UNIVERSITY OF MISKOLC

FACULTY OF
EARTH AND ENVIRONMENTAL
SCIENCES AND ENGINEERING

ARTIFICIAL LIFTING II.

MSc in Petroleum Engineering **MFKOT730031**

COURSE DESCRIPTION

FACULTY OF EARTH AND
ENVIRONMENTAL SCIENCES AND ENGINEERING
MINING AND ENERGY INSTITUTE

2024. Spring Term

Course Data Sheet

Course Title: Artificial Lifting II. **Instructor:** Dr. Gábor TAKÁCS professor emeritus	**Code:** MFKOT730031 **Responsible department/institute:** DPE/IPNG (OMTSZ/KFGI) **Course Element: Compulsory**
Position in curriculum* **(which semester)**: 4 (3)	**Pre-requisites (if any):** Artificial lifting I. (MFKOT720017)
No. of contact hours per week (lecture + seminar): 3+0	**Type of Assessment (examination / practical mark / other):** examination
Credits: 3	**Course:** full time

Course Description:

1. Introduction to ESP operations: history, main features.
2. Hydraulic, electrical backgrounds.
3. Components and their operation: centrifugal pump, performance curves.
4. Construction of the electric motor, operational features, starting. Temperature conditions of ESP motors. Functions and main parts of protectors.
5. Construction and operation of gas separators.
6. The downhole cable: construction, materials, operational features. Ancillary downhole equipment.
7. Application of ESP units in special conditions.
8. Producing high viscosity fluids. Production of gassy fluids: pump performance deterioration. Possible solutions: use of natural gas separation, gas separators, others.
9. Abrasive, high-temperature fluid pumping.
10. Variable speed drives: construction and operation of VSD drives. Design of ESP installations for low and high gas contents.
11. Analysis of ESP system operation: NODAL Analysis. Energy conditions of ESP operation.
12. Monitoring of system operation, typical failures, their elimination.
13. Main features of PCP systems. System components: PCP pump, rod string, surface drives.
14. Basics of PCP installation design.

Competencies to evolve:

Knowledge:

Knows the economic processes related to the hydrocarbon industry.

Knows the processes and phenomena occurring during production in petroleum and natural gas water wells.

Knows the equipment used for different types of production; and the methods ensuring the appropriate selection of the necessary equipment and procedures.

Knows the methods and tools of computerized design and analysis in the hydrocarbon industry.

Ability:

Able to interpret the economic processes related to the hydrocarbon industry and to give adequate answers to them.

Capable of monitoring and forecasting the processes taking place in oil and natural gas water wells.

Able to choose the optimal production method, design and select the production equipment.

Able to supervise and inspect equipment related to pipeline transportation of crude oil, natural gas and water.

Able to select equipment for field and transmission line transport and supervise the operation of the equipment and manage the participating groups.

Capable of hydrocarbon industrial computer design and analysis.

Attitude:

Autonomy and responsibility:

Able to independently manage hydrocarbon industrial complex planning works and perform project management tasks, or participate in them.

Autonomously able to plan the production of fluid-producing wells, to achieve optimal production conditions; for the appropriate selection of the necessary equipment and procedures; to implement solutions that ensure maximum profit.

Able to autonomously plan the use of energy carriers produced from renewable natural resources and residual materials in the energy supply system, and manage the operation of the established system.

Takes responsibility for his/her professional decisions and the work processes carried out by him/her or under his/her control.

Assessment and grading	Grading scale
Assessment and grading: Students will be assessed with using the following elements. Attendance: 5 %	Grading scale: % value — Grade 90 -100% — 5 (excellent)

Short quizzes	10 %	80 – 89%	4 (good)
Midterm exam	40 %	70 - 79%	3 (satisfactory)
Final exam	45 %	60 - 69%	2 (pass)
Total	100%	0 - 59%	1 (failed)

Compulsory or recommended literature resources:

- Cholet, H.: Progressing cavity pumps. Editions Technip, Paris. 1997. 112p. ISBN 2-7108-0724-6.
- G Takacs.: Sucker-rod pumping manual. Tulsa : PennWell, 2003. 395 p. ISBN 0 87814 899 2
- Production Operations Engineering, Petroleum Engineering Handbook Vol 4, SPE, 2006
- George V. Chilingarian et.al.: Surface Operations in Petroleum Production II, Elsevier, 1989.
- Szilas, A.P.: Production and Transport of Oil and Gas. Part B., Akadémiai Kiadó, Budapest, 1986., ISBN 963-05-3363-4

Takács G.: Production technology 2. Univ. of Miskolc, 1991. 216p.

Course Schedule for 2023/24 school year, spring term

Date	**Topic**
2024.02.13	Introduction to ESP operations: history, main features. Hydraulic, electrical backgrounds. Components and their operation: centrifugal pump, performance curves.
2024.02.20	Construction of the electric motor, operational features, starting. Temperature conditions of ESP motors. Functions and main parts of protectors. Construction and operation of gas separators.
2024.02.27	The downhole cable: construction, materials, operational features. Ancillary downhole equipment. Application of ESP units in special conditions.
2024.03.05	Producing high viscosity fluids. Production of gassy fluids: pump performance deterioration. Possible solutions: use of natural gas separation, gas separators, others.
2024.03.12	Abrasive, high-temperature fluid pumping.
2024.03.19	Variable speed drives: construction and operation of VSD drives. Design of ESP installations for low and high gas contents.
2024.03.26	Analysis of ESP system operation: NODAL Analysis. Energy conditions of ESP operation. Monitoring of system operation, typical failures, their elimination.
2024.04.09	Main features of PCP systems. System components: PCP pump, rod string, surface drives. Basics of PCP installation design.
2024.04.23	Test writing.

Test Example

OPEN BOOK

___________, 2024

Student Name:…………………………………..

Student ID.:…………………………………..

Problem No.	Marks	Score
1	32	
Total	**32**	

"I pledge that I have neither given nor received any unauthorized assistance on this exam."

Student's Signature: ________________________

Problem Statement:

Select the main components of an ESP installation running at 60 Hz in a well with negligible gas production.

Pump Setting D. = 4,500 ft	WHP = 100 psi	Sp.Gr. Oil =0.85
Perforations @ 5,000 ft	CHP = 10 psi	Sp.Gr. Water = 1.0
Tubing Size 2 3/8" new	Liquid Rate = 1,700 STB/d	Sp.Gr. Gas = 0.60
Casing Size 6 5/8"	Static Liquid Level = 1,820 ft	PI = 2 bpd/psi
Bottomhole Temp = 200F	Water Cut = 80%	Frequency = 60 Hz

Instructions:

Follow the steps outlined on the following sheets.

Solution.

Inflow Calculations

Calculate liquid Sp.Gr. from water cut. $SpGr_l$ =

Calculate SBHP = 0.433 (L_{perf} – L_{stat}) $SpGr_l$ = psi

Calculate FBHP = SBHP – Q/PI = psi

Calculate pump intake pressure (**Eq. 5.2**)

PIP =FBHP - 0.433 (L_{perf} – L_{pump}) $SpGr_l$ = psi

Find dynamic liquid level from **Eq. 5.6** (use $grad_g$ = 0):

L_{dyn} = ft

Find solution GOR from **Eq. 5.3**:

Oil API = 141.5/SpGr Oil – 131.5 =

y =

R_s = scf/STB

Calculate oil volume factor @ PIP from **Eq. 5.5**

F =

B_o =

Calculate liquid rate at pump intake from **Eq. 5.4**:

Q = bpd

Calculate TDH

Find Frictional head loss from **Fig. A-1**: Δh_{fr} (ft/1,000 ft) =

ΔH_{fr} = Δh_{fr} x Setting Depth/1,000 = ft

h_0 = 2.31 WHP / SpGr = ft

TDH = L_{dyn} + ΔH_{fr} + h_0 = ft

Select Pump Type using **Table C-1**

Series = Pump Type =

Performance Parameters @ desired rate from attached Performance Curve:

Head/Stage		ft/stage
BHP/Stage		HP/stage
Shut-In Head/Stage		ft/stage
Allowed Shaft Power		HP
Shaft Diameter		in

Housing Burst Pressure		psi

Calculate Number of Stages Required

No. of Stages = TDH / (ft/stage) = stages

Pump Housing # with Stages (from the table attached).

Check Pump for Mechanical Strength

Pump BHP= No. of Stages x BHP/stage x $SpGr_l$ = HP

Shaft Checks OK not OK.

Max, internal housing pressure = Shut-In Head/Stage x Stages x 0.433 x $SpGr_l$ =

= psi

Housing Checks OK not OK.

Select Protector

Downthrust from Pump = lbs (**Eq. 5.12**)

Series Selected =

Type Selected =

Load Rating @ BHT= lbs OK not OK.

Shaft Power Rating = HP OK not OK.

Select Motor

Motor Series considered: Series _____

Check flow velocity around motor: (**Eq. 5.13**)

v_l = ft/s OK not OK

Required Motor HP = Pump BHP = BHP

Select Motor from **Table D-1**:

Power = HP

Voltage= V

Current= A

Motor Loading = %

Actual Motor Current = A

Motor Efficiency = %

Motor Power Factor = .

Select Cable

Cable Current = Actual Motor Amps = A

Cable Length = Pump Depth + 100 ft = ft

Cable Type Selected =

Select Cable Size using program **CABLES**.

When running the program, use the following parameters:

Cable life = 60 months (5 years)

Power cost = 5 c/kWh

Interest rate = 12%

Selected Cable Size from program **CABLES** = AWG #

Calculate Voltage Drop in Cable, V/1,000 ft

Drop Read from Graph = V/1,000 ft from **App. E**

Adjusted Drop:

$V_{adj} = V_{graph}$ (1 + 0.00214 (BHT -77))=

= V/1,000 ft

Voltage Drop in Cable: V_{adj} x Cable Length / 1,000 = =

Volts

Find Power Lost in Cable

Total Resistance of Cable

Ohms/1,000 ft for AWG #6 (**Table 3.2**)= ______

R_T = Length / 1,000 _____ x (1 + 0.00214 (BHT -77) =

= Ohms

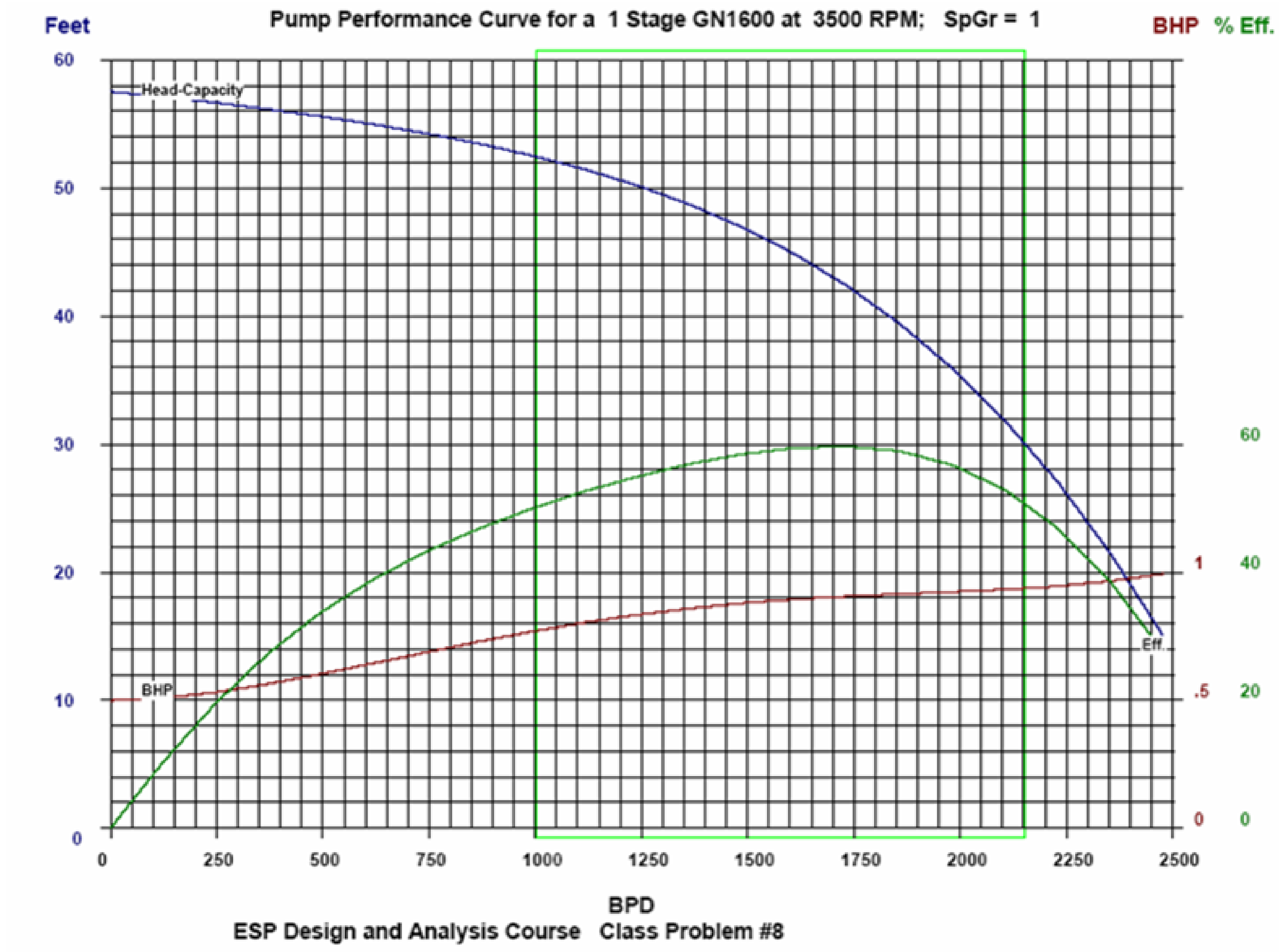
Power Loss = 3 $Current^2$ R_T / 1,000 = kW.

Calculate Surface Voltage, Power

Surface Voltage= Motor Voltage + Drop in Cable = Volts

Surface kVA = 1.732 x Surface Voltage x Cable Current / 1,000 = kVA

Predicted Power Requirement = kVA x Power Factor = kW.


Pump Performance Curve for a 1 Stage GN1600 at 3500 RPM; SpGr = 1
Feet
BHP % Eff.
60
50
40
30
20
10
0
Head-Capacity
BHP
Eff.
1
.5
0
60
40
20
0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
BPD
ESP Design and Analysis Course Class Problem #8

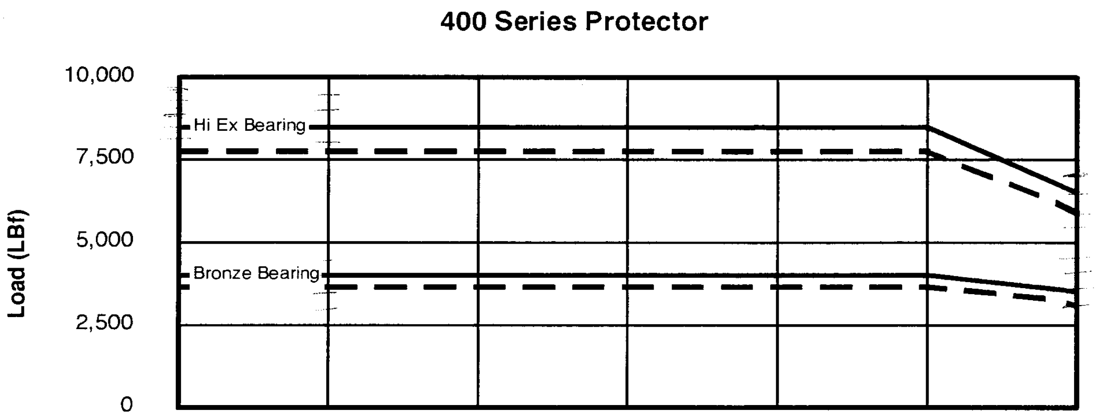
Available housings for GN1600 pumps.

Housing #	Max. Stages
10	12
20	28
30	43
40	59
50	75
60	90
70	106
80	122
90	137

ESP Cable Dimensional and Pricing Data

AWG Size	OD, in	Weight, lbs/ft	Price, $/ft
1	1.357	1.69	11.30
2	1.280	1.44	9.69
4	1.091	1.00	6.46
6	1.000	0.75	5.11

ESP Protector Load Rating Data

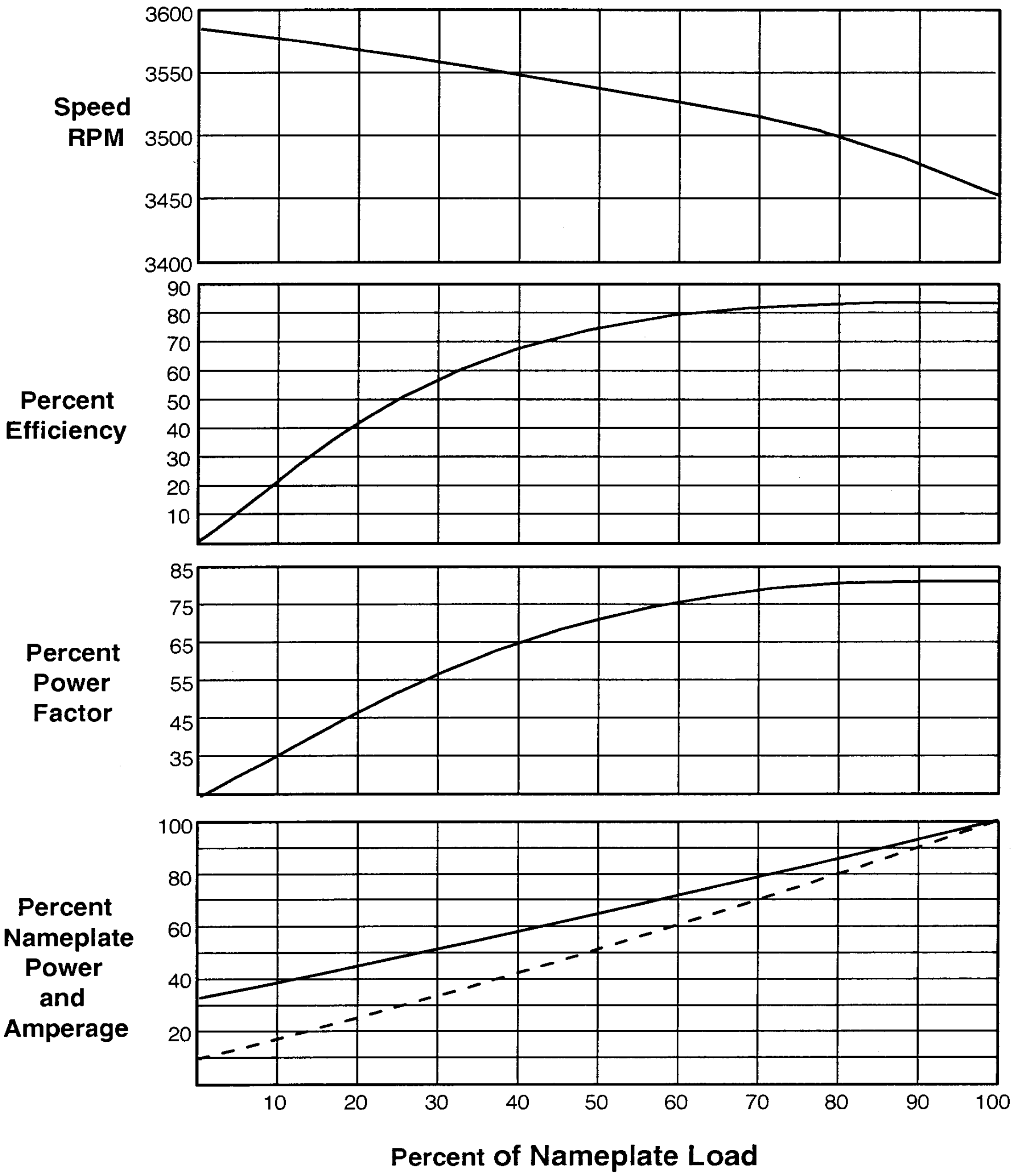


BHT (F) 0 50 100 150 200 250 300

ESP Protector Shaft Rating Data

Series	Shaft Diameter, in	Rated HP
375	0.875	256
400	0.875	256
540	1.187	637
562	1.187	637

ESP Motor Performance Curves



Examination review questions

Final Exam

CLOSED BOOK

January 28, 2013

Student Name:…………………………………..

Student ID.:…………………………………..

Problem No.	Marks	Score
1		
2		
Total		

"I pledge that I have neither given nor received any unauthorized assistance on this exam."

Student's Signature: ________________________

Problem No. 1

1. List the components of a conventional ESP installation from the well bottom upwards:
   1. ______________ 2. ______________ 3. ________________
   4. ______________ 5. ______________ 6. ________________
   7. ______________ 8. ______________

2. List the three most important advantages of ESPs:
   1. ____
   2. ____
   3. ____

3. List the three most important disadvantages of using ESPs:
   1. ____
   2. ____
   3. ____

4. The total head to be developed by an ESP pump has the following three components:
   1. ____
   2. ____
   3. ____

5. The ESP pump's stage consists of the following two parts:
   The stationary part is called the _______________
   The rotating part is called the _______________

6. If pumping viscous fluids, the following changes will happen in the operation of the ESP pump:
   Pump capacity ___________
   Head developed _______________
   Required power ________________
   Pump efficiency ________________

7. When using ESP equipment in a gassy well, the main solutions to overcome the detrimental effects of free gas are:
   a. ____
   b. ____
   c. ____

8. Indicate the correctness of the following statements.

	YES	NO
The effect of high viscosity on the performance of the ESP pump		
Capacity drops		
Head developed increases		
Required power to drive pump increases		
Pump efficiency increases		
The effect of free gas on the performance of the ESP pump		
Small gas bubbles distributed in the liquid are OK		
Higher pump intake pressures are advantageous		
The casing annulus must be kept open		
Do not set pump below perforations to improve gas tolerance		
Radial flow pumps can handle large gas volumes		
Mixed flow pumps handle greater gas volumes than radial pumps		

9. Solids in the produced fluid damage the ESP pump by two basic mechanisms:
   a. _________________

b. _________________

10. If sand or solids production is a problem then floating impeller pumps are not recommended:
FALSE or TRUE

11. Describe the Affinity Laws used for defining the operation of the ESP pump at different speeds.
    a. The pumping rate changes with the _____________.
    b. The head developed changes with the ________________________________.
    c. The required power changes with the ________________________________.

12. Compare a "soft start" with a VSD unit to a normal start of the ESP equipment. Give details on the variation of speed and motor current with time.
____
____
____

Problem No. 2

The basic data for an ESP installation are as follows:

Pump Setting Depth = 5,000 ft	Depth of Perforations = 6,000 ft
Desired Pumping rate = 4,500 bpd	Liquid Sp.Gr. = 0.95
Tubing Size = 3 ½" (old pipe)	Wellhead Pressure = 200 psi

Calculate the TDH for three different cases:

Case A: The dynamic liquid level is at 4,500 ft

Case B: The static liquid level is at 1,000 ft
The well's PI is 3 bpd/psi

Case C: SBHP = 2,200 psi
PI = 2.8 bpd/psi

Instructions:
First calculate the dynamic liquid level then find frictional losses.
List your calculation results in the table provided.

Case	**L_{dyn}**	**TDH**
A		
B		
C		

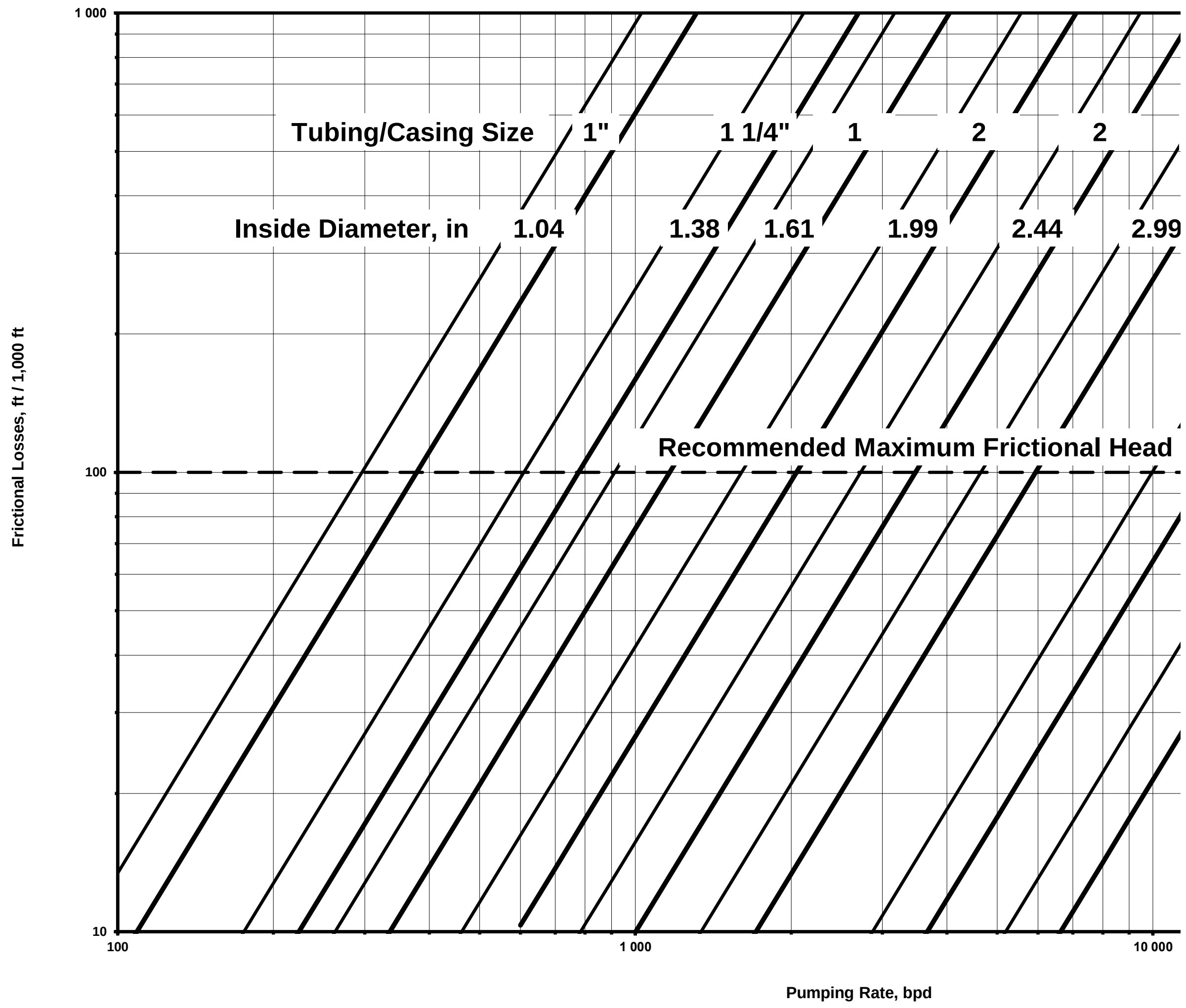


Fig. A-1

Diagram to estimate frictional head losses vs. pumping rate in standard API tubing and casing.