WELL ANALYSIS & CONTROL

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ABSTRACT

Electronic equipment is available for installation on electric motor driven beam pumping units which provides load and displacement data for a complete well analysis including rod stress, gearbox torque and downhole pump card calculations. The electronic equipment also monitors the load and displacement and shuts the well down for a predetermined amount of time when a pumped-off condition occurs and also shuts the well down and sets an alarm when a rod part is detected.

When well data is needed for analysis the load and displacement data can be plotted on a dynamometer and at the same time the load and displacement data is recorded on an electronic memory card for replay into a computer. The electronic memory card records one full cycle of the pumping unit in equal time increments for use in gearbox torque and downhole pump card calculations.

The decline of oil production and the increase in service cost have increased the need for more efficient operation of sucker rod pumping systems. Advances in electronic technology have made available equipment which is permanently installed on electric motor driven beam type pumping units and allows the user to both control and analyze the well. The user can (1) plot a full calibrated dynamometer card and record the data for future playback into a computer and (2) use the dynamometer card as a reference for controlling the pump-off condition of a well and testing for rod parts. The components of this system are shown in Fig.1 and consist of a load cell, a position transducer, and a control box mounted near the pumping unit which accepts the load and position data. A standard X-Y plotter or electronic dynamometer can be adapted to plug directly into the control box to plot a calibrated dynamometer card and to adjust the point at which the pumping unit will shut off after pump-off. An additional device can be added to the plotter which records the load and position data onto a solid-state memory card. The solid state memory card can be transported to a computer data terminal. Through the use of an input unit the well data can be entered into a computer program for gearbox torque and downhole pump card analysis.

The load cell is cylindrical shaped with strain gauge measurement and mounts between the carrier bar and polished rod clamp. The position transducer mounts on the sampson post and is mechanically linked to the walking beam to provide a voltage signal which is proportional to the angle swept by the walking beam movement. Careful design to avoid mechanical side loading and the use of conductive plastic-type potentiometers make the operational life of the position transducer from 3 to 5 years. The load and position data are linked through a cable to the control box which is usually located near the electric power box. The box contains the electronics for determining when a well is pumped-off and for outputting a calibrated dynamometer card to the external plotter.

The dynamometer card is often used to check if the pump is filling properly. Fig.2 shows a typical dynamometer card for a properly filling pump while Fig.3 shows a dynamometer card for the same well with the pump partially filling. The downstroke load in Fig.3 remains high as compared to Fig.2 until the pump plunger impacts the fluid in the pump and forces the travelling valve open resulting in the loss of load on the polished rod. It should be pointed out that there are several reasons why a pump may be partially filling including a restricted pump intake, sticking standing valve and insufficient fluid in the casing to fill the pump. The remaining discussions in this paper shall assume that all partial pump fillage conditions are a result of insufficient fluid and this well condition is defined as pumped off.

The control box uses the load and position information to examine the load on the downstroke and determine if the load is greater or less than a preset level. The dynagraph of Fig.4 shows a well as it pumps from a full to a pumped off condition. The reference point is shown as a dot on the dynagraph and when the control logic detects the downstroke load to be greater than the reference point the pumping unit is shut off for a preset time after which the well is restarted and the checking begins again. The reference point can be moved to any position in the stroke to allow the user to set how deep into the stroke the well pumps-off.

The control circuitry can also be used to check for rod parts by examing the load on the upstroke portion of the stroke. When the load on the upstroke is less than the reference point the control circuitry shuts off the pumping unit and sets an alarm to indicate a rod part has occurred.

The control circuitry can also be used to output a calibrated dynamometer card to an X-Y plotter. Standing valve, travelling valve, zero load line and counterbalance effect measurements can be output to the plotter to provide all the information required for well analysis. The ability to plug a plotter into a control box provides a fast and accurate method for checking the fundamental operation of the pump such as valve leaks and proper pump fillage. For more detailed analysis such as rod stress, gearbox torque or downhole pump card, computer assistance is required to perform these calculations in an efficient manner. The well data from the control circuitry can be input directly into a computer in one of two ways. The first is to telemeter the data directly into the computer by laying cable or the use of radio transmitters to input the data into the computer. The second method is to attach a data recording unit to the plotter which plugs into the control circuit such that as the dynamometer card is drawn on the plotter it is also digitized and stored on a solid state memory card. The solid state memory card is a small digital memory which plugs into the recording unit and accepts one full cycle of the pumping unit. The memory card can be unplugged and a new memory card inserted so that several wells can be recorded on one trip to the field. After each well is analyzed the memory card can be reused on another well. The first method of sending data to a computer, direct cable, has the advantage of providing the operator immediate data on the operating condition of the well. The second method, local recording, has the advantages of (1) faster initial operation - any well can be analyzed at any time; (2) visual inspection of the well site by the operator; (3) much lower cost in installation and maintenance of data gathering equipment; (4) the operator does not necessarily need to be skilled in well analysis. Since the direct cable systems are operational the remainder of this paper shall address itself to local data retrieval.

There are several factors that should be considered in the design of a local data retrieval system to enhance its operation in the field. The means of storing the data should be a solid state memory card so that there are no moving parts exposed to the dirt present at well sites, such as there are when recording with magnetic tape. The data recording unit itself should have a playback feature which allows the operator to playback onto the plotter the well data recorded so that the operator can verify the data. Finally the data recording system should be all digital to insure compatibility between units and avoid "slew" problem that can occur when trying to match analog and magnetic tape equipment.

The data recorder divides each pumping stroke into 120 to 220 discrete intervals and each is recorded in equal time increments and stored on the memory card. The exact number of points stored depends on the speed of the pumping unit. The recording unit can also be adapted to an electronic dynamometer so that the well data can be recorded without the control circuitry.

Once the dynamometer card has been recorded onto the solid state memory the memory card can be carried to the computer terminal where the memory card plugs into a data input unit. The data input unit interfaces with any standard computer terminal and converts the data on the memory card into data useful to the computer.

The data on the memory card can be used for downhole pump card analysis or gearbox torque analysis or both. The data shown in Fig.5 must be input by the operator. When the computer program is ready for the dynamometer card data the operator presses the start on data input unit. After the data input unit inputs the data the computer outputs the program data of surface card (Fig.6), downhole pump card (Fig.7), computed data (Fig.8), torque analysis (Fig.9), and a plot of torque vs. angle (Fig.10).

Equipment is now available that can be mounted on a beam type pumping unit to control pump-off and to provide load and displacement data for a calibrated dynamometer card. Computer programs and the recording equipment are also available for inputting the load and displacement data into a computer for downhole pump card and gearbox torque analysis.

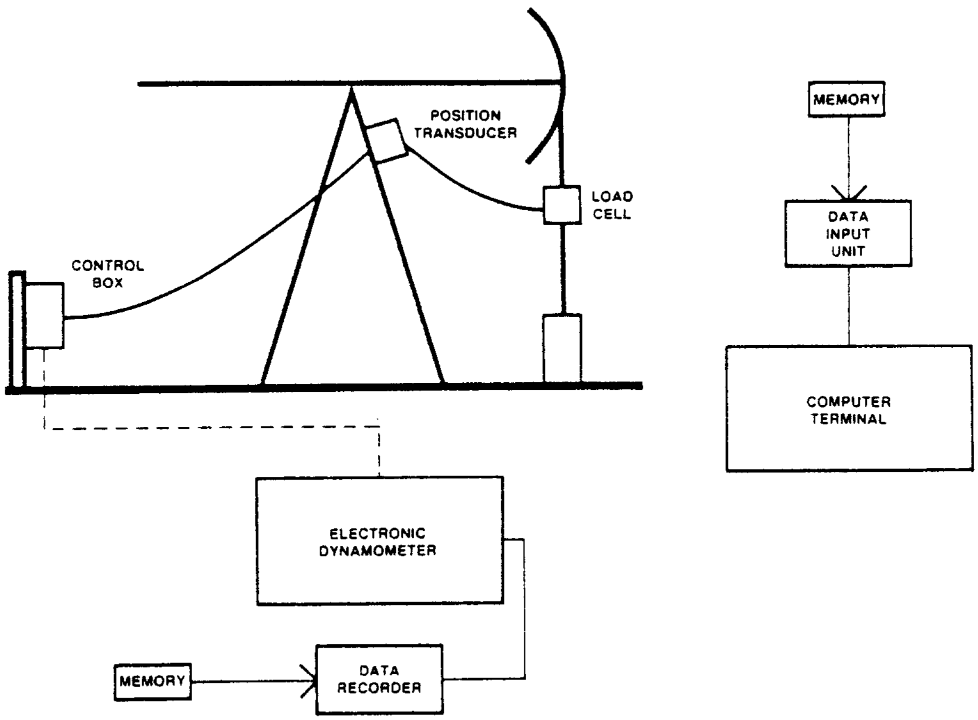


FIGURE 1

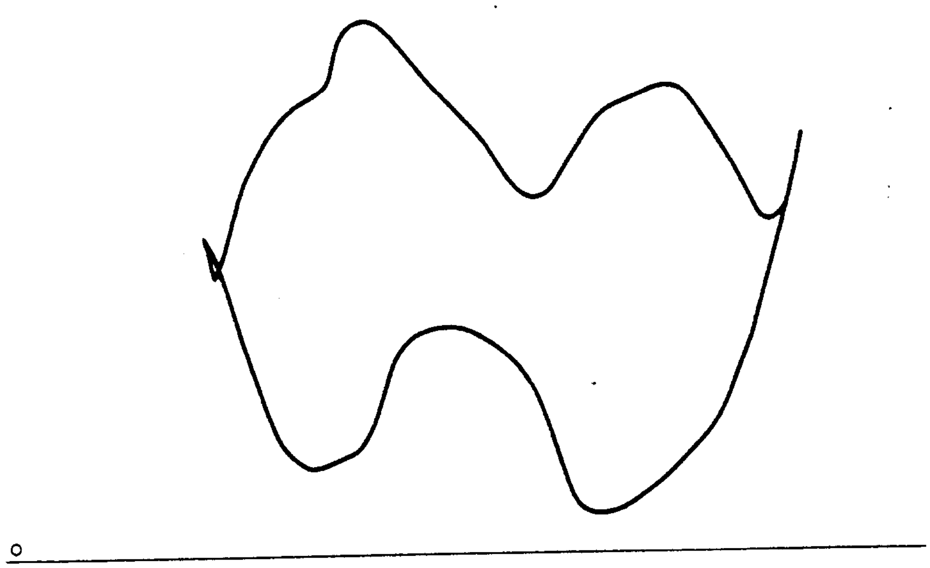


FIGURE 2

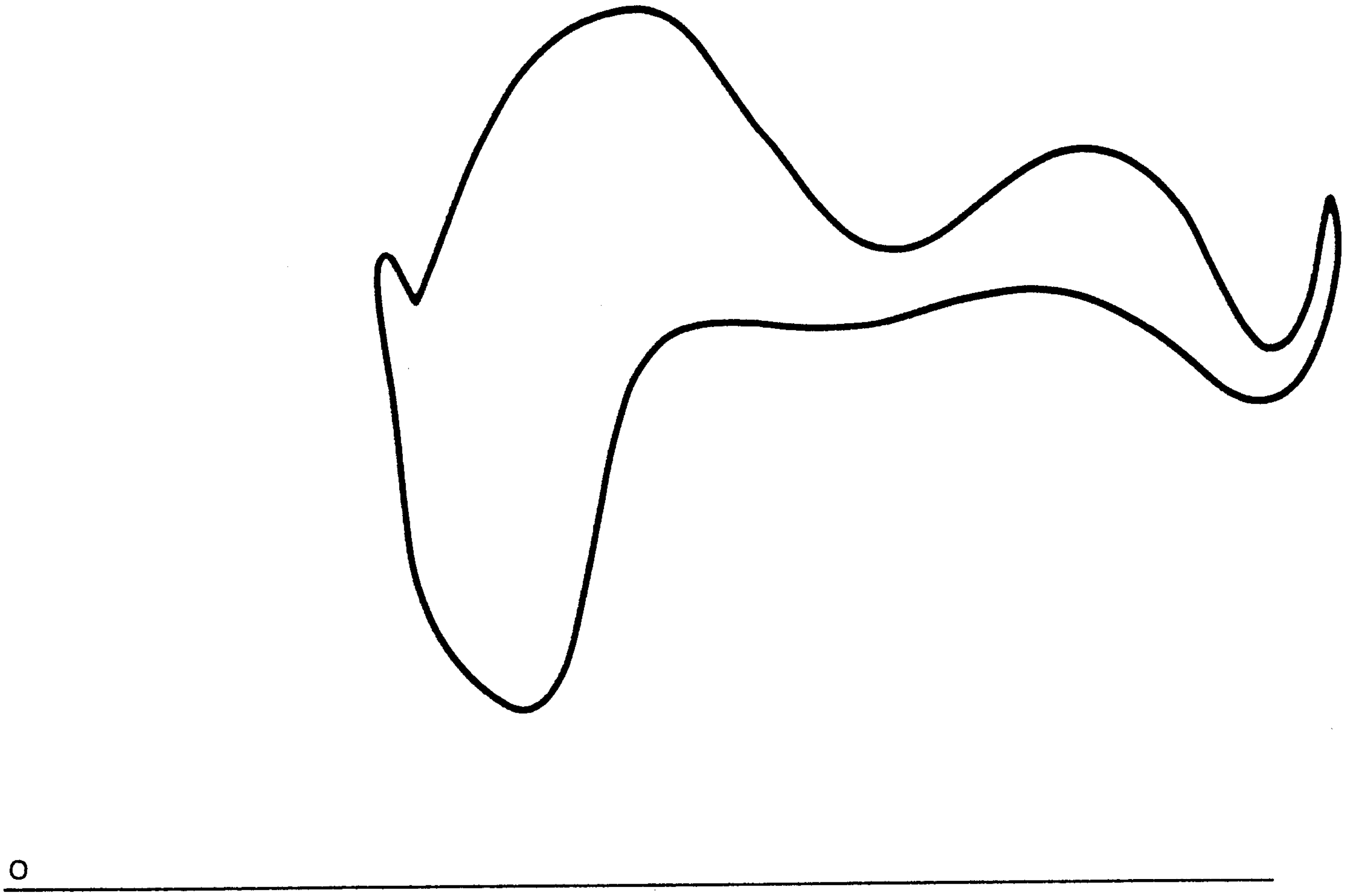


FIGURE 3

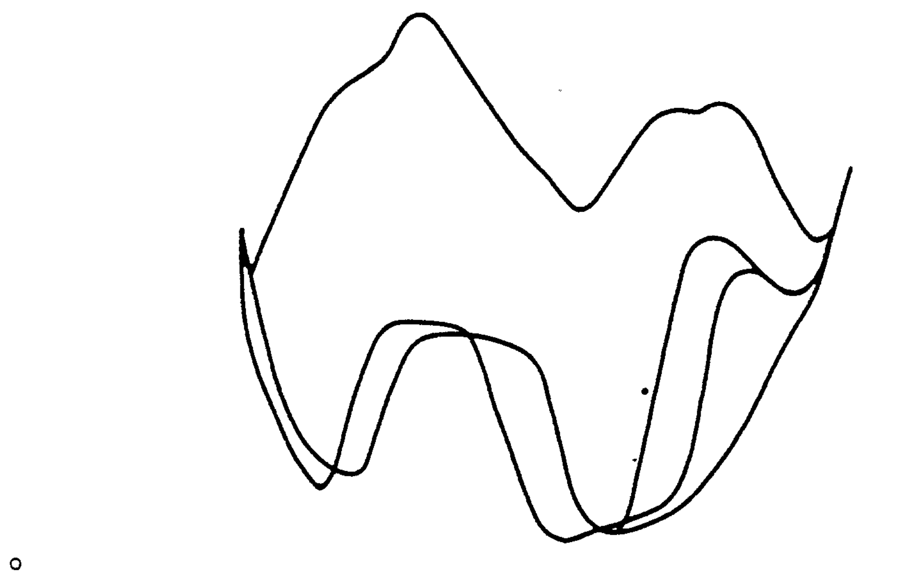


FIGURE 4

PUMP* DATA ENTRY

1.	Well identification	(WID)	=	WOR2
2.	Pumping speed	(SPM)	=	12
3.	Pump plunger diameter	(PPD)	=	1.25
4.	Load scale (lbs/cm)	(LS)	=	2000
5.	Polished rod position scale (in/cm)	(RPS)	=	10
6.	Oil production in BPD	(OIL)	=	35
7.	Specific gravity of oil	(SGO)	=	.847
8.	Water production in BPD	(WTR)	=	15
9.	Specific gravity of water	(SGW)	=	1.
10.	Grade of rods (K,C,D, or E)	(GRD)	=	D
11.	Sucker or corods (SR/CR)	(RDS)	=	SR
12.	API number of rod string	(API)	=	65
13.	Length of largest rod	(RL)	=	6225,2575
14.	Sinker bars (Yes/No)	(SB)	=	NO
15.	Type pumping unit (C = Conventional, AB = Air Balance, M = Mark II)	(TPU)	=	C
16.	The damping factor to be entered for normal friction is 10 percent. Enter damping factor...	(DCO)	=	1
17.	Start of stroke and end of stroke values in centimeter	(SOS,EDS)	=	6.9 , 14
18.	MPRL and PPRL values in centimeter	(MPRL,PPRL)	=	11.1 , 15.5
19.	Zero line value (CM)	(ZLV)	=	6.9

TORQUE INPUT

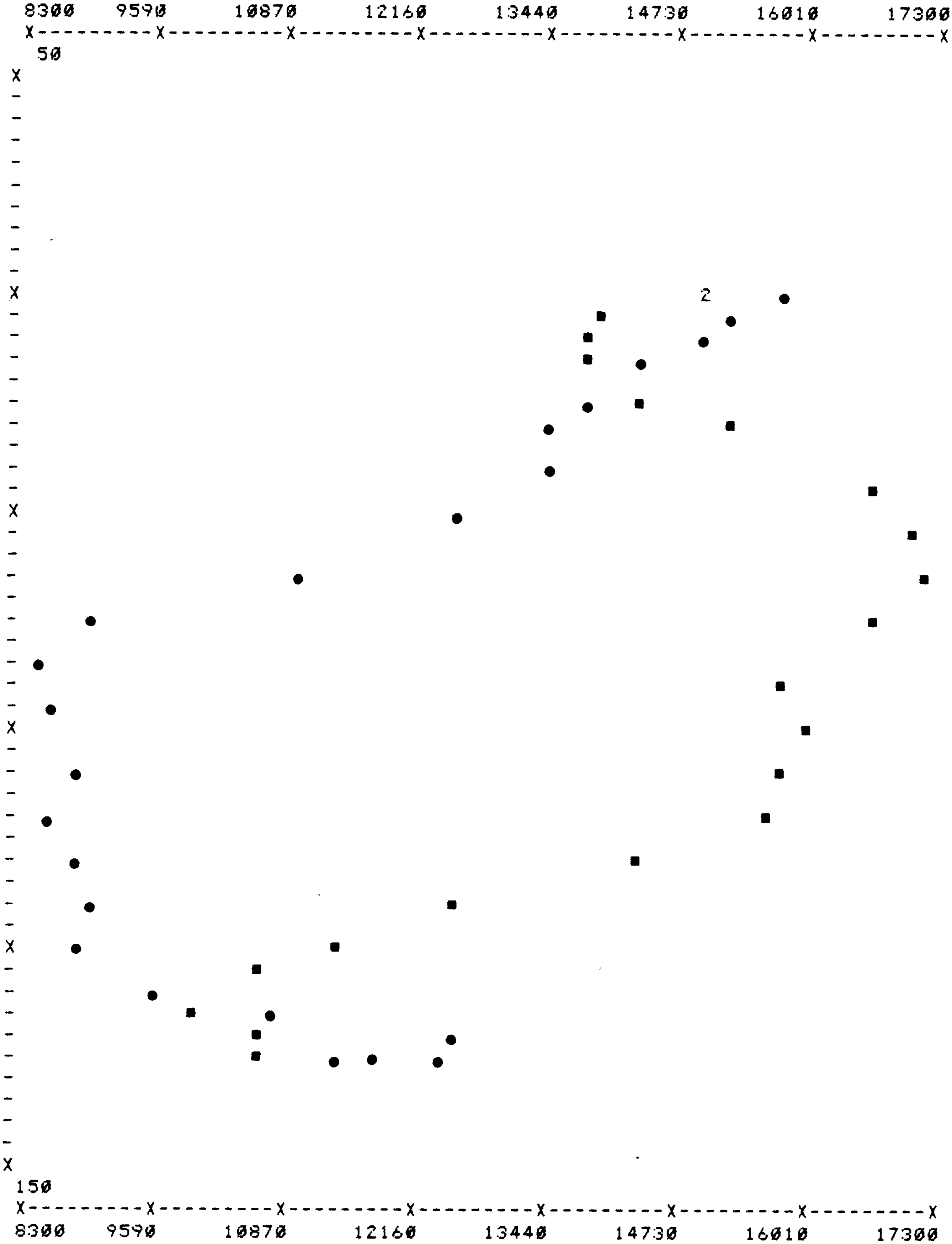
1. Enter pumping unit dimensions
   Enter A,C,P,H,I,G,R, (per API 11E), seperated by commas

A	C	P	H	I	G	R
129	129	138.25	222.75	129	101.5	35.4

2.	Maximum gearbox torque (thousands of inch-pounds) ..	(MGT)	=	320
3.	Direction of rotation (CW/CCW)	(DOR)	=	CW
4.	Counterbalance effect in CM	(CBE)	=	12.6
5.	Was CBE measured on upstroke or downstroke U/D..	(CBEM)	=	D
6.	CBE position in CM	(CBEP)	=	10.6
7.	Structural unbalance	(SU)	=	1135
8.	Data output is available in 5 or 10 or 15 degree increments. 15 degree increments is the normal output. Enter desired increment (5,10,15)	(CAI)	=	15

FIGURE 5

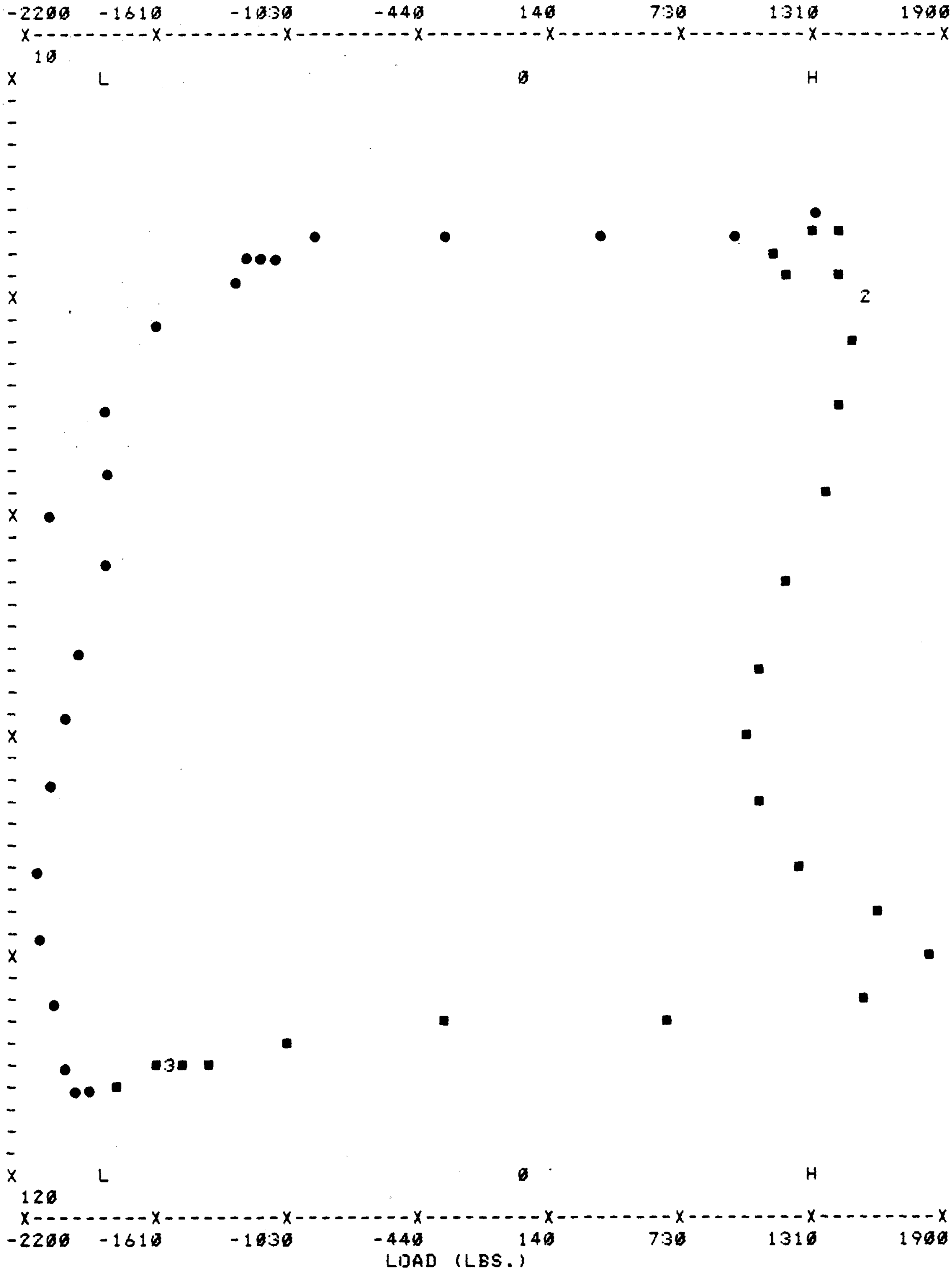
WELL-WOR2 LEASE- FIELD- ** DELTA-3 SURFACE CARD **
MMDDYY- CASE - OPER - **************************



LOAD (LBS.)
SCALE - LOAD= 129. LBS. DISP= 2.0 IN.

FIGURE 6

WELL-WOR2 LEASE- FIELD- ** DELTA-3 PUMP CARD **
MMDDYY- CASE - OPER - ***********************



SCALE - LOAD= 59. LBS. DISP= 2.2 IN.
CHANGE DAMPING FACTOR(DCO)...(YES/NO)?NO

FIGURE 7

* *

SURFACE DATA

STROKE LTH	PPRL	MPRL	TORQUE	FLUID LOAD	FLUID GRD
71.5	17200.	8400.	157300.	3140.	0.387

ROD DATA

DIA	MAX STRESS	MIN STRESS	MGD LMT	%MGD
6	38939.	19017.	39447.	98.
5	19423.	0.	28750.	68.

TOTAL ROD LENGHT 8800.0 TOTAL ROD WEIGHT 13097.8

PUMP DATA

INTAKE PRES	GROSS STROKE	GROSS PROD	GROSS EFFN
844.	87.6	191.5	26.1
	NET STROKE	NET PROD	NET EFFN
	76.6	167.5	29.9

PUMP FILLAGE 87.5%

AV MAX LOAD	AV MIN LOAD	AV MAX DISP
1320.	-1819.	76.6
MAX LOAD	MIN LOAD	MAX DISP
1860.	-2128.	87.6

* *

FIGURE 8

WELL IDENTIFICATION: WOR2

TORQUE CALCULATIONS FOR CONVENTIONAL UNIT
WITH COUNTERBALANCE EFFECT = 11584.

UPSTROKE

CRANK ANGLE	TORQUE	PERMISSIBLE LOAD	ACTUAL LOAD
15.0	34221.	44442.	14531.
30.0	92960.	24291.	13800.
45.0	175991.	19522.	14927.
* 60.0	268897.	18214.	16837.
75.0	247369.	18501.	16618.
90.0	179685.	19829.	15985.
105.0	108158.	22008.	15407.
120.0	-13164.	25084.	12494.
135.0	-65679.	29555.	10531.
150.0	-53622.	37372.	10356.
165.0	-23692.	58643.	10874.
180.0	3511.	936946.	11402.

DOWNSTROKE

CRANK ANGLE	TORQUE	PERMISSIBLE LOAD	ACTUAL LOAD
195.0	20747.	-32517.	11996.
210.0	34777.	-8887.	11698.
225.0	86979.	-1945.	9299.
240.0	103091.	902.	8985.
* 255.0	112672.	2081.	8633.
270.0	100679.	2354.	8680.
285.0	74675.	1977.	8874.
300.0	-58186.	951.	12045.
315.0	-112846.	-987.	13400.
330.0	-128561.	-4783.	14334.
345.0	-106696.	-14696.	15163.
360.0	-40960.	106825.	14953.

* INDICATES PEAK TORQUE.

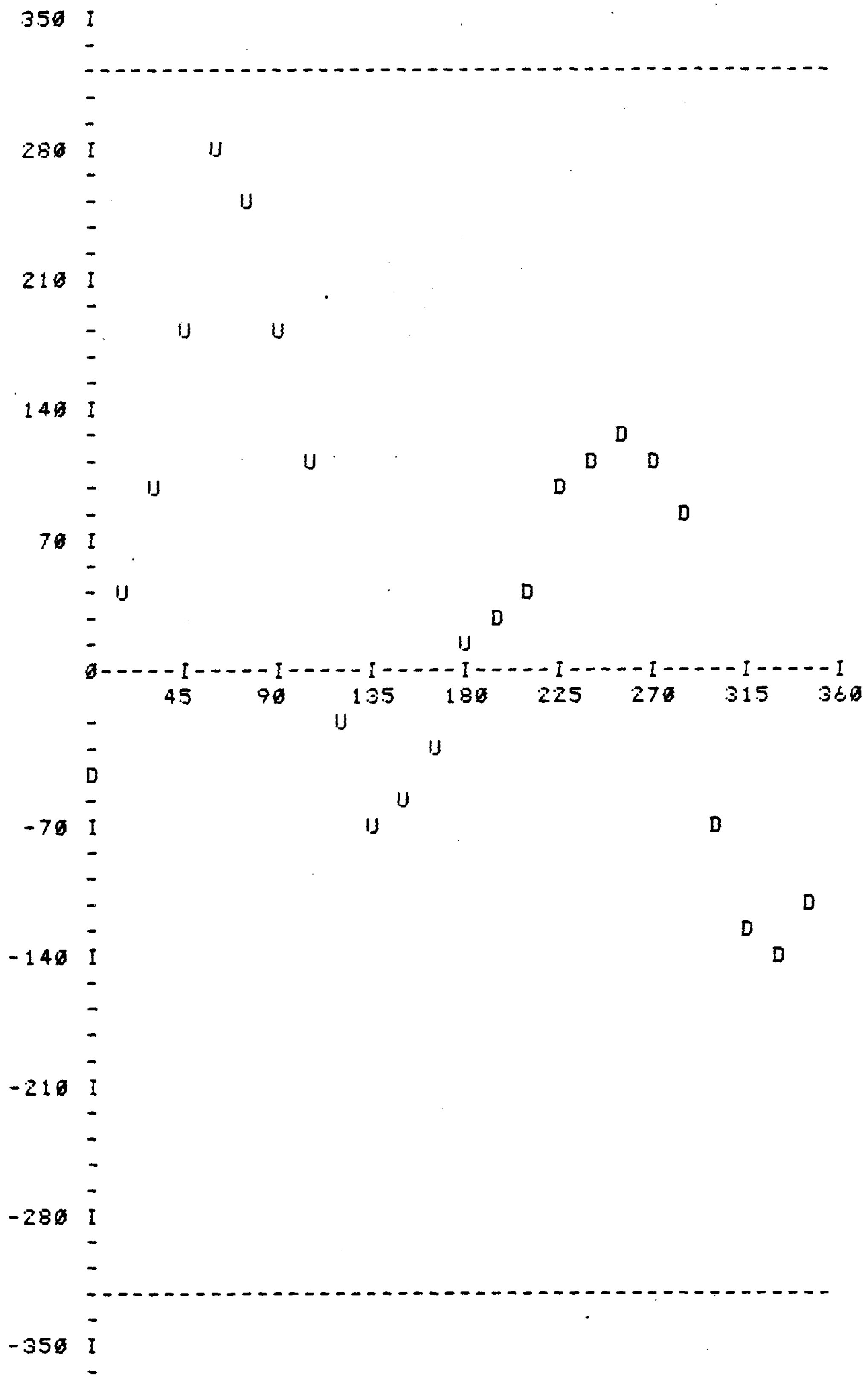
PEAK TORQUE WHEN COUNTERBALANCED..................= 195044.

CBE REQUIRED TO COUNTERBALANCE UNIT...............= 14044.

* *

FIGURE 9

GEARBOX TORQUE VS. ANGLE
FOR CONVENTIONAL UNIT RATED AT 320000. INCH-POUNDS
TORQUE SCALE IN THOUSANDS OF INCH-POUNDS



EACH TORQUE INCREMENT EQUALS 14000 INCH-POUNDS
DASHED LINES INDICATE RATED GEARBOX TORQUE

FIGURE 10