From: "Davis, James T." <JTDAVIS@southernco.com>
To: "Christian Araguas" <CJA2@nrc.gov>
Date: 4/16/2007 6:19:29 PM
Subject: RAI Letter #6 Hydrology Response 3 of 4

<<AR-07-0639_3 of 4.pdf>>

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Subject: RAI Letter #6 Hydrology Response 3 of 4
Creation Date: 4/16/2007 6:19:29 PM
From: "Davis, James T." <JTDAVIS@southernco.com>

Created By: JTDAVIS@southernco.com

Recipients
"Christian Araguas" <CJA2@nrc.gov>

Post Office	**Route**
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Priority: Standard
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None

Concealed Subject: No
Security: Standard

GEORGIA POWER COMPANY

Sheet ____ of ____

Subject ____ Project ____

Computed by ____ Date ____ Checked by ____ Date ____

SOLUTION:

I. FORMULAE

SEE FIGURE 4

II COMPUTE SYSTEM PIPING HEAD LOSS —

$$h_l = \frac{0.00259\, K Q^2}{d^4}$$

K = 25 ft for LONG RADIUS 45° ELBOW
K = 30 ft for 90° ELBOW
K = 1 for PIPE EXIT
$K = f\frac{L}{D}$ for STRAIGHT PIPE
PIPE ENTRANCE NOT CONSIDERED

K FOR PIPE

$K = f_1\frac{L}{D} + f_2\frac{L}{D}$ (FOR HOSE & C.S. PIPE)

$f_1 = 0.015$ FOR CARBON STEEL; $f_2 = 0.02$ FOR HOSE (ESTIMATED)

$$\therefore K = \frac{(0.015)(306)(12)}{7.981} + \frac{(0.02)(30)(12)}{8.329}$$

$K = 6.9 + 0.86 = 7.76$ FOR PIPING

$K = (2)(25)(0.015) = .75$ FOR 2-45° LR ELS (CONSIDERED HOSE/PIPE JUNCTA LREL)
$K = (2)(30)(0.015) = .9$ FOR 2-90° ELS

$K_{TOTAL} = 1 + 0.75 + 0.9 + 7.76 = 10.41$

GEORGIA POWER COMPANY

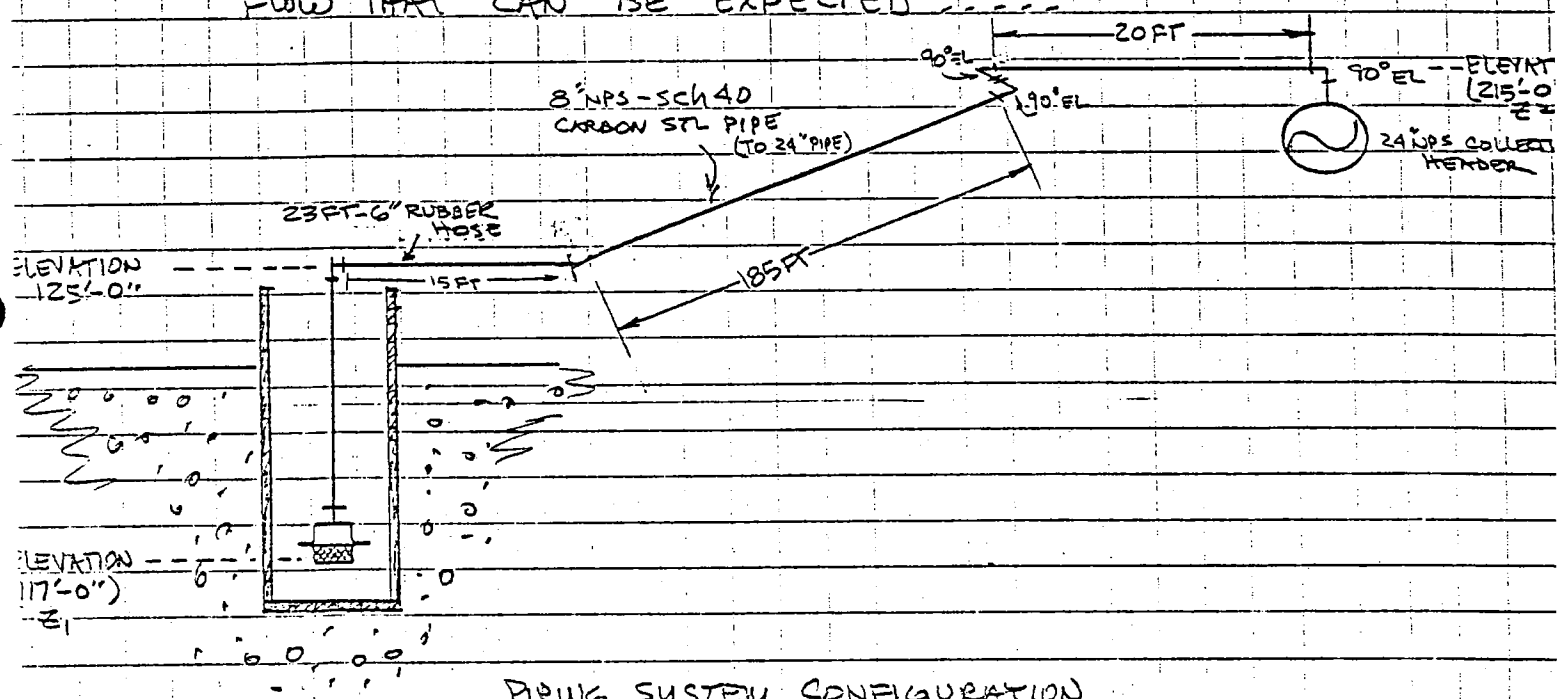
Sheet ____ of ____

Subject: DEWATERING PUMP PERFORMANCE — POWER BLOCK SOUTH SLOPE - PUMP B

Project: VOGTLE

Computed by: D. DAY Date: 8-8-80 Checked by: ____ Date: ____

GIVEN: WATER AT (60°F) IS FLOWING THROUGH THE PIPING SYSTEM AS DETAILED BELOW. DEVELOP SYSTEM CURVE AND PUMP CURVE TO DETERMINE MAXIMUM RATE OF FLOW THAT CAN BE EXPECTED.



PIPING SYSTEM CONFIGURATION

PUMP SPECS: (SEE DATA SHEET ATTACHED)

GORMAN-RUPP MODEL S8A1-1

RATED 2600 GPM @ 55 FT HD

$d_1 = 6.065$ $d_2 = 7.981$

$f_{T_1} = 0.015$ $f_{T_2} = 0.014$

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

II COMPUTE SYSTEM PIPING HEAD LOSS

$$h_l = \frac{0.00259\, K Q^2}{d^4}$$

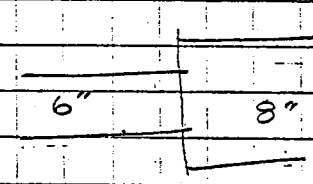
$K = 30 f_T$ for 90° ELBOWS

$K_2 = 0.53$ for SUDDEN ENLARGEMENT

$K = 1$ for PIPE ENTRANCE

$K = 1$ for PIPE EXIT

$K = f\frac{L}{D}$ for PIPING



$\beta = \frac{d_1}{d_2} = 0.76$

$K_2 = \frac{(1-\beta^2)^2}{\beta^4} = 0.53$

K for PIPE

$$K = f_{T_1}\frac{L}{D_1} + f_{T_2}\frac{L}{D}$$

$$K = \frac{(0.015)(23)(12)}{6.065} + \frac{(0.014)(205)(12)}{7.981}$$

$$K = 0.68 + 4.32 = 5.0$$

$K = (4)(30)(0.015) = 1.8$ for 4-90° ELBOWS

$K_{TOTAL} = 1.8 + 0.53 + 1.0 + 1.0 + 5.0 = 9.33$

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

III COMPUTE h_l OVER RANGE OF INTEREST –

$$h_l = \frac{0.00259\, K Q^2}{d^4} \qquad K_{TOTAL} = 9.33$$

$$h_l = \frac{0.00259\,(8.65)(Q^2)}{(7.981)^4} + \frac{(0.00259)(0.68)(Q^2)}{(6.065)}$$

$$h_l = (5.5\times10^{-6})(Q^2) + (1.3\times10^{-6})(Q^2)$$

$h_l = 1.38 + 0.33 = 1.71$ FT for 500 GPM
$h_l = 5.50 + 1.3 = 6.8$ FT for 1000 GPM
$h_l = 22.0 + 5.2 = 27.2$ FT for 2000 GPM
$h_l = 37.18 + 8.79 = 45.97$ FT for 2600 GPM
$h_l = 49.5 + 11.7 = 61.2$ FT for 3000 GPM

IV $H_{REQ'D} = Z_1 - Z_2 + h_{l_{1-2}} + \frac{V_2^2}{2g}$ $\qquad \left[\frac{V_2^2}{2g} = \frac{\left(\frac{0.408\,Q}{d^2}\right)^2 \text{ FT}^2/\text{SEC}^2}{64.4 \text{ FT/SEC}^2}\right]$

a. $H_{REQ'D_{3000}} = 98 + 61.2 + 5.73 = 164.93$ FT for 3000 GPM

b. $H_{REQ'D_{2600}} = 98 + 45.97 + 4.31 = 148.28$ FT for 2600 GPM

c. $H_{REQ'D_{2000}} = 98 + 27.2 + 2.55 = 127.3$ FT for 2000 GPM

d. $H_{REQ'D_{1000}} = 98 + 6.8 + 0.64 = 105.4$ FT for 1000 GPM

e. $H_{REQ'D_{500}} = 98 + 1.71 + 0.16 = 99.9$ FT for 500 GPM

2766—12M—1-31-68

GEORGIA POWER COMPANY

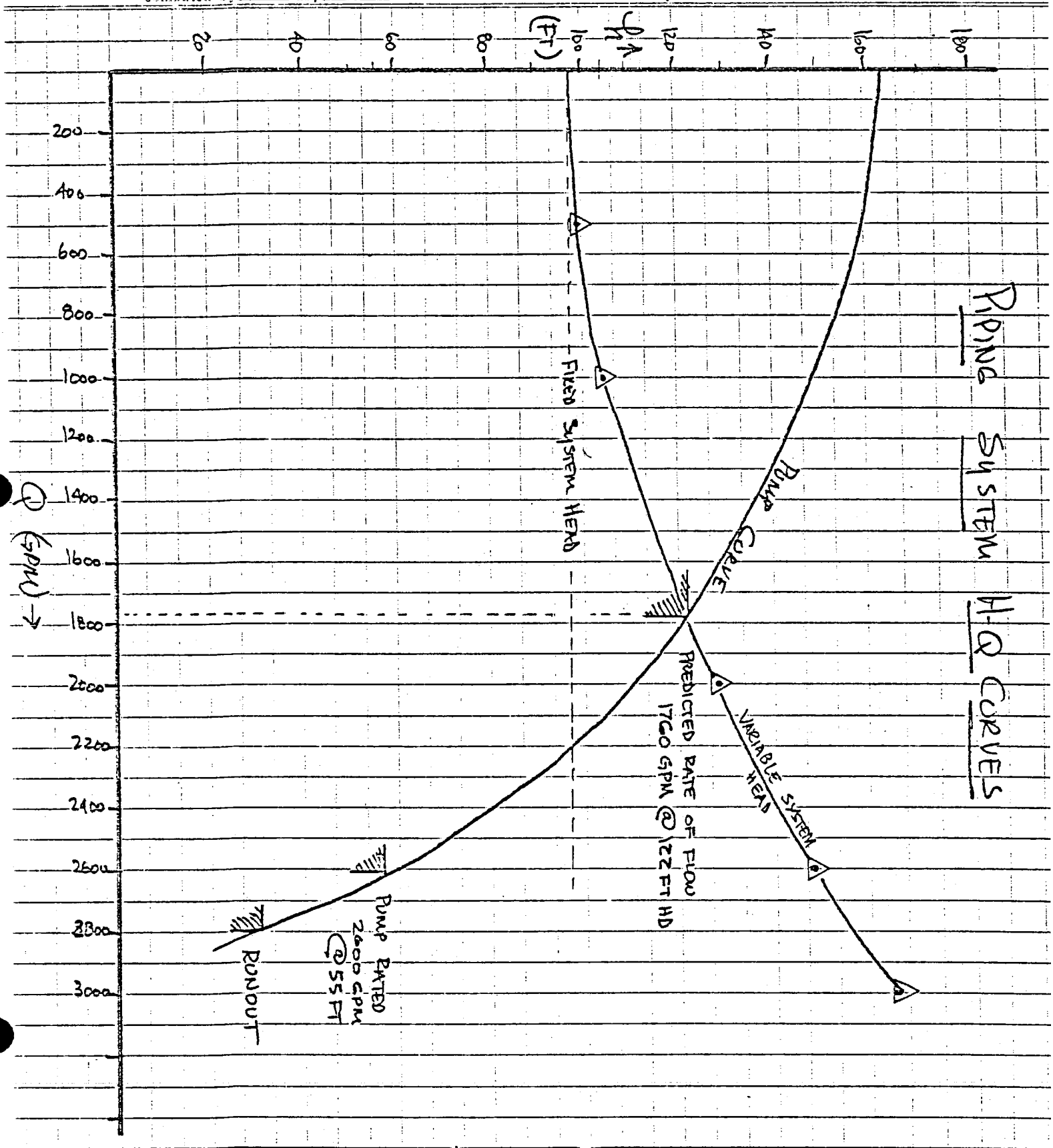
Sheet 4 of 5

Subject DEWATERING PUMP PERFORMANCE

Project VOGTLE

POWER BLOCK SOUTH SLOPE - PUMP B

Computed by D. DAY Date 8-8-80 Checked by Date



APPENDIX B-4

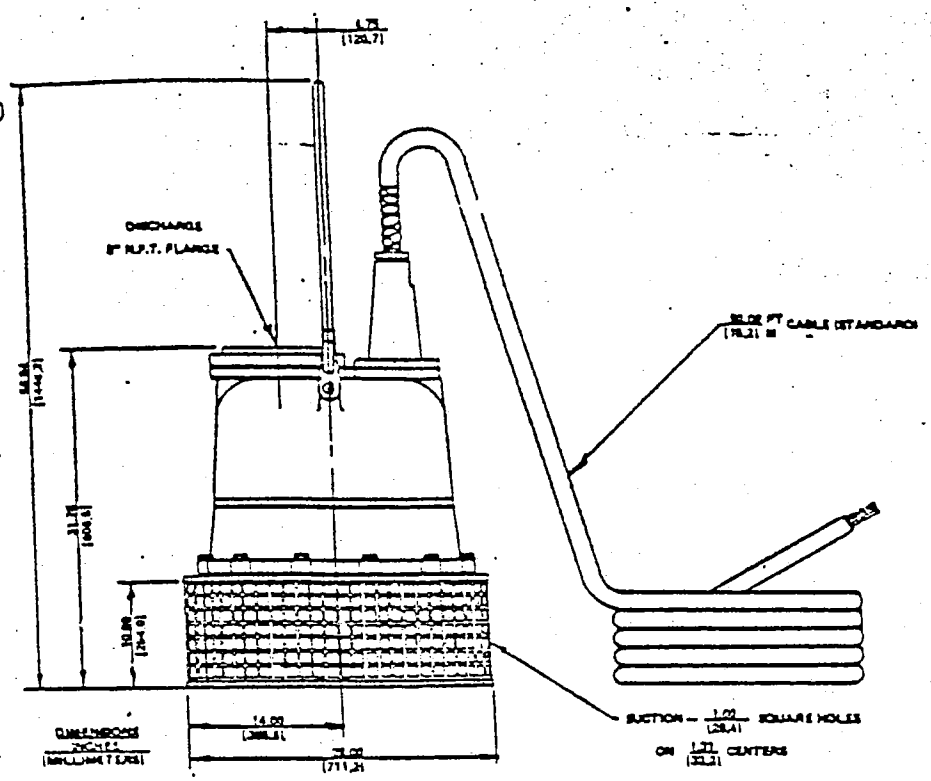
SHEET 5 OF 5

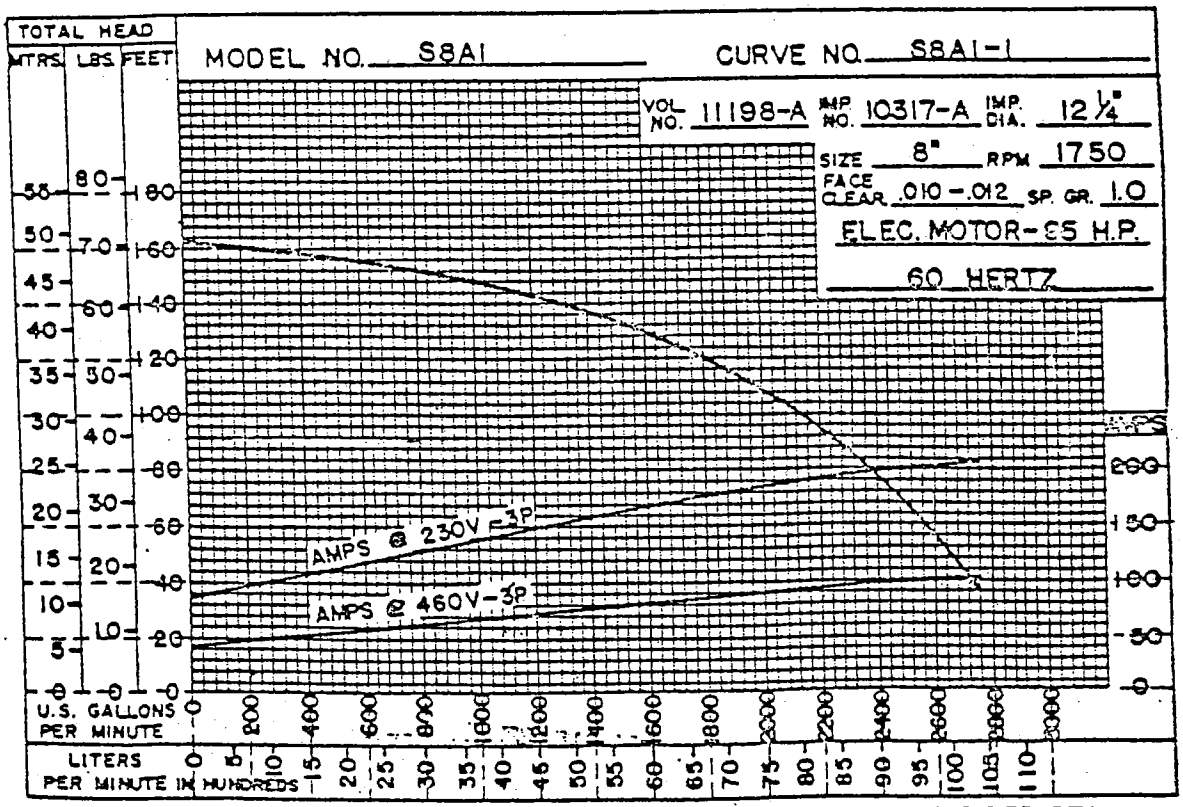
PUMP AND CABLE: Net Weight 935 lbs.
Shipping Weight 1070 lbs.
MOTOR CONTROL: Shipping Weight 150 lbs.
EXPORT SIZE: Pump: 36.0 Cu. Ft.

SPECIFICATION DATA

OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

SECTION 130, PAGE 700





T-10-10-75-REV.

GORMAN RUPP

THE GORMAN-RUPP COMPANY • MANSFIELD, OHIO

GORMAN RUPP OF CANADA LIMITED • ST. THOMAS, ONTARIO, CANADA

APPENDIX B-5

2706—12M—1-31-66

GEORGIA POWER COMPANY

Sheet ____ of ____

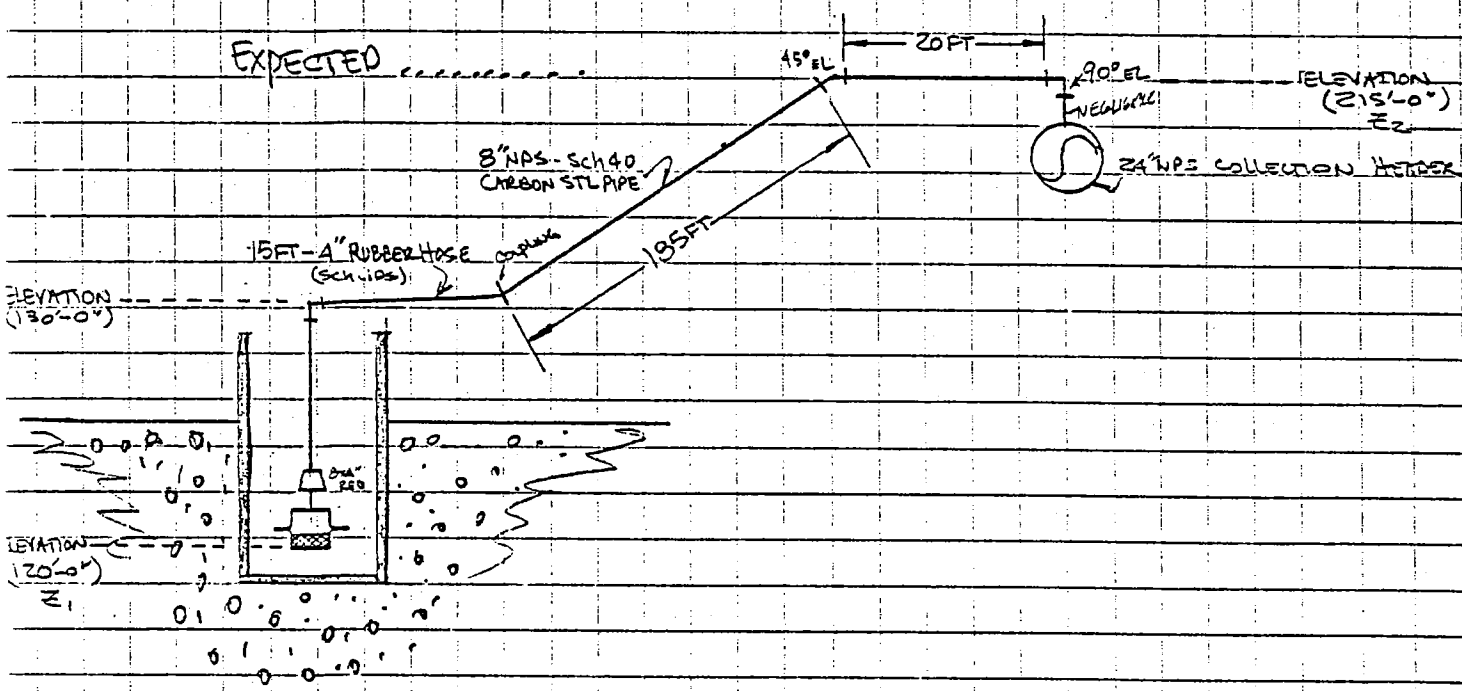
Subject DEWATERING PUMP PERFORMANCE

Project VOGTLE

POWER BLOCK SOUTH SLOPE - PUMP C

Computed by D. DAY Date 8-7-80 Checked by ____ Date ____

GIVEN: WATER AT (60°F) IS FLOWING THROUGH THE PIPING SYSTEM AS DETAILED BELOW. DEVELOP SYSTEM CURVE AND PUMP CURVE TO DETERMINE MAXIMUM RATE OF FLOW THAT CAN BE EXPECTED.....



PIPING SYSTEM CONFIGURATION

PUMP SPECS: (SEE DATA SHEET ATTACHED)

GORMAN-RUPP MODEL S8A1-1

RATED 2600 GPM @ 55FT HD

$d_1 = 7.981$ C.S. $d_2 = 4.260$

APPENDIX G-1

Subject Project

Computed by Date Checked by Date

SOLUTION:

I. FORMULAE

1)

See FIGURE 4

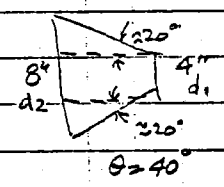
Subject Project

Computed by Date Checked by Date

II. COMPUTE SYSTEM PIPING HEAD LOSS —

$$h_f = \frac{0.00259\,KQ^2}{d^4}$$

K = 16 ft for 45° ELBOWS
K = 30 ft for 90° ELBOWS
K = 8.76 for 8x4 REDUCER
K = $f\frac{L}{D}$ for PIPING
PIPE ENTRANCE & EXIT NOT INCLUDED



$$K = \frac{0.8 \sin\frac{\theta}{2}(1-\beta^2)}{\beta^4}$$

$$\beta = \frac{d_1}{d_2} = \frac{4}{8} = .5$$

K for PIPE —

$$K = f_1\frac{L}{D} + f_2\frac{L}{D} \text{ (FOR HOSE \& C.S. PIPE)}$$

$f_1 = 0.015$ FOR C.S. PIPE ; $f_2 = 0.02$ FOR RUBBER HOSE (ESTIMATED)

$$K = \frac{(0.015)(205)(12)}{7.981} + \frac{(0.02)(15)(12)}{4.260}$$

$$K = 4.62 + 0.85 = 5.47$$

$f_T = 0.015$ (ESTIMATED ALL COMPONENTS)

K = (2)(16)(0.015) = 0.48 for 2-45° ELS
K = (2)(30)(0.015) = 0.9 for 2-90° ELS

$$K_{TOTAL} = 0.48 + 0.90 + 8.76 + 5.47 = 15.61$$

III Compute h_l over range of interest—

$$h_f = \frac{0.00259\,KQ^2}{d^4} \qquad K_{TOTAL} = 15.61 \qquad K_{7.981} = 0.48 + 0.45 + 4.62 = 5.55$$

$$K_{4.260} = 0.45 + 8.76 + 0.85 = 10.06$$

$$h_l = \frac{(0.00259)(5.55)(Q^2)}{(7.981)^4} + \frac{(0.00259)(10.06)(Q^2)}{(4.260)^4}$$

$$h_l = (3.54\times10^{-6})(Q^2) + 7.9\times10^{-5}(Q^2)$$

$h_l = 0.89 + 19.75 = 20.64$ for 500 GPM
$h_l = 3.54 + 79.0 = 82.54$ for 1000 GPM
$h_l = 14.16 + 316.0 = 330.16$ for 2000 GPM
$h_l = 23.93 + 534.0 = 557.93$ for 2600 GPM
$h_l = 31.86 + 711.0 = 742.86$ for 3000 GPM

IV $H_{REQ'D} = Z_1 - Z_2 + h_{l_{1-2}} + \frac{V_2^2}{2g}$

$$\left[\frac{V_2^2}{2g} = \frac{\left(\frac{0.408Q}{d^2}\right)^2 \text{ FT}^2/\text{SEC}^2}{64.4 \text{ FT/SEC}^2}\right]$$

a. $H_{REQ'D_{3000}} = 95 + 742.86$ x for 3000 GPM

b. $H_{REQ'D_{2600}} = 95 + 557.93$ x for 2600 GPM

c. $H_{REQ'D_{2000}} = 95 + 330.16$ x for 2000 GPM

d. $H_{REQ'D_{1000}} = 95 + 82.54$ x for 1000 GPM

e. $H_{REQ'D_{500}} = 95 + 20.64$ for 500 GPM

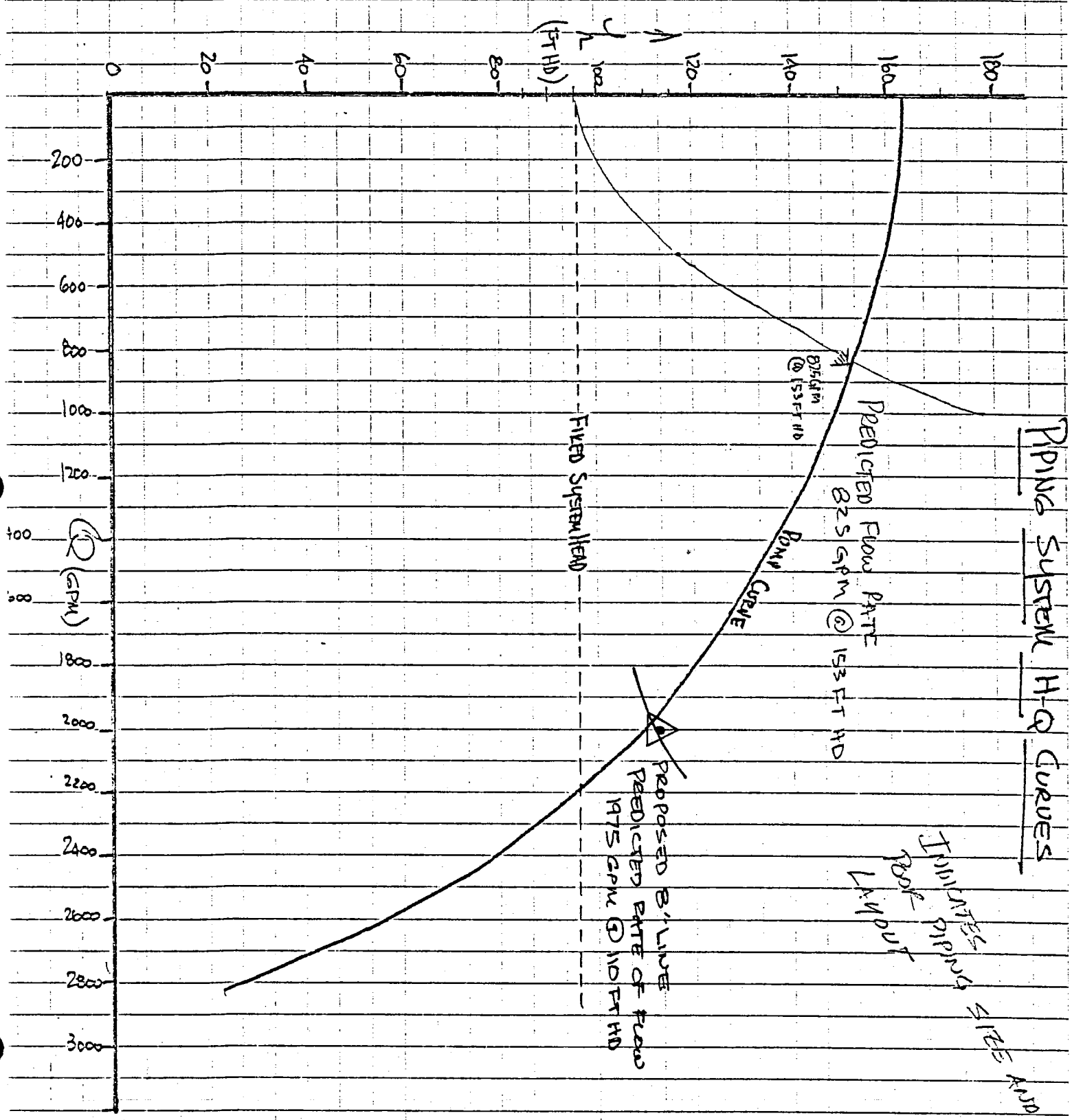
GEORGIA POWER COMPANY

Sheet ____ of ____

Subject: DEWATERING PUMP PERFORMANCE — POWER BLOCK SOUTH SLOPE - PUMP C

Project: VOGTLE

Computed by: D. DAY Date: 8-13-80 Checked by: ____ Date: ____



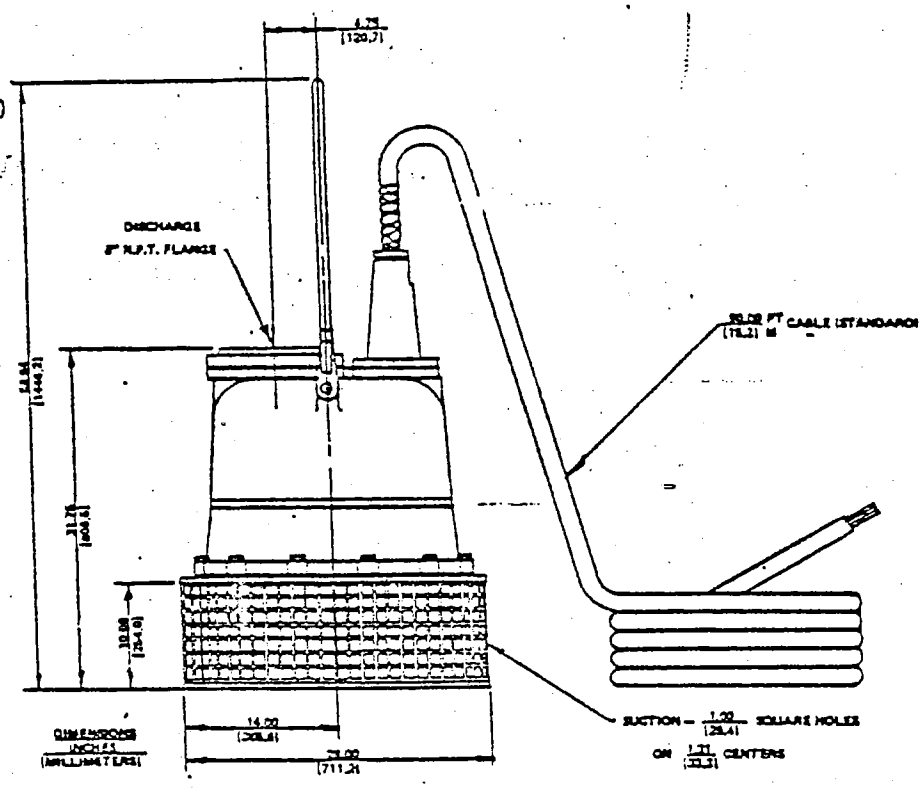
APPENDIX C-5

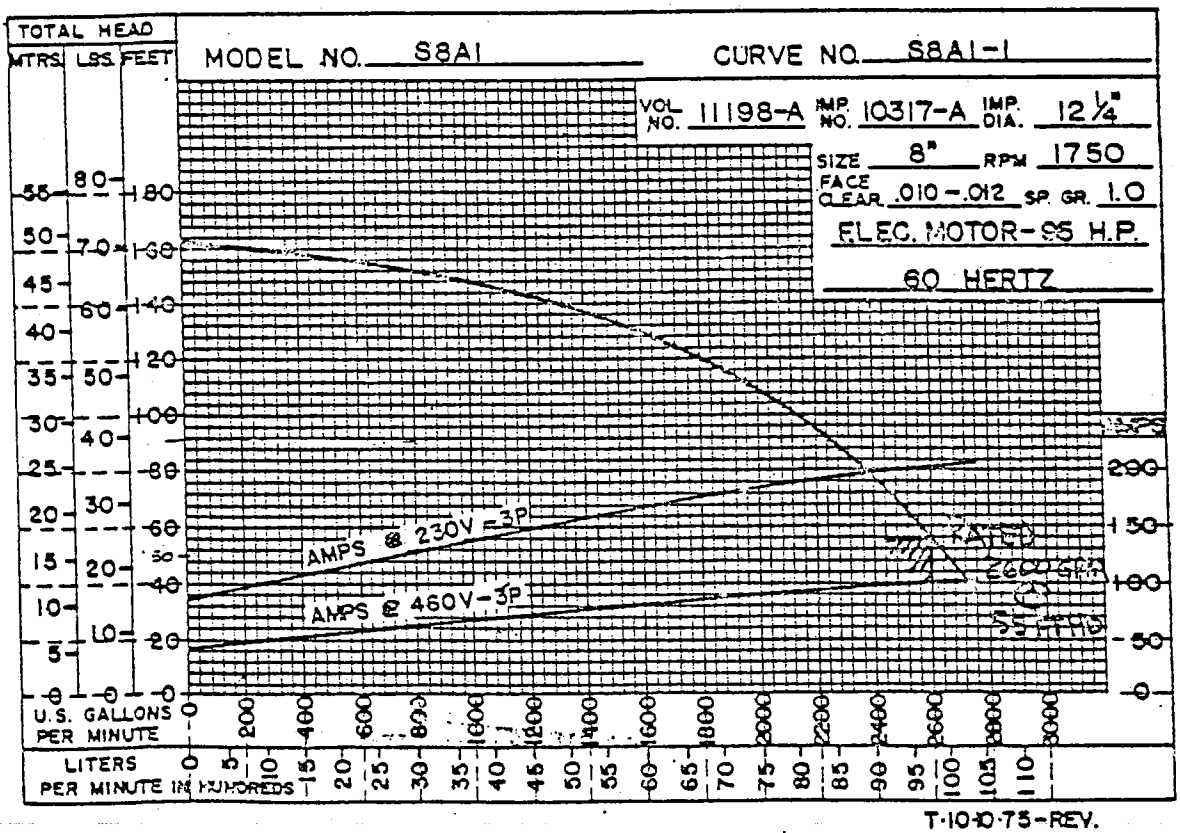
PUMP AND CABLE: Net Weight 935 lbs.
Shipping Weight 1070 lbs.
MOTOR CONTROL: Shipping Weight 150 lbs.
EXPORT SIZE: Pump; 36.0 Cu. Ft.

SPECIFICATION DATA

OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

SECTION 130, PAGE 700





T-10-10-75-REV.

APPENDIX C-6

Subject DEWATERING PUMP PERFORMANCE Project VOGTLE

POWER BLOCK SOUTH SLOPE – PUMP D

Computed by D. DAY Date 8-8-80 Checked by Date

PIPING SYSTEM LOSSES FOR THIS PUMP ARE ALMOST IDENTICAL TO THOSE LOSSES ENCOUNTERED IN THE PUMP E CONFIGURATION. FOR THAT REASON, A SEPARATE ANALYSIS FOR THIS PUMP WILL NOT BE PERFORMED. BASED ON SIMILARITY APPROACH, VALUES OBTAINED IN PUMP E CALCULATION SHALL APPLY FOR PUMP D WITH AN ESTIMATED ERROR NOT TO EXCEED -1% TO +5% OF PREDICTED FLOW RATE.

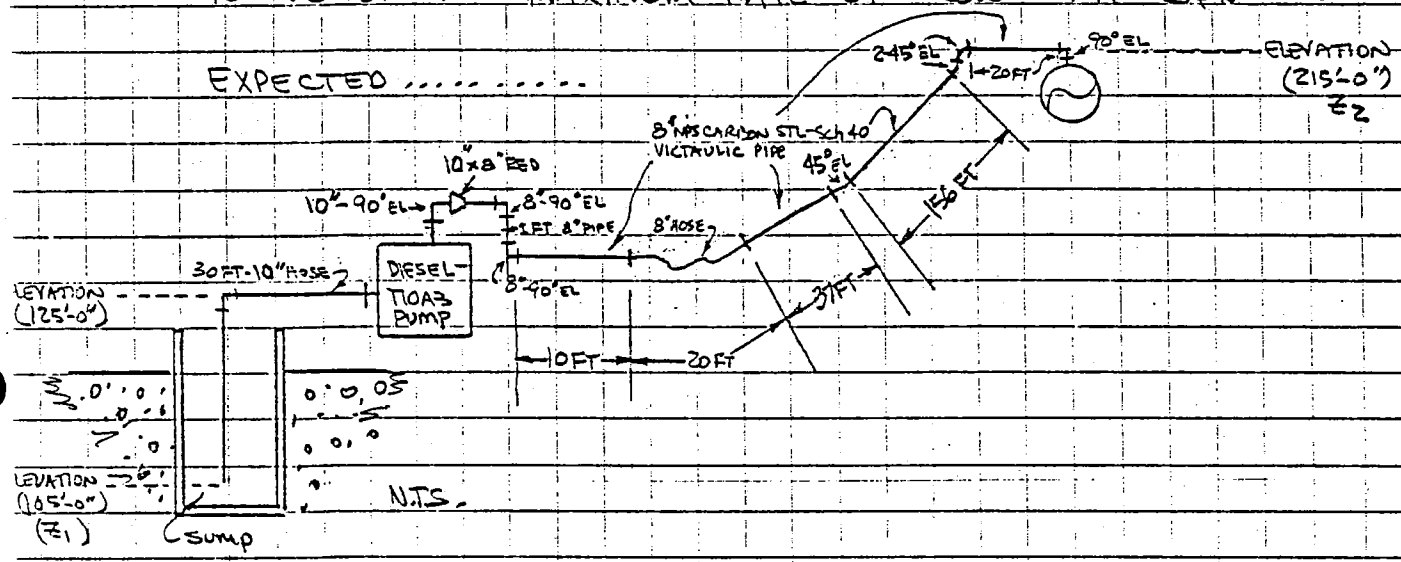
(SEE APPENDIX E)

Subject DEWATERING PUMP PERFORMANCE Project VOGTLE

POWER BLOCK SOUTHEAST CORNER - PUMP E

Computed by D. DAY Date 8-6-80 Checked by Date

GIVEN: WATER AT (60°F) IS FLOWING THROUGH THE PIPING SYSTEM AS DETAILED BELOW. DEVELOP SYSTEM CURVE AND PUMP CURVE TO DETERMINE MAXIMUM RATE OF FLOW THAT CAN BE EXPECTED .....



PIPING SYSTEM CONFIGURATION

PUMP SPECS: (SEE DATA SHEET ATTACHED)

GORMAN-RUPP MODEL T10A3-B-4031-C, SIZE 10"x10"

RATED 2750 GPM @ 90 FT HD

$d_1 = 10.420''$ (10" HOSE)

$d_2 = 7.981$ (8" PIPE)

$d_3 = 8.329$ (8" HOSE)

$f_T = 0.015$

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

SOLUTION =

I FORMULAS

1.

SEE FIGURE 4

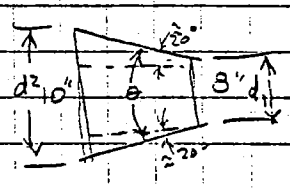
Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

II COMPUTE SYSTEM PIPING HEAD LOSS –

$$h_l = \frac{0.00259\,KQ^2}{d^4}$$

K = 30 ft for 90° ELBOWS
K = 16 ft for 45° ELBOWS
K = 2 for 10"x8" REDUCER
K = $f\frac{L}{D}$ for STRAIGHT PIPE
PIPE ENTRANCE & EXIT NOT INCLUDED



CRANE A-26

$$K = \frac{0.8 \sin\frac{\theta}{2}(1-\beta^2)}{\beta^4}$$

$$\beta = \frac{d_1}{d_2}$$

K for PIPE

$$K = f_1\frac{L}{D} + f_2\frac{L}{D} \text{ (FOR HOSE \& CS PIPE)}$$

f_1 = 0.015 for C.S. ; f_2 = 0.02 FOR RUBBER HOSE (ESTIMATED)

$$K = \underbrace{\frac{(0.015)(224)(12)}{7.981}}_{\text{(C.S. PIPE)}} + \underbrace{\frac{(0.02)(20)(12)}{8.329}}_{\text{(8" HOSE)}} + \underbrace{\frac{(0.02)(30)(12)}{10.420}}_{\text{(10" HOSE)}}$$

K = 6.32 for PIPING

f_T = 0.015 (ESTIMATED ALL COMPONENTS)

K = (5)(0.015)(30) = 2.25 for 5-90° ELBOWS
K = (3)(0.015)(16) = .72 for 3-45° ELBOWS

K_{TOTAL} = 2.25 + 0.72 + 6.32 + 2 = 11.29

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

III COMPUTE h_l OVER RANGE OF INTEREST

$$h_l = \frac{0.00259 K Q^2}{d^4}$$ K = 5.05 for 8" CS PIPE ; K = .58 for 8" hose ; K = 0.69 for 10" hose

$$h_l = \frac{(0.00259)(5.05)(Q)^2}{(7.981)^4} + \frac{(0.00259)(0.58)(Q)^2}{(8.329)^4} + \frac{(0.00259)(0.69)(Q)^2}{(10.420)^4}$$

$$h_l = (3.2\times10^{-6})(Q^2) + (3.1\times10^{-7})(Q^2) + (1.5\times10^{-7})(Q^2)$$

$h_l = 0.80 + 0.08 + 0.04 = 0.92$ for 500 GPM
$h_l = 3.2 + 0.31 + 0.15 = 3.66$ for 1000 GPM
$h_l = 12.8 + 1.24 + 0.6 = 14.64$ for 2000 GPM
$h_l = 21.63 + 2.10 + 1.01 = 24.74$ for 2600 GPM
$h_l = 28.80 + 2.79 + 1.35 = 32.94$ for 3000 GPM

IV $H_{REQ'D} = z_1 - z_2 + h_{l_{1-2}} + \frac{V_2^2}{2g}$ $\left[\frac{V^2}{2g} = \frac{\left(\frac{0.408 Q}{d^2}\right)^2 \text{FT}^2/\text{SEC}^2}{64.4 \text{ FT/SEC}^2} \right]$

a. $H_{REQ'D_{3000}} = 110 + 32.94 + 5.73 = 148.67$ FT for 3000 GPM

b. $H_{REQ'D_{2600}} = 110 + 24.74 + 4.31 = 139.05$ FT for 2600 GPM

c. $H_{REQ'D_{2000}} = 110 + 14.64 + 2.55 = 127.19$ FT for 2000 GPM

d. $H_{REQ'D_{1000}} = 110 + 3.66 + 0.64 = 114.3$ FT for 1000 GPM

e $H_{REQ'D_{500}} = 110 + 0.92 + 0.16 = 111.08$ FT for 500 GPM

GEORGIA POWER COMPANY

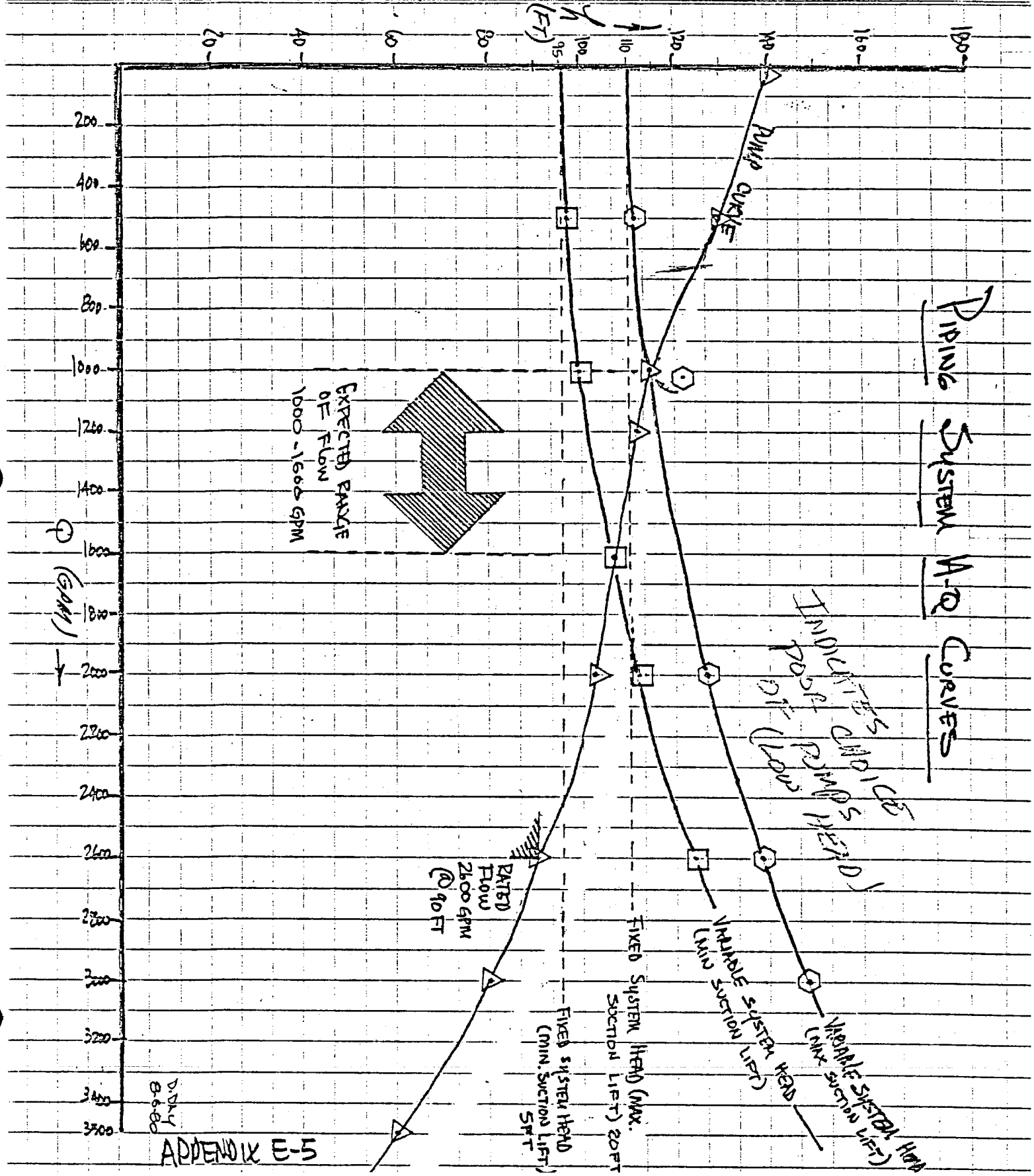
Sheet 5 of 7

Subject DEWATERING PUMP PERFORMANCE

Project VOGTLE

POWER BLOCK SOUTHEAST CORNER - PUMP E

Computed by D. DAY Date 8-6-80 Checked by Date



D. DAY 8-6-80

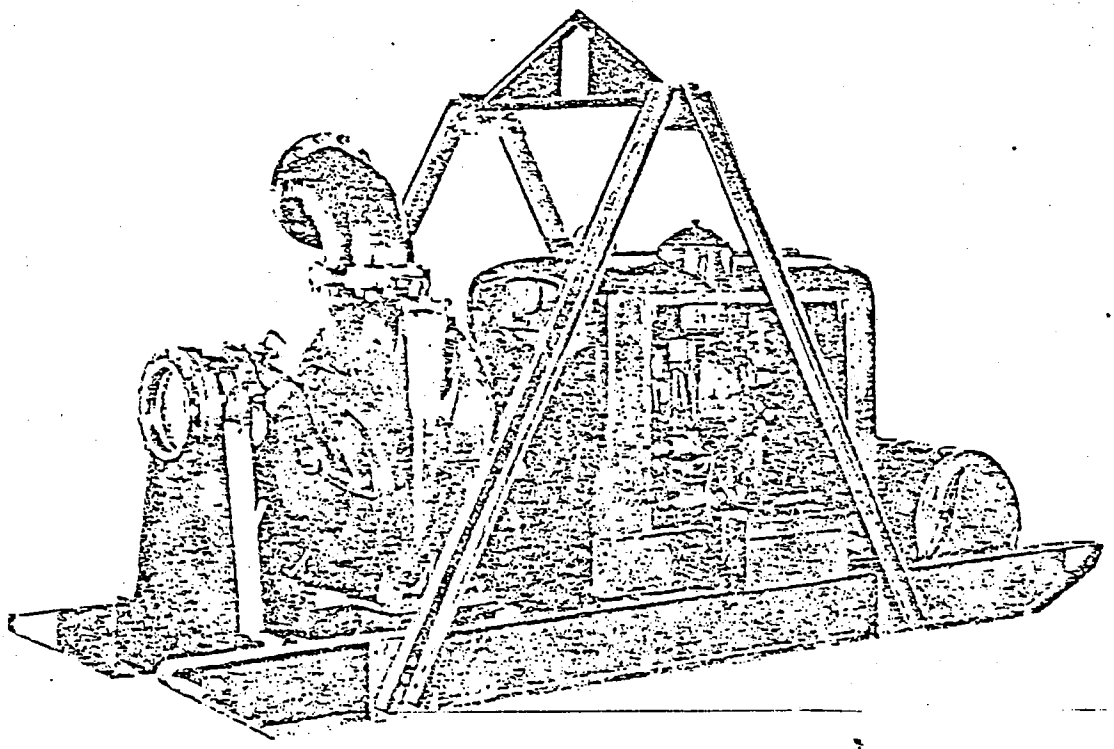
ADDENDIX E-5

Self Priming Centrifugal

DIESEL ENGINE DRIVEN

MODEL T10A3-B-4031-C

Size 10" x 10"



PUMP SPECIFICATIONS

Size: 10" Suction - 10" Discharge
Suction: Standard fitted with NPT Flange
Discharge: Standard fitted with NPT Flange
All Flanges: Gray Iron No. 30 – Class 125 Rated
Casing: Gray Iron No. 30 – Hydrostatic Test Pressure 150 lbs. Maximum Operating Pressure 80 lbs.
Impeller; Open Type, 2-Vane: Ductile Iron No. 60-40-18. Handles 3" spherical solids
Clean Out Cover: Removable – Gray Iron No. 30
Wear Ring: Ductile Iron No. 120-90-02
Wear Plate: Steel
Shaft Sleeve: Type 304 Stainless Steel
Impeller Shaft: Type 17-4 PH Stainless Steel
Bearing Housing: Gray Iron No. 30
Ball Bearings: Sealed, permanently lubricated
Seal: Oil lubricated, mechanical, with tungsten titanium carbide seal rings
O-Rings: Neoprene
Gaskets: Buna/Cork

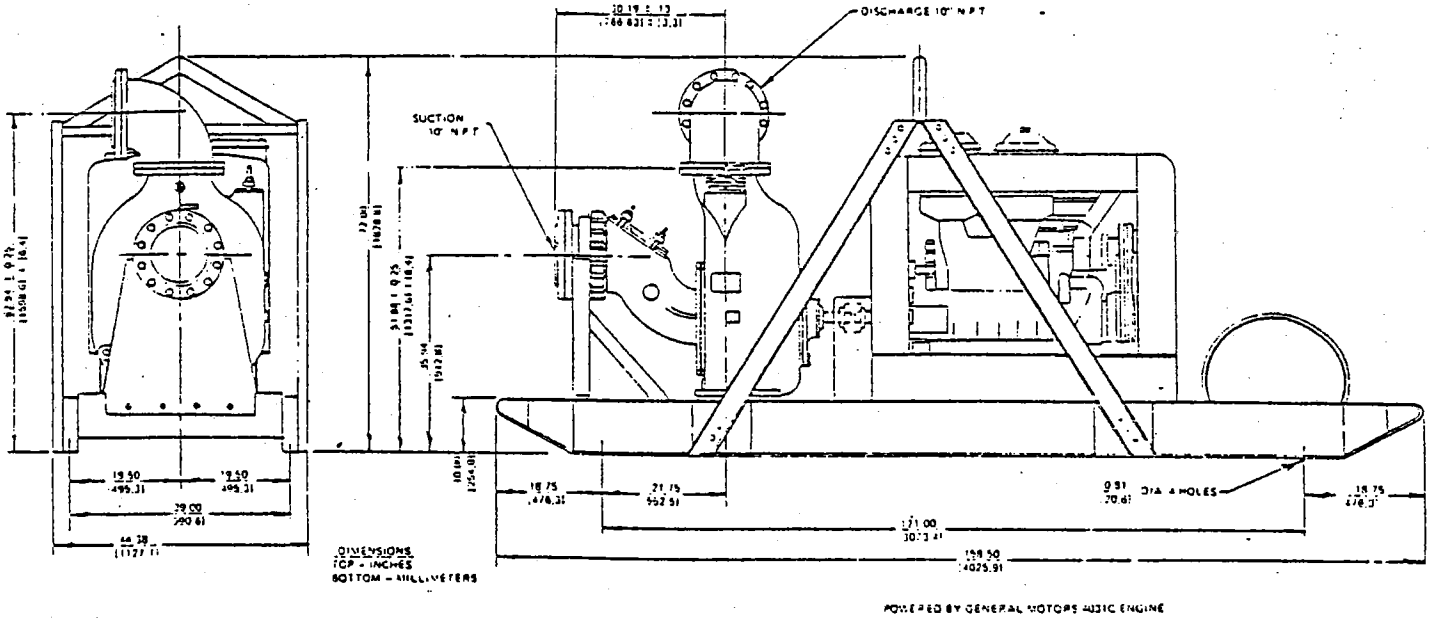
ENGINE SPECIFICATIONS

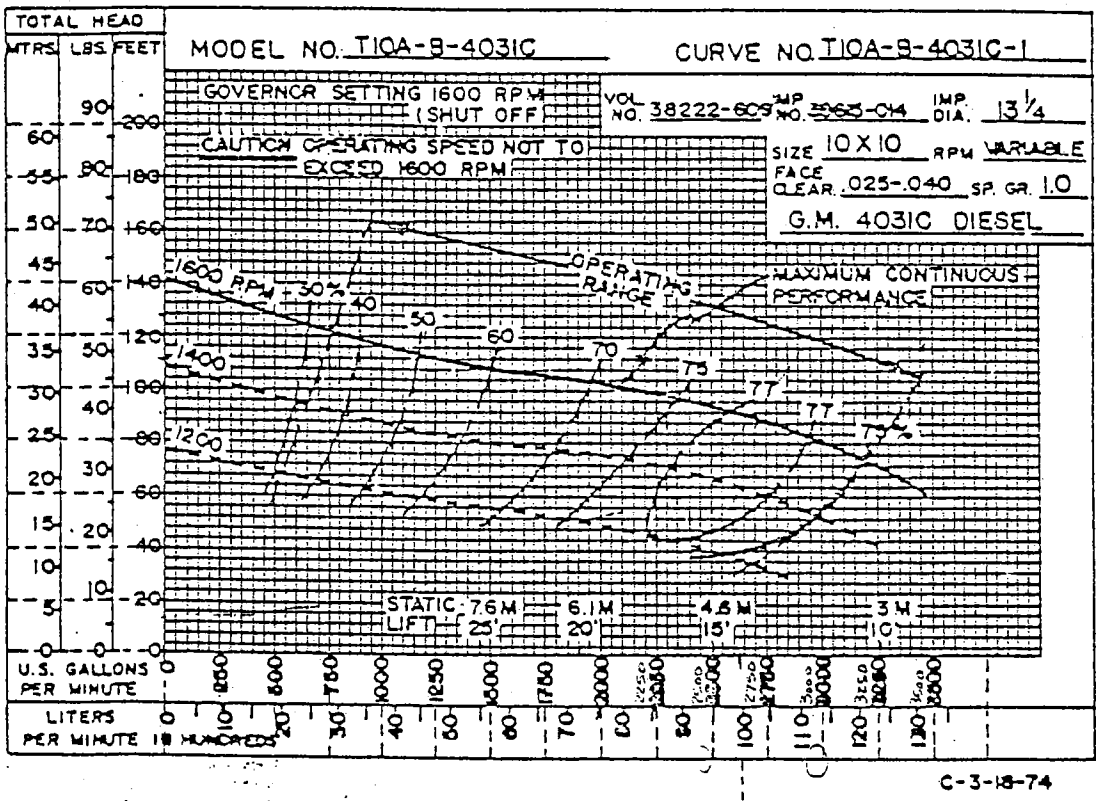
Model: GMC 4031C
Type: 4 cylinder, 2 cycle Diesel engine
Displacement: 284 cu. in.
Governor: Hydraulic
Lubrication: Forced Feed
Fuel Metering: Injectors
Air Cleaner: Oil Bath
Oil Reservoir: 17 Qt.
Starter: 12 volt electric
Fuel Tank: 55 Gal.
Engine Run Time: 9.55 Hours
GMC Published Performance
Max. Dyn. BHP 101 @ 1800 RPM
Max. Cont. BHP 85 @ 1600 RPM

SPECIFICATION DATA

OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

NET UNIT WEIGHT – 4900 lbs.





C-3-18-74

GORMAN-RUPP

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APPENDIX E-7

2786—1231—1-31-68

GEORGIA POWER COMPANY

Sheet ____ of ____

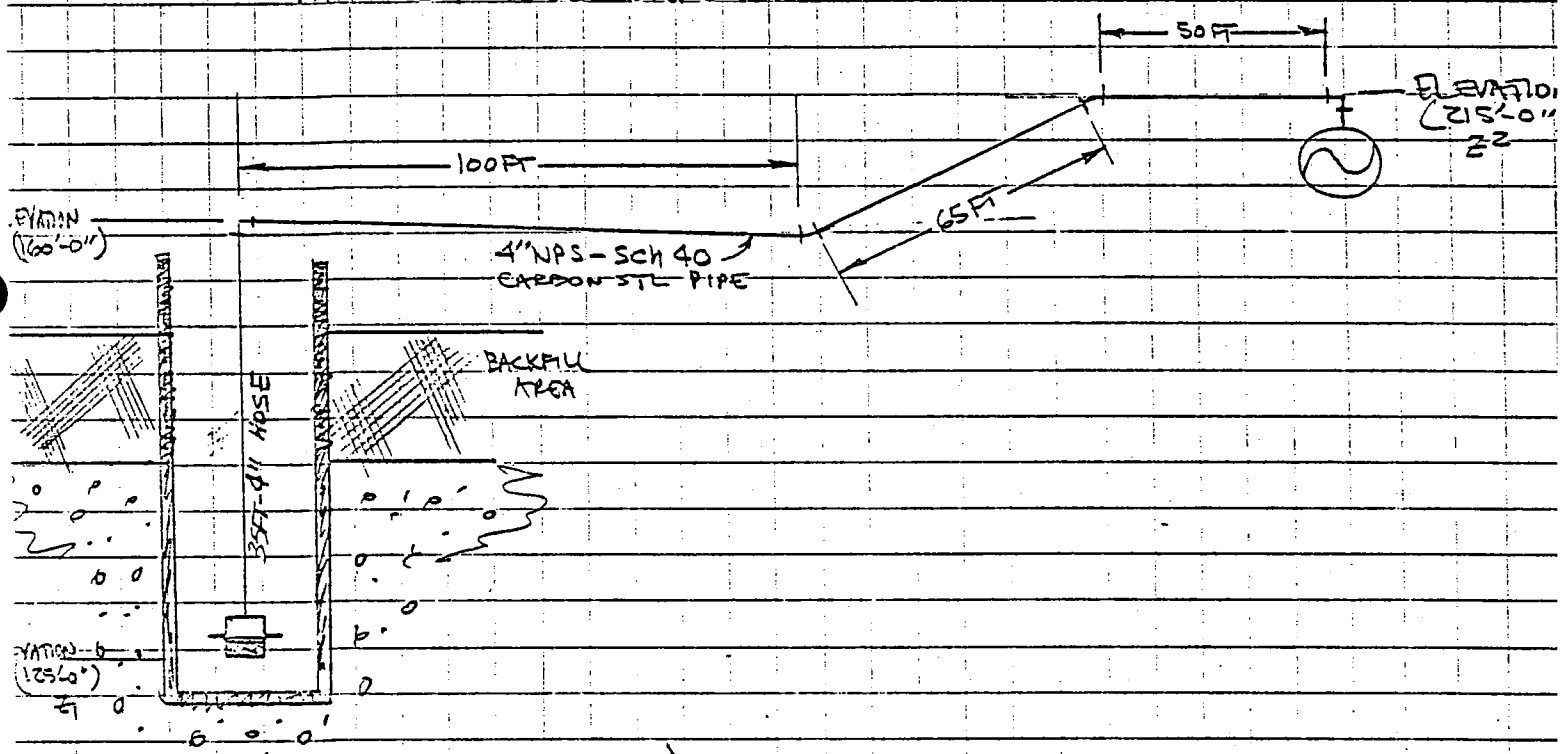
Subject: DEWATERING PUMP PERFORMANCE

Project: VOGTLE

POWER BLOCK SOUTH SLOPE - BACKFILL AREA - PUMP F

Computed by: D. DAY Date: 8-12-80 Checked by: ____ Date: ____

I. GIVEN: WATER AT (60°F) IS FLOWING THROUGH THE PIPING SYSTEM AS DETAILED BELOW. DEVELOP SYSTEM CURVE AND PUMP CURVE TO DETERMINE MAXIMUM RATE OF FLOW THAT CAN BE EXPECTED.....



PUMP SPECS: (SEE ATTACHED DATA SHEET)

GORMAN-RUPP MODEL S8A1-1

RATED 2600 GPM @ 55 FT HD

APPENDIX F-1

2766—12M—1-31-66 GEORGIA POWER COMPANY Sheet ____ of ____

Subject ____ Project ____

Computed by ____ Date ____ Checked by ____ Date ____

II COMPUTE SYSTEM PIPING HEAD LOSS —

$$h_l = \frac{0.00259\, KQ^2}{d^4}$$

K = 30 FT for 90° ELs
K = 16 FT for 45° ELs
K = 1 for PIPE ENTRANCE
K = 1 for PIPE EXIT
$K = f\frac{L}{D}$ for PIPING

K for PIPE

$$K = f\frac{L}{D} = \frac{(0.017)(250)(12)}{4.026}$$

K = 12.67

K = (2)(.017)(30) = 1.02 for 2-90° ELs
K = (2)(.017)(16) = 0.54 for 2-45° ELs

K_{TOTAL} = 1.02 + 0.54 + 1.0 + 1.0 + 12.67

K_{TOTAL} = 16.23

PROPOSED 8" LINE

$$K = f\frac{L}{D}$$

$$K = \frac{(0.014)(250)(12)}{7.981}$$

K = 5.26

K_{TOTAL} = 8.82

III COMPUTE h_l OVER RANGE OF INTEREST —

$$h_l = \frac{0.00259 K Q^2}{d^4} \qquad K_{TOTAL} = 16.23$$

$$h_l = \frac{(0.00259)(16.23)\,Q^2}{(4.026)^4}$$

$$h_l = 1.6 \times 10^{-4} Q^2$$

$h_{l_{500}} = 40$ FT $\qquad h_{l_{800}} = 102.4$

$h_{l_{1000}} = 160$ FT

$h_{l_{2000}} = 640$ FT

$h_{l_{2600}} = 1081.6$ FT

$h_{l_{3000}} = 1440$ FT

INDICATES EXTRAORDINARY SYSTEM HEAD LOSSES (INCORRECT PIPE SIZE SELECTION)

RECOMMENDED 8" LINE

$K_{TOTAL} = 8.82$

$h_{l_{500}} = 1.41$ FT

$h_{l_{1000}} = 5.63$ FT

$h_{l_{2000}} = 22.52$ FT

$h_{l_{2600}} = 33.06$ FT

$h_{l_{3000}} = 50.67$ FT

IV $$H_{REQ'D} = z_1 - z_2 + h_{l_{1-2}} + \frac{V_2^2}{2g}$$

$$\frac{V_2^2}{2g} = \frac{\left(\frac{0.408\,Q}{d^2}\right)^2 \text{FT}^2/\text{SEC}^2}{64.4 \text{ FT/SEC}^2}$$

$H_{REQ'D\ 3000} = 90 + 1440 +$

$H_{REQ'D\ 2600} = 90 + 1081.6 +$

$H_{REQ'D\ 2000} = 90 + 640 +$

$H_{REQ'D\ 1000} = 90 + 160 +$

$H_{REQ'D\ 500} = 90 + 40 + 2.46 = 132.5$

RECOMMENDED 8" LINE

$H_{REQ'D\ 3000} = 90 + 50.67 + 5.73 = 1$

$H_{REQ'D\ 2600} = 90 + 38.06 + 4.31 = 1$

$H_{REQ'D\ 2000} = 90 + 22.52 + 2.55 = 1$

$H_{REQ'D\ 1000} = 90 + 5.63 + 0.64 = 9$

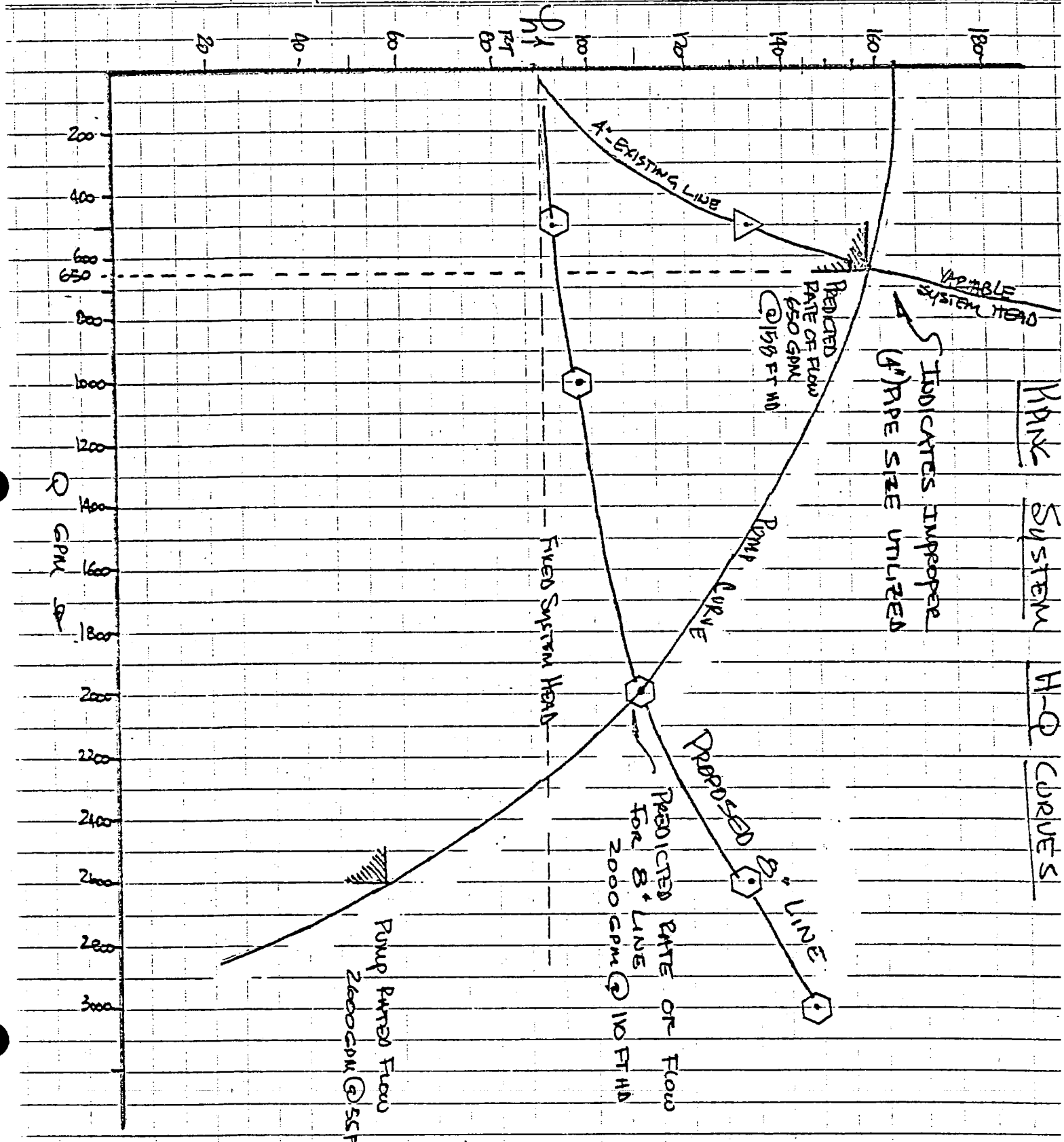
$H_{REQ'D\ 500} = 90 + 1.41 + 0.16 = 9$

1766—12M—1-31-66 GEORGIA POWER COMPANY Sheet ____ of ____

Subject DEWATERING PUMP PERFORMANCE Project VOGTLE

POWER BLOCK SOUTH SLOPE - PUMP F

Computed by D. DAY Date 8-13-80 Checked by ____ Date ____



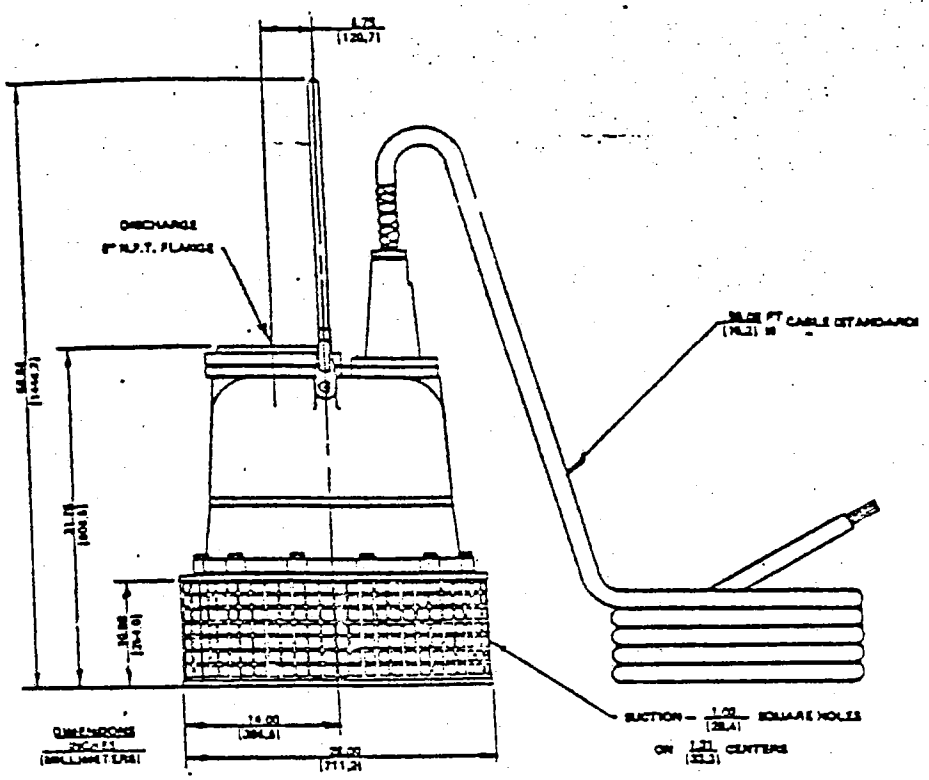
ADDENDUM F4

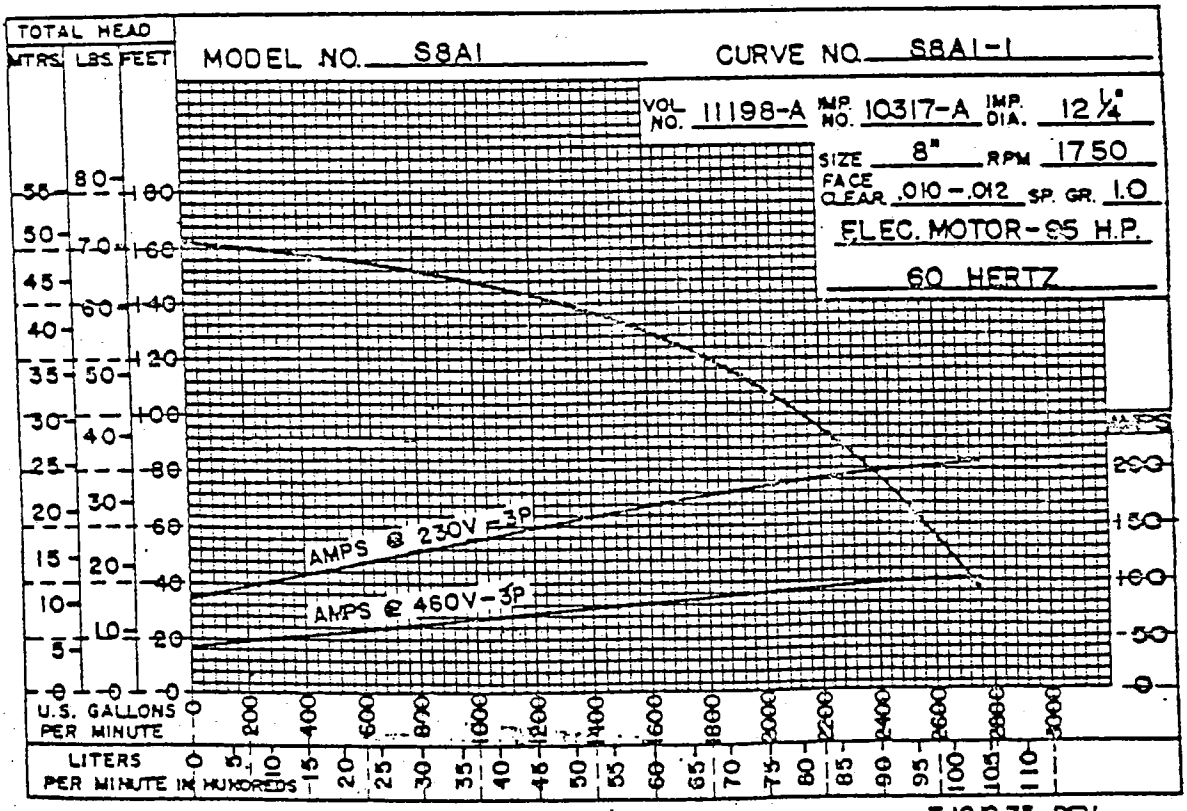
PUMP AND CABLE: Net Weight 935 lbs.
Shipping Weight 1070 lbs.
MOTOR CONTROL: Shipping Weight 150 lbs.
EXPORT SIZE: Pump; 36.0 Cu. Ft.

SPECIFICATION DATA

OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

SECTION 130, PAGE 700





T-10-10-75-REV.

GORMAN-RUPP

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APPENDIX F-5

2766—12M—1-31-66

GEORGIA POWER COMPANY

Sheet 1 of 6

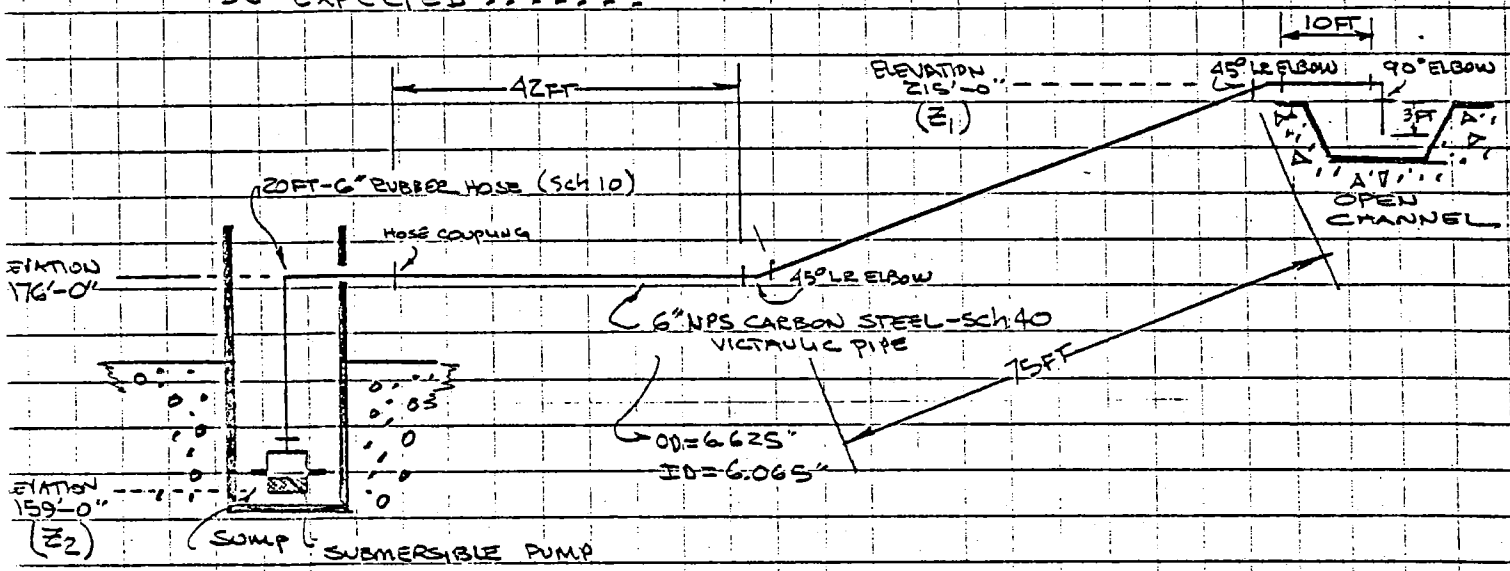
Subject DEWATERING PUMP PERFORMANCE

Project VOGTLE

POWER BLOCK NORTHEAST CORNER - PUMP G

Computed by D. DAY Date 8-6-80 Checked by Date

I. GIVEN: WATER AT (60°F) IS FLOWING THROUGH THE PIPING SYSTEM AS DETAILED BELOW. DEVELOP SYSTEM CURVE AND PUMP CURVE TO DETERMINE MAXIMUM RATE OF FLOW THAT CAN BE EXPECTED .....



PIPING SYSTEM CONFIGURATION

PUMP SPECS: (SEE DATA SHEET ATTACHED)

GORMAN RUPP MODEL S8A1-1

RATED - 2600 GPM @ 55 FT HD

$d = 6.065_{GP} \ \& \ 6.357_{HOSE}$

$f_T = 0.015$

APPENDIX G-1

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

SOLUTION:

I. FORMULAE

SEE FIGURE 4

II. COMPUTE SYSTEM PIPING HEAD LOSS —

$$h_l = \frac{0.00259\,KQ^2}{d^4}$$

K = 25 ft LONG RADIUS 45° ELBOWS
K = 30 ft 90° ELBOWS
K = 1.0 PIPE EXIT
$K = f\frac{L}{D}$ STRAIGHT PIPE

PUMP FLANGE REDUCER, HOSE COUPLING AND VICTAULIC COUPLINGS NOT CONSIDERED

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

II CONT'D

K FOR PIPE —

$K = f_1 \frac{L}{D} + f_2 \frac{L}{D}$ (FOR HOSE & C.S. PIPE)

$f_1 = 0.015$ FOR CARBON STL ; $f_2 = 0.02$ FOR RUBBER HOSE (ESTIMATED)

$\therefore K = \frac{(0.015)(120)(12)}{6.065} + \frac{(0.02)(20)(12)}{6.357}$ (USED SCH 10S FOR HOSE ID)

$K = 4.32$ FOR PIPING

$f_T = 0.015$ (ESTIMATED ALL COMPONENTS)

$K = (2)(0.015)(25) = 0.75$ FOR 2-45° LR ELS

$K = (2)(0.015)(30) = 0.9$ FOR 2-90° ELS

$K_{TOTAL} = 0.75 + 0.9 + 4.32 = 5.97$

III. COMPUTE h_l OVER RANGE OF INTEREST

$h_l = \frac{0.00259 K Q^2}{d^4}$

$h_l = \frac{(0.00259)(5.97)(Q)^2}{(6.065)^4} = (1.143 \times 10^{-5})(Q)^2$

$h_l = (1.143 \times 10^{-5})(100)^2 = .11$ FT for 100 GPM

$h_l = (1.143 \times 10^{-5})(500)^2 = 2.86$ FT for 500 GPM

$h_l = (1.143 \times 10^{-5})(1000)^2 = 11.43$ FT for 1000 GPM

$h_l = (1.143 \times 10^{-5})(2000)^2 = 45.72$ FT for 2000 GPM

$h_l = (1.143 \times 10^{-5})(2600)^2 = 77.27$ FT for 2600 GPM

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

$$\frac{V^2}{2g} = \frac{\left(\frac{0.408Q}{d^2}\right)^2 FT^2/SEC^2}{64.4\ FT/SEC^2}$$

IV $H_{REQ'D} = (Z_1 - Z_2) + h_{l_{1-2}} + \frac{V^2}{2g}$

a. $H_{REQ'D_{2600}} = 56 + 77.27 + 12.91 = 146.18$ FT for 2600 GPM

b. $H_{REQ'D_{2000}} = 56 + 45.72 + 7.64 = 109.36$ FT for 2000 GPM

c. $H_{REQ'D_{1000}} = 56 + 11.43 + 1.91 = 69.34$ FT for 1000 GPM

d. $H_{REQ'D_{500}} = 56 + 2.86 + 0.48 = 59.34$ FT for 500 GPM

2766—12M—1-31-66

GEORGIA POWER COMPANY

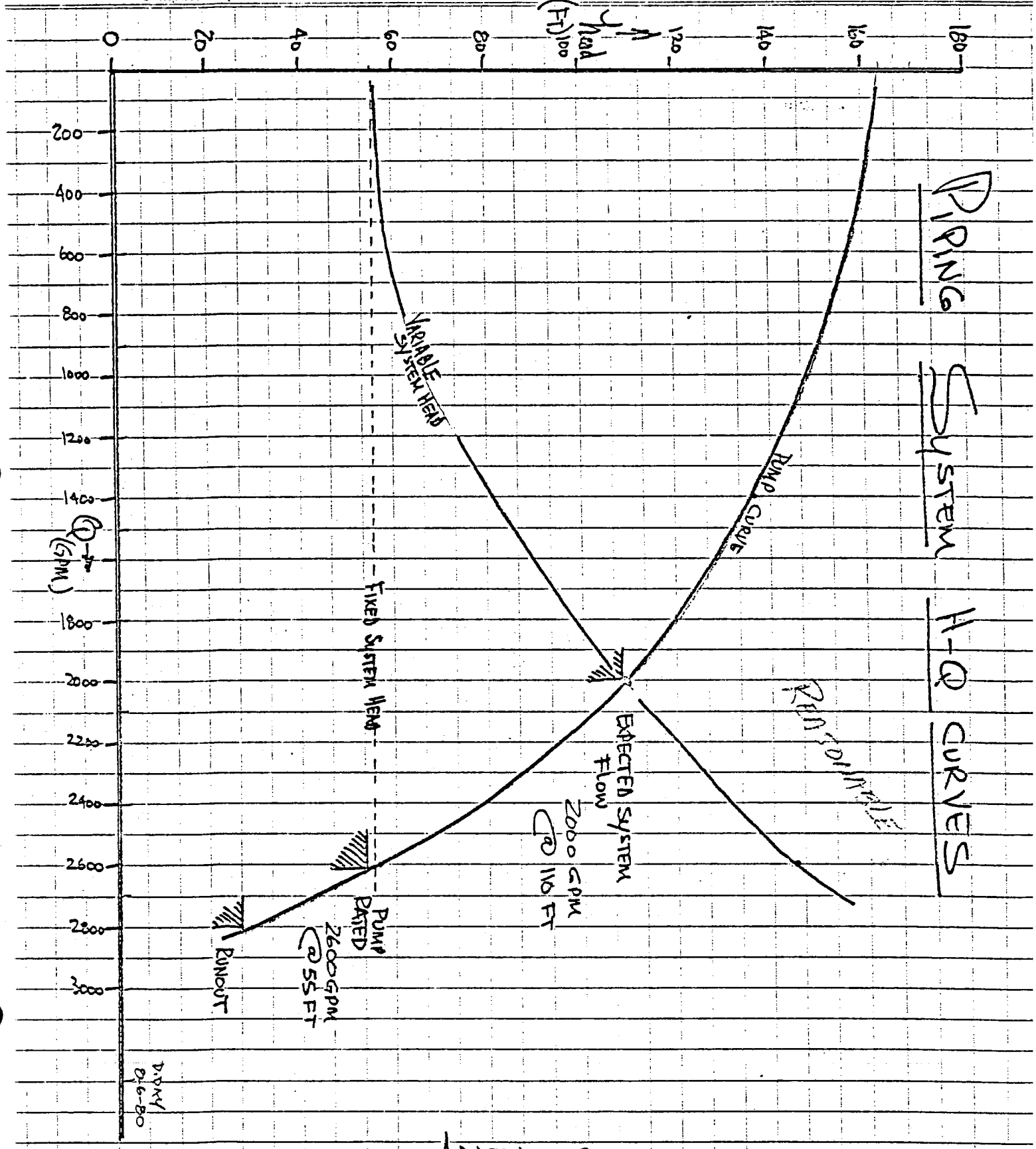
Sheet 5 of 6

Subject DEWATERING PUMP PERFORMANCE

Project VOGTLE

POWER BLOCK NORTHEAST CORNER - PUMP 6

Computed by D. DAY Date 8-6-80 Checked by Date



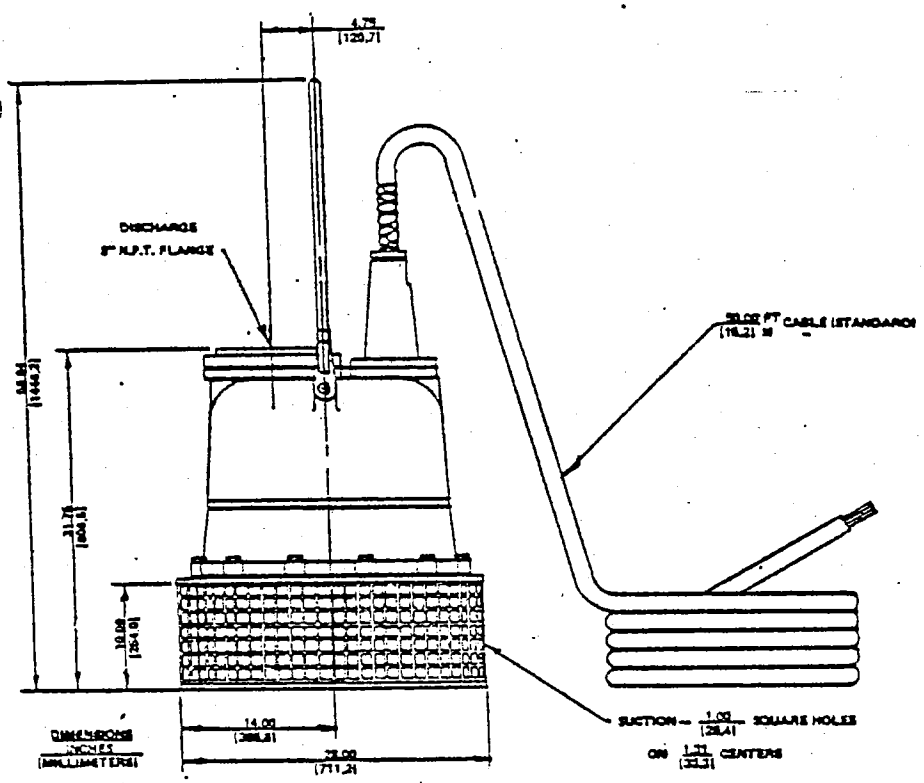
ADDENDIX G-5

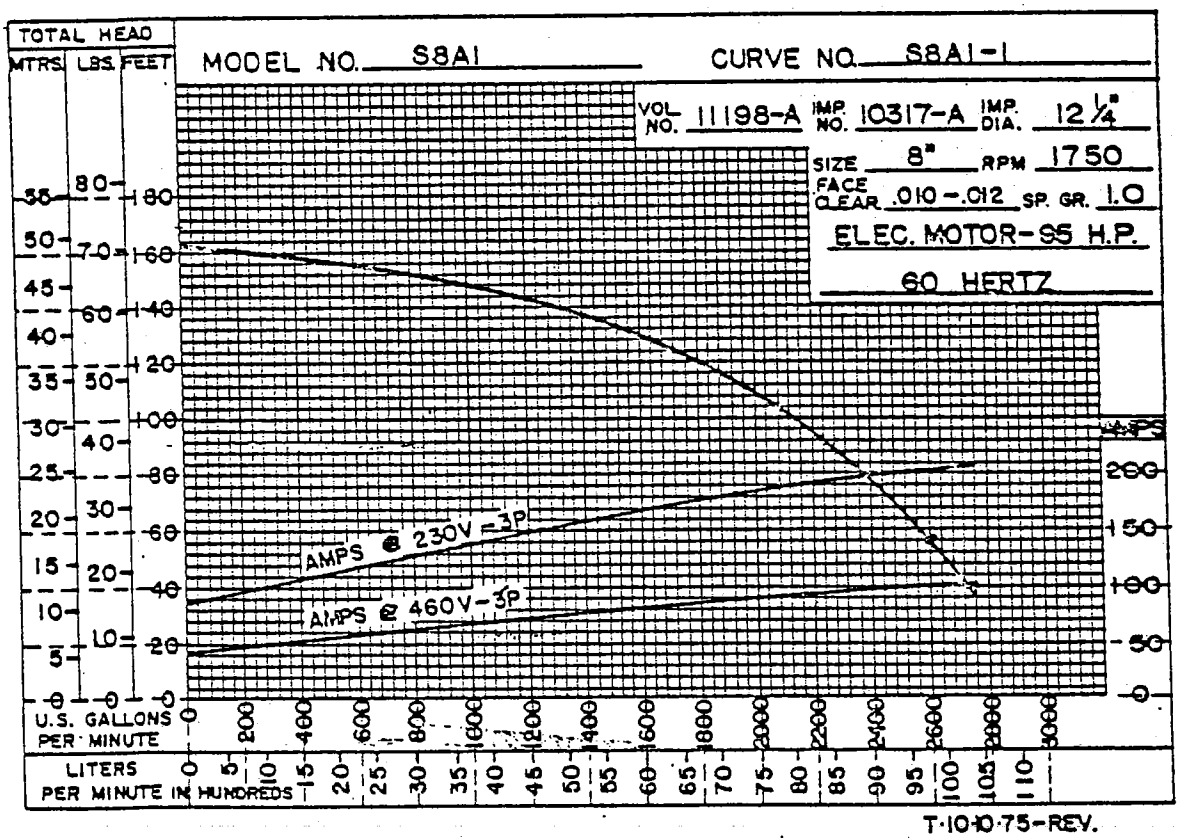
PUMP AND CABLE: Net Weight 935 lbs.
Shipping Weight 1070 lbs.
MOTOR CONTROL: Shipping Weight 150 lbs.
EXPORT SIZE: Pump; 36.0 Cu. Ft.

SPECIFICATION DATA

OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

SECTION 130, PAGE 700





T-1010-75-REV.

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APPENDIX G-6

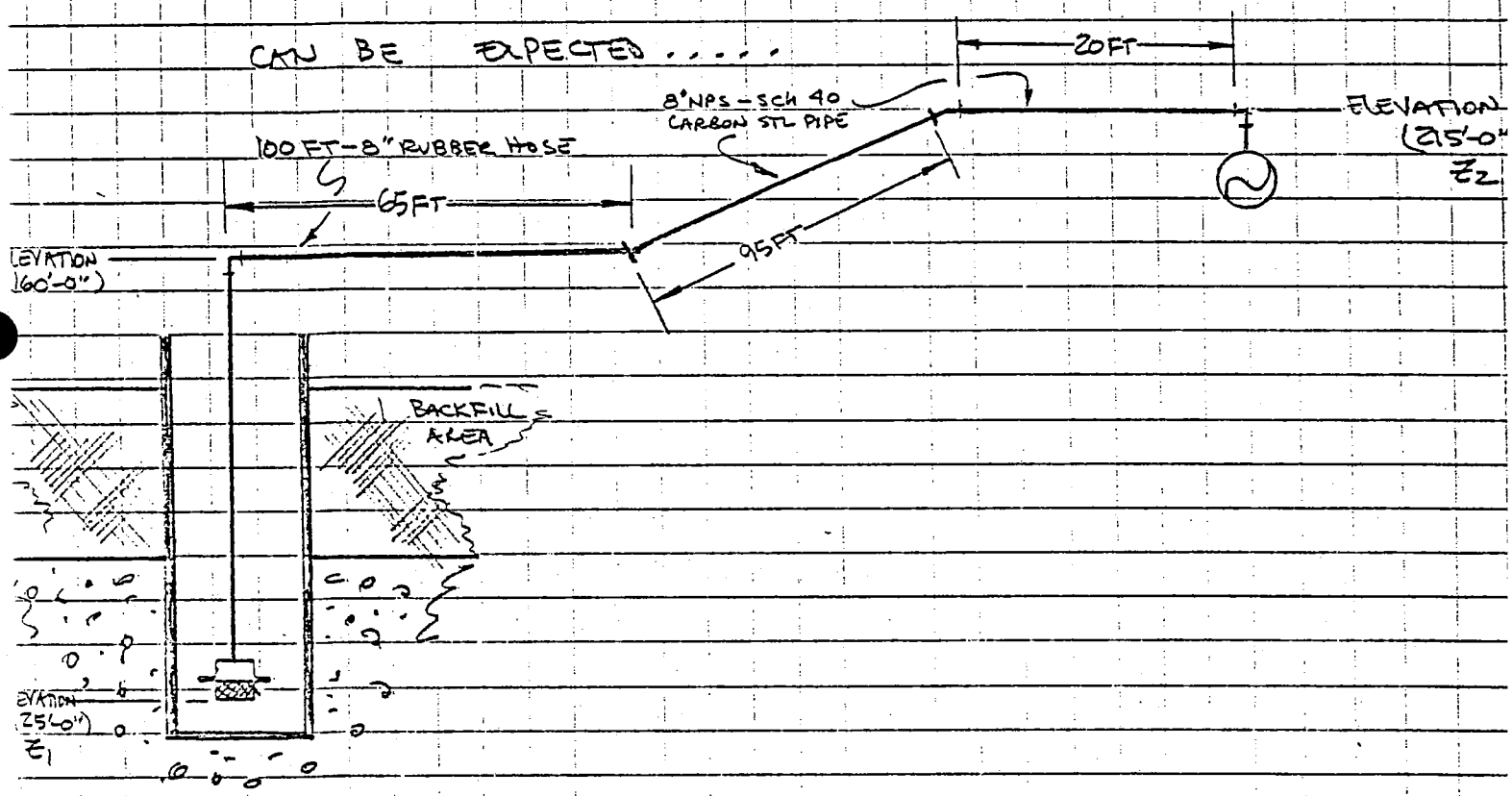
2766—12M—1-81-66 GEORGIA POWER COMPANY Sheet ____ of ____

Subject DEWATERING PUMP PERFORMANCE Project VOGTLE

POWER BLOCK SOUTH SLOPE – BACKFILL AREA – PUMP H

Computed by D. DAY Date 8-8-80 Checked by ____ Date ____

GIVEN: WATER AT (60°F) IS FLOWING THROUGH THE PIPING SYSTEM AS DETAILED BELOW. DEVELOP SYSTEM CURVE AND PUMP CURVE TO DETERMINE MAXIMUM RATE OF FLOW THAT CAN BE EXPECTED.....



PUMP SPECS: (SEE ATTACHED DATA SHEET)

GORMAN-RUPP MODEL S8A1-1

RATED 2600 GPM @ 55 FT HD

II COMPUTE SYSTEM PIPING HEAD LOSS —

$$h_l = \frac{0.00259\,KQ^2}{d^4}$$

K = 30 FT for 90° ELBOW
K = 16 FT for 45° ELBOW
K = 1 for PIPE ENTRANCE
K = 1 for PIPE EXIT
$K = f\frac{L}{D}$ for PIPING

K for PIPE

$$K = f\frac{L}{D} = \frac{(0.015)(215)(12)}{7.981}$$

K = 4.85

K = (2)(30)(0.015) = 0.90 for 2-90° ELS
K = (2)(16)(0.015) = 0.48 for 2-45° ELS

$K_{TOTAL} = 0.90 + 0.48 + 1.0 + 1.0 + 4.85 = 8.23$

III COMPUTE h_l OVER RANGE OF INTEREST —

$$h_l = \frac{0.00259 K Q^2}{d^4} \qquad K_{TOTAL} = 8.23$$

$$h_l = \frac{(0.00259)(8.23)(Q^2)}{(7.981)^4}$$

$$h_l = (5.25 \times 10^{-6})(Q^2)$$

$h_{l_{500}} = 1.31$ FT for 500 GPM

$h_{l_{1000}} = 5.25$ FT for 1000 GPM

$h_{l_{2000}} = 21.02$ FT for 2000 GPM

$h_{l_{2600}} = 35.52$ FT for 2600 GPM

$h_{l_{3000}} = 47.28$ FT for 3000 GPM

IV $H_{REQ'D} = Z_1 - Z_2 + h_{l_{1-2}} + \frac{V_2^2}{2g}$ $\qquad \left[\frac{V_2^2}{2g} = \frac{\left(\frac{0.4080Q}{d^2}\right)^2 \text{ FT}^2/\text{SEC}^2}{64.4 \text{ FT/SEC}^2}\right.$

$H_{REQ'D_{3000}} = 47.28 + 90 + 5.73 = 143.01$ FT for 3000 GPM

$H_{REQ'D_{2600}} = 35.52 + 90 + 4.31 = 129.83$ FT for 2600 GPM

$H_{REQ'D_{2000}} = 21.02 + 90 + 2.55 = 113.57$ FT for 2000 GPM

$H_{REQ'D_{1000}} = 5.25 + 90 + 0.64 = 95.89$ FT for 1000 GPM

$H_{REQ'D_{500}} = 1.31 + 90 + 0.16 = 91.47$ FT for 500 GPM

2766—12M—1-31-66

GEORGIA POWER COMPANY

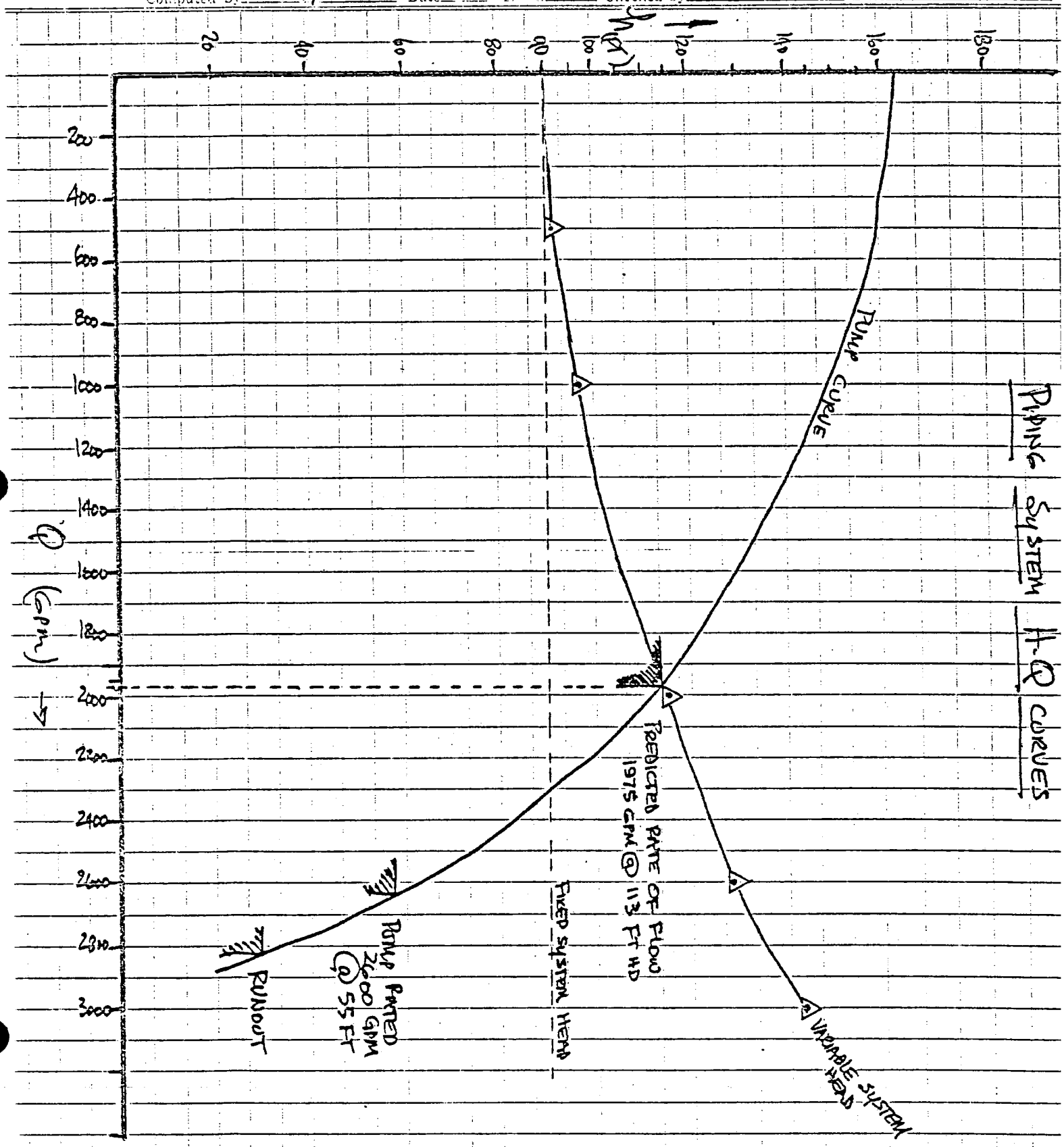
Sheet _____ of _____

Subject DEWATERING PUMP PERFORMANCE

Project VOGTLE

POWER BLOCK SOUTH SLOPE - BACKFILL AREA - PUMP H

Computed by D. DAY Date 8-8-80 Checked by _____ Date _____

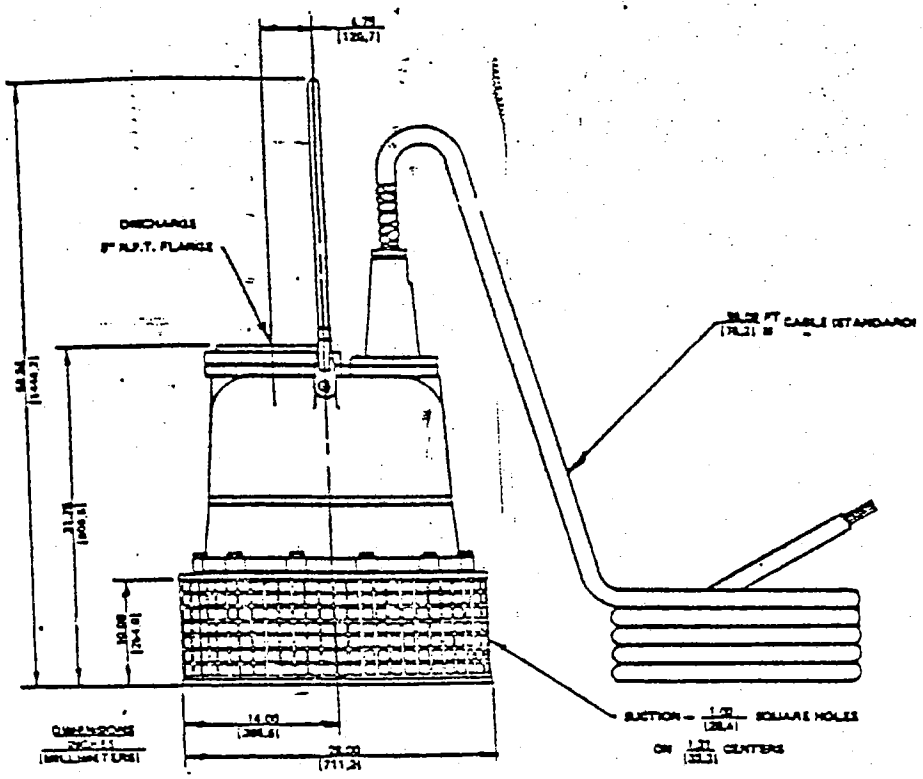


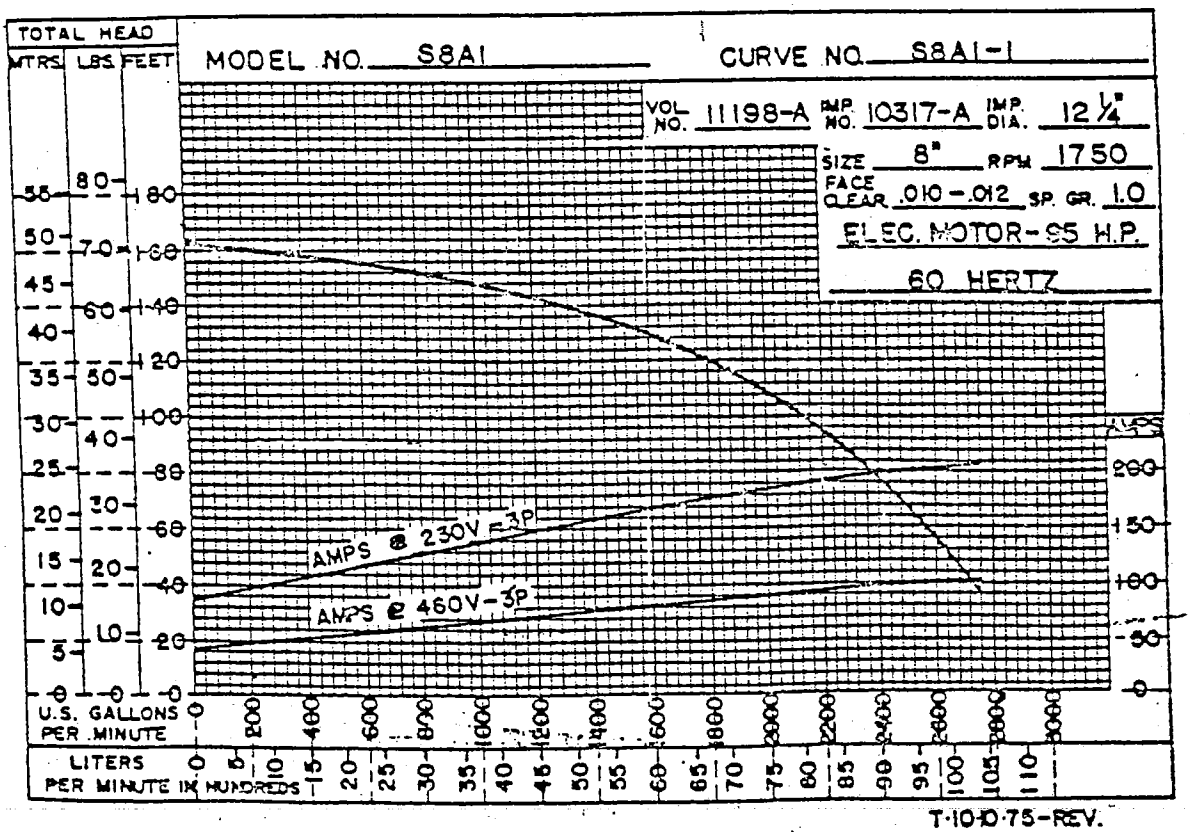
PUMP AND CABLE: Net Weight 935 lbs.
Shipping Weight 1070 lbs.
MOTOR CONTROL: Shipping Weight 150 lbs.
EXPORT SIZE: Pump; 36.0 Cu. Ft.

SPECIFICATION DATA

OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

SECTION 130, PAGE 700





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APPENDIX II-E

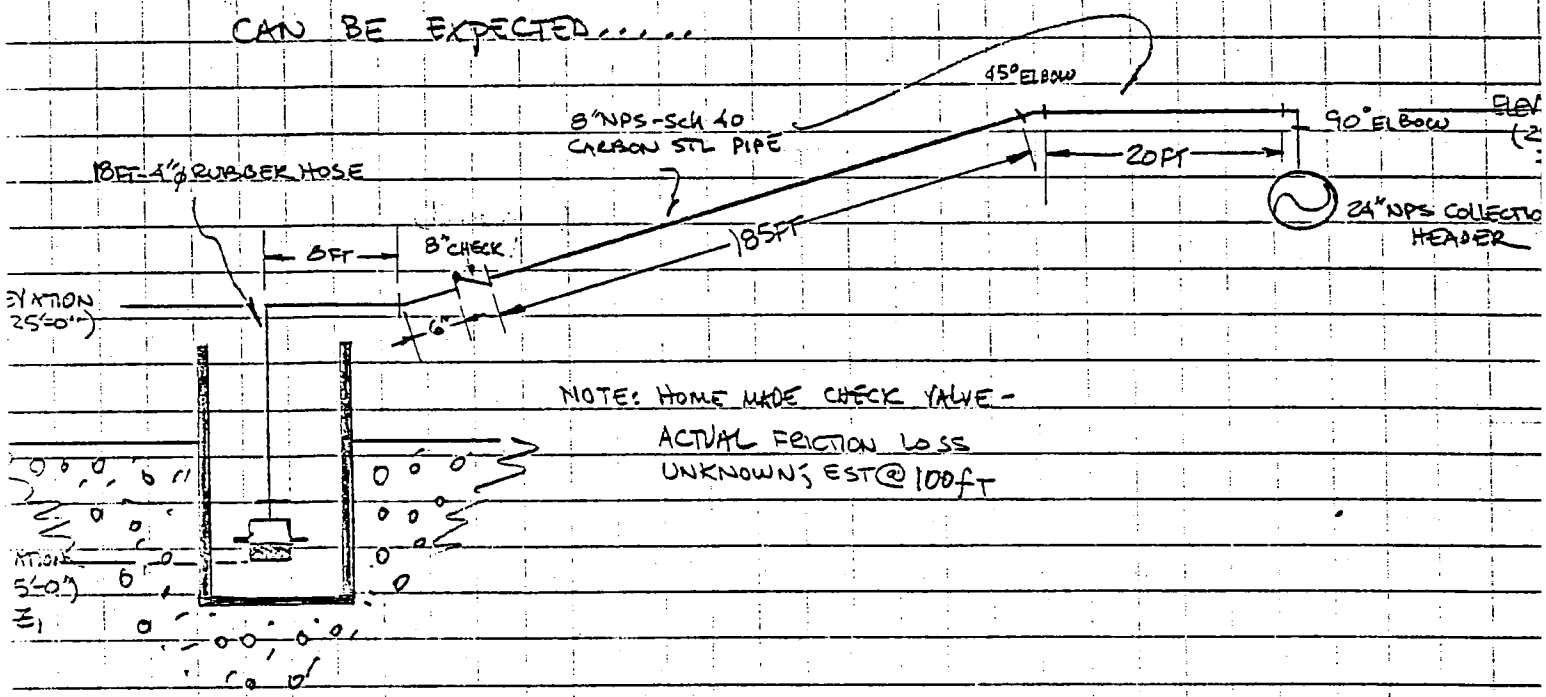
1766—12M—1-31-66 GEORGIA POWER COMPANY Sheet ____ of ____

Subject DEWATERING PUMP PERFORMANCE Project VOGTLE

POWER BLOCK SOUTH SLOPE - PUMP J

Computed by D. DAY Date 8-8-80 Checked by ____ Date ____

GIVEN: WATER AT (60°F) IS FLOWING THROUGH THE PIPING SYSTEM AS DETAILED BELOW. DEVELOP SYSTEM CURVE AND PUMP CURVE TO DETERMINE MAXIMUM RATE OF FLOW THAT CAN BE EXPECTED.....



PUMP SPECS: (SEE DATA SHEET ATTACHED)

GORMAN-RUPP MODEL S4B1

RATED 900 GPM @ 90 FT HD

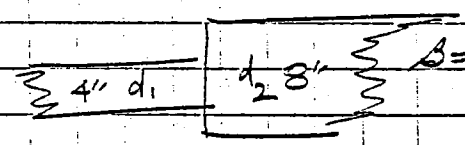
$d_1 = 4.026$ $d_2 = 7.981$

$f_{T_1} = 0.017$ $f_{T_2} = 0.014$

II COMPUTE SYSTEM HEAD LOSS –

$$h_l = \frac{0.00259\,K Q^2}{d^4}$$

SUDDEN ENLARGEMENT



$\beta = \frac{d_1}{d_2} = 0.4$

CRANE A

$$K_2 = \frac{(1-\beta^2)^2}{\beta^4} = 9$$

$K = 30 f_T$ for 90° ELBOW
$K = 1$ for PIPE EXIT
$K = 1$ for PIPE ENTRANCE
$K = 100 f_T$ for home made CHECK VALVE
$K = 9.0$ for SUDDEN ENLARGEMENT
$K = f \frac{L}{D}$ for PIPING
$K = 16 f_T$ for 45° ELBOW

K for PIPE –

$$K = f_{T1}\frac{L}{D} + f_{T2}\frac{L}{D}$$

$$K = \frac{(0.017)(18)(12)}{4.026} + \frac{(0.014)(206)(12)}{7.981}$$

$$K = 0.91 + 4.34 = 5.25$$

$K = (2)(30)(.014) = 0.84$ for 2-90° ELS
$K = (1)(16)(.014) = 0.22$ for 1-45° EL
$K = (1)(100)(.014) = 1.4$ for 1-CHECK VALVE

$$K_{TOTAL} = 0.84 + 1.0 + 1.0 + 1.4 + 9.0 + 5.25 + 0.22 = 18.71$$

2766—12M—1-21-66 GEORGIA POWER COMPANY Sheet ____ of ____

Subject ____ Project ____

Computed by ____ Date ____ Checked by ____ Date ____

III COMPUTE h_l OVER RANGE OF INTEREST—

$$h_l = \frac{0.00259\,KQ^2}{d^4} \qquad K_{TOTAL} = 18.71$$

$$h_l = \frac{0.00259\,(0.91)(Q^2)}{(4.026)^4} + \frac{0.00259\,(4.34)(Q^2)}{(7.981)^4}$$

$$h_l = (8.97\times10^{-6})(Q^2) + (2.77\times10^{-6})(Q^2)$$

$h_l = 0.36 + 0.11 = 0.47$ FT for 200 GPM
$h_l = 1.44 + 0.44 = 1.88$ FT for 400 GPM
$h_l = 3.23 + 1.00 = 4.23$ FT for 600 GPM
$h_l = 5.74 + 1.77 = 7.51$ FT for 800 GPM
$h_l = 8.97 + 2.77 = 11.74$ FT for 1000 GPM

IV $H_{REQ'D} = Z_1 - Z_2 + h_{l_{1-2}} + \frac{V_2^2}{2g}$

$$\boxed{\frac{V_2^2}{2g} = \frac{\left(\frac{0.408\,Q}{d^2}\right)^2 \text{ FT}^2/\text{SEC}^2}{64.4 \text{ FT/SEC}^2}}$$

$R_{e_{8"}} = \frac{123.9\,dv\rho}{\mu} = 2.8\times10^5$

friction factor by Crane A-25 = 0.017 for 8"

a. $H_{REQD_{1000}} = 100 + 11.74 + 0.64 = 112.38$ FT

b. $H_{REQD_{800}} = 100 + 7.51 + 0.41 = 107.92$ FT

c. $H_{REQD_{600}} = 100 + 4.23 + 0.23 = 104.46$ FT

d. $H_{REQD_{400}} = 100 + 1.88 + 0.10 = 101.98$ FT

e. $H_{REQD_{200}} = 100 + 0.47 + 0.02 = 100.49$ FT

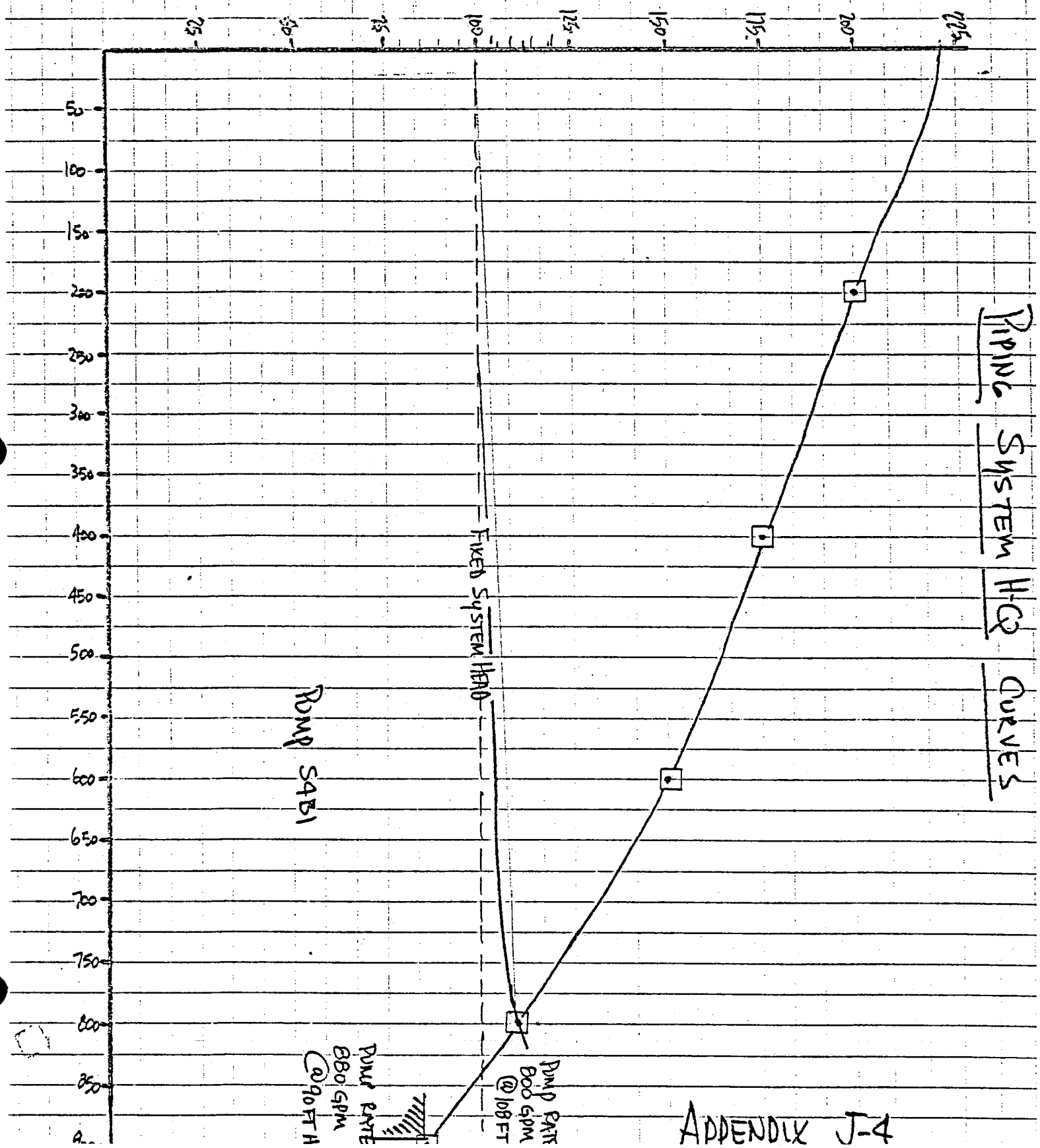
GEORGIA POWER COMPANY

Sheet ____ of ____

Subject: DEWATERING PUMP PERFORMANCE — POWER BLOCK SOUTH SLOPE - PUMP J

Project: VOGTLE

Computed by: D. DAY Date: 8-8-80 Checked by: ____ Date: ____



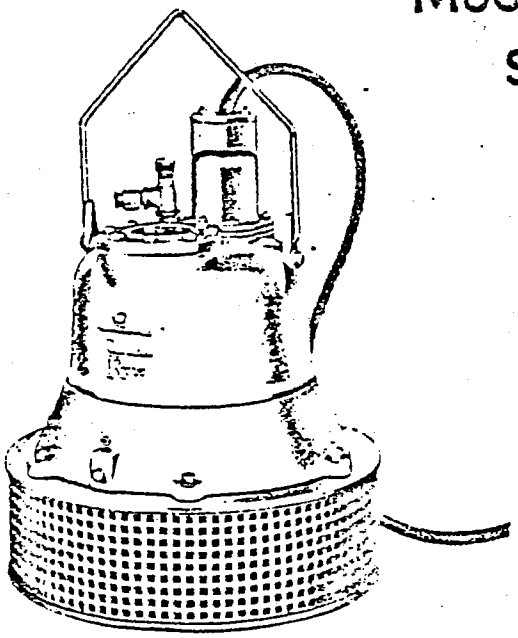
APPENDIX J-4

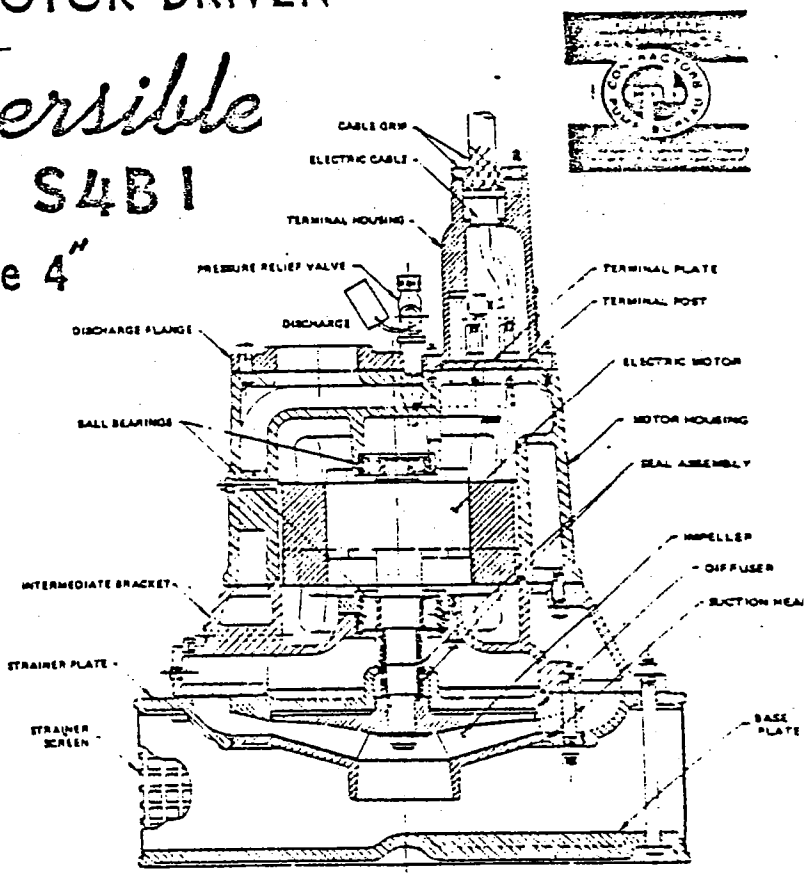
ELECTRIC MOTOR DRIVEN

Submersible

Model S4B1

Size 4"



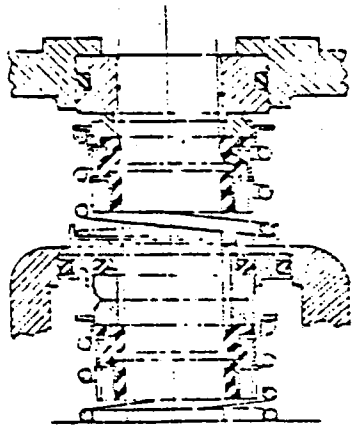


S4B1

PART	MATERIAL
Motor Housing	Aluminum
Intermediate Bracket	Aluminum
Impeller	Ductile Iron
Suction Head	Ductile Iron
Diffuser	Ductile Iron
Hardware (Internal)	Stainless Steel
Bearings, Ball	1 Single, 1 Double Row
Control Box	Standard
Hoisting Bail	Standard
Strainer 358 sq.in.area	5/8 inch sq. openings
Staging Adapter	Optional
Liquid level switch	Optional
Liquid level control	Optional

WARNING
DO NOT USE IN EXPLOSIVE ATMOSPHERE OR FOR PUMPING VOLATILE LIQUIDS

SEAL – Two. Operate in Oil.
UPPER – Carbon and Ni-Resist Wearing Faces
LOWER – Tungsten Carbide Wearing Faces.



MOTOR: Oil Filled, 50 H.P., 60 Hertz, 1750 RPM.
Max. KW Input: 43 KW

Available: Three Phase, 460 and 575 Volts.

CABLE: 6 Wire, 3 Conductor, 3 ground, No. 6 AWG, Type GGC. Available in lengths required. 50 Ft. provided standard. For different lengths, specify at time of order.

STANDARD CONTROL BOX: Type 3R Rainproof Starter, 3 pole with 3 coil overload relay and 3 pole magnetic trip circuit breaker; three position selector switch; automatic off-manual.

Max. Temp. of liquid pumped, 120°F

Recommended generator for across the line starting, 60 KW.

SPECIFICATION DATA

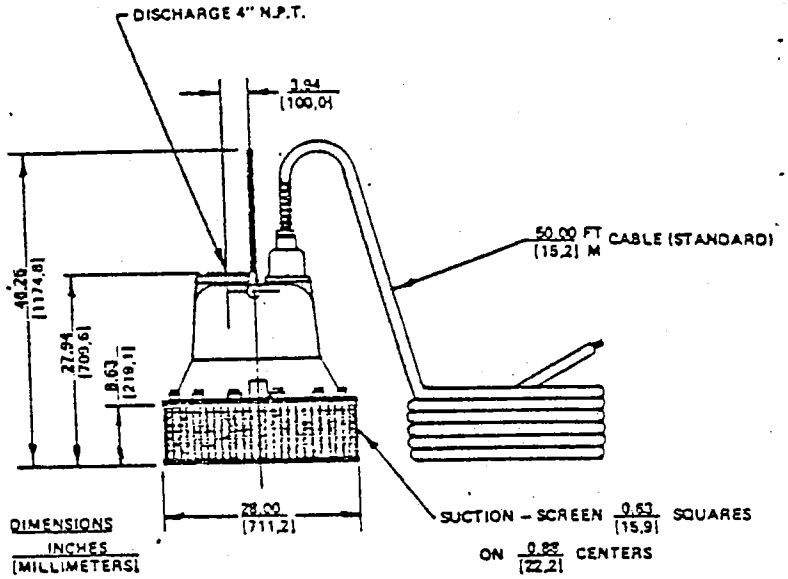
OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

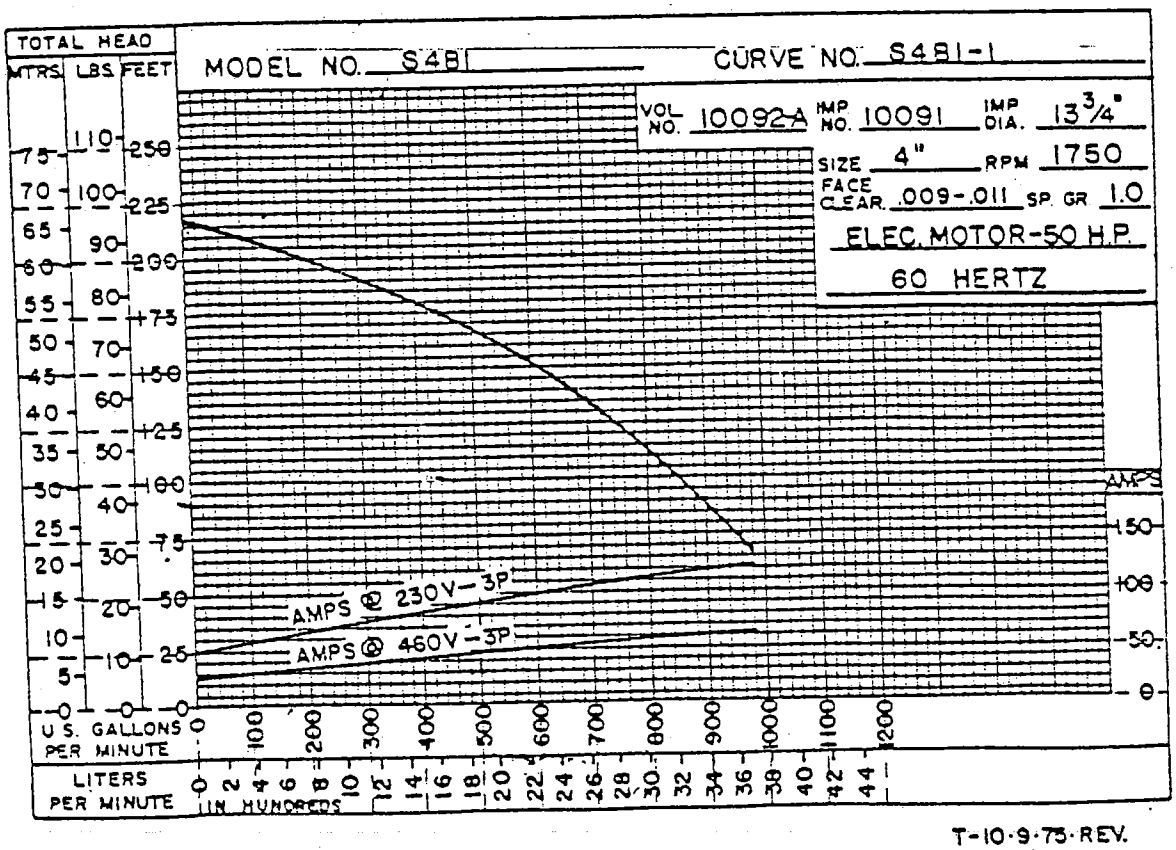
SECTION 130, PAGE 400

PUMP AND CABLE: Net Weight
460 & 575V — 400 lbs.
Shipping Weight
460 & 575V — 530 lbs.

MOTOR CONTROL: Shipping Weight
460 & 575V — 140 lbs.

EXPORT SIZE: Pump: 31 cu. ft.
Control: 9.5 cu. ft.





880 GPM
@
90 FT HD

T-10-9-73-REV.

THE GORMAN-RUPP COMPANY • MANSFIELD, OHIO

APPENDIX J-6

GEORGIA POWER COMPANY

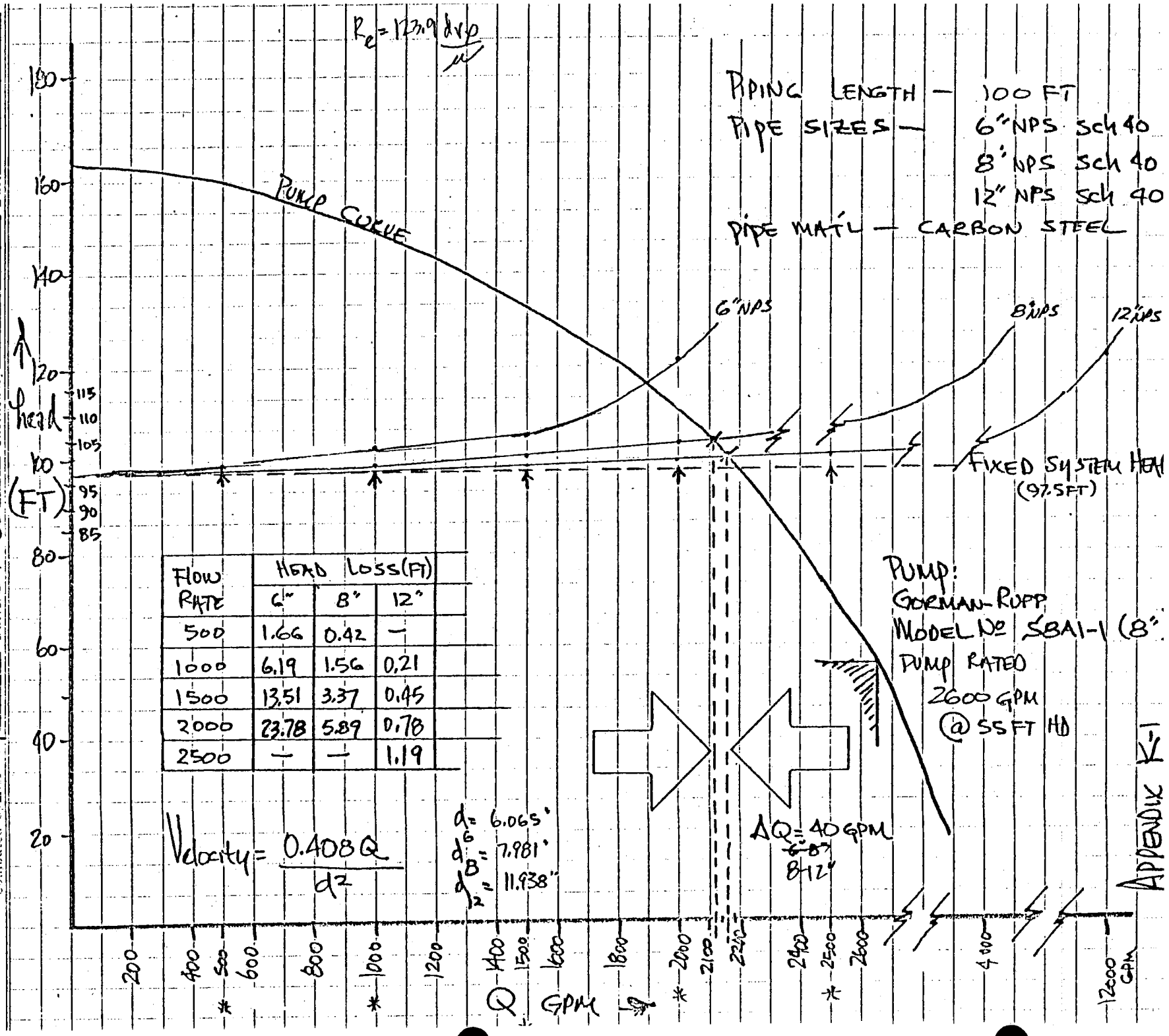
Subject: DEWATERING PUMP PERFORMANCE — COMPARATIVE PIPE LOSSES FOR 6"-8"-12" NPS

Project: VOGTLE

Sheet 1 of 2

Computed by: D. DAY Date: 8-10-80 Checked by: Date:

$R_e = 123.9 \frac{dvp}{\mu}$



Flow Rate	Head Loss (FT) 6"	8"	12"
500	1.66	0.42	—
1000	6.19	1.56	0.21
1500	13.51	3.37	0.45
2000	23.78	5.89	0.78
2500	—	—	1.19

Subject _____ Project _____

Computed by _____ Date _____ Checked by _____ Date _____

CONCLUSIONS:

I. FOR THE 8" PUMP, THE SIX-INCH LINE BEGINS TO EXHIBIT HIGH LOSSES AT THE UPPER FLOW RATES BEYOND 2000 GPM .... (UNDERSIZED)

II. THE 8" LINE IS OPTIMUM FOR THE PUMP FLOW RATES INVOLVED....

III THE 12" LINE IS MUCH LARGER THAN REQUIRED FOR THE FLOW RATES INVOLVED (OVERSIZED). CHANGING LINE SIZES FROM 8" TO 12" FOR THIS APPLICATION ONLY RESULTS IN A CHANGE IN FLOW OF 40GPM IN THE 2000 GPM REGION AND WOULD BE IMPRACTICAL AND ECONOMICALLY UNJUSTIFIED...

IV FOR GENERAL WATER FLOW SERVICE, REASONABLE VELOCITIES FOR THE FLOW OF WATER THROUGH PIPE IS FROM 4-10 FEET PER SECOND .... MAINTAINING REASONABLE VELOCITIES MINIMIZES SYSTEM HEAD LOSSES ATTRIBUTABLE TO PIPING.

2766—12M—1-31-66 GEORGIA POWER COMPANY Sheet ____ of ____

Subject DEWATERING SYSTEM Project VOGTLE

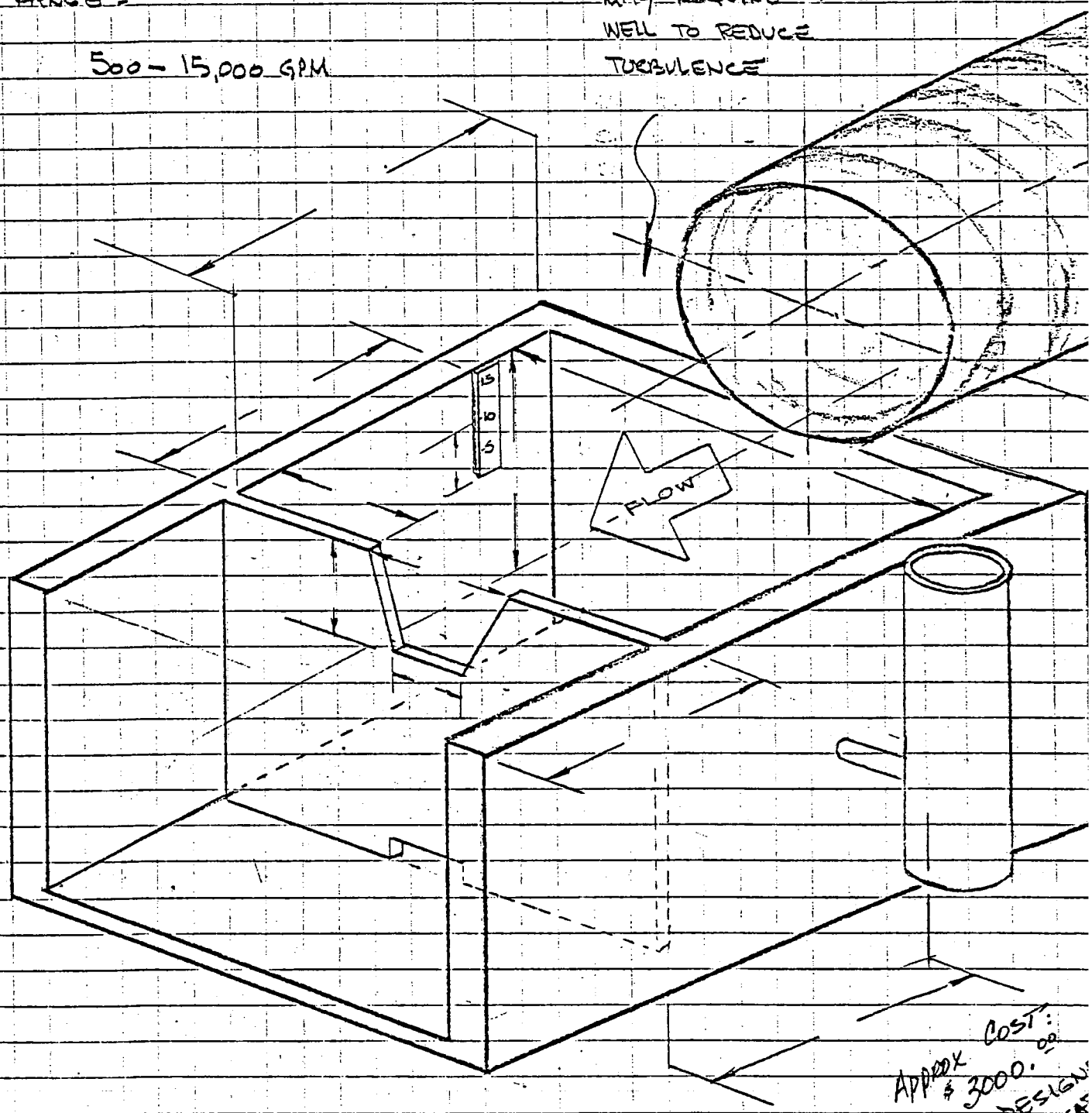
WEIR CONSTRUCTION DETAILS

Computed by D. DAY Date 8-14-80 Checked by ____ Date ____

FLOW RANGE:

500 – 15,000 GPM

MAY REQUIRE STILLING WELL TO REDUCE TURBULENCE



APPROX COST: $3000.00 SITE DESIGN AND FABRICA

5-FT CIPPOLETTI WEIR

FIGURE 5-1

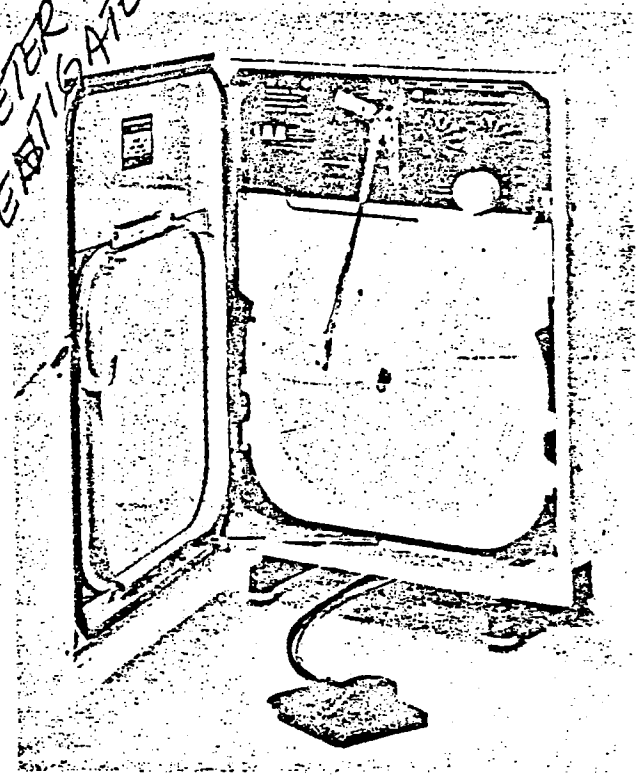
MMI FLOWMETER

Model 250

ALTERNATE FLOWMETER BEING INVESTIGATED!

The Velocity-Modified FLOWMETER (VMFM), Model 250, is used extensively in:

- **Industrial and municipal waste water systems**
- **Process liquid and slurry systems**
- **EPA Permit Application studies**
- **Storm water management systems**



The Velocity-Modified FLOWMETER, Model 250, uniquely measures volumetric fluid flow in open-channel and pipe systems of any configuration.

Readily installed without system modifications, and often without interrupting operations, the Model 250 continuously senses fluid velocity and level. Recorded volumetric flow is the automatically computed product of flow velocity times the instantaneous cross-sectional area of fluid in the conduit. This extraordinary instrument provides accurate, trouble-free service even in sludge, floating debris, and dilute acids or caustics.

Designed for permanent installation, the Model 250 is both compact and durable. Its control console, circuitry, and recorder are packaged in a dust-proof, cast-aluminum enclosure. The enclosure, in turn, is cabled to encapsulated dual sensors mounted on a conduit adaptor appropriate for the system geometry. The capsule contains an electromagnetic velocity sensor and a compact, bubble-type level-transducer. It is this powerful combination that creates the capability to measure forward and reverse flows accurately in open channels and filled or partially filled pipes of any shape.

The advanced features of the Model 250 FLOWMETER overcome obstacles that are major problems for other measurement techniques: The effects of manhole surcharging are automatically eliminated. Estimates of conduit roughness and slope of a fluid surface, needed to generate error-prone Manning-equation approximations, are not required by the Model 250. The characteristic flow reversals in tidal or storage systems are accommodated up to 5% of system capacity. Although volumetric flow is computed and recorded, both the velocity and level of the fluid may be read out at the flick of a switch.

The total life-cycle cost of the Model 250 FLOWMETER is highly favorable. Because its use requires no system modifications, installation costs are minimal; and being simple to operate and maintain, little added training of personnel is demanded. The accurate data that it delivers can be relied upon when pivotal operating decisions must be made, or capital plans and budgets formulated.

The economics and long, trouble-free service life of the Velocity-Modified FLOWMETER, Model 250, ensure that you will find it to be an entirely satisfactory purchase. We invite your inquiry.

SPECIFICATIONS

MEASUREMENT

Volumetric flow in millions of gallons per day (MGD) in filled or partially filled pipes from 8-in. to 60-in. diameters

Velocity Measurement

Method: Electromagnetic (Faraday effect)
Range: -0.5 to +10 ft/sec (-0.5 to +20 ft/sec optional); zero stability ±0.05 ft/sec
Accuracy: ±2%

Level Measurement

Method: Air bubbler with electronic pressure transducer
Range: 0.5 in. to 60 in. of water depth
Accuracy: ±2%

Flow Calculation

Method: Conversion of water level and pipe size to flow area; conversion of point velocity reading to average velocity; multiplication of flow area by average velocity
Range: 11 selectable ranges up to 0-200 MGD with 5% reverse-flow capability
Accuracy: ±2%
Repeatability: ±0.5%

STANDARD OUTPUTS

Recorder

Flow Range: See above
Flow Velocity: -0.5 to ±10 ft/sec full scale
Flow Level: 0 to 100% of full conduit size
4-20 mA: Optional
Time Pulse: Optional
Flow Proportional Contact Closure: ≈180-ms pulse every x000 gallons (x is customer-selected)

Flow Totalizer

Display: 6 digits, non-resettable
Resolution: 1000 gallons per count

MATERIALS

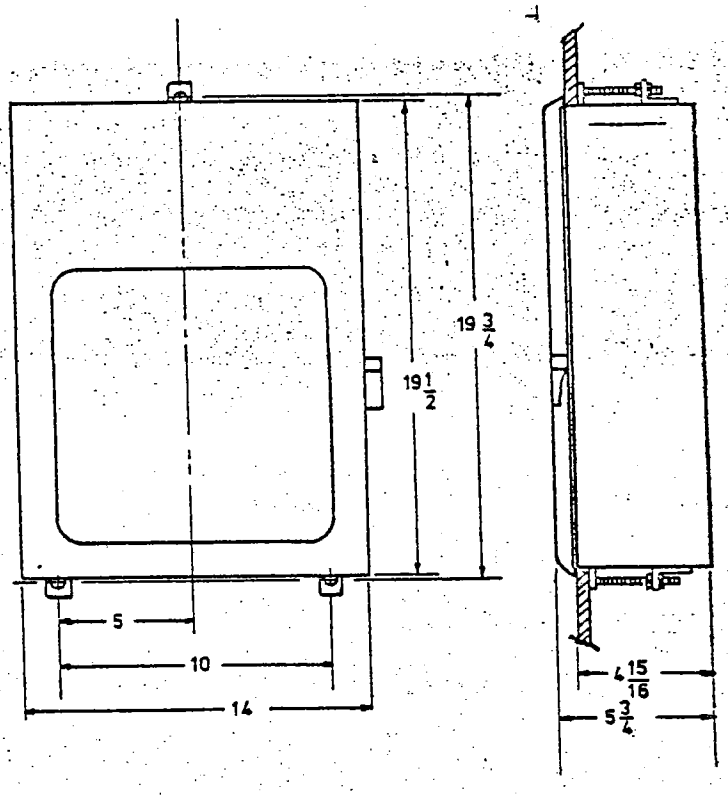
Sensor: Polyurethane exposed to flow
Sensor Cable: Twinax polyurethane rubber outer jacket exposed to flow
Air Tubes: Tygon
Sensor Mounting Band: Type 304 stainless steel exposed to flow
Recorder Housing: Cast aluminum dust-proof enclosure

ENVIRONMENTAL CONDITIONS

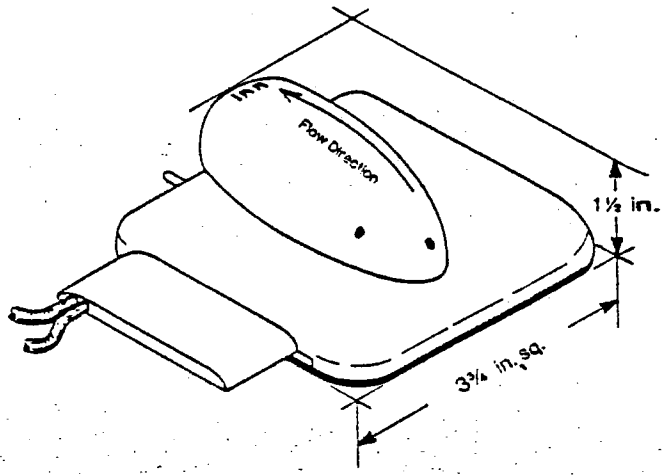
Electronics: Temperature limits 30°F to 112°F (-1°C to +40°C); outdoor installations require weatherproof enclosure
Sensor: Flow temperature range 32°F to 160°F (0°C to 65°C)

POWER REQUIREMENTS

120 VAC, 60 Hz (220 VAC, 50 Hz optional)
25 W rms



Enclosure Dimensions



Sensor Dimensions

Cascade Control Company
INSTRUMENTATION AND CONTROL EQUIPMENT
P.O. BOX 825
ROSWELL, GA. 30077
PHONE (404) 475-9504

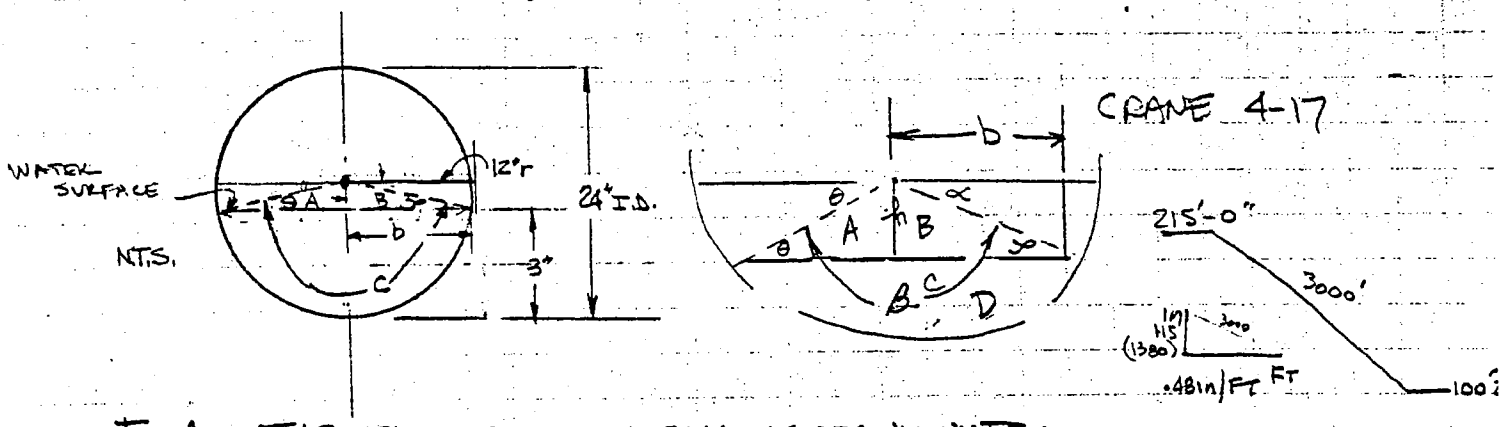
Jan. '80

GEORGIA POWER COMPANY

Subject: ESTIMATION OF DEWATERING LINE EFFLUENT Project: VOGTLE

D. DAY 8-14-80

GIVEN: A GALVANIZED CARBON STEEL CORRUGATED PIPE HAS A STEADY UNIFORM FLOW OF WATER @ 60°F WHICH FILLS THE PIPE 3" FROM THE BOTTOM. THE PIPE HAS AN INSIDE DIAMETER OF 24-inches and a SLOPE OF 0.5 inch PER FOOT. NOTE THE SKETCH THAT FOLLOWS: (OBSERVED 8-14-80, 3 P.M.)



Find: THE FLOW RATE IN GALLONS PER MINUTE;

Solution:

PIPE IS 0.125 OR 1/8 FULL

1. $Q = 19.65\sqrt{\frac{h_l D}{L}}$

Since pipe is flowing partially full an equivalent diameter based upon hydraulic radius is substituted for D in Equation 1 — $D = 4R_H$

2. $Q = 19.65\, d^2 \sqrt{\frac{h_l 4R_H}{fL}} = 39.3\, d^2 \sqrt{\frac{h_l R_H}{fL}}$

3. $R_H = \frac{\text{CROSS SECTIONAL FLOW AREA (SQ FT)}}{\text{WETTED PERIMETER (FT)}}$

4. $R_e = \frac{473 q \rho}{R_H \mu} = 1.054 \frac{Q \rho}{R_H \mu}$

5. DEPTH OF FLOWING WATER EQUALS — 3"

6. $\text{AREA}_{24''/2} = \pi R^2/2 = \frac{(3.14)(12)^2}{2} = 226 \text{ sq in}$

7. $\sin \theta = \frac{9}{12} = 0.75$

$\theta = 48.6°$

$\alpha = 48.6°$

$\beta = 180 - 2(48.6) = 82.8°$

8. AREA D = AREA C − AREA A − AREA B

9. $\text{AREA C} = \frac{\pi d^2}{4}\left[\frac{180-(2)(48.6)}{360}\right]$

$= \frac{\pi d^2}{4}[0.23]$

$= 104 \text{ in}^2$

$\tan \alpha = \frac{b}{a}$

$\tan 48.6° = \frac{9}{b}$

$b = \frac{9}{\tan 48.6} = \frac{9}{1.13} = 7.93"$

10. $\text{AREA A} = \text{AREA B} = \frac{1}{2} bh = \frac{1}{2}(7.93)(9) = 35.71 \text{ in}^2$

11. $\text{AREA D} = 104 \text{ in}^2 - 2(35.71)\text{in}^2 = 32.59 \text{ in}^2$

12. CROSS SECTIONAL FLOW AREA $= (32.59 \text{ in}^2)(6.944 \times 10^{-3}) = 0.225$ SQ FT

13. $d^2 = \frac{4a}{\pi} = \frac{4(32.59)}{\pi} = 41.52$

14. $h_l = \Delta h = \frac{0.48}{12} = 0.04$ FT/FT

15. WETTED PERIMETER $= \pi d \left(\frac{180-82.8}{360}\right) = \frac{20.36 \text{ in}}{12} = 1.7$ FT

16. $R_H = \frac{0.225}{1.7} = 0.132$