time Hrs.	Drum Motor	STBD Sheave BRG	Port Sheave BRG	10 HP Electric Motor	K Valve	Pump Head	Globe Valve	Pipe 1 Hyd. Motor	Pipe 2 Hyd. Motor	Oil Reservoir	Remarks
0	7	4	4.	7.5	5	6	5	6	6	9	
.1	22	4	4	12	15	10.5	22	21.5	22	10.5	(1)
1/4	33	4.4	4.6	16.5	30	21	34.5	33.5	34.5	14	
1/2	45	5		20.5	44	35	46.5	44	46	18	
3/4	49	5.3	5.8	24	50	42	51	48	50	21.5	(2)thru(7)
1	54	.	6.9	26	53	39	50	52	54	25	(8)
1 1/4	54	8.2	9.1	31	51	36	48	50	52	28	(9) (10)
1 1/2	54.5	12.5	13.8	35	50	37	48	49	52	32	
1 3/4	55	15.5	16.6	35.5	50.5	38	49	50	53	34	
2	54	17.1	19.5	39	52	39	50	51.5	54	37	(11)
2 1/2	58	21		43	54.5	42	53	54	56	42	
3	59	.	25.6	45	56	43	57	55	57	45	
3 1/2	61	27.1	27.8	47	57	45	58	57	59.5	46.5	
4	61	29.2	29.7	49.5	58	46	58.5	58	60	50	
4 1/2	61	31.5	32	51.5	58	47	59	58	61	52.5	(12)
5 1/4	61	33.3	34.8	53	57.5	47	56.5	55	57.5	55	
6 1/4	60	32.6	33.6	52	56	43	57	55	57.5	55	
7	63	35.6	37.5	51.5	59	45	58	57.5	60	55	(13)

REMARKS (TABLE 3)

(1) Machine shut down to lubricate pump coupling.

(2) Cable Tension pressure gage indication 380 psi.

(3) Cable Haul In pressure 800 psi.

(4) Cable Pay out pressure 950 psi.

(5) Control pressure 300 psi.

(6) Replenishing pressure 150 psi.

(7) Extend cylinder pressure relief valve set at 400 psi.

(8) Fan was turned "ON" to blow on pump head.

(9) Fan added to blow on oil reservoir and control pressure pump.

(10) Increased cable Tension pressure to 1400 psi.

(11) Reduced cable Tension pressure to 780 psi.

(12) Machine stopped and started several times to look for source of odd type noise - determined noise was in cable, continued test.

(13) Shut down machine to tighten sheave support bearings.

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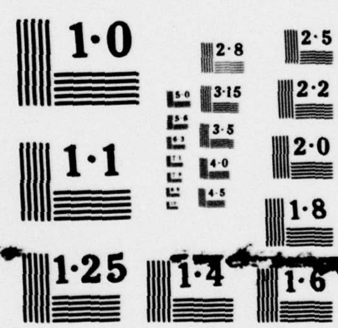

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TABLE 4

TEST RUN - 3-30-66

TEMP. RISE (^oC)

Running Time Hrs.	Drum Motor	STBD Sheave BRG	Port Sheave BRG	10 HP Electric Motor	K Valve	Pump. Head	Globe Valve	Pipe 1 Hyd. Motor	Pipe 2 Hyd. Motor	Oil Reservoir	Remarks
5 3/4	64	45	45	55	61	47	58	58.5	61	57	(1) (2)
6	64	48	45	55	61	47	58.3	58.5	61	57	
6 1/2	64	51	45	56	61	47	58.3	58.5	61	57	
7	64	53.5	45.5	57	61.3	47	58.3	58.5	61	57.5	(3) (5)
7 1/2	64	54.5	78	57.5	61	46	58	58.5	61	57.5	
8	64	56	49	57.5	60.5	46	58	58.5	61	57.5	
											(4)

REMARKS (TABLE 4)

(1) Recordings for the first 5 hours were basically the same as in table 3 at 780 psi cable Tension pressure.

(2) After 5 hours of run time cable Tension pressure was increased to 1000 psi.

(3) Cable Tension pressure increased to 1300 psi.

(4) Fans and Hydraulic motor water/oil coolant was turned "ON" at the beginning of the test run.

(5) It was noted that the cylinders extended 3/4 of an inch when cable Tension pressure was increased from 1000 psi to 1300 psi (indicating a cable stretch of 1 1/2 inches).

TABLE 5

TEST RUN - 3-31-66

TEMP. RISE (^{o}C)

Running Time Hrs.	Drum Motor	STBD Sheave BRG	Port Sheave BRG	Cable Tension Relief Valve	K Valve	Pump Head	Globe Valve	Pipe 1 Hyd. Motor	Pipe 2 Hyd. Motor	Oil Reservoir	Remarks
0											(1)
1/4	21			15	12	13	15	14	14	15	(2)
1/2	22.5			23	23	21	25	25	26	20	
1	45			27	41	29.5	41	42	44	25	
1 1/2	49.5			32	46.5	35	45	46	48	32.5	
2	52			37	50	38	48	50	52	38	
2 1/2	55			44	52.5	40.5	50.5	52	54	43	
3	58			47	55	43	53.5	54	57	47	
3 1/2	60			50.5	57.5	45	55.5	57	59	50	
4	60.5	35	35	52.5	60	47.5	57.5	59	61.5	53	
4 1/2	62	37.7	37.7	53.5	61	47	58	57.5	60	55	
5	62	40	40	54	60.5	46.5	57.5	58	60	55.5	
5 1/2	63	43.4	43.4	54.5	61	47	58	58	61	56.5	
6	63	45	45	54.5	61	47	58.3	58.5	61	57	
6 1/2	64	45	45	55	61	47	58.3	58.5	61	57.5	
7	64	45	45	56	61.3	47	58.2	58.5	61	57.5	(3)
7 1/2	64	54	47.5	57	60.5	46.5	58.2	58.5	61	57.5	
8	64	56	50	56.5	60.5	47	58	58.5	61	57.5	
8 1/4	64	56.5	51.5	57	60.5	47	58	58.5	61	57.5	

REMARKS (TABLE 5)

(1) Fans and hydraulic motor water/oil coolant was turned "ON" at the beginning of the test run.

(2) Cable Tension pressure 1000 psi.

(3) Cable Tension pressure was increased from 1000 psi to 1300 psi.

(4) The Towling Flexing machine was run for 8.5 continuous hours.

TABLE 6

TEST RUN - 4-1-66

TEMP. RISE (^oC)

Running Time Hrs.	Drum Motor	STBD Sheave BRG	Port Sheave BRG	Cable Tension Relief Valve	K Valve	Pump Head	Globe Valve	Pipe 1 Hyd. Motor	Pipe 2 Hyd. Motor	Oil Reservoir	Remarks
0	10	8	8	10	9	10	11	11	10	13	(1) (2)
1/4	32	9	9	20	31.5	23	37	37	38.5	19	
1/2	46	9	9	24	45	35.5	48.5	47	49	22	
3/4	54	9.5	9	28.5	54	45	56.5	54	56	26	(3)
1	55	13	12	33	57	50	57.5	57	58.5	30.5	
1 1/4	56	14	12.5	35.5	58.5	52	59	58	59.5	33.5	
1 1/2	58	15	13	39	60.5	54	60.5	60	61.5	37	
1 3/4	60	16	14	41.5	62	55.5	62	61	63	40	(4) (5)
2	62	17.5	15	44.5	63.5	57	63.5	62.5	64	43.5	
2 1/2	61	16.5	15.5	45.5	61	56.5	62.	59.5	61.5	45	(6)
2 3/4	62	16.5	16	46.5	62	59.5	64	59.5	62	46.5	(7)
3	62	17.5	17	45.5	58.5	46	57	57	60	47.5	(8)
											(9)
3 1/4	57	21.5	22.5	35	54	42	53	53.4	56	51	(10)
3 1/2	60	29	29.5	26.5	57	43.5	55	55	58	51.5	
3 3/4	61	34	34.7	25.5	58	45	56	56	59	52	
4	61	38	39	25	58.5	45	56	56.5	59.5	52.5	
4 1/4	62	42.5	43	25	59	45.5	57	56.5	59.5	53	
4 1/2	62	46	46	25	58	43.5	54	55	57	52.5	(11)(12)

REMARKS (TABLE 6)

(1) Fans and water coolant were purposely left "OFF" at beginning of thest run.

(2) Cable Tension Pressure was set at 500 psi.

(3) Hydraulic motor water/oil coolant was turned "ON".

(4) Cable Haul In pressure reading 750 psi.

(5) Cable Pay out pressure reading 900 psi.

(6) Drum drive was turned"OFF" for 5 minutes.

(7) Both fans turned "ON".

(8) Increased Cables Tension Pressure from 500 psi to 1700 psi - cable Tension cylinders extended 6 1/4 inches indicating a cable stretch of 12 1/2 inches.

(9) Machine was shut down for 1/2 hour to adjust and tighten cable reciprocation cams.

(10) Cable Haul In pressure indication 1050 psi Cable Pay Out pressure indication 1200 psi.

NOTE

(11) OUT SIDE LAY OF TEST CABLE FURNISHED BY USN/ASL FAILED. THE TEST MACHINE WAS INSTANTANEOUSLY SHUT OFF, PREVENTING FUTHER OPERATION.

(12) IT WAS NOTED THAT THE CYLINDERS WERE EXTENDED 11 1/8 INCHES FROM ORIGINAL 500 PSI SETTING - THEREFORE

TEST CABLE MUST HAVE STRETCHED 22 1/4 INCHES BEFORE FAILURE.

5.3.2 CYCLE TIME

The cycling of the machine for a 12 foot cable stroke was timed, based on 30 complete cycles. The length of time for 30 cycles was clocked at 14 minutes and 10 seconds.

$$\text{therefore } \frac{14 \times 60 + 15}{30}$$

$$= 28\ 1/2 \text{ seconds per cycle}$$

5.3.3 CABLE RECIPROCATING SPEED

The timing of the cable reciprocating speed was based on timing the energizing and deenergying of the pump stroking valve "CC" for 30 cycles. The length of expended time was 7 minutes and 27 seconds, (447 seconds) and the cable travel, at full pump speed, in each direction was equal to 8' 9" (8.75 feet) therefore total travel was 8.75 x 2 x 30 or 525 feet,

therefore the maximum cable speed is

$$\frac{525}{447} \text{ or } 1.1745 \text{ feet per second}$$

or 1.1745 x 60

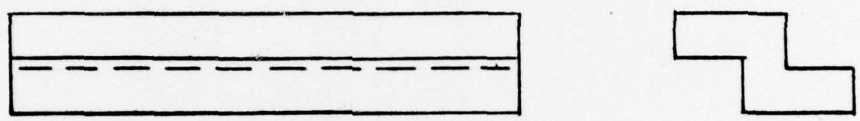
$$= 70.5 \text{ feet per minute}$$

5.3.4 CABLE STROKE

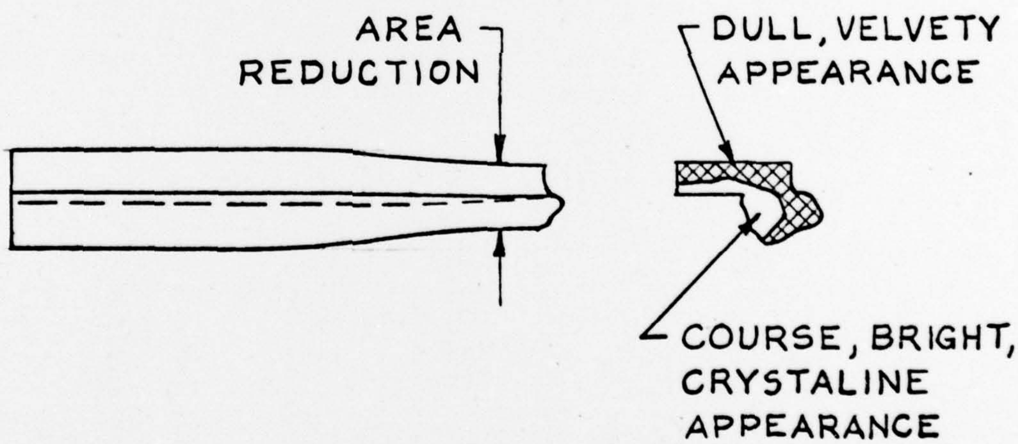
Cable stroke was measured to be between 5 and 20 feet.

6.0 CABLE FAILURE ANALYSIS

When failure of cable occured, the cable was examined for the type of failure. The outward and first impression was a failure due to tension. Upon further examination, the cable appeared to be as follows:



ORIGINAL CROSS SECTION
(BEFORE FAILURE)



CROSS SECTION AFTER FAILURE

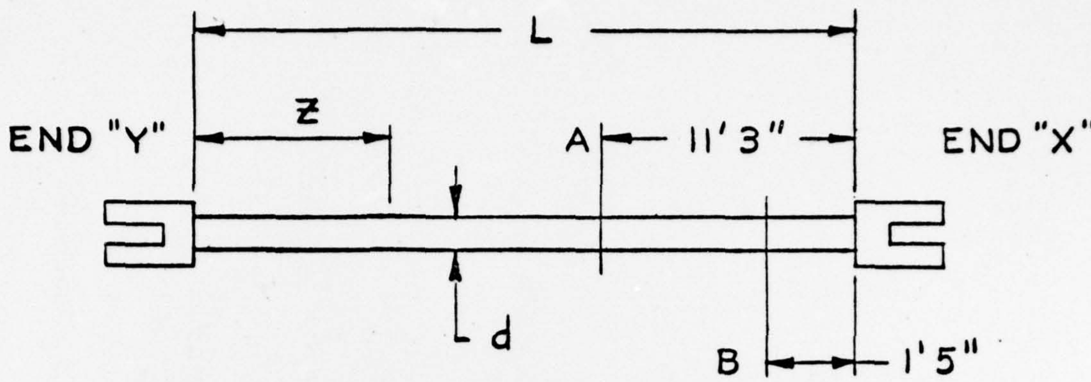
The dull velvety appearance indicates a fracture due to Fatigue Failure in Bending whereas the coarse bright crystaline appearance indicates an Instantaneous Failure such as Tension. Therefore the conclusion can be reached that the armor had failed under Bending Fatigue while under Tension, where the Cable Tension is equal to a load represented by a hydraulic pressure of 1700 psi (estimated at 100,420 lbs.). (See Table 1)

6.1 CABLE DISECTION, PROCEDURE AND OBSERVATIONS

The outer lay of cable consisted of 40 strands of which 30 strands failed. Failure accurred 11 feet 3" from End "X". End "X" was on the lower side when installed onto the VDS Towline Flexing machine (Refer to figure 17). The following procedure was used and the following points were observed:

A) OUTER ARMOR LAY

1) Seize the cable at both sides of failure.
2) Remove failed test cable to inspection facility.
3) Check Diameter of cable in several places (other than in immediate damaged area).
4) Failure of 30 outer strand members failed 11' 3" from fitting at end "X".



5) Diameter of cable 1' 5" from fitting at end "X" was 1.297 inches.

6) Diameter of cable at points from End "Y" were as follows.

DIM. "Z"	DIAMETER "d"
1 Ft.	1.294 Inches
3 Ft.	1.290 Inches
6 Ft.	1.279 Inches
8 Ft.	1.278 Inches
11 Ft.	1.278 Inches
13 Ft.	1.278 Inches

7) The cable was cleaned of all oil, grease, and foreign matter for visual inspection.

8) Magnification inspection did not indicate or reveal any further or additional failures.

9) Helix of the outer armor lay was right hand - length was not measured due to failure.

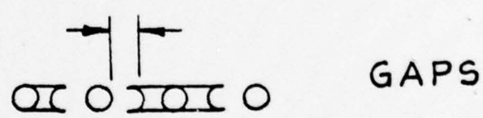
10) Dimensional Length L was 29 feet 0 1/2 inches.

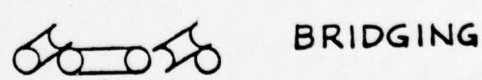
B) 4th ARMOR LAY

1) Diameter of cable at points from end "Y" were as follows:

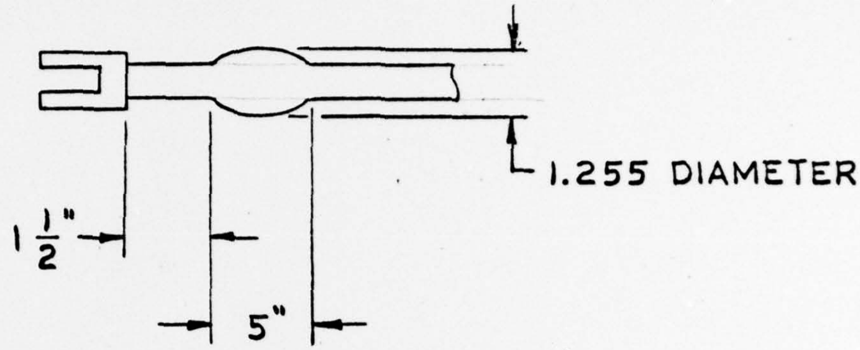
DIM "Z"	DIAMETER "d"
1 Ft.	1.090 Inches
3 Ft.	1.085 Inches
6 Ft.	1.090 Inches
8 Ft.	1.055 Inches
11 Ft.	1.065 Inches
13 Ft.	1.055 Inches

2) Several gaps between the armor wires were noticeable as well as the bridging of the armor strands.





3) Bird caging appeared at end "Y"



4) No strands were damaged or indications of damage.

5) Sign of abrasion wear was visible on outside diameter of this lay.

6) Zinc dust was visible between armor strands.

7) The helix angle was Left Hand lay.

8) Due to the Bridging and gap, no helix length was measured at this time.

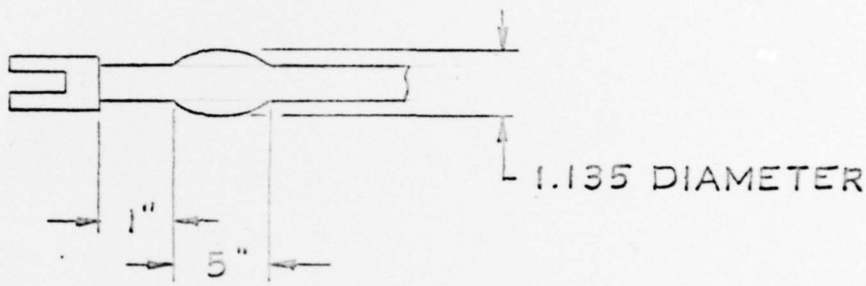
C) <u>3rd ARMOR LAY</u>

1) Helix length varied as follows (from end "Y")

DIM "Z"	HELIX LENGTH
1 Ft.	5 3/4 In.
6 Ft.	5 5/8 In.
12 Ft.	5 3/8 In.
adjacent to failure	5 3/8 In.
End X	5 9/16 In.

2) Helix angle was Left Hand Lay.

3) Bird cage appeared at end "Y".



4) Diameter "d" measured between .818 and .831 inches thru-out entire length.

5) Zinc dust was visible between armor strands.

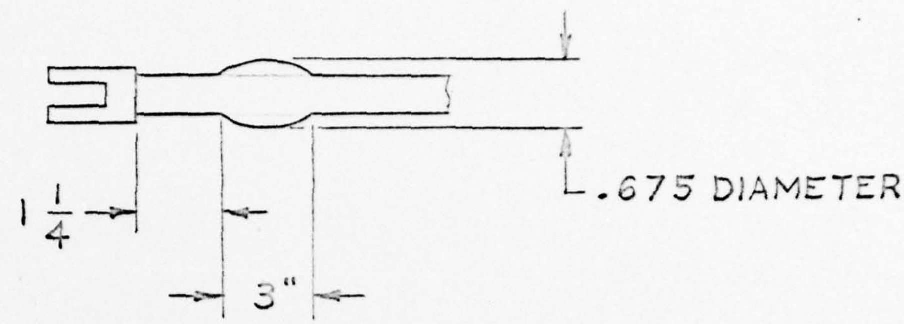
D) 2nd ARMOR LAY

1) Helix Length varies as follows (from end "Y")

DIM. "Z"	HELIX LENGTH
4 feet	3 3/8 inches
8 feet	3 11/16 inches
16 feet	3 11/16 inches
18 feet	3 5/8 inches

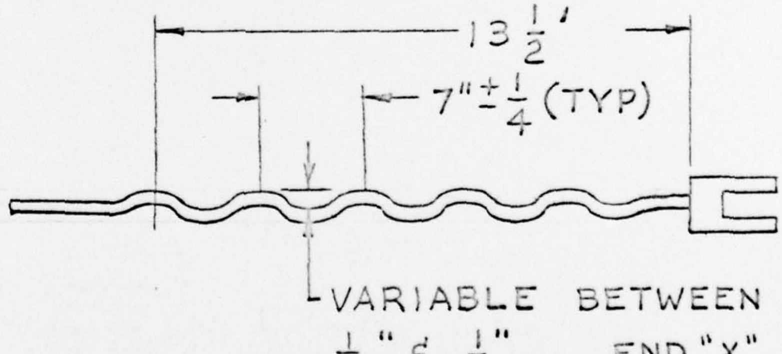
2) Helix angle was Left Hand Lay.

3) Bird cage appeared at End "Y".



4) Diameter "d" measured between .612 and .626 inches.

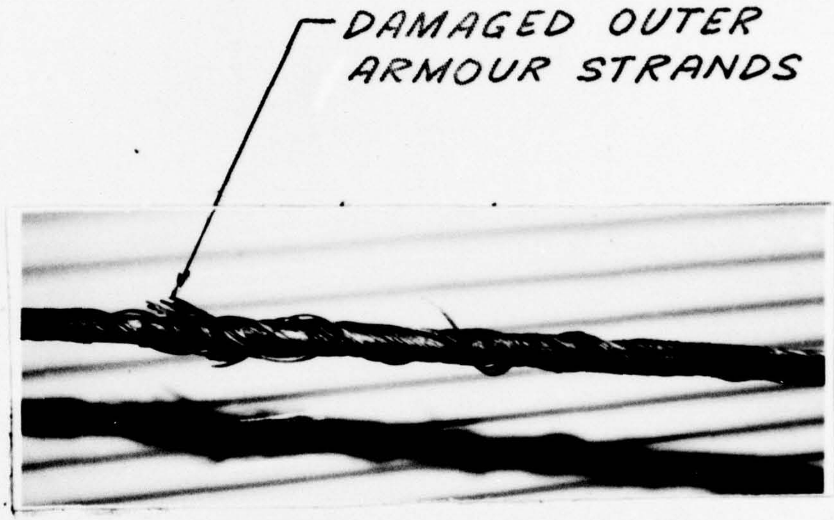
5) Several kinks were evident in the cable, which was as follows:



6) Zinc dust was visible between armor strands.

E) ALL OTHER LAYS AND STRANDS

All other armor strands and lays appeared to be in good condition, no sign of damage or wear was evident except for kinks in the cable as was evidenced in the Second Armor Lay, paragraph (D).



FIGUR 18 CABLE FAILURE CLOSE UP

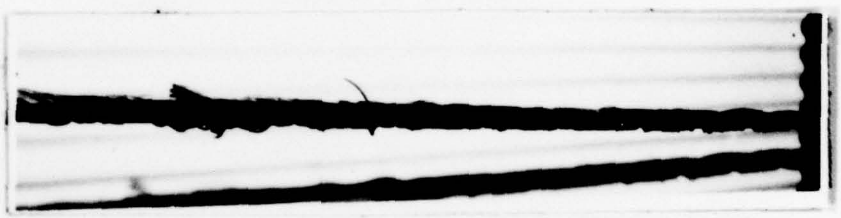


FIGURE 19 CABLE FAILURE VIEWED FROM SHEAVE END

FIGURE 20 CABLE FAILURE VIEWED FROM FITTING END