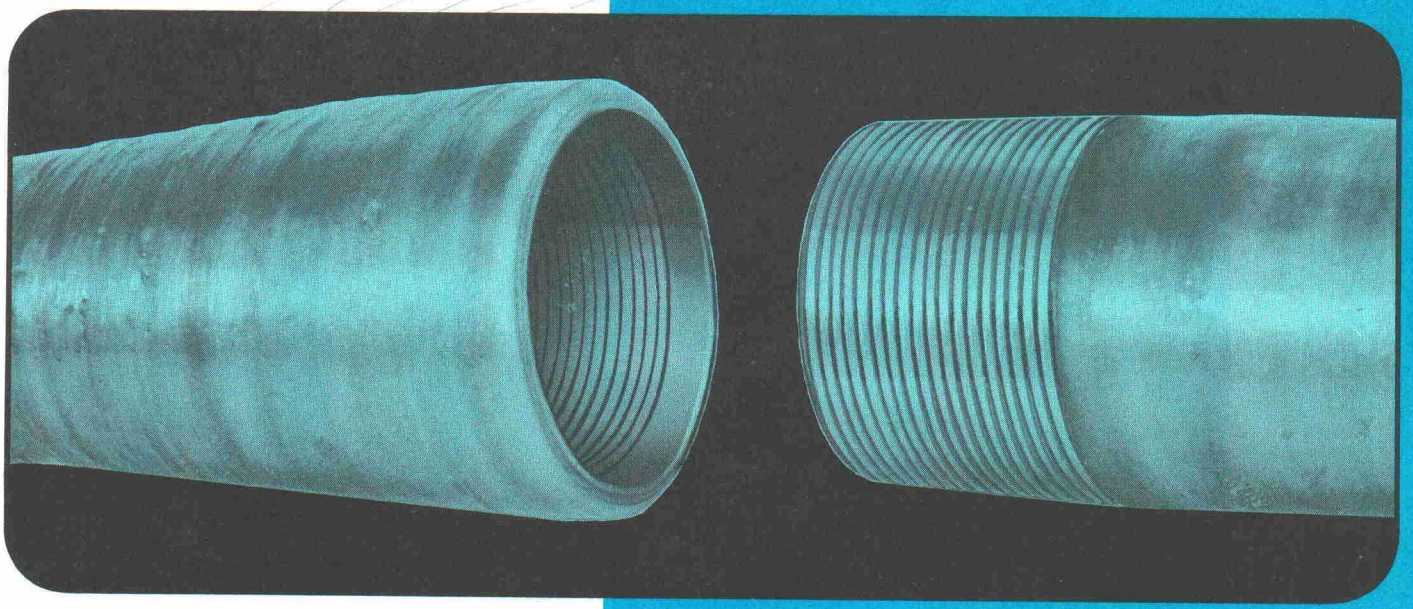
ROCK ISLAND

FIBER GLASS PIPE and TUBING

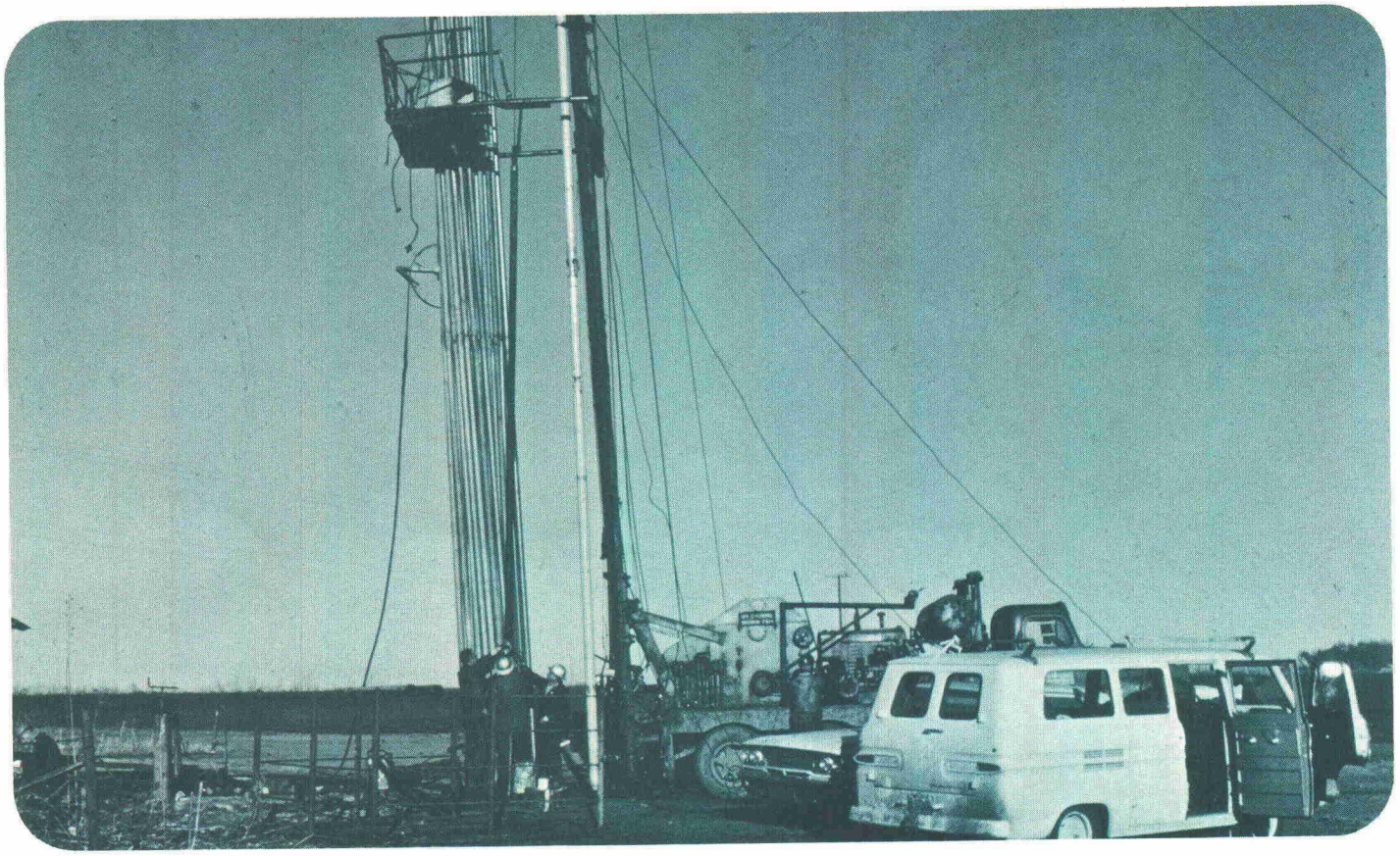
Engineering Manual No. 10-64



BEFORE EXAMINER UTZ
OIL CONSERVATION COMMISSION
Oppl EXHIBIT NO. 5
CASE NO. 3291

ROCK ISLAND OIL & REFINING CO., INC.
FIBER GLASS PIPE DIVISION, WICHITA, KANSAS
PHONE . . . AREA CODE 316 WHitehall 2-3237

FIELD TESTED and PROVED



History and development

Any new product must have conclusive proof of performance, and Rock Island's Fiber Glass Pipe has been subjected to rigorous testing.

It was laboratory-developed and tested early in 1957. Major field installations have been in operation for many years. Thousands of feet of Rock Island's new tubing and line pipe are now installed in many Midcontinent oil fields . . . and are proving extremely effective under conditions requiring severe corrosion or paraffin control, as well as those calling for high pulsating pressures.

It is performing in salt water disposal wells, waterflood systems, and many other types of installations.

Description

Rock Island Fiber Glass Pipe has unusual strength. This has been accomplished through a significant development which creates maximum strength through pre-stressing.

Similar in principle to pre-stressed concrete, Rock Island Fiber Glass Pipe is manufactured by pre-stressing alternate longitudinal and lateral plies of glass roving that are saturated and bonded together with epoxy resin. Maximum burst and tensile strength is developed, because this method places the load *on the glass* rather than on the epoxy resin.

Manufactured in light, medium, medium-heavy, and heavy-duty weights, in diameters from 1 in. to 30 in. Joints are available either in 20 ft or 30 ft lengths. All weights have integral joints and the light and medium-service weights have upset ends for added rigidity and strength.

"Integral joints for MAXIMUM STRENGTH"

Rock Island Fiber Glass Pipe and Tubing are designed with integral joints with the highest tensile strength yet developed in fiber glass pipe and tubing. This new development permits much wider applications of fiber glass pipe. It permits longer strings of disposal tubing, larger submergible pumps, wider application with tension packers and makes multiple completions easier.

The pipe and tubing have Standard EUE 8-round threads, which eliminates need for special fittings and connections.

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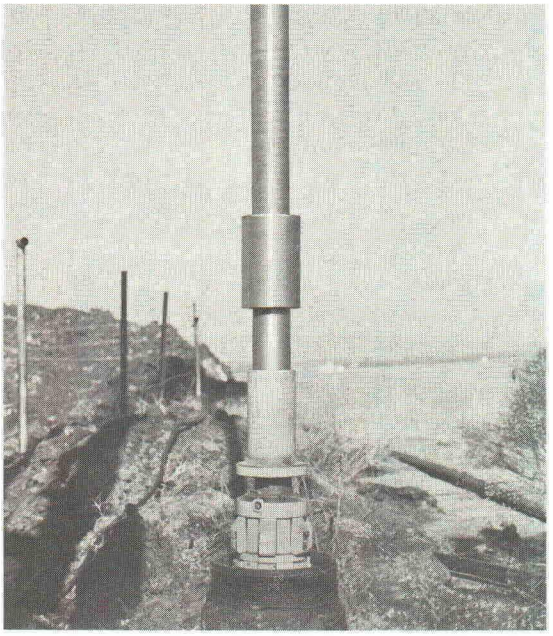
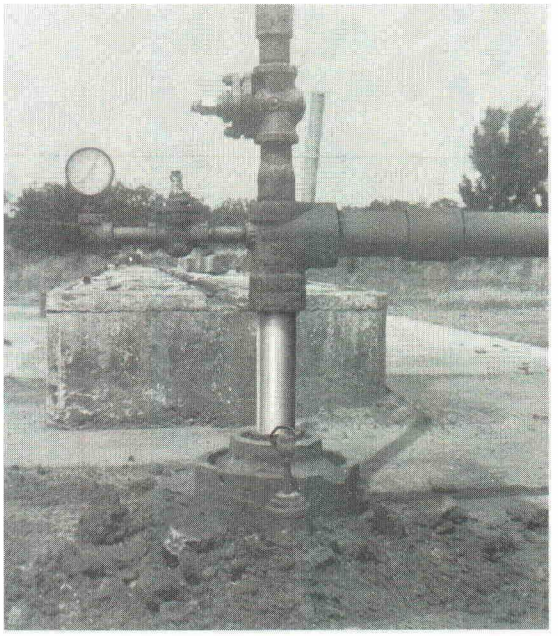


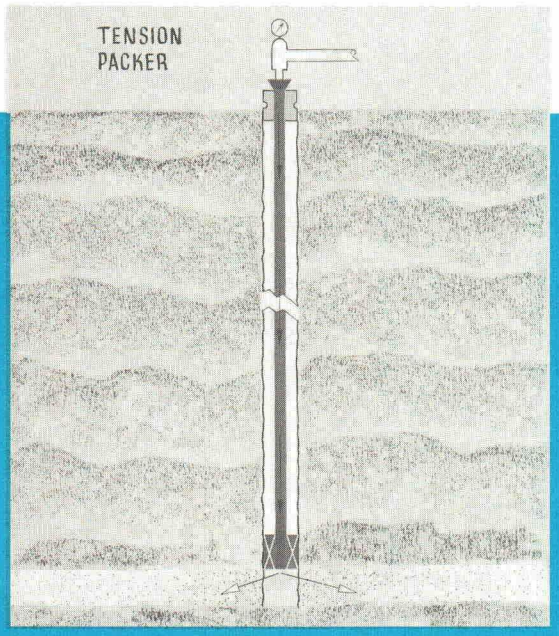
Tension Packer

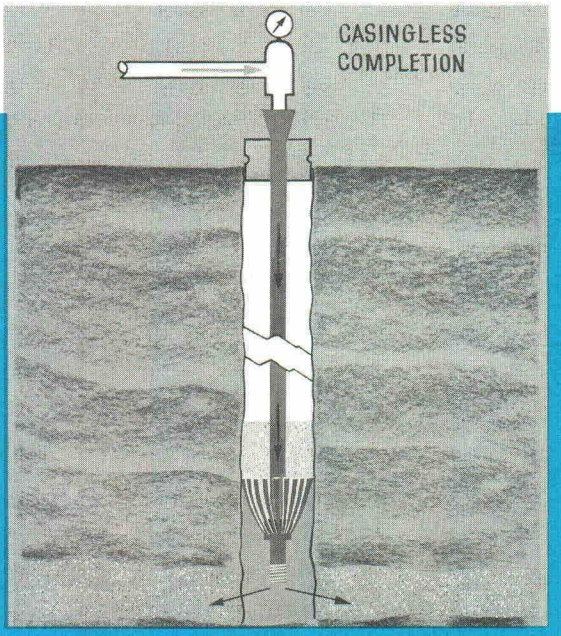
2,600 ft of 2 in. heavy-duty tubing held in 7,500 lb tension with steel slips. In service since late 1961 on major oil company lease in Osage County, Oklahoma.



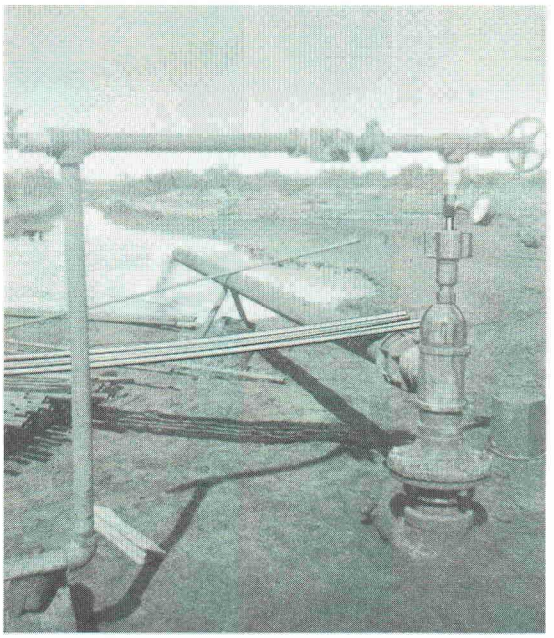
Permanent Packer

3,750 ft of 2½ in. medium-weight tubing, set in permanent packer with locater seal. Two-thirds of weight hung on slips. Well is on vacuum. In operation since late 1961 on major oil company lease near Seminole, Oklahoma.



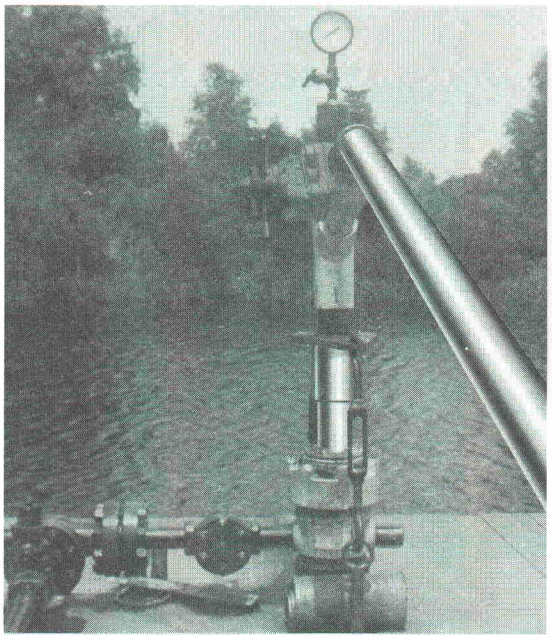


FIELD APPLICATIONS



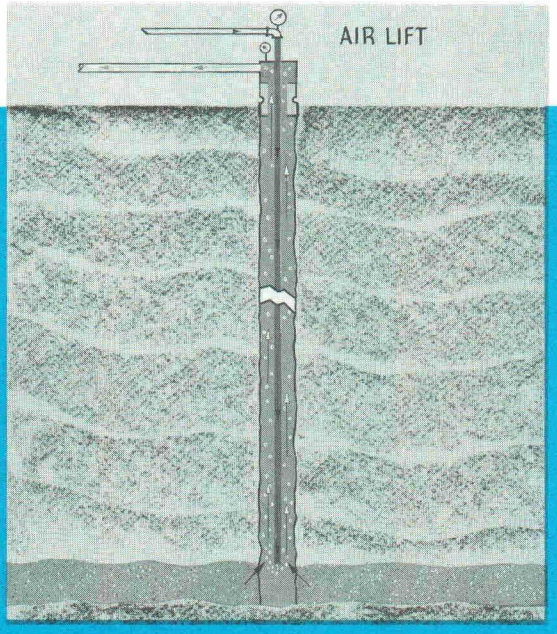
Air Lift Production

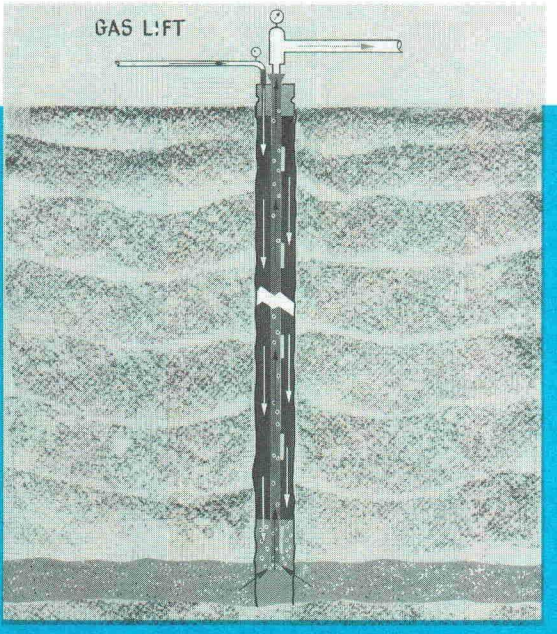
1,000 ft of 1 in. medium-service tubing, carrying 380 psi air pressure, and lifting 20,000 bbl of water daily on a major oil company lease near Wink, Texas.



Gas Lift

4,000 ft of 3 in. heavy-duty tubing, free-swinging on slips. Gas lifting at 840 lb annulus pressure through six gas lift valves and lifting 4,000 bbl of salt water at 145°F temperature. In service since March, 1962, on major oil company lease near New Orleans, Louisiana.



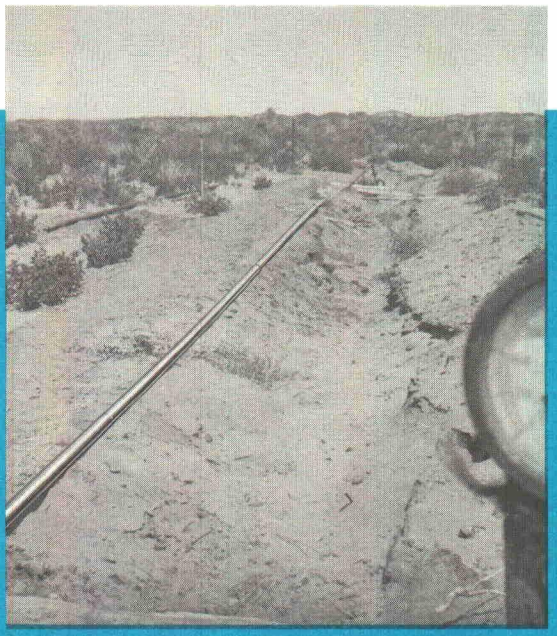


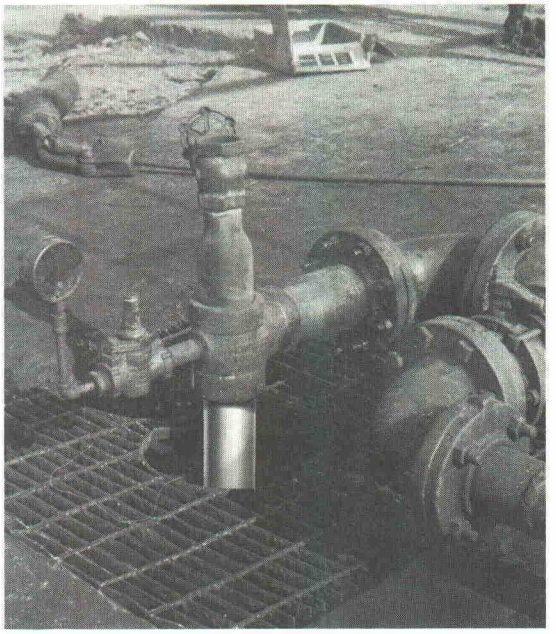
Line Pipe

6,600 ft of 4 in. lightweight pipe picking up water from four tank batteries to a disposal well. In service since early 1961 in West Texas.

High-Pressure Injection Water Flood

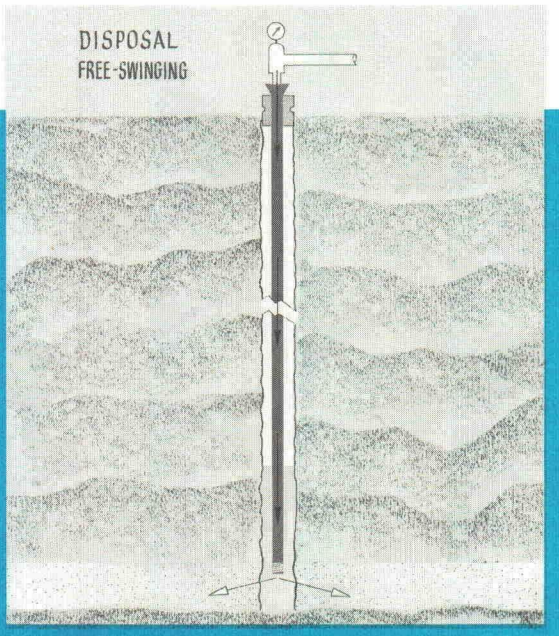
1,500 psig pressure from Multiplex pump. Temperature variation; —13° to 145°F. In service since May, 1961, near Kermit in West Texas.



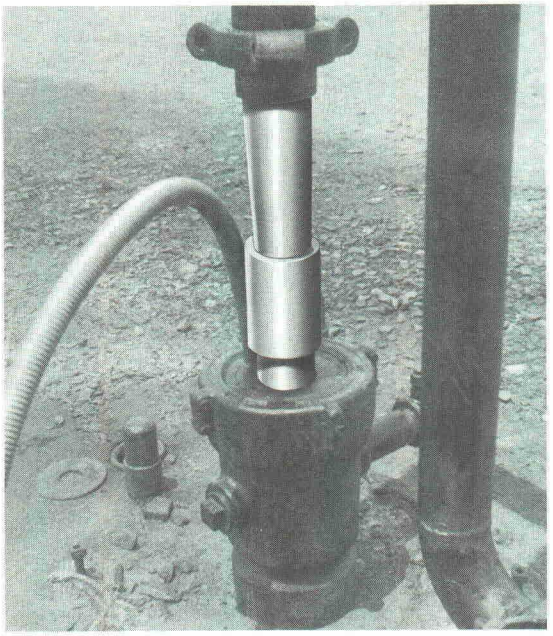


Salt Water Disposal

4,200 ft of 3 in. medium-weight tubing, free-swinging on slips. Annulus loaded with hydrocarbon. Well is on vacuum in major oil company lease near St. Louis, Oklahoma. Numerous other installations since 1961.

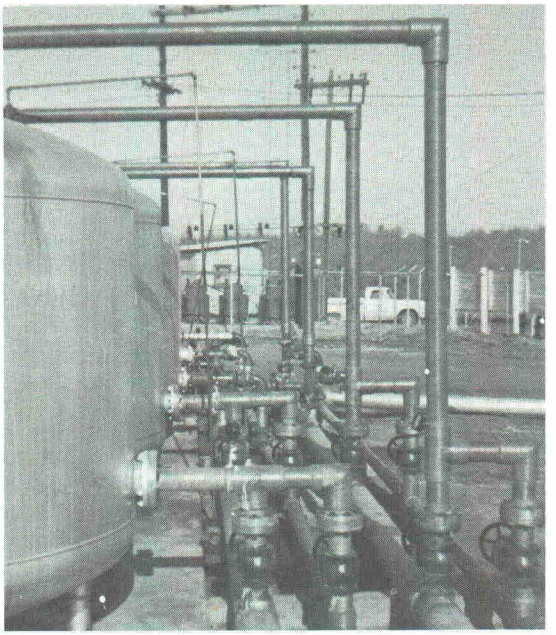


FIELD APPLICATIONS



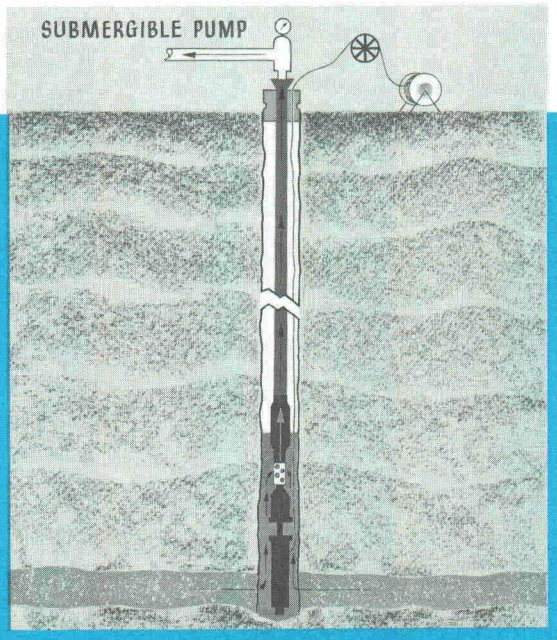
Submergible Pump

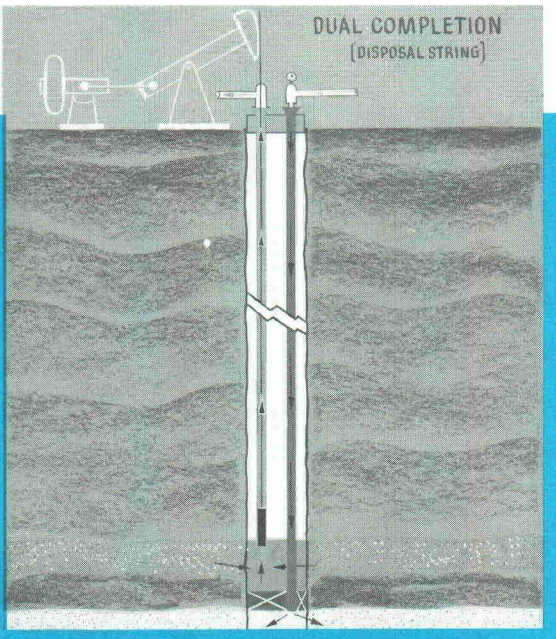
940 ft of 2½ in. heavy-duty tubing, 60 hp submergible pump. Hung in submergible pump wellhead located near Stroud, Oklahoma. In continuous service since November, 1961.



Fittings

A full line of fiber glass fittings is available in complete size and pressure ranges for your oilfield needs. Special fabrication upon request. State your needs.





II. FULL LINE OF FIBER GLASS FITTINGS

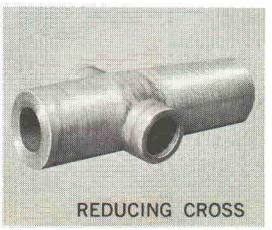
Rock Island, makers of oilfield fiber glass pipe and tubing, also provides these stock fittings for every pipe size from 1 in. to 8 in. and for pressures up to 1,500 psi. These fittings are designed for use with Rock Island pipe and tubing, and are available with EUE 8-round, 60° stub, grooved or regular API iron pipe threads. Manifolds and any other special connection used in the oilfield are custom fabricated for any hook-up with the same performance standards of Rock Island pipe and tubing.

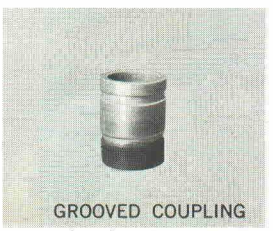
Glass-epoxy type fittings in stock sizes from 1 in. to 8 in.

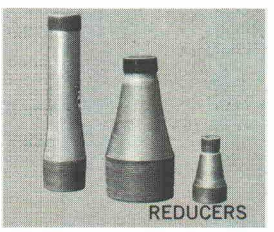
Fabricated for working pressures up to 1,500 psi.

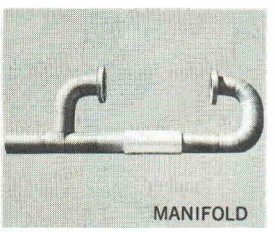
Stocked with EUE 8-round, 60° stub, grooved, or API iron pipe threads.

CUSTOM-MADE CROSSOVERS OF ALL KINDS


REDUCING CROSS


GROOVED COUPLING


REDUCERS


MANIFOLD

Whatever your needs, for Rock Island stock fittings or for special custom fabrication, your inquiry is welcome, and will receive immediate attention.

III. TYPICAL PIPE PROPERTIES

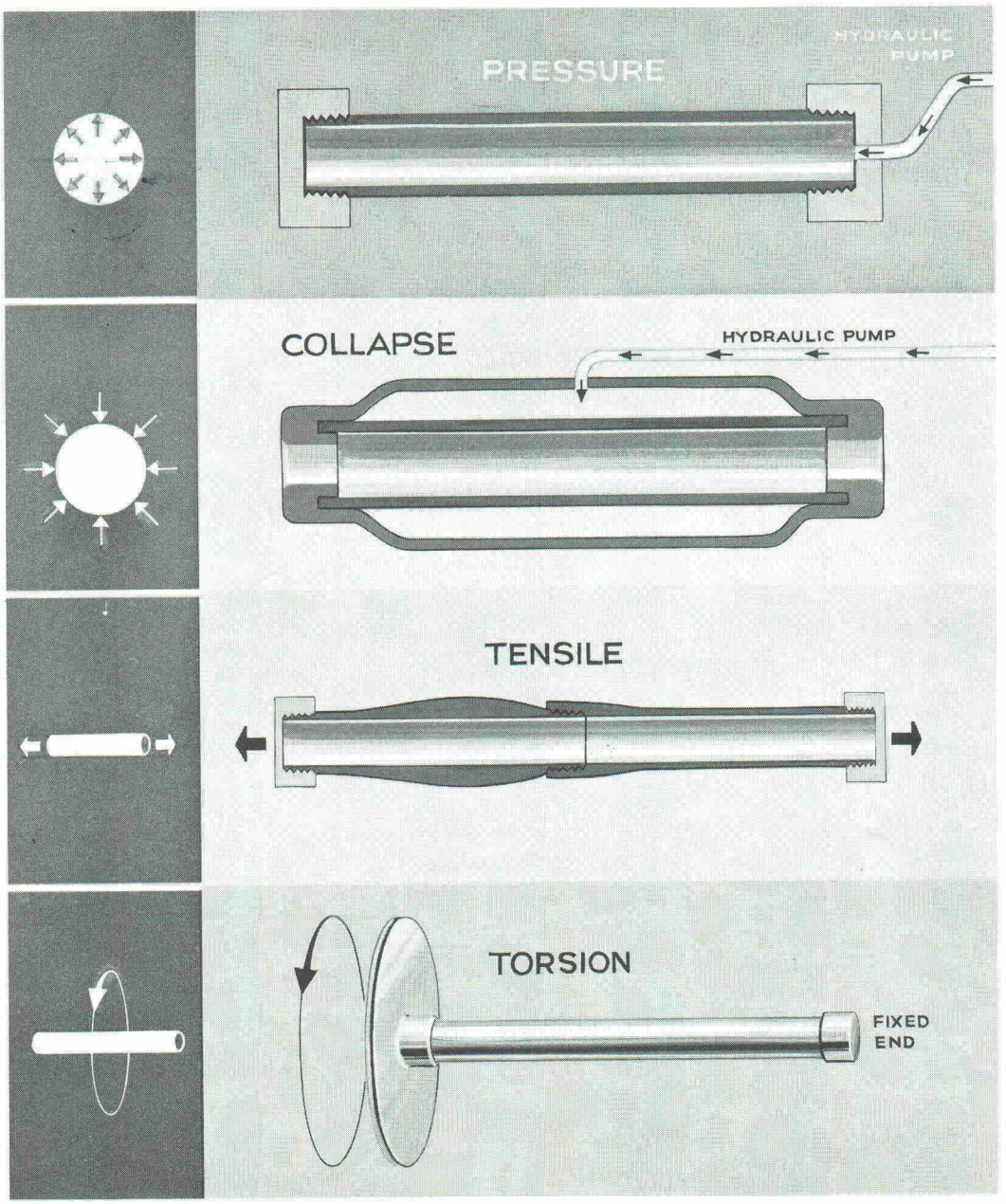


TABLE 1

Physical Properties

Specific gravity	2.0
Density, lb/cu in.	0.072
Thermal conductivity Btu/hr-ft²-°F/ft	0.2
Coefficient of thermal expansion in./in.-°F.	less than 6×10^6
Specific heat, Btu/lb-°F	0.22
Maximum service temperature	200°F
Flammability	slow to self-extinguishing
Water absorption %, 24 hr	0.05 - 0.1

Mechanical Properties

Tensile strength, psi	59,900
Compressive strength, psi	31,500
Torsional strength, psi	8,200
Impact strength, Izod, (ft-lb)/in. of notch	40
Interlaminar shear strength, psi	3,000
Modulus of elasticity in tension, psi	2.4×10^6
Compressive modulus, psi	2.6×10^6
Modulus of rigidity, psi (torsion)	0.7×10^6
Rockwell hardness (M scale)	over 100
Elongation at break, %	3

IV. CHEMICAL RESISTANCE DATA

Except organic acids and strong solvents like ketones, methylene chloride, toluene, etc., Rock Island pipe is very resistant to crude oils and other petroleum products, mild solvents, inorganic acids, alkalies, oxidizing agents, salt solutions, and brine. Our preliminary data on chemical resistance can be reported below:

TABLE 2

	TEMEPATURE °F	
Petroleum Products and Solvents	70	140
Crude Oils (sour and sweet)	O. K.	O. K.
Kerosene	O. K.	O. K.
Gasoline	O. K.	O. K.
Diesel Fuels	O. K.	O. K.
Motor Oils	O. K.	O. K.
Naphtha	O. K.	O. K.
Benzene	O. K.	—
Carbon Tetrachloride	O. K.	—
Salt Water	O. K.	O. K.
Water — 3% potassium dichromate	O. K.	O. K.
Water — bromine or chlorine	no	—
Acids		
Acetic, >10%	no	—
Carbonic	O. K.	—
Hydrochloric, conc.	O. K.	O. K. (Discoloration)
Hydrofluoric, 15%	O. K. (Short Duration)	—
Hydrogen Sulfide (dry & aq. soln.)	O. K.	O. K.
Nitric, 10%	O. K.	O. K.
Sulfuric, 50%	O. K.	O. K.
Phosphoric, 85%	O. K.	no
Oxalic, 5%	no	no
Alkalis		
Sodium Hydroxide, 10-50%	O. K.	O. K.
Ammonium Hydroxide	O. K.	—
Salt Solution		
Aluminum Potassium Sulfate, saturated	O. K.	—
Calcium Hypochlorite, 5%	O. K.	—
Sodium Sulfide, Saturated	O. K.	—

TABLE 3

NOMINAL SIZE		LINE PIPE OR LIGHT SERVICE						TUBING OR MEDIUM SERVICE							MEDIUM HEAVY DUTY			HEAVY DUTY					
		2″	2½″	3″	4″	6″	8″	1″	1½″	2″	2½″	3″	4″	6″	2″	2½″	3″	1″	1½″	2″	2½″	3″	4″
OD, in.		2.18	2.65	3.28	4.32	6.38	8.38	1.26	1.85	2.22	2.70	3.42	4.53	6.56	2.35	2.85	3.45	1.36	1.96	2.38	2.85	3.50	4.62
Wall Thickness, in.		0.13	0.13	0.13	0.13	0.17	0.17	0.12	0.15	0.15	0.15	0.15	0.22	0.28	0.20	0.20	0.20	0.17	0.21	0.23	0.23	0.23	0.28
ID, in.		1.92	2.39	3.02	4.06	6.04	8.04	1.02	1.55	1.92	2.40	3.12	4.09	6.00	1.95	2.45	3.05	1.02	1.55	1.92	2.39	3.04	4.06
Max. Coupling Diam., in. ± 1/16 in.		3.20	3.59	4.43	5.34	7.65	9.60	1.95	2.55	3.50	3.80	4.45	5.88	8.10	3.50	4.05	4.65	2.09	2.90	3.77	4.25	4.80	6.00
lb/ft		0.68	0.92	1.07	1.92	2.70	4.50	0.41	0.73	0.92	1.20	1.43	2.78	5.30	1.14	1.45	1.77	0.53	1.00	1.36	1.70	2.10	4.00
Thread Type EUE (Rd.)		8	8	8	8	8	8	10	10	8	8	8	8	8	8	8	8	10	10	8	8	8	8
Maximum Operating Conditions @ 100° - 150°F	Internal Pressure psig	400	300	250	200	200	200	650	600	550	550	330	450	500	1,000	1,000	800	2,000	1,500	1,500	1,500	1,500	1,500
	Collapse Pressure psig	275	100	90	75	75	—	750	500	500	330	150	200	250	750	550	450	1,250	1,000	1,000	800	800	800
	Axial Tensile lbs	4,500	4,500	5,000	5,000	7,000	—	3,000	4,000	6,000	7,500	8,000	9,000	10,000	7,500	8,500	10,000	5,000	6,000	8,500	10,000	12,000	15,000
Cross Sectional Area of Pipe Wall in. ²		0.833	1.029	1.388	1.712	3.315	4.382	0.432	0.801	0.990	1.202	1.524	2.977	5.521	1.350	1.664	2.041	0.636	1.131	1.563	1.893	2.364	3.798
Inside Sectional Area, ft ²		0.0201	0.0311	0.0497	0.0899	0.1990	0.2648	0.0057	0.0131	0.0201	0.0314	0.0531	0.0912	0.1963	0.0207	0.0327	0.0507	0.0057	0.0131	0.0201	0.0311	0.0504	0.0899
Cu ft/lin ft		0.0201	0.0311	0.0497	0.0899	0.1990	0.2648	0.0057	0.0131	0.0201	0.0314	0.0531	0.0912	0.1963	0.0207	0.0327	0.0507	0.0057	0.0131	0.0201	0.0311	0.0504	0.0899
*Gal/lin ft		0.1504	0.2326	0.3718	0.6725	1.4884	1.9805	0.0424	0.0980	0.1504	0.2349	0.3972	0.6822	1.4682	0.1548	0.2446	0.3792	0.0424	0.0980	0.1504	0.2326	0.3770	0.6725
Total Wt lb/ft	Pipe plus water	1.934	2.860	4.170	7.530	15.098	20.998	0.764	1.547	2.174	3.159	4.740	8.471	17.530	2.429	3.49	4.929	0.884	1.817	2.614	3.640	5.240	9.602
	**Pipe plus brine	2.053	3.045	4.466	8.001	16.269	22.565	0.797	1.625	2.293	3.346	5.058	9.012	18.692	2.552	3.681	5.229	0.917	1.895	2.733	3.825	5.544	10.134

*1 Gal = 0.02381 bbl
** Specific gravity = 1.095

VI. ANNULAR CAPACITIES

A. Between API Casing and Rock Island Light Service Pipe

TABLE 4

CASING PIPE (in.)	Size, OD, in.	4½	5	5½	6⅝	7	7⅝	8⅝
	lb/ft, plain end	13.04	14.87	16.87	23.58	28.72	33.04	39.29
	ID, in.	3.920	4.408	4.892	5.921	6.184	6.765	7.725
2	A. Cu ft/lin ft	0.0365	0.080	0.1046	0.1653	0.1827	0.2237	0.2996
	B. Water in annulus — lb/lin ft	2.3	5.0	6.5	10.3	11.4	14.0	18.7
	C. Kerosene in annulus — lb/lin ft	1.9	4.1	5.4	8.5	9.3	14.4	15.3
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	0.720	1.208	1.692	3.721	2.984	3.565	4.525
	b. Annulus area, sq in.	0.4029	7.22	10.75	19.49	21.99	27.91	38.83
2½	A. Cu ft/lin ft	0.0241	0.0677	0.0922	0.1529	0.1703	0.2113	0.2872
	B. Water in annulus — lb/lin ft	1.5	4.2	5.8	9.5	10.6	13.2	17.9
	C. Kerosene in annulus — lb/lin ft	1.2	3.5	4.7	7.8	8.7	10.8	14.7
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	0.330	0.818	1.302	2.331	2.594	3.175	4.135
	b. Annulus area, sq in.	1.950	5.14	8.67	17.41	19.91	25.82	36.75
3	A. Cu ft/lin ft	———	———	0.0718	0.1325	0.1499	0.1909	0.2668
	B. Water in annulus — lb/lin ft	———	———	4.5	8.3	9.4	11.9	16.6
	C. Kerosene in annulus — lb/lin ft	———	———	3.7	6.8	7.7	9.8	13.7
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	———	———	0.462	1.491	1.754	2.335	3.295
	b. Annulus area, sq in.	———	———	3.39	12.13	14.62	20.54	31.46
4	A. Cu ft/lin ft	———	———	———	0.0894	0.1069	0.1479	0.2237
	B. Water in annulus — lb/lin ft	———	———	———	5.6	6.7	9.2	14.0
	C. Kerosene in annulus — lb/lin ft	———	———	———	4.6	5.5	7.6	11.4
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	———	———	———	0.581	0.844	1.425	2.385
	b. Annulus area, sq in.	———	———	———	5.14	7.63	13.55	24.47

VI. ANNULAR CAPACITIES

B. Between API Casing and Rock Island Medium Service Pipe

TABLE 5

CASING PIPE (in.)	Size, OD, in.	4½	5	5½	6⅝	7	7⅝	8⅝
	lb/ft, plain end	13.04	14.87	16.87	23.58	28.72	33.04	39.29
	ID, in.	3.920	4.408	4.892	5.921	6.184	6.765	7.725
1	A. Cu ft/lin ft	0.0538	0.0973	0.1218	0.1825	0.1999	0.2410	0.3168
	B. Water in annulus — lb/lin ft	3.4	6.1	7.6	11.4	12.5	15.0	19.8
	C. Kerosene in annulus — lb/lin ft	2.8	5.0	6.2	9.3	10.2	12.3	16.2
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	1.970	2.460	2.942	3.971	4.234	4.815	5.775
	b. Annulus area, sq in.	9.09	12.28	15.81	24.55	27.05	32.96	43.89
1½	A. Cu ft/lin ft	0.0438	0.0873	0.1119	0.1726	0.1899	0.2310	0.3068
	B. Water in annulus — lb/lin ft	2.7	5.4	7.0	10.8	11.8	14.4	19.1
	C. Kerosene in annulus — lb/lin ft	2.2	4.5	5.7	8.8	9.7	11.8	15.7
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	1.370	1.860	2.342	3.371	3.634	4.215	5.175
	b. Annulus area, sq in.	6.97	10.16	13.69	22.43	24.93	30.84	41.77
2	A. Cu ft/lin ft	0.0356	0.0791	0.1036	0.1643	0.1817	0.2227	0.2986
	B. Water in annulus — lb/lin ft	2.2	4.9	6.5	10.3	11.3	13.9	18.6
	C. Kerosene in annulus — lb/lin ft	1.8	4.0	5.3	8.4	9.3	11.4	15.3
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	0.420	0.908	1.392	2.421	2.684	3.265	4.225
	b. Annulus area, sq in.	2.45	5.64	9.17	17.91	20.41	26.33	37.25
2½	A. Cu ft/lin ft	———	0.062	0.0908	0.1515	0.1688	0.2100	0.2857
	B. Water in annulus — lb/lin ft	———	4.1	5.7	9.5	10.5	13.1	17.8
	C. Kerosene in annulus — lb/lin ft	———	3.4	4.6	7.8	8.6	10.7	14.6
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	———	0.608	1.092	2.121	2.384	2.965	3.925
	b. Annulus area, sq in.	———	3.92	7.45	16.19	18.69	24.61	35.53
3	A. Cu ft/lin ft	———	———	0.0669	0.1276	0.1449	0.1860	0.2618
	B. Water in annulus — lb/lin ft	———	———	4.2	8.0	9.0	11.6	16.3
	C. Kerosene in annulus — lb/lin ft	———	———	3.4	6.5	7.4	9.5	13.4
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	———	———	0.442	1.521	1.784	2.365	3.325
	b. Annulus area, sq in.	———	———	3.24	11.99	14.48	20.40	31.32
4	A. Cu ft/lin ft	———	———	———	0.0793	0.0966	0.1377	0.2136
	B. Water in annulus — lb/lin ft	———	———	———	4.9	6.0	8.6	13.3
	C. Kerosene in annulus — lb/lin ft	———	———	———	4.1	4.9	7.0	10.9
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	———	———	———	0.041	0.304	0.885	1.845
	b. Annulus area, sq in.	———	———	———	0.38	2.88	8.80	19.72

VI. ANNULAR CAPACITIES

C. Between API Casing and Rock Island Heavy-Duty Pipe

TABLE 6

CASING PIPE (in.)	Size, OD, in.	4½	5	5½	6⅝	7	7⅝	8⅝
	lb/ft, plain end	13.04	14.87	16.87	23.58	28.72	33.04	39.29
	ID, in.	3.920	4.408	4.892	5.921	6.184	6.765	7.725
1	A. Cu ft/lin ft	0.0524	0.0959	0.1204	0.1811	0.1985	0.2400	0.3154
	B. Water in annulus — lb/lin ft	3.3	6.0	7.5	11.3	12.4	15.0	19.7
	C. Kerosene in annulus — lb/lin ft	2.7	4.9	6.2	9.3	10.2	12.3	16.1
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	1.830	2.318	2.802	3.831	4.094	4.675	5.635
	b. Annulus area, sq in.	8.64	11.83	15.36	24.10	26.60	32.52	43.44
1½	A. Cu ft/lin ft	0.0415	0.0850	0.1096	0.1703	0.1876	0.2287	0.3046
	B. Water in annulus — lb/lin ft	2.6	5.3	6.8	10.6	11.7	14.3	19.0
	C. Kerosene in annulus — lb/lin ft	2.1	4.3	5.6	8.7	9.6	11.7	15.6
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	1.020	1.508	1.992	3.021	3.284	3.865	4.825
	b. Annulus area, sq in.	5.47	8.66	12.19	20.93	23.43	29.34	40.27
2	A. Cu ft/lin ft	0.0316	0.0751	0.0996	0.1603	0.1777	0.2188	0.2946
	B. Water in annulus — lb/lin ft	2.0	4.7	6.2	10.0	11.1	13.7	18.4
	C. Kerosene in annulus — lb/lin ft	1.6	3.8	5.1	8.2	9.1	11.2	15.1
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	0.150	0.638	1.122	2.151	2.414	2.995	3.955
	b. Annulus area, sq in.	0.91	4.10	7.63	16.38	18.87	24.78	35.71
2½	A. Cu ft/lin ft	———	0.0617	0.0862	0.1469	0.1643	0.2049	0.2812
	B. Water in annulus — lb/lin ft	———	3.9	5.4	9.2	10.3	12.8	17.5
	C. Kerosene in annulus — lb/lin ft	———	3.2	4.4	7.5	8.4	10.5	14.4
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	———	0.158	0.642	1.671	1.930	2.515	3.475
	b. Annulus area, sq in.	———	1.08	4.61	13.35	16.63	21.76	32.69
3	A. Cu ft/lin ft	———	———	0.0637	0.1244	0.1417	0.1828	0.2587
	B. Water in annulus — lb/lin ft	———	———	4.0	7.8	8.8	11.4	16.1
	C. Kerosene in annulus — lb/lin ft	———	———	3.3	6.4	7.3	9.4	13.2
	D. Clearance between casing and pipe coupling							
	a. Gap in inches	———	———	0.092	1.121	1.384	1.965	2.925
	b. Annulus area, sq in.	———	———	0.70	9.44	11.94	17.85	28.78

VII. FRICTION HEAD LOSS THROUGH ROCK ISLAND PIPE

A. FLOW OF INCOMPRESSIBLE LIQUIDS:

Rock Island fiber glass pipe is smooth and paraffin resistant. The Hazen Williams "C" factor is very close to 150. For friction head loss calculations, a simplified equation, which is applicable for Reynolds No. between 4000 and 4.3×10^5, has been derived for Rock Island pipes

$$h_f = K \; q^{1.8} \; \sqrt{}^{0.2}$$

where hf — Head loss in feet of fluid per 100 feet of pipe

$\sqrt{}$ — Kinematic viscosity at a specified temperature in centistokes

— Volumetric flow rate, cfs

K — Constant, depending on Rock Island pipe size

It can be noted that only fluid viscosity is required for any head loss calculations. The viscosity data for petroleum products, and the effect of temperature, etc., are shown in Table 8 and Figs. 5-6 (p. 23) in the Appendix. Flow charts for water, brine, and crude oil are plotted in Figs. 1-3 (pp. 19-21) based on the above equation.

PIPE SIZE (in.)	K
1	5680
1½	808
2	299
2½	102
3	28.8
4	8.0
6	1.283
8	0.3326

B. FLOW OF GASES:

1. Low Pressure Flow: The change of gas density in this case is not significant. The equation derived by Huff and Logan (Am. Gas. Assoc. Proc., 1935, p. 687) is relatively simple:

$$Q = \frac{2331 \; (\triangle p)^{0.543} \quad d^{2.631}}{S^{0.468} \quad l^{0.543}}, \text{ cu ft/hr}$$

where

$\triangle p$ = Pressure drop, inches of water

S = Specific gravity of flowing gas (air = 1 at room temperature and 30 in. of Hg.)

l = Length of pipe, ft

2. High Pressure Flow: The well known Weymouth formula [Trans. Am. Soc. Mech. Engrs. *34*, 1091-1104, (1912)] can be simplified for Rock Island pipes by using a natural gas specific gravity of 0.6 at a flowing temperature of 60°F and 14.65 psia:

$$Q = C \left[\frac{P_1^2 - P_2^2}{L} \right]^{1/2}, \text{ cu ft/hr}$$

where

P_1 = Inlet line pressure, psia

P_2 = Outlet line pressure, psia

L = Length of line, miles

C = Constant, depending on Rock Island pipe size

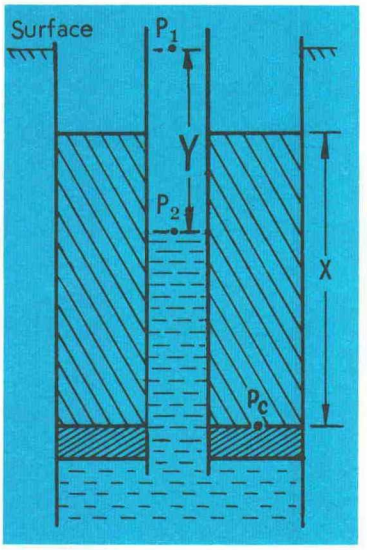
A flow chart is shown in Fig. 4.

PIPE SIZE (in.)	C
1	36.3
1½	116.9
2	206.9
2½	373.8
3	678.8
4	1,462
6	4,315
8	12,720

VIII. SELECTION OF ROCK ISLAND PIPE

— Working Example

A. DATA REQUIRED:



1. Depth of well
2. Size of casing
3. Pumping rate through tubing
4. Size of steel tubing formerly used
5. Completion method — Load requirement
6. Static level of well
7. Tubing internal pressure at the top of well
8. Type of fluid in annulus and height above static level.
9. Type of fluid in tubing

B. SELECTION PROCEDURE:

1. Maximum axial tensile, T, of tubing required:
   T, lb = lb/ft × tubing length in ft + wt of fluid in tubing*
   + tension needed for packer or pump in lb
   — wt of fluids displaced by tubing in lb

   * when submergible pump is used

2. Friction head loss through tubing:
   The proper flow chart can be used as shown in the Appendix (pp. 19-22)

3. Maximum internal pressure at the static level when the annulus is not filled:
   $P_2 = 0.433$ (Sp Gr) Y + P_1

where

P_1, P_2 = Fluid pressure in tubing at the top and static level of well respectively, psi
Y = Distance between P_1 and P_2, ft
Sp Gr = Specific gravity of fluid in tubing
Fig. 8 on p. 25 is plotted for brine.

4. Maximum collapse pressure at the static level, when the annulus is filled:
   $P_c = 0.433$ (sp gr) X
   Sp gr = Specific gravity of fluid in annulus
   P_c = Maximum collapse pressure, psi
   X = Height of fluid in annulus above static level of well, ft
   Fig. 9 on p. 26 is for inhibited fresh water, brine, and kerosene.

5. Compare the calculated requirements of tubing with the specified maximum operating specifications of Rock Island. If the calculated values are higher than the tubing specification, frequently the operating conditions of well can be modified slightly.

6. Check the maximum coupling diameter of the selected tubing against the ID of casing to make sure enough clearance is allowed.

C. WORKING EXAMPLE:

Given:

Well — 4,400 ft
API Casing — 5½ in.
Tension Packer — 2,500 lb required for 60 durometer rubber
Flow Rate — 600-800 bbl/day
Size of steel tubing had been used — 2 in.
Internal Pressure — Vacuum to 100 psi at the top of well
Static Level — 4,000 ft from surface
Inhibited water can be used in annulus

Solution:

1. Maximum axial tensile: If the annulus is not filled, with 2 in. Rock Island heavy-duty tubing, the axial tensile can be calculated by first referring to Table 3 on p. 11 to get wt per ft of tubing (1.36) and the cross sectional area of the pipe wall (1.563 sq in.). Use a brine density of 72 lb per cu ft, hence:

$$T = 4{,}400\ (1.36) + 2{,}500 - \left(\frac{1.563}{144}\right)(4{,}400 - 4{,}000)\ 72$$
$$= 5{,}980 + 2{,}500 - 313$$
$$= 8{,}177 \text{ lb}$$

It is obvious that the buoyancy factor, 313 lb, is not significant. In most cases it can be neglected.

2. Pressure drop through 2 in. tubing: Using Fig. 2, on p. 20, the head loss is 1.5 ft/100 ft at 800 bbl/day.

$$\text{Total head loss} = 4{,}400\left(\frac{1.5}{100}\right) = 66 \text{ ft} = 33 \text{ psi for brine of 72 lb/cu ft}$$

3. Maximum Internal Pressure: If annulus is not fiilled:

Use Fig. 8 on p. 25, when $P_1 = 100$ psi, and $Y = 4{,}000$ ft
$P_2 = 2{,}100$ psi maximum

4. Maximum collapse pressure: If annulus is filled with inhibited fresh water, use Fig. 9 on p. 26, for water, when $X = 4{,}000$ $P_c = 1.750$ psi

5. Comparison:

	CALCULATED	ROCK ISLAND SPECIFICATIONS
Maximum Internal Pressure, psi	2,100	1,500
Maximum Collapse Pressure, psi	1,750	1,000
Maximum Axial Tensile, lb	8,177	8,500

It is obvious that 2 in. heavy-duty Rock Island tubing does not meet the requirements completely. However, if the annulus is filled with inhibited water to 1,600 ft above static level, the same tubing will handle the situation very well. Repeating the above calculations, the following result can be obtained:

a) Maximum Internal Pressure: P_2 will remain 1,750 psi at the static level; however, this will be balanced by the fluid in the annulus in operation. The maximum internal pressure in this case can be obtained by using $Y = (4{,}400 - 2{,}000)$ from Fig. 8.

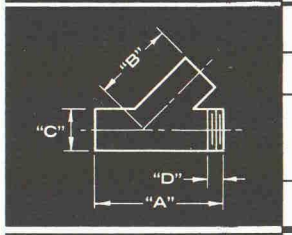
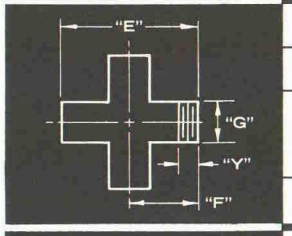
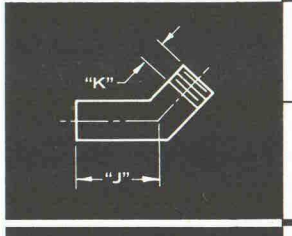
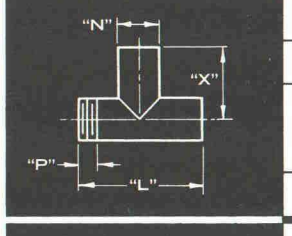
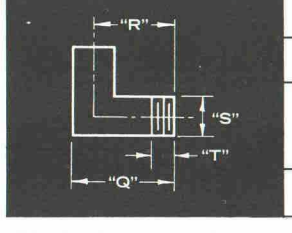
$P_2 = 1{,}300$ psi

b) Maximum Collapse Pressure: Use $X = 1{,}600$ and Fig. 9.

$P_c = 700$ psi

6. The maximum coupling diameter of Rock Island 2 in. heavy-duty tubing is 3.77 in. $\pm$ 1/16 which is well below the ID of any 5½ in. API casing.

TABLE 7

	SIZE	1 in.		1½ in.		2 in.		2½ in.		3 in.		4 in.		6 in.		8 in.	
	(in.)	IP	10 Rd	IP	10 Rd	IP	8 Rd	IP	8 Rd	IP	8 Rd	IP	8 Rd	IP	8 Rd	IP	8 Rd
	A	6⅜	6⅞	8⅛	8⅞	8⅞	10⅞	10⅛	11⅞	11⅛	13¾	12⅞	15¼	15⅞	18¼		
	B	3¾	4⅛	4⅞	5½	5⅝	6¾	6⅜	7½	7¼	8⅜	8½	9⅞	11¼	12⅜		
	C	M 2½ H 2⅝	M 2⅝ H 2⅞	M 3 H 3¼	M 3¼ H 3½	M 3½ H 3¾	M 3¾ H 4	M 4 H 4¼	M 4¼ H 4½	M 4⅝ H 4⅞	M 4⅞ H 5⅛	M 5⅝ H 5⅞	M 5⅞ H 6	L 8 M 8¼	L 8 M 8¼		
	D	1¼	1⅜	1¾	2	1½	2⅜	1¾	2½	1⅞	3	2	3	2	3¼		
	E	5	6	7	8	8	9	9	10	10	12	11	13	14	16	18	20
	F	2½	3	3½	4	4	4½	4½	5	5	6	5½	6½	7	8	9	10
	G	M 2½ H 2⅝	M 2⅝ H 2⅞	M 3 H 3¼	M 3¼ H 3½	M 3½ H 3¾	M 3¾ H 4	M 4 H 4¼	M 4¼ H 4½	M 4⅝ H 4⅞	M 4⅞ H 5⅛	M 5⅝ H 5⅞	M 5⅞ H 6	L 8 M 8¼	L 8 M 8¼	L 10 M 10¼	L 10 M 10¼
	Y	1¼	1⅜	1¾	2	1½	2⅜	1¾	2½	1⅞	3	2	3	2	3¼	2¼	3½
	J	2	2½	3	3¼	3¼	3¾	3¾	4	4	5	4¾	5	5¼	6¼		
	K	1¼	1⅜	1¾	2	1½	2⅜	1¾	2½	1⅞	3	2	3	2	3¼	2¼	3½
	L	5	6	7	8	8	9	9	10	10	12	11	13	14	16	18	20
	X	2½	3	3½	4	4	4½	4½	5	5	6	5½	6½	7	8	9	10
	N	M 2½ H 2⅝	M 2⅝ H 2⅞	M 3 H 3¼	M 3¼ H 3½	M 3½ H 3¾	M 3¾ H 4	M 4 H 4¼	M 4¼ H 4½	M 4⅝ H 4⅞	M 4⅞ H 5⅛	M 5⅝ H 5⅞	M 5⅞ H 6	L 8 M 8¼	L 8 M 8¼	L 10 M 10¼	L 10 M 10¼
	P	1¼	1⅜	1¾	2	1½	2⅜	1¾	2½	1⅞	3	2	3	2	3¼	2¼	3½
	Q	3⅝	4¼	4⅞	5½	5⅝	6¼	6⅜	7	7¼	8¼	8¼	9¼	10⅞	11⅞	13⅞	14⅞
	R	2½	3	3½	4	4	4½	4½	5	5	6	5½	6½	7	8	9	10
	S	M 2½ H 2⅝	M 2⅝ H 2⅞	M 3 H 3¼	M 3¼ H 3½	M 3½ H 3¾	M 3¾ H 4	M 4 H 4¼	M 4¼ H 4½	M 4⅝ H 4⅞	M 4⅞ H 5⅛	M 5⅝ H 5⅞	M 5⅞ H 6	L 8 M 8¼	L 8 M 8¼	L 10 M 10¼	L 10 M 10¼
	T	1¾	1⅜	1¾	2	1½	2⅜	1¾	2½	1⅞	3	2	3	2	3¼	2¼	3½

L = Light Service M = Medium Service H = Heavy-Duty

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CHART 1

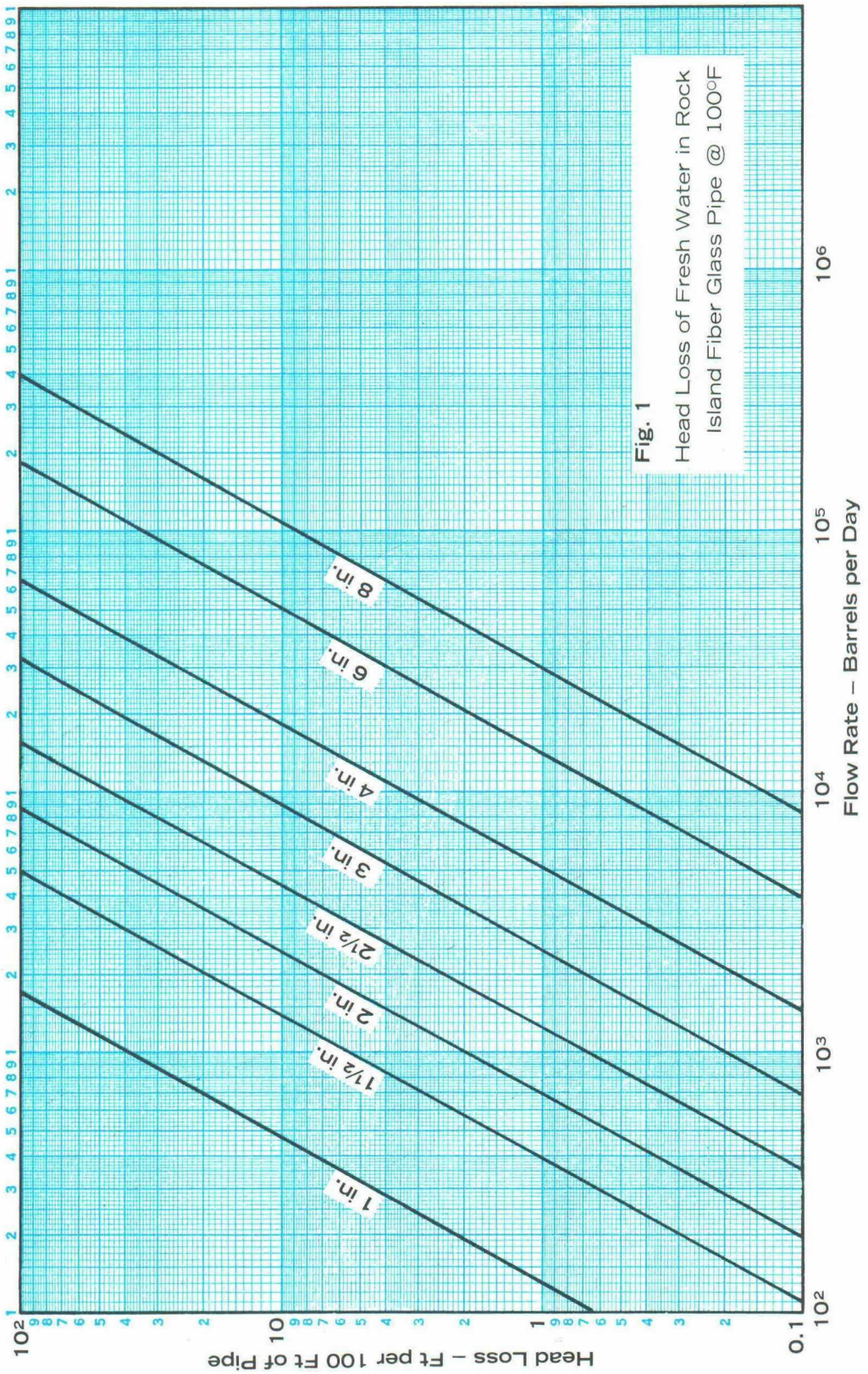

Fig. 1
Head Loss of Fresh Water in Rock Island Fiber Glass Pipe @ 100°F

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CHART 2

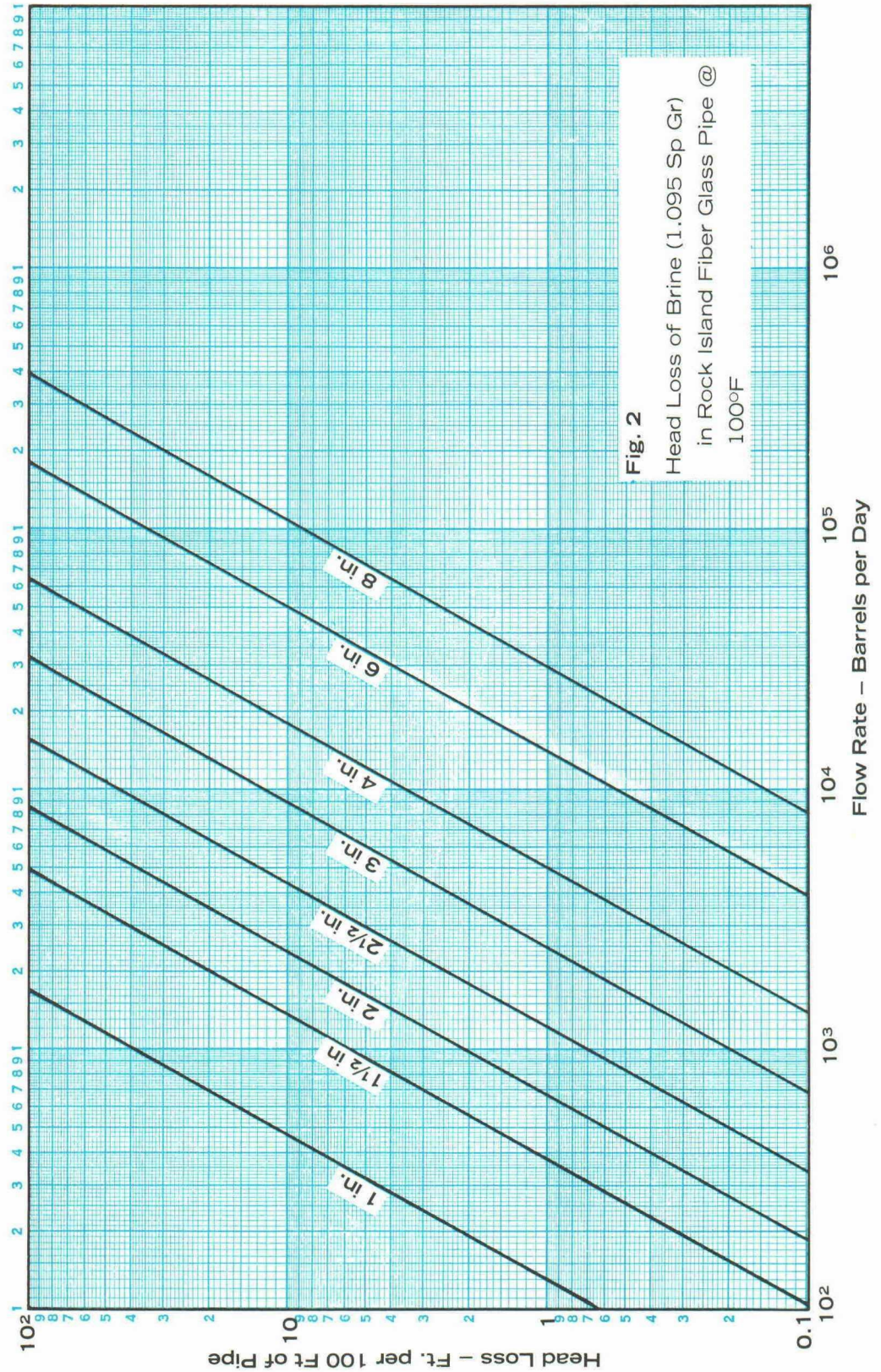

Fig. 2
Head Loss of Brine (1.095 Sp Gr) in Rock Island Fiber Glass Pipe @ 100°F

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CHART 3

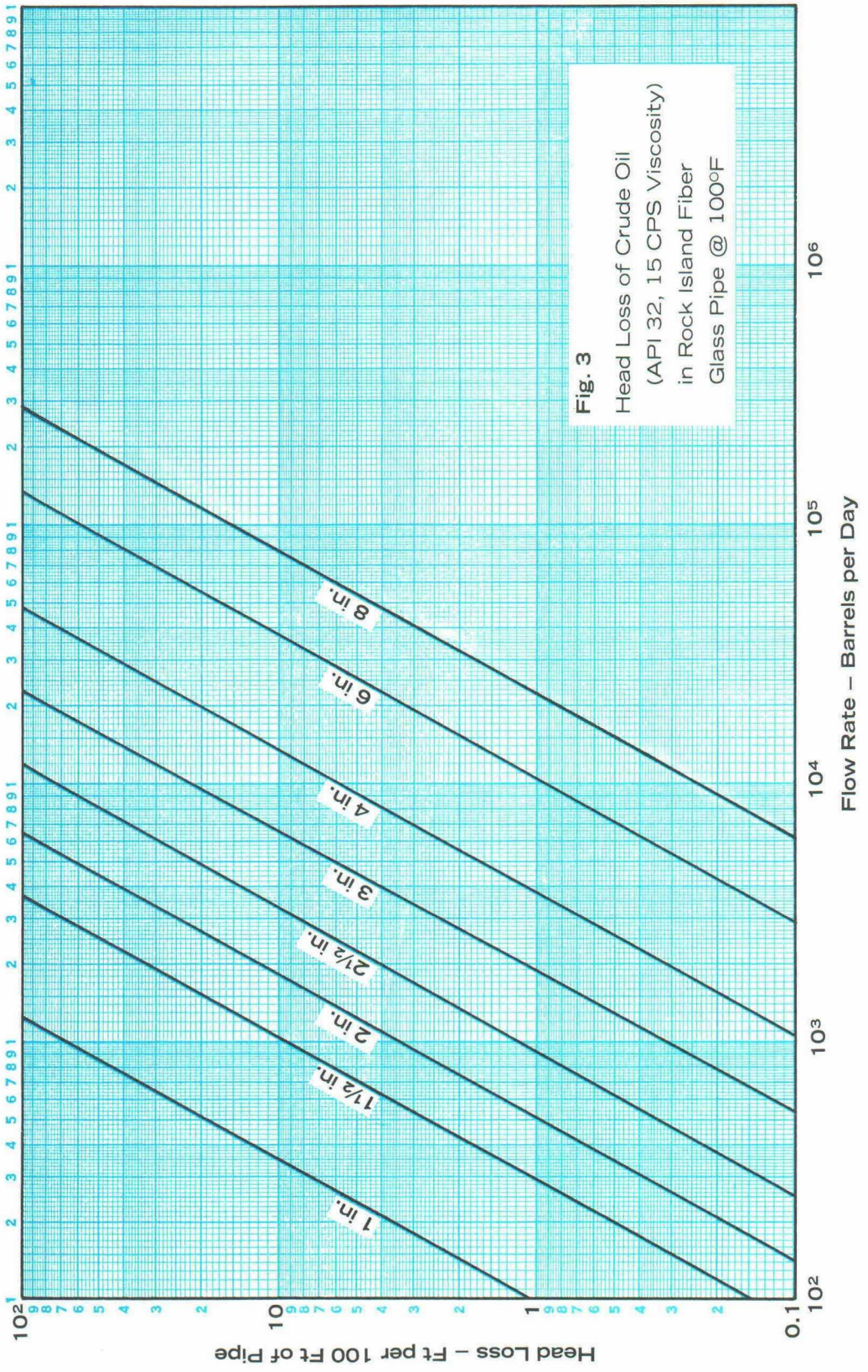

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CHART 4

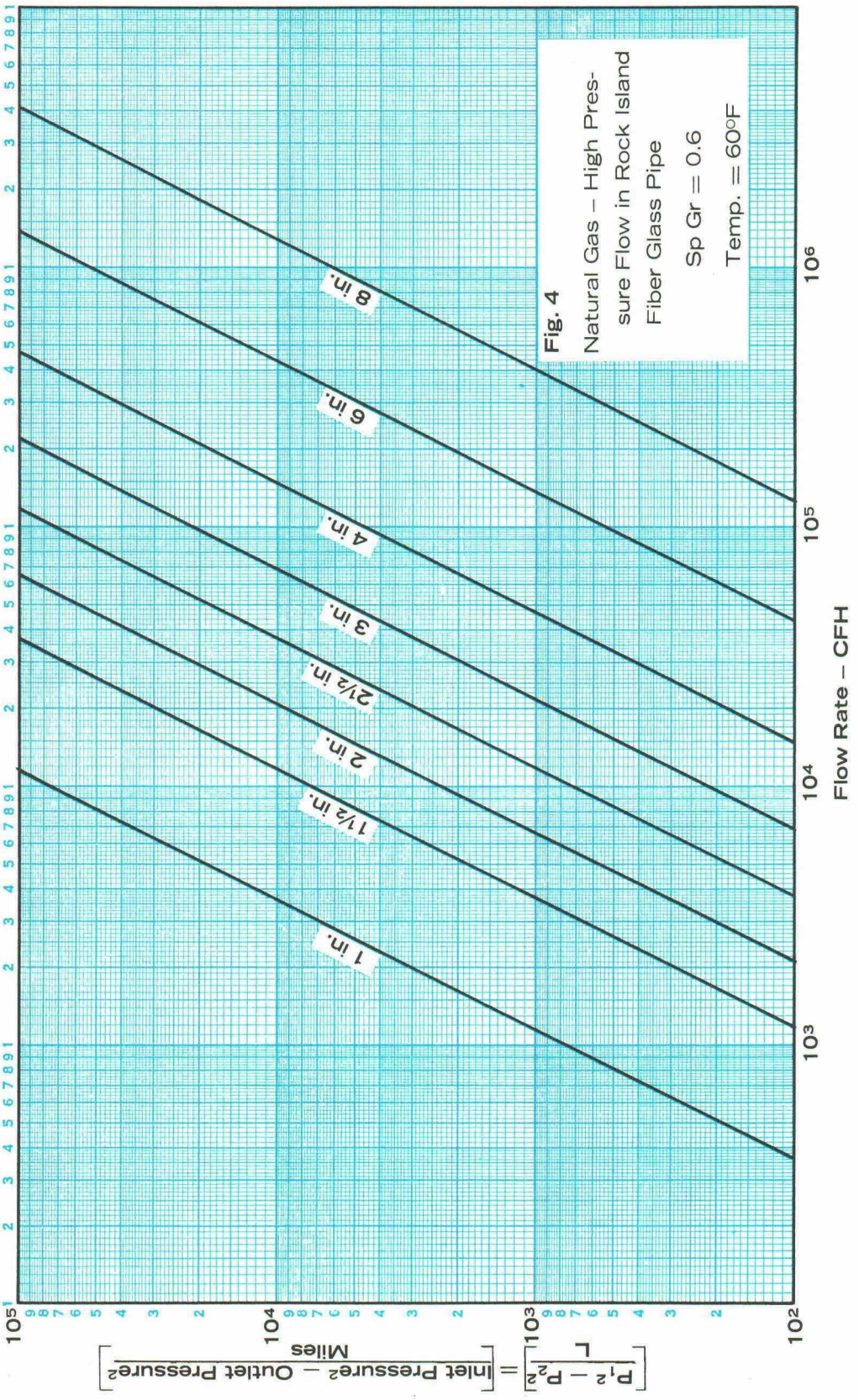

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TABLE 8

A. Viscosity and Specific Gravity Data of Petroleum Products

	Sp Gr	VISCOSITY, CENTISTOKES ★ 60°F	100°F
CRUDE OILS			
Texas, Oklahoma	0.81 - 0.916	20 - 198 @ 70°F	2.4 - 45
Wyoming, Montana	0.86 - 0.88	20 - 240 @ 70°F	6.2 - 70
California	0.78 - 0.92	20 - 1,000 @ 70°F	2.4 - 198
Pennsylvania	0.8 - 0.85	20 - 43 @ 70°F	3.8 - 17
GASOLINE	0.68 - 0.74	0.8	0.8
JET FUEL	0.74 - 0.85	2.56	2.56
KEROSENE	0.78 - 0.82	3.6	1.9
FUEL OIL			
No. 1	0.82 - 0.95	3.6	1.9
No. 2	0.82 - 0.95	7.4	4.3
No. 3	0.82 - 0.95	12.4	5.9
No. 5A	0.82 - 0.95	87.6	20.2
No. 5B	0.82 - 0.95	132.0	87.6
No. 6	0.82 - 0.95	—	1980.0
DIESEL FUEL OILS —			
No. 2D	0.82 - 0.95	12.5	6.0
No. 3D	0.82 - 0.95	25.0	10.2
No. 4D	0.82 - 0.95	132.0	29.0
No. 5D	0.82 - 0.95	1100.0	198.0
LUBRICATION OILS			
SAE 10	0.88 - 0.935	132 - 198	36 - 48
SAE 20	0.88 - 0.935	198 - 660	48 - 125
SAE 30	0.88 - 0.935	660 - 1000	125 - 176
SAE 40	0.88 - 0.935	1000 - 1320	176 - 240
SAE 50	0.88 - 0.935	1320 - 2200	240 - 400

★ Centipoises = Centistokes × (Sp Gr)

CHART 5

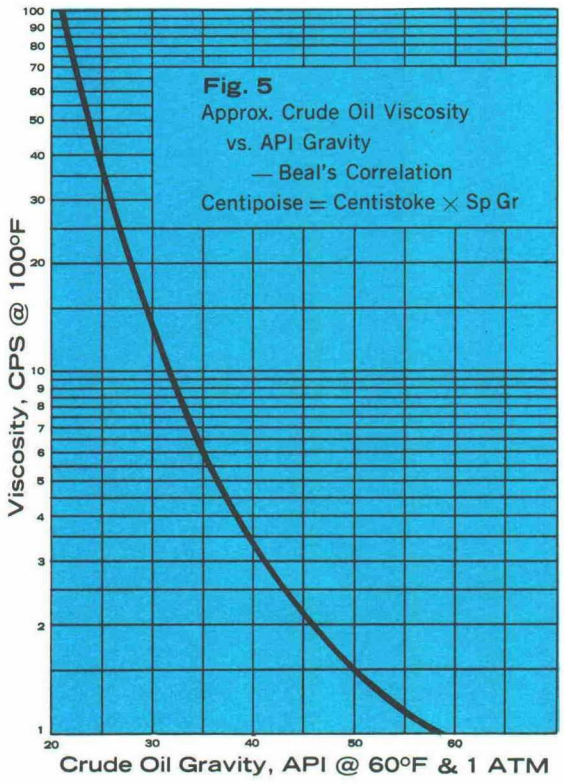

CHART 6

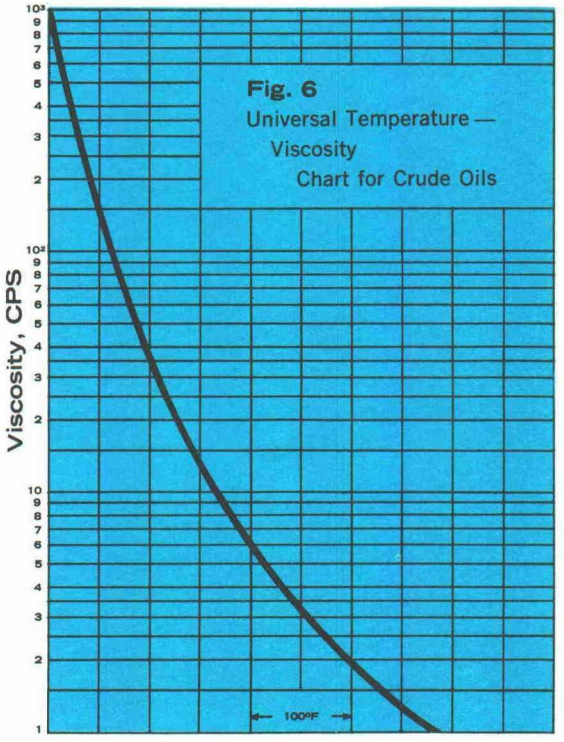

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CHART 7

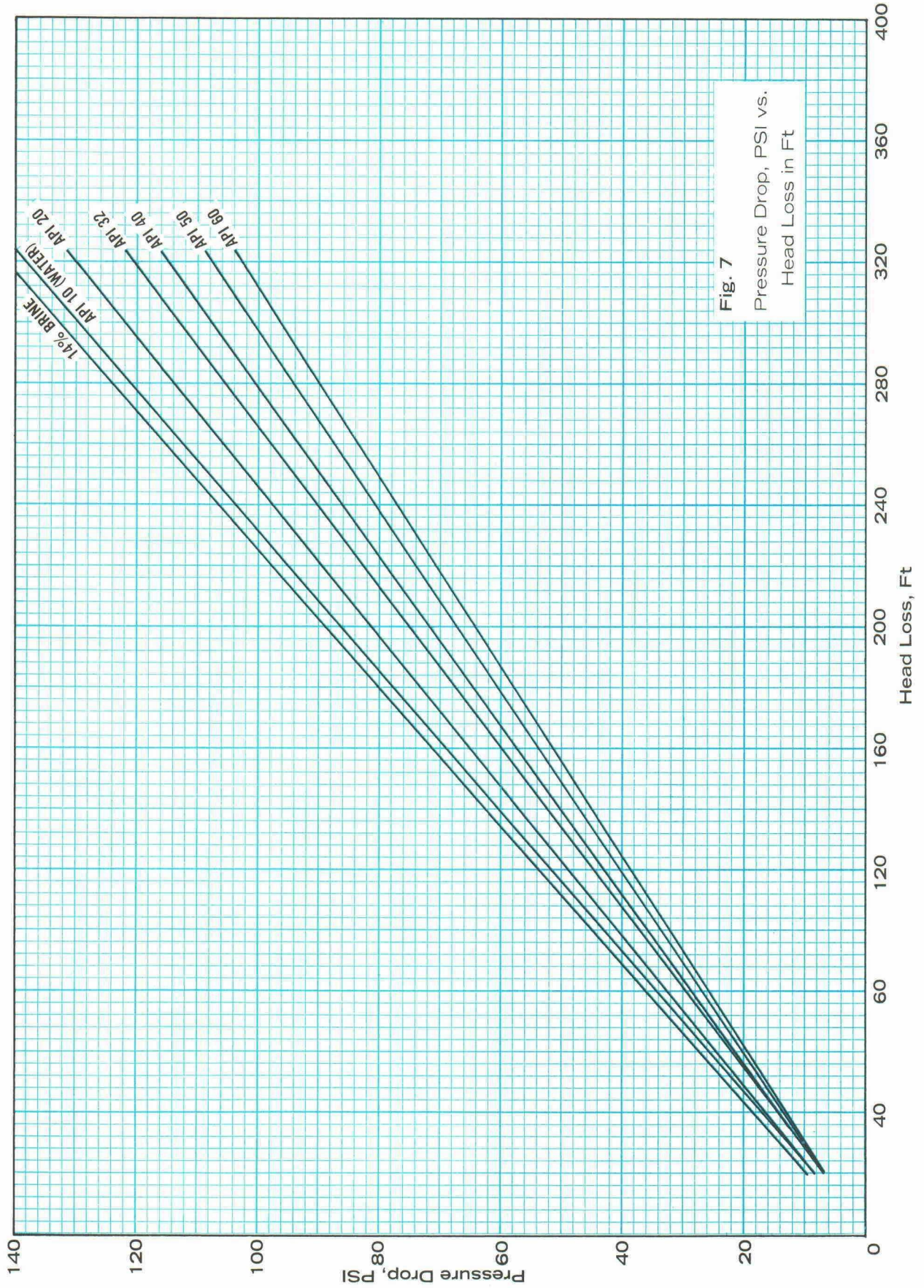

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CHART 8

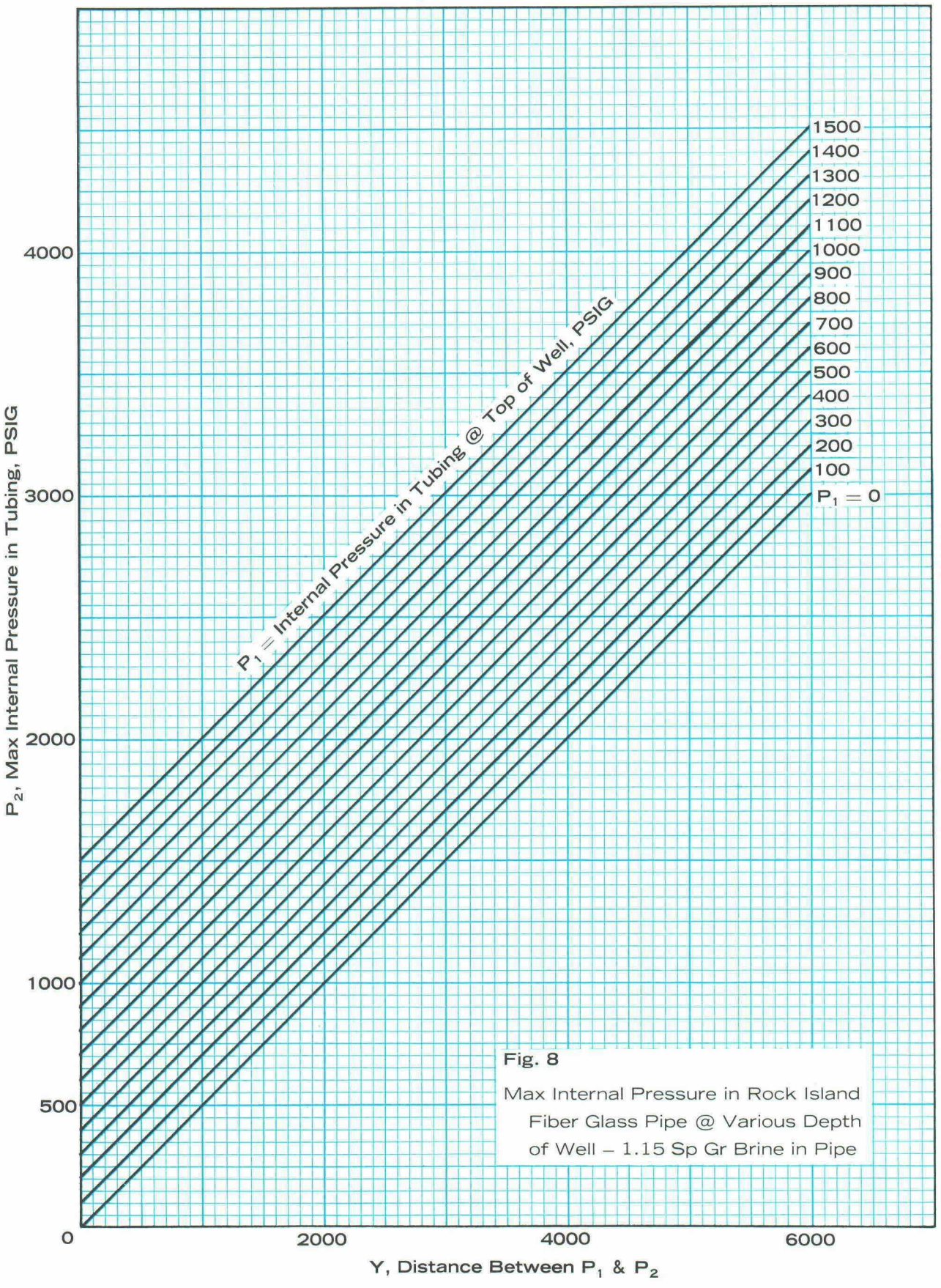

Fig. 8

Max Internal Pressure in Rock Island Fiber Glass Pipe @ Various Depth of Well – 1.15 Sp Gr Brine in Pipe

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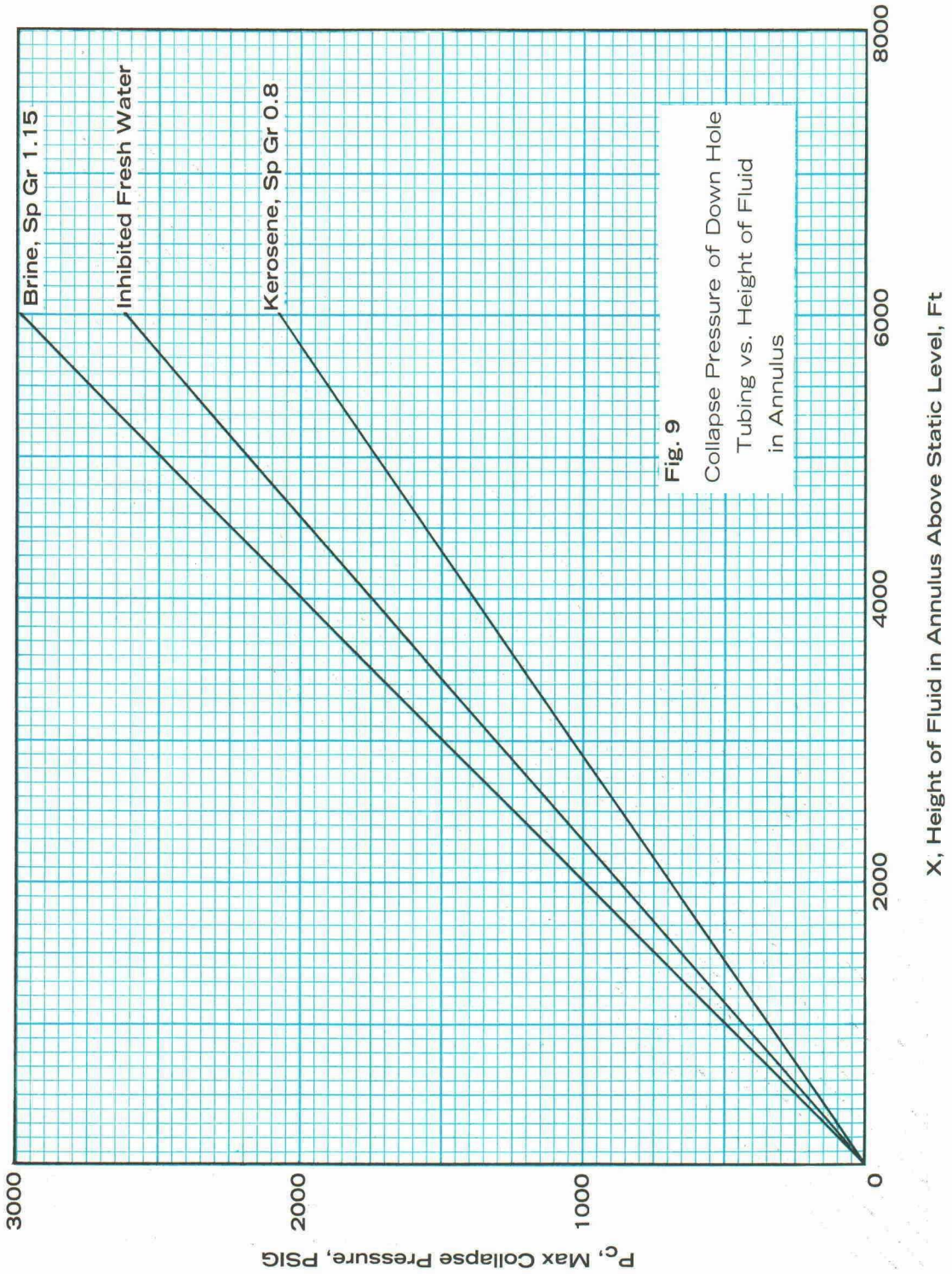
CHART 9



X. APPENDIX

CONVERSION FACTORS

Acre	=	43,560.	square feet
Acre	=	4,048.	square meters
Acre	=	160.	square rods
Acre	=	5,645.4	square varas (Texas)
Acre	=	.4047	hectares
Acre foot	=	7,758.	barrels
Atmosphere	=	33.94	feet of water
Atmosphere	=	29.92	inches of mercury
Atmosphere	=	760.	millimeters of merc.
Atmosphere	=	14.70	pounds per sq in.
Barrel	=	5.6146	cubic feet
Barrel	=	42.	gallons
Bbl of water @ 60°F	=	.1588	metric ton
Barrel (36° API)	=	.1342	metric ton
Barrel per hour	=	.0936	cu ft per minute
Barrel per hour	=	.700	gallon per minute
Barrel per hour	=	2.695	cu in. per second
Barrel per day	=	.02917	gallon per minute
British thermal unit	=	.2520	kilogram calorie
British thermal unit	=	.2928	watt hour
Btu per minute	=	.02356	horse-power
Centimeter	=	.3937	inch
Centimeter of merc.	=	.1934	pound per sq in.
Chain	=	66.	feet
Chain	=	4.	rods
Cubic centimeter	=	.06102	cubic inch
Cubic foot	=	.1781	barrel
Cubic foot	=	7.4805	gallons (U. S.)
Cubic foot	=	.02832	cubic meter
Cubic foot	=	.9091	sacks cement (set)
Cu ft per minute	=	10.686	bbl per hour
Cu ft per minute	=	28.800	cu in. per second
Cu ft per minute	=	7.481	gallons per minute
Cubic inch	=	16.387	cubic centimeters
Cubic meter	=	6.2897	barrels
Cubic meter	=	35.314	cubic feet
Cubic meter	=	1.308	cubic yards
Cubic yard	=	4.8089	barrels
Cubic yard	=	46,656.	cubic inches
Cubic yard	=	.7646	cubic meter
Foot	=	30.48	centimeters
Foot	=	.3048	meter
Foot	=	.3600	vara (Texas)
Foot of water @ 60°F	=	.4331	pound per sq in.
Foot per second	=	.68182	mile per hour

X. APPENDIX

CONVERSION FACTORS

Foot pound	=	.001286	British thermal unit
Ft pound per second	=	.001818	horse-power
Gallon (U. S.)	=	.02381	barrel
Gallon (U. S.)	=	.1337	cubic feet
Gallon (U. S.)	=	231.000	cubic inches
Gallon (U. S.)	=	3.785	liters
Gallon (U. S.)	=	.8327	gallon (Imperial)
Gallon (Imperial)	=	1.2009	gallon (U. S.)
Gallon (Imperial)	=	277.274	cubic inches
Gallon per minute	=	1.429	bbl per hour
Gallon per minute	=	.1337	cu ft per minute
Gallon per minute	=	34.286	bbl per day
Grain (Avoirdupois)	=	.06480	gram
Grain per gallon	=	17.118	parts per million
Grain per gallon	=	142.86	lb per million gal
Grain per gallon	=	.01714	gram per liter
Gram	=	15.432	grains
Gram	=	.03527	ounce
Gram per liter	=	58.418	grains per gallon
Hectare	=	2.471	acres
Hectare	=	.010	square kilometer
Horse-power	=	42.44	Btu per minute
Horse-power	=	33,000.	ft-lb per minute
Horse-power	=	550.	ft-lb per second
Horse-power	=	1.014	horse-power (metric)
Horse-power	=	.7457	kilowatt
Horse-power hour	=	2,547.	British thermal unit
Inch	=	2.540	centimeters
Inch of mercury	=	1.134	feet of water
Inch of mercury	=	.4912	pound per sq in.
Inch of water @ 60°F	=	.0361	pound per sq in.
Kilogram	=	2.2046	pounds
Kilogram Calorie	=	3.968	British thermal unit
Kilogram per sq cm	=	14.223	pounds per sq in.
Kilometer	=	3,281.	feet
Kilometer	=	.6214	mile
Kilowatt	=	1.341	horse-power
Link (Surveyor's)	=	7.92	inches
Liter	=	.2642	gallon
Liter	=	1.0567	quarts
Meter	=	3.281	feet
Meter	=	39.37	inches
Mile	=	5,280.	feet
Mile	=	1.609	kilometers

X. APPENDIX

CONVERSION FACTORS

Mile	=	1,900.8	varas (Texas)
Mile per hour	=	1.4667	feet per second
Ounce (Avoirdupois)	=	437.5	grains
Ounce (Avoirdupois)	=	28.3495	grams
Part per million	=	.05835	grain per gallon
Part per million	=	8.345	lb per million gal
Pood (Russian)	=	36.112	pounds
Pound	=	7,000.	grains
Pound	=	.4536	kilogram
Pound per sq in.	=	2.309	feet of water @ 60°F
Pound per sq in.	=	2.0353	inches of mercury
Pound per sq in.	=	51.697	millimeters of merc.
Pound per sq in.	=	.0703	kilograms per sq cm
Lb per million gal	=	.00700	grain per gallon
Lb per million gal	=	.11982	parts per million
Quart (Liquid)	=	.946	liter
Quintal (Mexican)	=	101.467	pounds
Rod	=	16.5	feet
Rod	=	25.0	links
Sack cement (set)	=	1.1	cubic feet
Square centimeter	=	.1550	square inch
Square foot	=	.0929	square meter
Square foot	=	.1296	square vara (Texas)
Square inch	=	6.452	square centimeters
Square kilometer	=	.3861	square mile
Square meter	=	10.76	square feet
Square mile	=	2.590	square kilometers
Square vara (Texas)	=	7.716	square feet
Temp Centigrade	=	5/9 (°F −32)	
Temp Fahrenheit	=	9/5 °C +32	
Temp Absolute C	=	°C +273	
Temp Absolute F	=	°F +460	
Ton (Long)	=	2,240.	pounds
Ton (Metric)	=	2,205.	pounds
Ton (Short or Net)	=	2,000.	pounds
Ton (Metric)	=	1.102	tons (short or net)
Ton (Metric)	=	1,000.	kilograms
Ton (Metric)	=	6.297	bbl of water @ 60°F
Ton (Metric)	=	7.454	bbl (36° API)
Ton (Short or Net)	=	.907	ton (metric)
Vara (Texas)	=	2.7778	feet
Vara (Texas)	=	33.3333	inches
Watt-hour	=	3.415	British thermal units
Yard	=	.9144	meter

XI. FIBER GLASS PIPE DIVISION OFFICE AND PLANT

2501 South West Street
Wichita, Kansas

WHitehall 2-3237
Area Code 316

SALES AND ENGINEERING REPRESENTATIVES:

	Area Code	Number
Billings, Montana	406	252-1144
Great Bend, Kansas	316	GLadstone 3-6370
Houston, Texas	713	CApital 2-2497
Lafayette, Louisiana	318	232-3841
Midland, Texas	915	682-3161
Oklahoma City, Oklahoma	405	WIndsor 6-1647
Robinson, Illinois	618	544-7397

SALES, INSTALLATION, AND
WARRANTY POLICY
OF ROCK ISLAND FIBER GLASS PRODUCTS

Conditions of Sales...

☐ All sales applications are subject to approval by Rock Island on the basis of operating conditions supplied by the customer. ☐ No discounts for quantity sales are allowed. ☐ All prices are FOB Wichita, Kansas. ☐ Prompt payment discount of ½ of 1% (0.5%) in ten (10) days is allowed. ☐ All prices are subject to change without notice. ☐ Unused Rock Island Fiber Glass products may be promptly returned for full credit via customer prepaid, when these products are received in the same condition as shipped by Rock Island.

Conditions of Installation...

☐ A Rock Island Service Engineer will be available for all initial installations to advise the customer on proper installation procedures for Rock Island Fiber Glass products. No charge is made for this advisory service. ☐ Subsequent service calls are charged at the rate of $6 per hour plus a 10¢ per mile travel charge.

Conditions of Product Warranty...

☐ Each Rock Island Fiber Glass product is warranted for one (1) year against any defects in workmanship and materials, when installed under the above sales and installation conditions. Replacement of each defective unit will be made without additional charge when the unit in question is presented to a Rock Island Service Engineer for suitable examination and evaluation.

XII. REFERENCES

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2. Thomas C. Frick, "Petroleum Production Handbook," McGraw-Hill, New York, 1962.
3. Engineering Manual EM-611, Marlow Pumps, Division of Bell & Gossett Co.
4. Harold W. Knutsen, "Engineering Review," Burgess Publishing Co., Minneapolis, 1960.
5. Aan S. Foust, "Principles of Unit Operations," John Wiley & Sons, New York, 1960.
6. "Hydraulic Institute, Pipe Friction Manual," 3rd Edition, 1961.
7. E. Russell, "Hydraulics," 5th Edition, Holt, New York, 1949.
8. Symposium on Standards for Filament – Wound Reinforced Plastics, ASTM Special Technical, Publication No. 327, 1963.

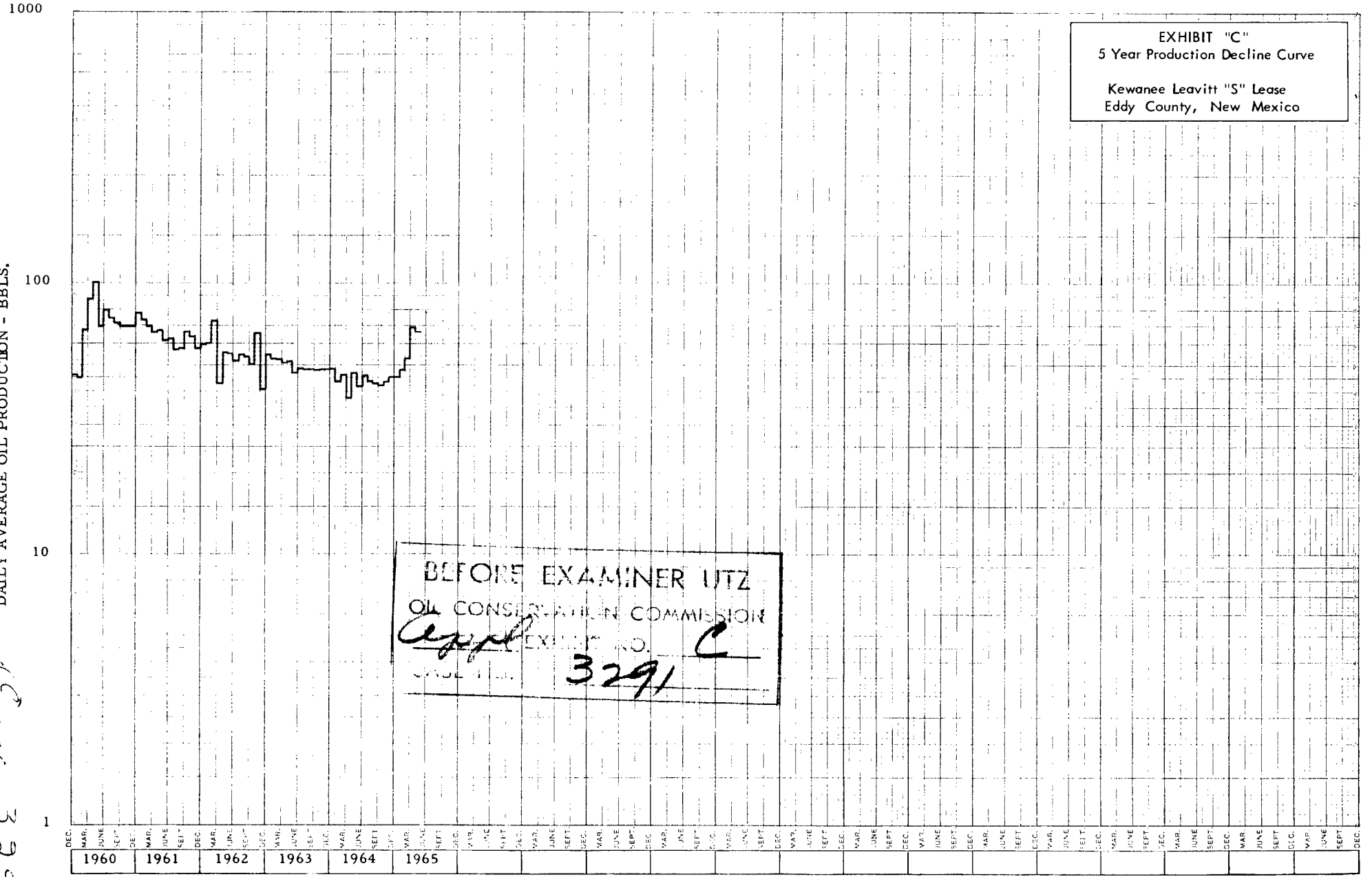


EXHIBIT "C"
5 Year Production Decline Curve
Kewanee Leavitt "S" Lease
Eddy County, New Mexico
DAILY AVERAGE OIL PRODUCTION - BBLS.
1000
100
10
1
1960
1961
1962
1963
1964
1965
BEFORE EXAMINER UTZ
OIL CONSERVATION COMMISSION
EXHIBIT NO.
CASE NO.
3291

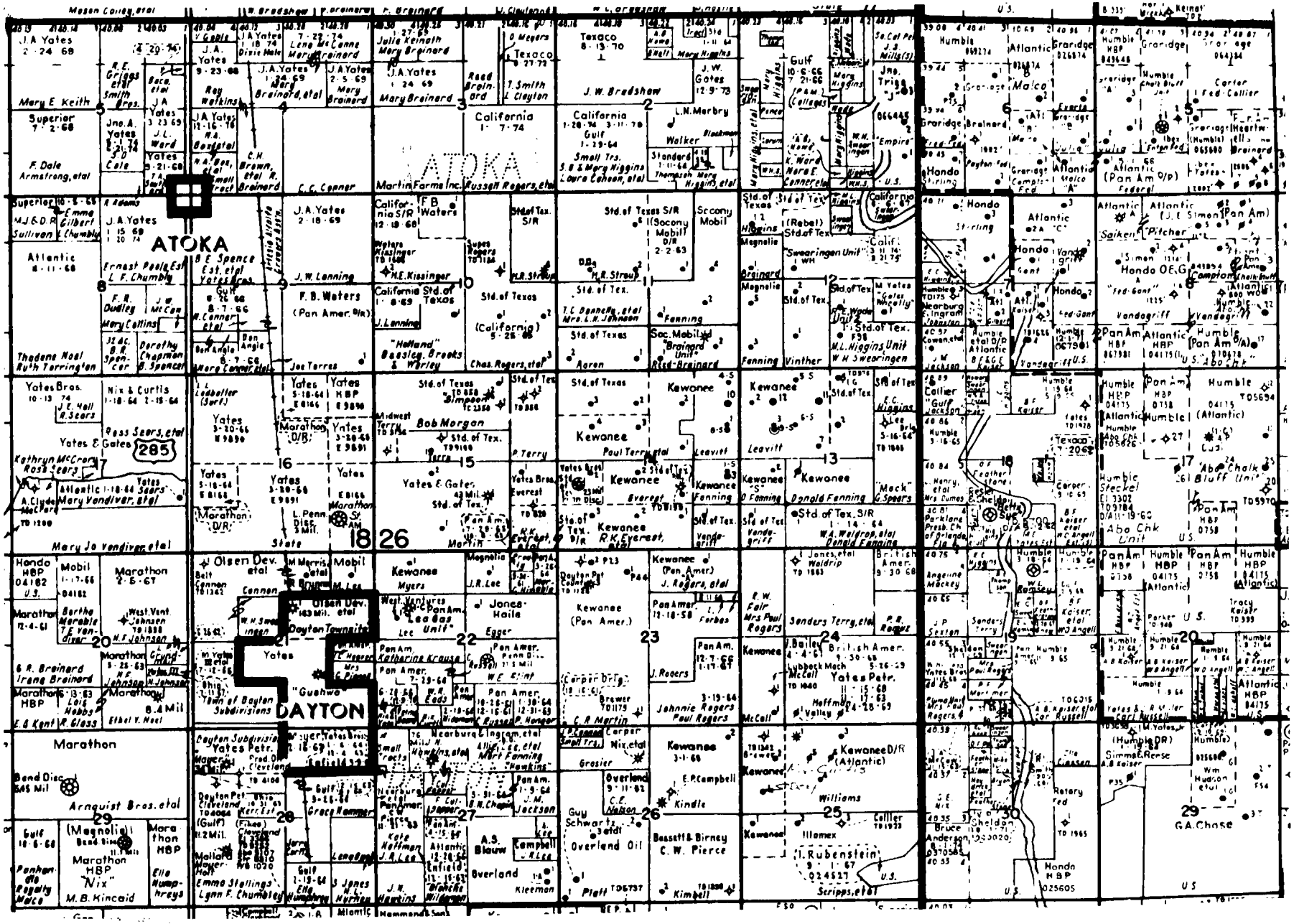
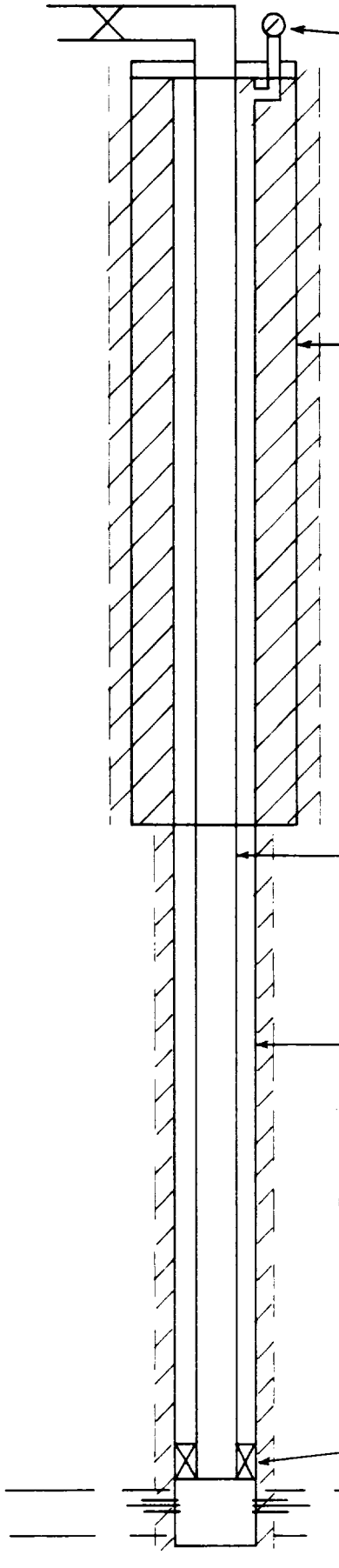


EXHIBIT "D"
Regional Ownership and Development
Atoka San Andres Field
Eddy County, New Mexico

LEAVITT S #9
SW/4 of NW/4, "E" Unit, Sec. 13, T-18-S, R-26-E



BEFORE EXAMINER UTZ
OIL CONSERVATION COMMISSION
EXHIBIT NO. F
CASE NO. 3291

KEWANEE OIL COMPANY
Atoka San Andres Field
Eddy County, New Mexico

EXHIBIT "F"