5987

DRILLING MANUAL

INTRODUCTION

The Cerro Prieto geothermal field is located in the north-western part of Mexico approximately 30 km to the south of Mexicali, Baja California, where the Cerro Prieto volcano serves as a point of reference in the Mexicali Valley.

The geothermal field is divided into three areas (Cerro Prieto I, II and III) because of the electric power plants and 104 wells that have been constructed there.

Completion of these wells has differed in regard to casings, depth into the production zone and problem zones, but all are similar in the formation drilled through, although it differs in thickness and in depth.

Drilling fluids.

A drilling fluid program has been prepared for purposes such as cleaning the bottom of the hole as well as the drill bit teeth in the formation, carrying cuttings from the well bottom to the surface, suspending cuttings and densifying material when the fluid circulation is interrupted, cooling and lubricating the drill bit and drilling string, controlling the formation pressures, forming a protective coating on the walls of the well, preventing damage to the production formation, facilitating the handling and operation of logging equipment, floating tolls within the well, and so forth. Furthermore, it solves problems that arise while drilling through the zones where the greatest danger exists, which in this field are hydratable shales, friable shales and zones with circulation loss, where differential sticking of tools and the drilling string getting caught must be prevented, etc. All of these functions are aimed at having a positive impact on safe and good drilling within well construction.

This program may be applied to any well constructed in this field, even though they vary in depth with production zones from 1,400 m to 3,500 m. Specifications for drilling fluid (commonly called mud) characterisitcs that will allow such fluids to fulfill their purposes have been established, together with the ranges or margins within which they should be maintained. This program and the correct application of chemical reagents in relation to the formulation to be drilled through were based on the compilation of mud analysis data, background in its application in this field and information from several drilling fluid companies.

It should be noted that well depths in this field, as well as the respective depth of casings and formations have been averaged for the program referred to below.

Hydraulics

Hydraulics is one of the principal techniques for good drilling progress. The hydraulic power required in the mud pump may be calculated according to the hydraulic power desired in the drill bit nozzle and the total fall in pressure in the system or the optimum diameter of the nozzle may be calculated according to the hydraulic power of the pumps. On the basis of the hydraulic power of the pump and a flow cross section, the type of flow that exists at a given point may be calculated, in addition to the critical and real velocities and pressure losses caused by friction in each part of the system or in the complete fluid cycle. The time of the fluid cycle or the time that it takes for formation cuttings to rise to the surface may also be calculated in accordance with the critical velocity of the fluid, the type of formation and drilling mud conditions. To improve friction caused pressure losses, the diameters of the pump bushings and the diameters of drilling casings may be changed, in accordance with the diameter of the drill bit.

An analysis of drilling in relation to hydraulics and optimum hydraulic conditions for improved drilling progress is presented in relation to drilling in the Cerro Prieto area with a model of an average depth of 2,400 m.

ABSTRACT

The objective of the drilling manual is to solve all problems directly related to drilling during the construction of a well. In this case, the topics dealt which are drilling fluids and hydraulics to be applied in the field to improve drilling progress, eliminate risks and achieve good weel-completion. There are other topics that are applicable such as drill bits and the drilling string, which are closely

linked to drilling progress. On this occasion drilling fluid and hydraulics programs are presented, in addition to a computing program for a Casio FX-502P calculator to be applied in the field to optimize hydraulics and in the analysis of hydraulics for development and exploration wells at their different intervals.

DRILLING FLUID DEVELOPMENT IN THE CERRO PRIETO, B.C., GEOTHERMAL FIELD.

This development is based on the formation to be drilled through and on a casing program.

Initially a bentonitic mud is prepared in the mud reservoirs (the water-bentonite ratio depends on the bentonite yield) to obtain the following characteristics:

VISCOSITY: 48-50 sec/l
DENSITY : 1.06-1.08 gr/cm^3

Drilling begins with a certain diameter and later a number of expansions are made until a 36-in. diameter hole is constructed (at approximately 50.0 m) and the 30-in. conductor casing is cemented. During this stage the drilling fluid should remain within the following characteristics:

DENSITY	VISCOSITY	VOL. OF SAND
1.12-1.14 gr/cm^3	48-50 sec/l	2% or less

The formation that will be encountered during drilling is plastic sandy clay with medium-grain sand (subangular, subrounded and rounded) where the density will increase due to the incorporation of sand into the system and viscosity will be suitable and pumpable to carry information cuttings effectively and keep the hole clean.

Care should also be taken with the surface equipment to control solids (shakers and desanders), which will work at their maximum capacity. The shakers should have screens (#20 in the upper part and #40 in the lower part) capable of processing the entire flow and eliminating the greatest possible quantity of formation cuttings. The desander, which has two phases for eliminating solids (a water cycle and a vibrating screen), should have a #120 screen. To place the 30-in. diameter conductor casing, the viscosity is decreased to 40-45 sec/l, which will also facilitate shifting during cementing.

After the cement for the 30-in. casing and the surface connections has set, when drilling through the drilling accessories and cement, treatment is applied to counteract contamination and to continue drilling and expanding to obtain a 26-in. diameter hole (at approximately 300.0 m) and in order to cement the 20-in. surface casing. During this stage, the characteristics of the drilling fluid, which should continue to be bentonitic, are maintained.

DENSITY 1.12-1.14 gr/cm^3.
VISCOSITY 48-50 sec/l.
FILTRATE N/C.
COATING 2-4 mm.
VOL. OF SAND 2% or less.

The formation to be encountered is brown plastic clay with fine-and medium grain-sand, fine-and medium-grain sandy lenses that vary in thickness from 100 to 200 m, gravel and pieces of peat. The function of the mud will thus be to provide effective carrying and to clean the hole and the viscosity will be kept at an average value for that purpose. The coating in this interval will be kept at ± 2 mm, although it may reach 4 mm in certain cases without causing problems. The percentage of sands is kept low in order to improve coating conditions and to prevent damage to hydraulic parts of the mud pumps. Density should be kept at a value that will provide control for the walls of the hole and for possible surface water flows that will thin the drilling fluid.

The most important factor is the time in which the well is constructed, since it does not give time for the filtrate to damage the walls by hydrating the clay, which would reduce the hole or cause the sandy lenses to collapse and trap in drilling casings.

In conditioning for the placement of the 20-in. diameter casing, the viscosity is reduced to 40-45 sec/l, which also facilitates spreading the cement slurry during cementing. The surface equipment to control solids is kept in the same conditions as previously.

Once the cementing of the 30-in. casing has set and the surface connections have been made, the cementing accessories and cement are drilled through after the drilling mud is treated to prevent cement contamination.

Drilling and expansion are continued until a hole 17 1/2 inches in diameter is obtained (at approximately 1,000 m), where the 13 3/8-in.diameter intermediate casing is placed and cemented. For this interval the characteristics of the drilling fluid are made more specific in order to solve the problems the formation may present. The mud changes and becomes lignitic.

DENSITY	1.12-1.14 gr/cm^3
VISCOSITY	45-48 sec/l
FILTRATE	$\pm$ 12 cm^3
COATING	2 mm
pH	8.5-9.0
VOL.OF SAND	1% or less
VOL.OF SOLIDS	10-14%
VOL.OF OIL	3-4%
VOL.OF WATER	82-87%
PLASTIC VISCOSITY	10-14 cps
YIELD POINT	2-5 lb/100 ft^2
GEL 0'	0 lb/100 ft^2
GEL 10'	2-4 lb/100 ft^2

These characteristics are based on the formation to be drilled through, the size of the cut and the time required to drill the hole. The formation is composed of brown plastic clay, fine- and medium-grain and (subangular, subrounded and rounded) and pieces of gravel. When drilling is initiated, sufficient diesel is added to provide the percentage required. Lignite, caustic soda and tannins are added as basic reagents for this interval. Efforts are made to inhibit clays, to reduce filtrates, to thin the coating, to spread and reduce viscosity, to deflocculate, to control alkalinity, to remove calcium, to emulsify, and so forth.

The surface equipment to control solids, which is important in maintaining the proper characteristics, is modified in accordance with the needs in the interval to be drilled. The shaker should have #20 screen above and #40 screen below and the desander should have #150 screen.

To place the intermediate casing, the viscosity is reduced to 40-45 sec/l, which also facilitates movement during cementing.

After the cement of the 13 3/8-in. diameter casing has set and the surface connections have been made, including the installations of the wellhead, the cementing accessories and cement are drilled following treatment to prevent cement contamination. A hole with a diameter of 12 1/4 inches is drilled (at approximately 2,000 m) and the 9 5/8-in. diameter production casing is cemented.

The characteristics become even stricter in order to solve the problem areas that arise during this stage, which are the most dangerous. Here, the mud remains lignitic until production temperature is noted and it is changed to chromolignosulfonate.

DENSITY	1.16-1.18 gr/cm^3 (up to 1.22 gr/cm^3).
VISCOSITY	42-45 sec/l
FILTRATE	8 cm^3 or less
COATING	1.5 mm
pH	9.5
VOL.OF SAND	1% or less
VOL.OF SOLIDS	11-16%
VOL.OF OIL	5-6%
VOL.OF WATER	78-84%
PLASTIC VISCOSITY	11-16 cps
YIELD POINT	3-6 lb/100 ft^2
GEL 0'	0 lb/100 ft^2
GEL 10'	2-4 lb/100 ft^2

The formation to be drilled is brown plastic clay, fine-and medium-grain sand, fine gravel, mudstone, friable shales, shales and sandstones. This interval is considered that of highest risk because of its stratigraphic structure and the first signs of temperature that alter the characteristics.

The percentage of diesel is immediately increased (5-6%) in this interval and reagents continue to be added. The treatment is strong and constant in order to change the characteristics to the suitable requirements. The reagents are lignite, caustic soda and tannins. Further on, when temperature increases appear, chromolignosulfonate is added as the base for the mud.

These specifications for the mud are based on the problems in the area to be drilled and its condition could be improved to a even greater extent, but would involve increased chemical material costs. We have verified that these characteristics are sufficiently sound for drilling at this stage except when the friable shale zone is of a greater thickness and changes in 2 or 3 characteristics are then required.

Here, the factors to be taken into account are: the mudstones, which are extremely hydratable, and friable shales that cause casings to become trapped, which means that the mud should provide inhibition, the filtrate should be reduced, the weight of the mud should be increased, the percentage of diesel should be raised throughout the system, flocculation should be prevented, and so forth.

The mud should provide extra characteristics for this interval which is the longest. Considering the length of the hole and the time it remains uncovered, it logically follows that the walls will be exposed to the mud for a certain time and problems may be caused.

The conditions of the surface equipment to control solids are maintained as listed below: the shaker should have a #40 screen in the upper part and a #60 screen in the lower part in order to process the flow and eliminate the formation cuttings effectively. The desander will continue to have a #150 screen, since the size of the sand is the same as during the previous stage, and the cooling tower with its ventilator will begin to operate when temperatures between 40-45°C are reached.

Conditioning the drilling fluid for temperature and electric logs and for placing the casing requieres the used of a reagent that keep the mud in suitable conditions while it is static (during these operations that last up to 32 hours). This reagent is a deflocculant polymer of low molecular weight that is effective for the geological and filtration properties of water-base muds at high temperatures where the effectiveness of lignities and chromolignosulfonates is reduced.

After the cementing of the 9 5/8-in. diameter casing has set and the surface connections have been made, the different cementing accessories and cement are drilled and the drilling mud is treated for decontamination in order to continue drilling with an 8 1/2-in. bit (at approximately 2,400.0 m) and then to haug and cement the 7-in. diameter short casing or liner.

While this interval is being drilled, the characteristics are once again modified to meet the requirements. The mud continues to be chromolignosulfonate.

DENSITY	1.12-1.14 gr/cm^3
VISCOSITY	42-45 sec/l
FILTRATE	± 12 cm^3
COATING	1.5 mm
pH	9.5-10
VOL.OF SAND	1% or less
VOL.OF SOLIDS	10-14%
VOL.OF OIL	2%
VOL.OF WATER	84-88%
PLASTIC VISCOSITY	10-14 cps
YIELD POINT	2-5 lb/100 ft^2
GEL 0'	0 lb/100 ft^2
GEL 10'	2-4 lb/100 ft^2

The formation to be drilled is very compact shale, siltstone shale and siltstone with intercalations of sandstone and cementing material of calcium carbonate and/or silica and high temperature minerals with particles of quartz. In some wells, gypsum has been detected.

During the course of drilling in this phase, the reagents previously mentioned continue to be added in order to maintain the proper characteristics, some of which have been slightly altered, as may be noted. The filtrate (loss of water) has increased because the formation is more compact and there is no problem of collapse. The weight of the mud (density) was also reduced for the same reason, as well as to not induce circulation loss. The percentage of oil (diesel) was reduced to 2% so as only to provide good lubrication in the mud system.

Between the friable zone and the production zone, a highly porous and permeable zone was located, which caused a temporary but total loss of circulation (up to 60 m^3 of mud). Subsequently, the circulation became normal as a result of the zone becoming saturated. Sometimes it has been necessary to add fine scaling material (fine nut shell or classified mica).

The increase in temperatures must also be taken into account, since it has an impact on the mud characteristics. Thus, the proper use of reagents is essential here because the economy of the drilling fluid depends on it and excessive use, apart from that mentioned above, brings about problems with solids in the system. The effective operation of the cooling tower and its capacity to reduce the temperature of the mud is also important here and is reflected in the consumption of reagents and the frequency with which drill bits must be replaced.

The surface equipment to control solids also undergoes changes in order to provide extra assitance in maintaining ideal drilling fluid conditions. The shaker uses #60 screen above and #80 screen below to eliminate formation cuttings effectively and #200 screens are installed in the desanders to reduce the amount of solids in the system to the minimum possible within the process.

Hydraulics in the drilling in the Cerro Prieto area.

Tables 1 and 2 indicate the drilling intervals, drilling diameters and weight tool diameters, in accordance with well drilling and completion in the Cerro Prieto area.

To obtain the results required for hydraulics in well drilling, there are different methods such as Bingham's plastic fluids method, the fluids method that obeys the law of potentials and methods that obey the law of potentials with yield point.

According to Bingham's plastic fluids method, unknown such as pump flow rate, the type of flow in each interval of the fluid cycle, the type of fluid, the fluid cycle, the type of fluid, the real and critical velocity in each interval and in the entire system, the hydraulic potential required for the pump and in the drill bit, impact stress, hydrostatic pressure at the bottom of the hole, circulation pressure at the bottom of the hole, equivalent density of mud circulation, optimum diameter of the drill nozzles and size of the drill bit casing may be calculated. To calculate drops in pressure, a table is presented below indicating the equations required for each type of flow and fluid in the system.

To obtain the results required to improve hydraulics in the field, a computing program has been prepared to be used on a Casio FX-502P calculator. This program was prepared with the assistance of the equations shown in Table 3. In this case, we divided the calculation into three parts, since the capacity of the calculator does not allow for the entire calculation to be made at once.

Figures 10 and 11 present a flow chart for the computing program with Bingham's plastic fluids method. Figures 12 and 13 present the calculation intervals for development and exploration wells.

To enter the program simply select the number of the program on the calculator and enter it. The data may be entered in accordance with the following memories:

Memory	Data
Min 1	Q(gal/min)
Min 2	D(in)
Min 3	d(in)
Min 4	Mp(cps)
Min 5	Pc(lb/100 ft^2)
Min 6	ρ(lb/gal)
Min 7	Nr(calculated)
Min 8	f(calculated)
Min 9	L(ft)

After introducing the program and the data, press the button of the program number and the data appear at approximately 3-second intervals, showing the values in the following sequence:

V	(ft/sec)
V_c	(ft/sec)
N_R	(nondimensional)
f	(nondimensional)
ΔP_f	(lb/in^2)

Since the capacity of the calculator is not very large, data must be entered for each interval investigated.

Because of the limited capacity of the FX-502P calculator, the program must be continued separately, that is, the program must be erased and the continuation of the program entered as of pressure losses due to circulation. With the data in the same memories previously mentioned, the button of the new program is pressed and results are obtained in the following sequence:

ΔP_t	(lb/in^2)
HHP_t	(horsepower)
HHP_j	(horsepower)
Fi	(lbs)
BHCP	(lb/in^2)
ECD	(lb/gal)

Application of hydraulics.

In accordance with the drilling intervals indicated in tables 1 and 2, an analysis of each of the intervals in the Cerro Prieto area is presented below.

The data are based on a triplex Continental Emsco F-800 pump 5" x 9"-in. using a 8 1/2-in. drill bit and three 1/2-in. nozzles and the drilling fluid data previously indicated for each drilling interval.

FIGURES

Fig.10. Flow chart

Fig.11. Flow chart

Fig.12. Drilling intervals in a development well in the Cerro Prieto area.

Fig.13. Drilling intervals of an exploration well in the Cerro Prieto area.

TABLES

Table 1 Development well

Table 2 Exploration well

Table 3 Flow equatios for Bingham and Newtonian plastic fluids.

TABLA NO. 1
POZO DE DESARROLLO

Prof.(mts)	Diám.Bna.	Diám.D.C.	Peso D.C.(lb/pie)	Long D.C.(mts)	Diám.T.P.
50.0	36"	8"	150.5	50.0	4 1/2"
300.0	26"	8"	150.5	106.6	4 1/2"
1000.0	17 1/2"	8"	150.5	135.0	4 1/2"
2000.0	12 1/4"	8"	150.5	135.0	4 1/2"
2400.0	8 1/2"	6"	99.1	135.0	4 1/2"

TABLA NO. 2
POZO EXPLORATORIO

Prof.(mts)	Diám.Bna.	Diám.D.C.	Peso D.C.(lb/pie)	Long D.C.(mts)	Diám.T.P.
100.0	26"	8"	150.5	100.0	4 1/2"
1000.0	17 1/2"	8"	150.5	135.0	4 1/2"
2000.0	12 1/4"	8"	150.5	135.0	4 1/2"
3000.0	8 1/2"	6 1/2"	99.1	165.0	4 1/2"
3500.0	6"	4 3/4"	43.5	165.0	4 1/2"

ANALISIS DE LA PERFORACION DE UN POZO DE DESARROLLO CON BOMBA CONTINENTAL EMSCO F-800 CON CAMISAS DE 5 X 9 PG, HHP MAXIMO DE BOMBA ES DE 853 Y PERFORANDO CON BARRENA DE 3 TOBERAS DE 1/2 PG C/V. CONVEXIONES SUPERFICIALES DEL TIPO NO. 4.

D A T O S

Intervalo de perf.	Intervalo de Análisis.	Gasto de bomba(gal/min)	D (pg)	d (pg)	p (cps)	Pc (lb/100p^2)	(lb/gal)	Longitud (pies)
0-50.0 m	Conex.Superf.	200.10	3.826	0	10	4.0	9.03	340.14
	Int. de Drill Collars.	200.10	2.75	0	10	4.0	9.03	164.00
	E.A.entre agujero y D.C.	200.10	12.25	8	10	4.0	9.03	142.20
	E.A.entre conductor y D.C.	200.10	48.00	8	10	4.0	9.03	21.80
	en la barrena	200.10	---	---	10	4.0	9.03	-----
	Conexiones Superf.	230.0	3.826	0	10	10	9.53	340.14
50.0-300.0	Interior de T.P.	230.0	3.826	0	10	10	9.53	636.32
	Int. de D.C.	230.0	2.75	0	10	10	9.53	347.68
	E.A.entre Ag. y D.C.	230.0	12.25	8	10	10	9.53	347.68
	E.A. entre Ag. y T.P.	230.0	12.25	4.5	10	10	9.53	472.32
	E.A. entre T.R. y T.P.	230.0	29.00	4.5	10	10	9.53	164.00
	en la barrena	230.0	---	---	10	10	9.53	-----
	T o t a l							
300-1000.0	Conex.Superf.	276.0	3.826	0	13	10	9.53	340.14
	Int. de T.P.	276.0	3.826	0	13	10	9.53	2837.2
	Int. de D.C.	276.0	2.75	0	13	10	9.53	442.8
	E.A. entre Ag. y D.C.	276.0	12.25	8	13	10	9.53	442.8
	E.A. entre Ag. y T.P.	276.0	12.25	4.5	13	10	9.53	1853.2
	E.A.entre T.R. y T.P.	276.0	19.00	4.5	13	10	9.53	984.0
	en la barrena	276.0	---	---	13	10	9.53	----
	T o t a l							

D A T O S

Intervalo	Intervalo de Análisis.	Gasto de Bomba (gal/min)	D (pg)	d (pg)	P (cps)	Pc $(lb/100p^2)$	(lb/gal)	Longitud (pies)
	Conex.Superf.	299.0	3.826	0	13	10	9.53	340.14
1000-2000m	Int.de T.P.	299.0	3.826	0	13	10	9.53	6117.20
	Int.de D.C.	299.0	2.75	0	13	10	9.53	442.8
	E.A. entre Ag. y D.C.	299.0	12.25	8	13	10	9.53	442.8
	E.A.entre Ag. y T.P.	299.0	12.25	4.5	13	10	9.53	2837.2
	E.A. entre T.R. y T.P.	299.0	12.415	4.5	13	10	9.53	3280.0
	en la barrena	299.0	---	---	13	10	9.53	---
	T o t a l							
	Conex.Superf.	299.0	3.826	0	14	12	9.53	340.14
2000-2400m	Int. de T.P.	299.0	3.826	0	14	12	9.53	7429.20
	Int. de D.C.	299.0	2.25	0	14	12	9.53	442.80
	E.A.entre Ag. y D.C.	299.0	8.50	6.5	14	12	9.53	442.80
	E.A.entre Ag. y T.P.	299.0	8.50	4.5	14	12	9.53	869.20
	E.A.entre T.R. y T.P.	299.0	8.681	4.5	14	12	9.53	6560.00
	en la barrena	299.0	---	---	14	12	9.53	----
	T o t a l							

Vel.Real (pies/seg)	Vel.Crítica (pies/seg)	NR.Adimensional.	Adimensional.	(lb/pg^2)	HHPb (hp)	HHPj (hp)	Fuerza Imp.lbs.	Pres.C. f.lb/pg²	Int.Eq. C.lb/gal.
5.58	2.85	17903	0.00682	6.62					
10.81	2.99	24908	0.00629	15.33					
0.95	2.48	---	---	0.74					
0.04	2.21	---	---	0.01					
	----	---	---	100.60					
			Total =	123.30	14.39	11.74	104.33	77.00	9.11
6.42	4.18	21717.80	0.00651	8.80					
6.42	4.18	21717.80	0.00651	16.47					
12.42	4.31	30215.38	0.00599	43.19					
1.09	3.63	---	---	4.30					
0.72	3.51	---	---	3.10					
0.11	3.40	---	---	0.34					
	----	---	---	140.27					
			Total =	216.47					

7.70	4.28	20047.20	0.00664	12.93	36.79	18.82	145.48	487.63	9.68
7.70	4.28	20047.20	0.00664	107.88					
14.91	4.45	27891.12	0.00611	80.81					
1.31	3.72	---	---	5.63					
0.87	3.55	---	---	12.30					
0.33	3.46	---	---	3.41					
				201.99					
			Total =	223.33	35.96	32.53	209.49	1625.43	9.66

Vel.Real (pies/seg)	Vel.Crítica (pies/seg)	NR.Adimensional.	Adimensional.	(lb/pg^2)	HHPb (hp)	HHPj (hp)	Fuerza Imp.lb.	P.C.f. lb/pg^2	Densidad Eq. circ. lb/gal.
8.34	4.28	21717.80	0.00651	14.88					
8.34	4.28	21717.80	0.00651	267.58					
16.15	4.45	30215.38	0.00599	29.96					
1.42	3.72	---	---	5.66					
0.94	3.55	---	---	18.88					
0.91	3.55	---	---	21.34					
---	---	---		237.06					
			Total =	595.36	103.85	41.35	245.86	3250.87	9.66
8.34	4.68	20166.53	0.00663	15.16					
8.34	4.68	20166.53	0.00663	331.04					
24.13	5.01	34292.06	0.00580	245.65					
4.07	4.55	---	---	19.59					
2.35	4.10	---	---	14.82					
2.21	4.08	---	---	105.78					
---	---	---		237.06					
			Total =	969.10	309.24	41.35	245.86	3901.0	9.87

A CONTINUACION SE PRESENTA LA HIDRAULICA DE UN POZO EXPLORATORIO EN TODOS SUS INTERVALOS DE PERFORACION.

D A T O S

Intervalo	Intervalo de Análisis	Gasto de bomba gal/min.	D (pg)	d (pg)	(cps)	Pc $lb/100p^2$	(lb/gal)	Long. (pies)	Vel.real (pies/seg)
	Conex.Sup.	200.10	3.826	0	10	4	8.86	340.14	5.58
	Int. D.C.	200.10	2.75	0	10	4	8.86	328.00	10.81
0-100 m	E.A. entre Ag.y D.C.	200.10	12.25	8	10	4	8.86	306.20	0.95
	E.A.entre cond.y D.C.	200.10	48.00	8	10	4	8.86	21.80	0.04
	en la bna.	200.10	---	---	10	4	8.86	----	
	T o t a l								
	Conex. Sup.	230.0	3.826	0	10	10	9.36	340.14	6.42
	Int.T.P.	230.0	3.826	0	10	10	9.36	2837.20	6.42
100-1000m	Int.D.C.	230.0	2.75	0	10	10	9.36	442.80	12.42
	E.A.entre Ag. y D.C.	230.0	12.25	8	10	10	9.36	442.80	1.09
	E.A.entre Ag. y T.P.	230.0	12.25	4.5	10	10	9.36	2509.20	0.72
	E.A.entre T.R. y T.P.	230.0	19.00	4.5	10	10	9.36	328.00	0.27
	en la bna.	230.0	---	---	10	10	9.36	----	
	T o t a l								

	Conex.Sup.	276.0	3.826	0	13	10	9.53	340.14	7.70
	Int. T.P.	276.0	3.826	0	13	10	9.53	6117.20	7.70
	Int. D.C.	276.0	2.75	0	13	10	9.53	442.80	14.91
1000-2000	E.A. entre								
	Ag. y D.C.	276.0	12.25	8	13	10	9.53	442.80	1.31
	E.A. entre								
	Ag. y T.P.	276.0	12.25	4.5	13	10	9.53	2837.20	0.87
	E.A. entre								
	T.R. y T.P.	276.0	12.415	4.5	13	10	9.53	3280.00	0.84
	en la bna.	276.0	---	4.5	13	10	9.53	---	0.84
	T o t a l								
	Conex.Sup.	299.0	3.826	0	14	12	9.53	340.14	8.34
	Int. T.P.	299.0	3.826	0	14	12	9.53	9298.80	8.34
	Int. D.C.	299.0	2.25	0	14	12	9.53	541.20	24.13
2000-3000	E.A. entre								
	Ag. y D.C.	299.0	8.50	6.50	14	12	9.53	541.20	4.07
	E.A. entre								
	Ag. y T.P.	299.0	8.50	4.50	14	12	9.53	2738.80	2.35
	E.A. entre								
	T.P. y T.P.	299.0	8.681	4.50	14	12	9.53	6560.00	2.22
	en la bna.	299.0	---	---	14	12	9.53	6560.00	2.22
	T o t a l								
	Conex.Sup.	299.0	3.826	0	14	12	9.70	340.14	8.34
	Int. T.P.	299.0	2.764	0	14	12	9.70	10938.80	15.98
	Int. D.C.	299.0	2.25	0	14	12	9.70	541.20	24.13
	E.A. entre								
	E.A. entre								
3000-3500	Ag. y D.C.	299.0	6.00	4.75	14	12	9.70	541.20	9.09
	E.A. entre								
	Ag. y T.P.	299.0	6.00	3.50	14	12	9.70	1098.80	5.14
	E.A. entre								
	T.R. y T.P.	299.0	6.184	3.50	14	12	9.70	3444.00	4.70
	E.A. entre								
	T.R. y T.P.	299.0	8.621	3.50	14	12	9.70	6396.00	1.93
	en la bna.	299.0	---	---	14	12			
	T o t a l								

Vel.Crítica (pies/seg)	NR. Adimensional.	Adimensional.	(lb/pg^2)	HHPb (hP)	HHPj (hp)	Fuerza Imp.lbs.	Pres.C. f.lb/pg^2	Int.Eq. C.lb/gal.
2.88	17566	0.00686	6.53					
3.03	24439	0.00631	30.23					
2.51	---	---	1.60					
2.23	---	---	0.10					
---	---	---	98.71					
			137.17	16.42	11.52	102.37	151.11	8.96
4.22	21330	0.00653	8.68					
4.22	21330	0.00653	72.45					
4.35	29676	0.00602	54.27					
3.67	---	---	5.48					
3.54	---	---	16.49					
3.47	---	---	1.14					
---	---	---	137.77					
			296.29	39.76	18.49	142.89	159.44	9.49
4.28	20047	0.00664	12.93					
4.28	20047	0.00664	232.60					
4.45	27891	0.00611	80.81					

3.72	---	---	5.63					
3.55	---	---	18.83					
3.55	---	---	21.29					
---	---	---	201.99					
			574.08	138.19	32.53	209.49	32.50	9.66
4.68	20166	0.00663	15.16					
4.68	20166	0.00663	414.35					
5.01	34292	0.00580	300.24					
4.55	---	---	23.95					
4.10	---	---	46.71					
4.08	---	---	105.78					
---	---	---	237.06					
			1143.25	199.43	41.35	245.86	4876.31	9.87
4.64	20526	0.00660	15.36					
4.81	28413	0.00608	2314.22					
4.96	34904	0.00578	304.25					
5.10	7305	0.00854	114.92					
4.32	8266	0.00829	36.21					
4.27	8109	0.00832	88.68					
3.96	---	---	80.52					
			241.29					
			3195.45	577.43	42.09	250.25	5790.51	10.24

TABLA NO. 3 ECUACIONES DE FLUJO PARA FLUIDOS PLASTICO DE BINGHAM Y NEWTONIANO

Flúido	Flujo en la Tubería	Flujo Anular
	Velocidad Promedio v	
Todos los flúidos	Para ecuaciones en anular use d = 0	$v = \frac{17.16\ (q, bbl/min)}{(d_o^2 - d_i^2)}$ $v = \frac{3.056\ (q, ft^3/min)}{(d_o^2 - d_i^2)}$ $v = \frac{(q,\ gpm)}{2.448\ (d_o^2 - s_i^2)}$
	Velocidad Crítica v_c	
Plástico de Bingham	$v_c = \frac{1.078\mu_p + 1.078\sqrt{\mu_p^2 + 12.34\ d^2 Pc\rho}}{\rho d}$	$v_{ca} = \frac{1.078\mu_p + 1.078\sqrt{\mu_p^2 + 9.256(d_o - d_i)^2 Pc\rho}}{\rho(d_o - d_i)}$
Newtoniano	Colocar Pc = 0 y $\mu_p = \mu$	Colocar Pc = 0 y $\mu_p = \mu$
	Flujo Laminar, $v \leq v_c$	
Plástico de Bingham	$P_f = \frac{\mu_p L v}{1500 d^2} + \frac{f_y L}{225 d}$	$P_f = \frac{\mu_p L v}{1000(d_o - d_i)^2} + \frac{PcL}{200(d_o - d_i)}$
Newtoniano	Colocar Pc = 0 y $\mu_p = \mu$	Colocar Pc = 0 y $\mu_p = \mu$
	Flujo Turbulento, $v > v_c$	
Plástico de Bingham	$P_f = \frac{fL_{\rho v}^2}{25.80 d}$ $N_R = 928\ \frac{dv\rho}{\mu_p}$ $f = \emptyset(N_R,\ e/d)$	$P_f = \frac{fL_{\rho v}^2}{25.80\ (d_o - d_i)}$ $N_{Ra} = 928\ \frac{(d_o - d_i)v\rho}{\mu_p}$ $f = \emptyset\ (N_{Ra},\ e/d)$
Newtoniano	Colocar $\mu_p = \mu$	Colocar $\mu_p = \mu_y\ (d_o - d_i$

DENSIDAD DEL FLUIDO DE PERFORACION

EN EL CAMPO GEOTERMICO DE CERRO PRIETO

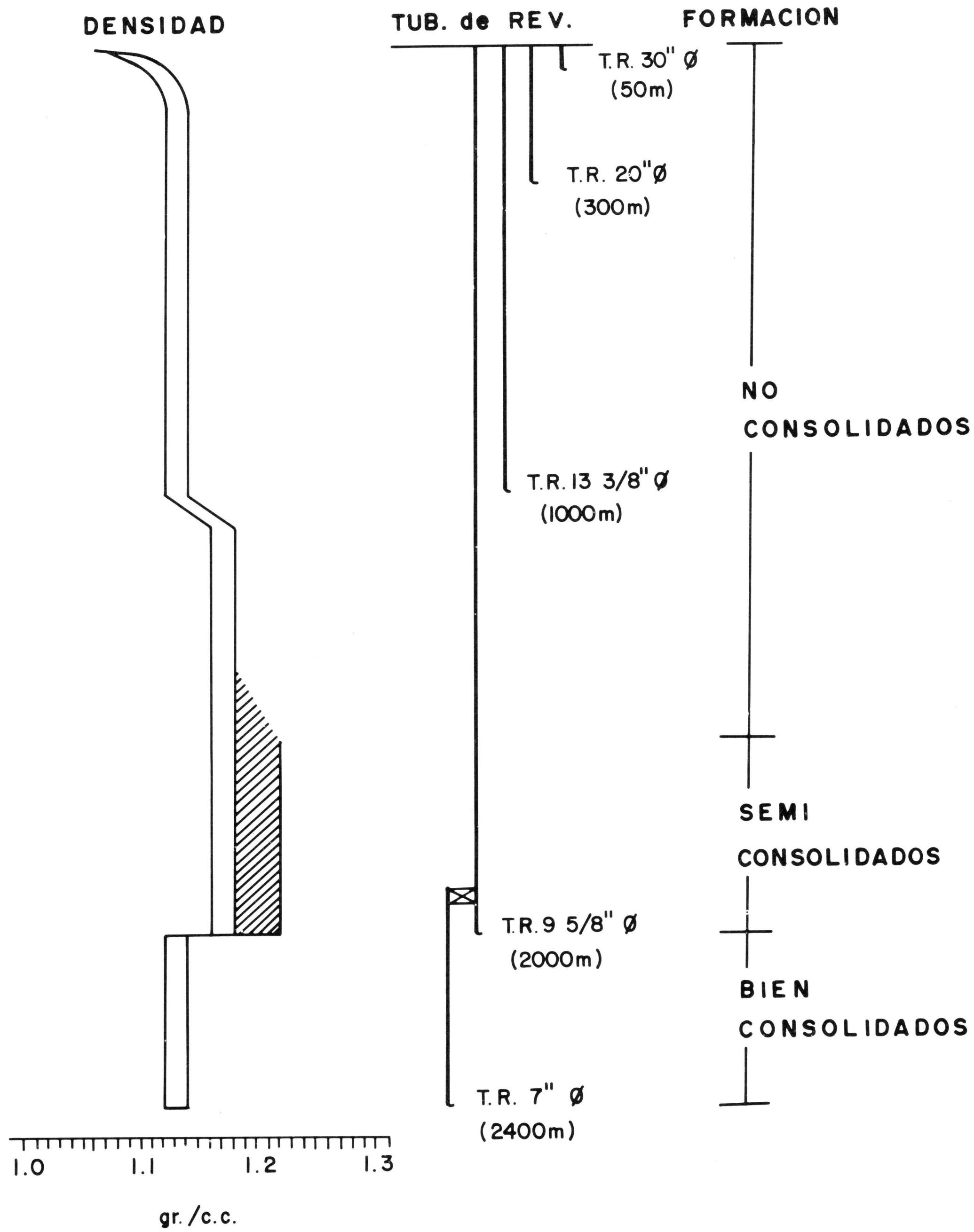


FIG. Nº 1

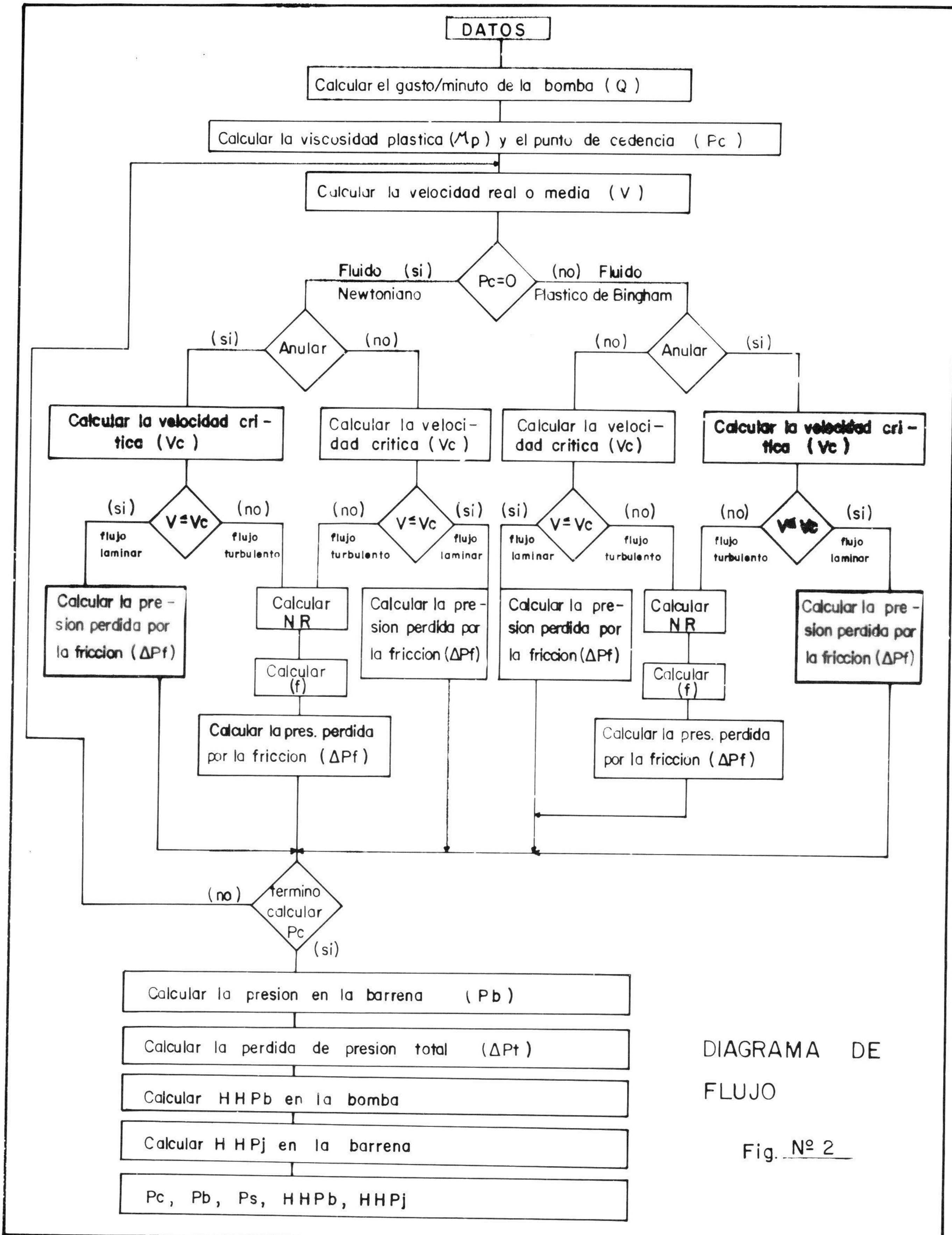


DIAGRAMA DE FLUJO

Fig. Nº 2

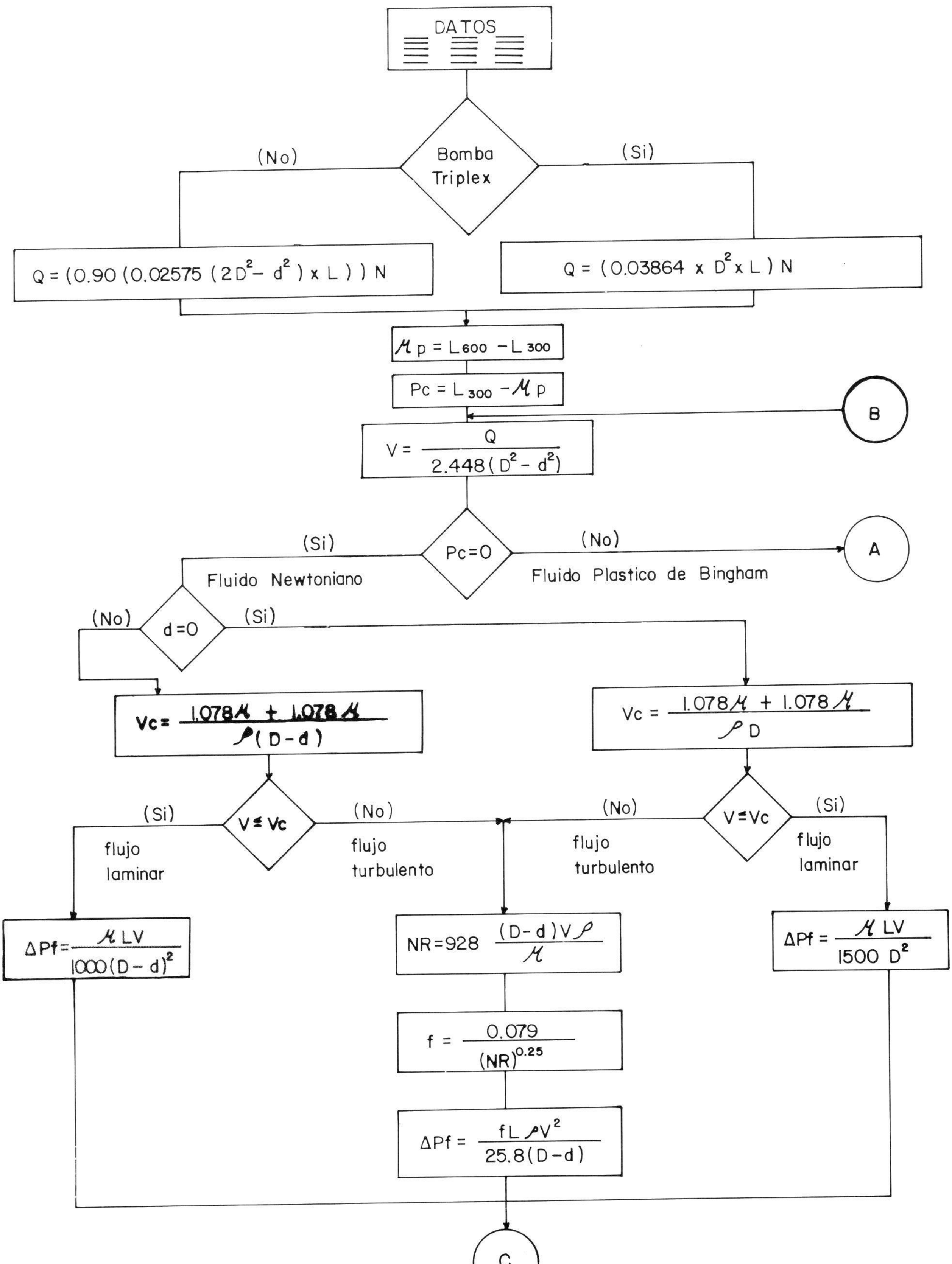
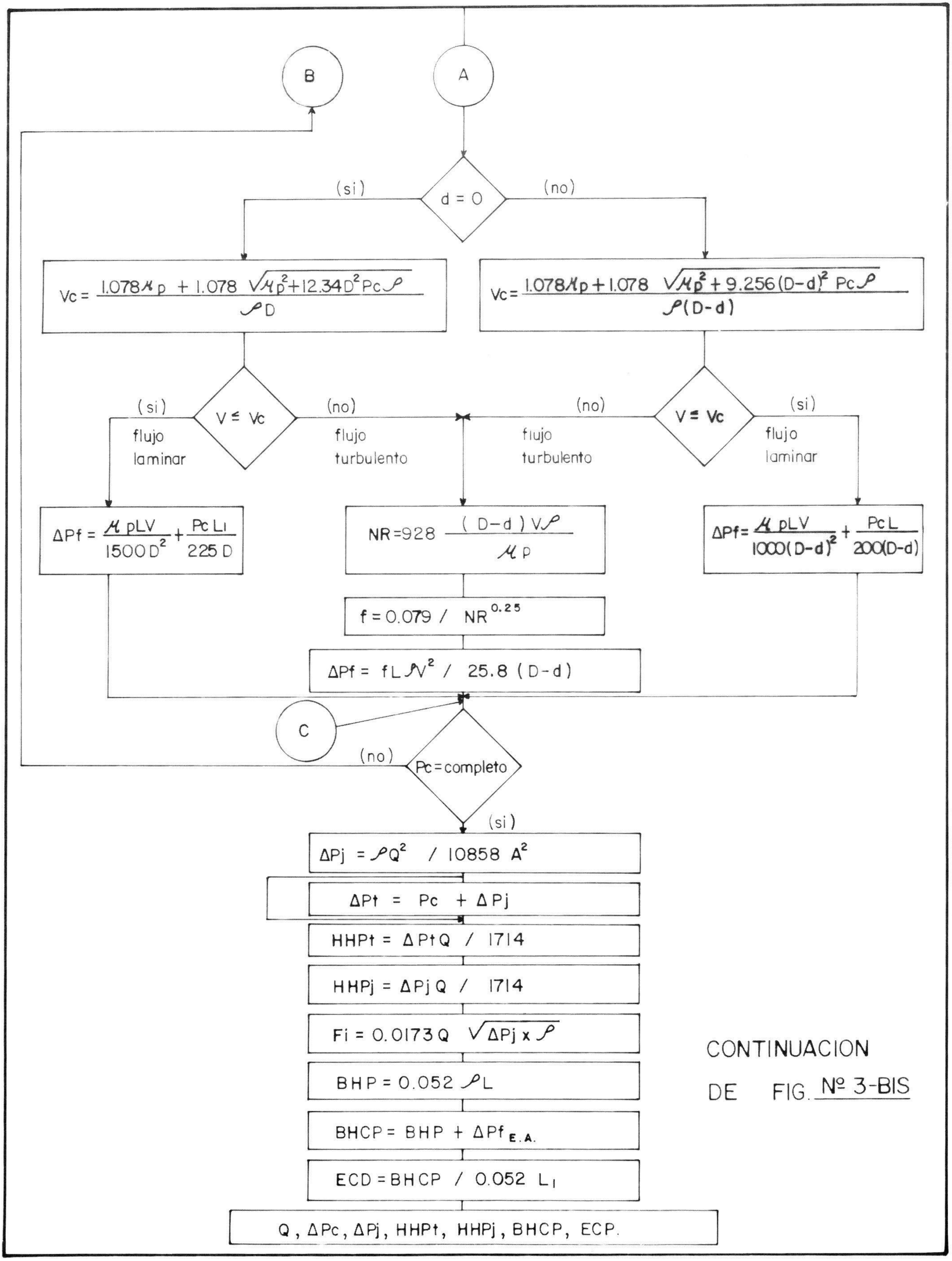


FIG. Nº 3 DIAGRAMA DE FLUJO



CONTINUACION DE FIG. Nº 3-BIS

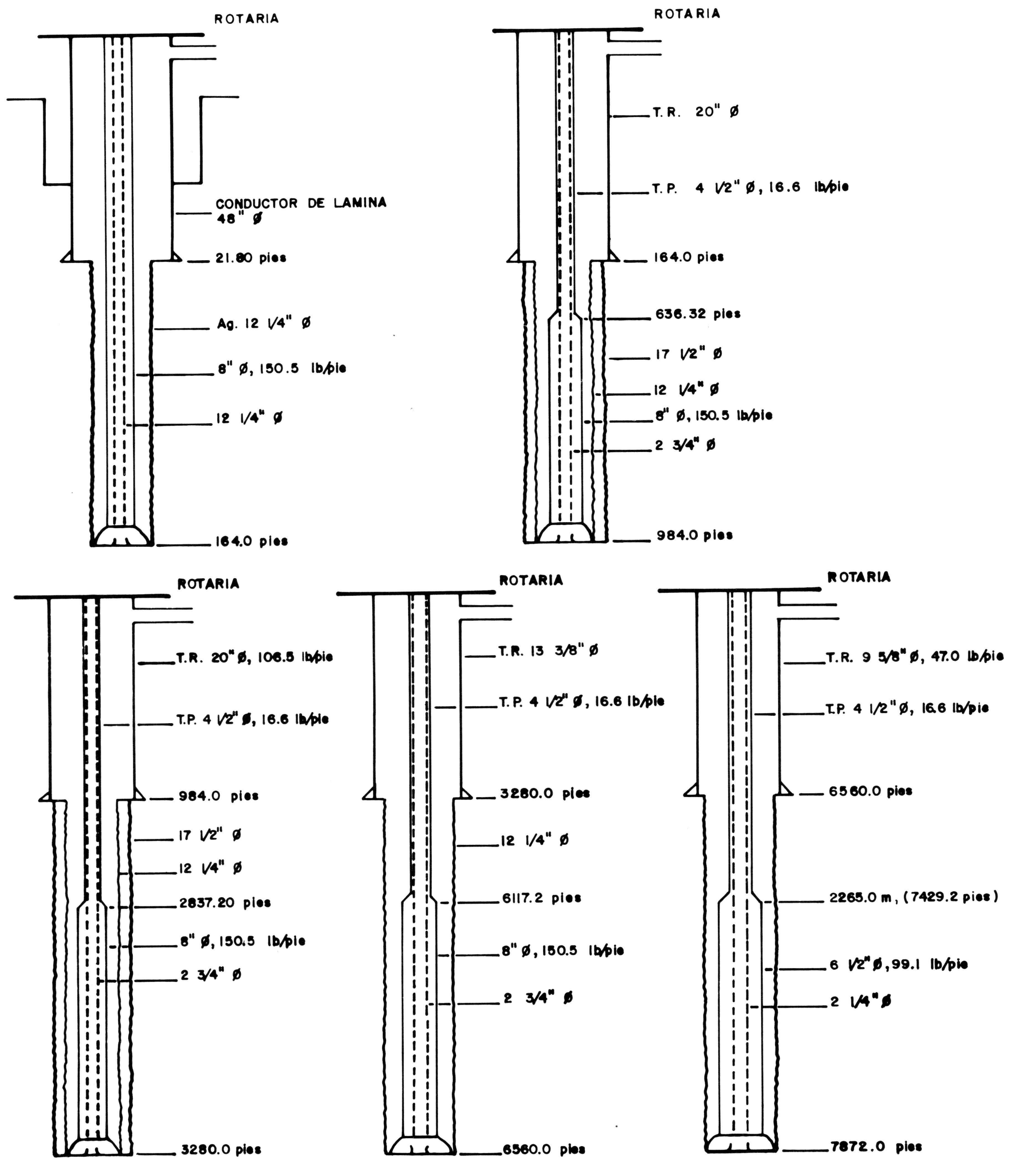


FIG. Nº 4 INTERVALOS DE PERFORACION EN UN POZO DE DESARROLLO EN EL AREA DE CERRO PRIETO.

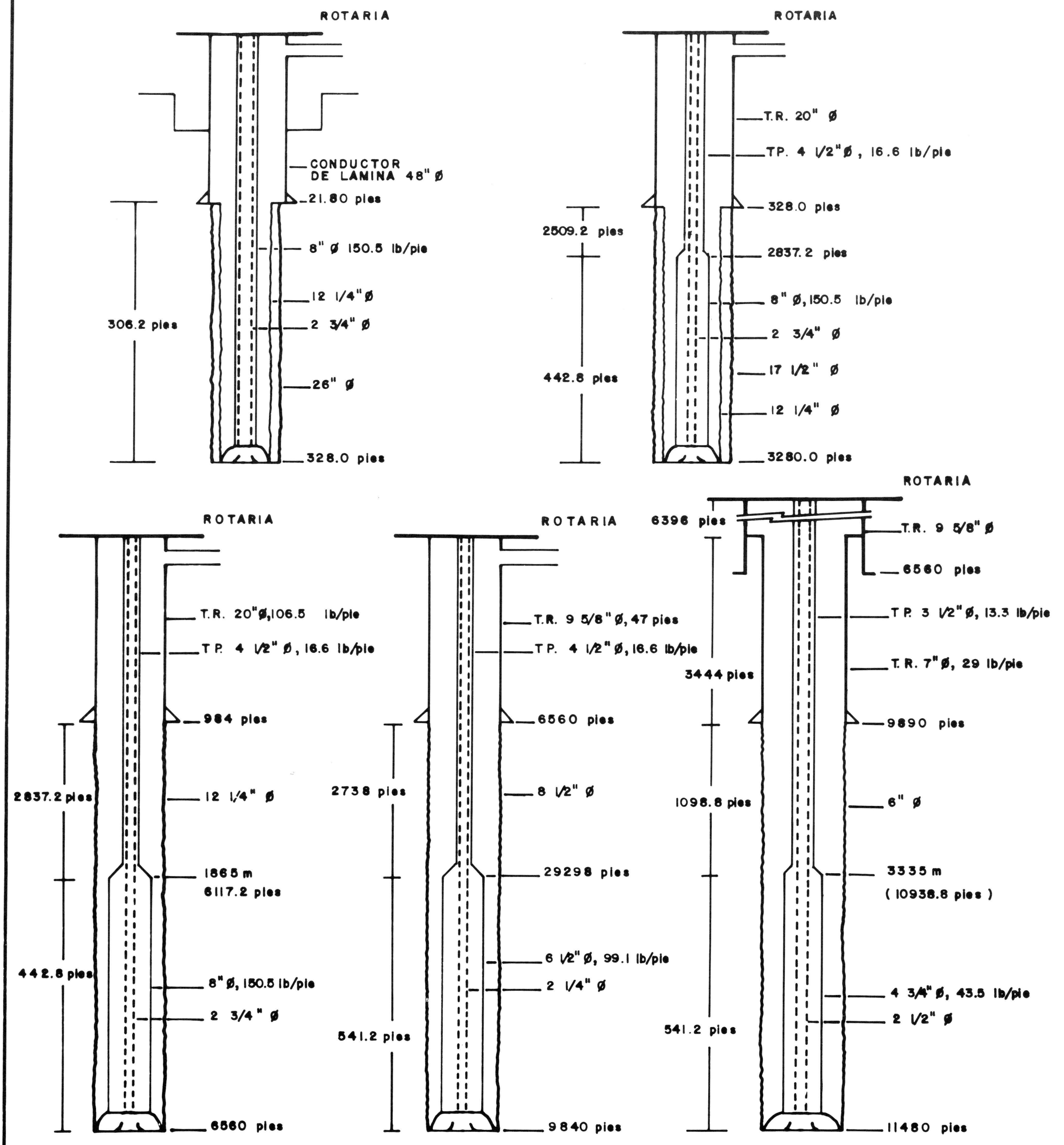
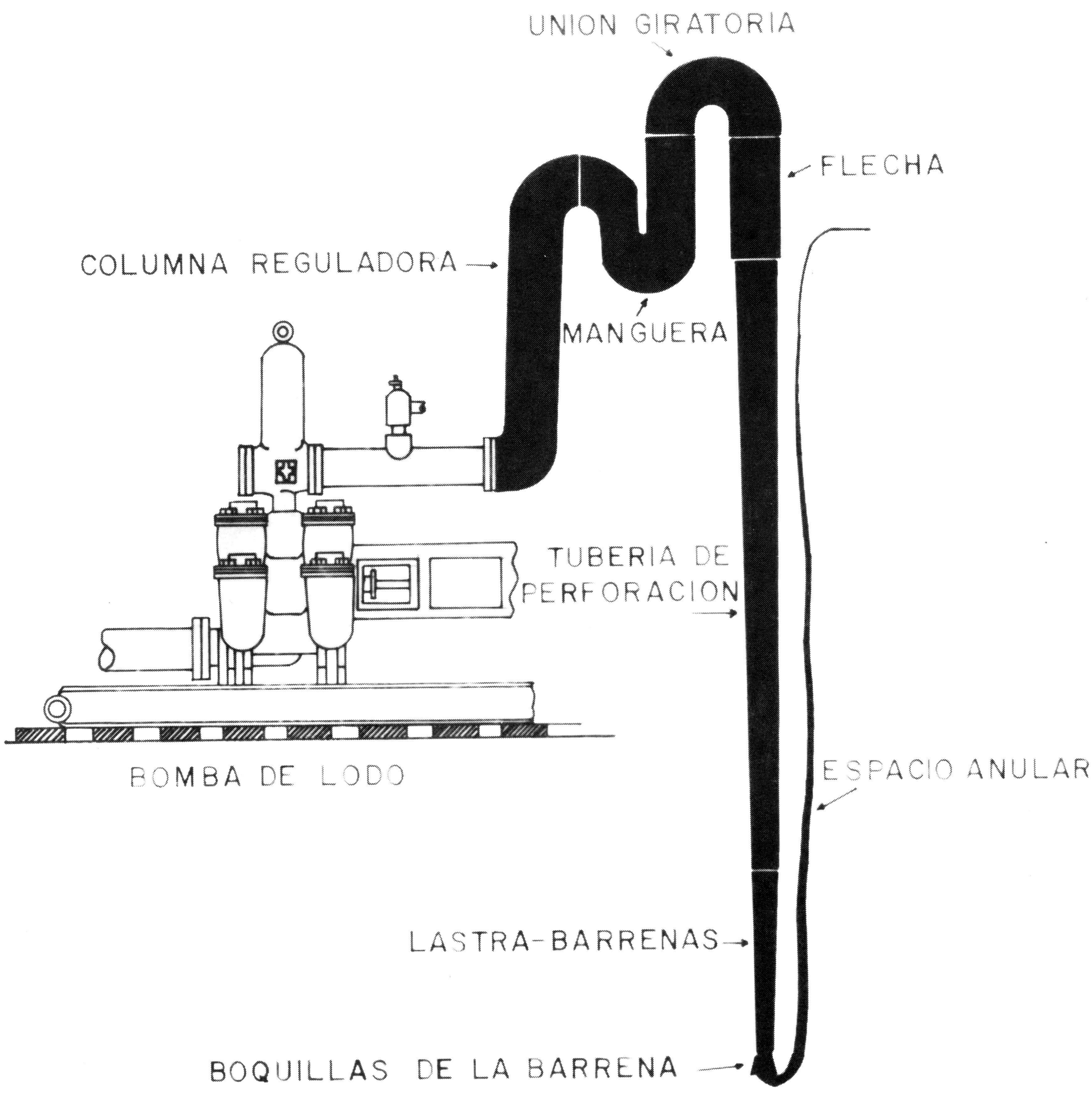


FIG. Nº 5 INTERVALOS DE PERFORACION EN UN POZO DE EXPLORACION EN EL AREA DE CERRO PRIETO.



EN ESTE ESQUEMA SE MUESTRA DONDE SE GASTAN LOS CABALLOS DE FUERZA QUE ENTRAN EN LA BOMBA DEL LODO.
EL GRUESO DE LA LINEA NEGRA REPRESENTA LA PRESION EN DIVERSOS PUNTOS DEL SISTEMA DEL LODO.

FIG. Nº 6