Design of hoist drive for well logging operations

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Návrh pohonu pre karotážnu sondu

Meracia sonda použitá pri karotáži, ktorá sa spúšťa a vyťahuje na lane počas každého meracieho cyklu konštantnou rýchlosťou, neposkytuje konštantnú rýchlosť hnacieho lana, spôsobujúc nepresné výsledky merania registrované na povrchu. Požadovaná zdvihová rýchlosť vyťahovania sondy sa môže dosiahnúť použitím prevodovkovým reduktorom a tyristorom. V práci sa prezentuje myšlienka jednoduchého a cenovo prijateľného pohonu pre meranie karotážou, zabezpečujúc konštantnú rýchlosť meracej sondy.

Key words: The Measuring probe, well logging.

Introduction

Well logging operations create a possibility to estimate, e.g. geological-reservoir rock properties. The respective measuring probe is driven down to the hole on a rope and driven up at an assumed velocity during one measuring cycle. In the course of pulling, the hoist co-operates with the probe and well logging equipment. The applied hoist drives for well logging equipment are often manually controlled to obtain a constant velocity based on velocity recorder indications (Zięba, 1944). With such solutions the velocity of the rope cannot be stable, thus also giving inaccurate results of measurements registered from the surface (ABEM, 1996). The required pulling velocity of the probe can be obtained through the application either of a gearbox or the so-called moto-reducer and inverter (Bednarz, 1994; Mathey, 1996), which is very costly.

The authors of the paper present a concept of a simple and economical solution of a hoist for well logging operations with a constant velocity of the probe maintained.

Functional-construction solution of a hoist drive

The suggested drive design (Fig. 1) consists of a motor 1, reducer 2, with co-operating brakes 3 and a brake release 4. A driving rope sheave 5 is mounted on a reducer (or motor) shaft 5, through which a rope 6 encompasses another rope sheave 7 set on a rope drum shaft 8 or attached to its edge. The rope 6 is attached to the probe with one end and to the rope drum with the other one. When the drive operates, the rope 6 co-operates with the driving rope sheave 5 frictionally, whereas with the rope sheave 7-with a glide providing an appropriate reeling of the rope on the rope drum. This requires a suitable frictional feedback between the elements and a selection of construction - geometrical properties of the drive. The diameter of the sheave 7 cannot be bigger than the diameter of the rope drum. What is more, the motor-rope drum system should be such that the angle of lateral deviation of the rope from the perpendicular area to the drum axis in the reversal position at the drum edges was less than $1^{o}30'$. The rope reversal is facilitated by a component of the rope drive operating to the drum inwardly.

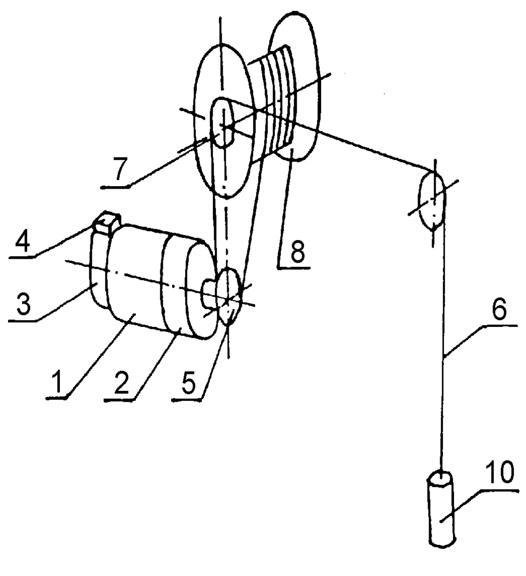

Fig. 1. Scheme of a driving construction.

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Both rope sheaves (5 and 7) should provide a good frictional feedback with the rope, and the rope drum should have possibly small bearing resistances (Bednarz, 1994).

Determination of basic parameters of the unit

Good work of the drive requires securing an appropriate frictional feedback between the rope and the rope sheaves 5 and 7. Assuming that the rope running down from the driving rope sheave 5 deviates from perpendicular negligibly, the following holds true for the set operation conditions (Fig. 2):

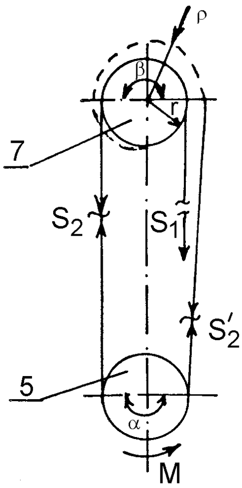


Fig. 2. Scheme of rigging.

- for the sheave 7:

$$S_2 r - S_1 r - S_2{}' \rho = 0 \qquad (1)$$

$$S_2 = S_1 \cdot e^{\mu_2 \beta} \qquad (2)$$

- for the sheave 5:

$$S_2 \le S_2{}' \cdot e^{\mu_1 \alpha} \qquad (3)$$

where: μ_1, μ_2 - coefficients of frictional feedback between the rope and rope sheaves 5 and 7;

α and β - angle of contact of rope driven on the sheave 5 and 7, respectively;

S_1 - force of tension of rope driven on sheave 7, resulting from the probe weight, rope weight and resistance of motion in the hole.

When determining S'_2 on the basis of equation (1) and also (2) and (3), the following can be obtained:

$$e^{\mu_1 \alpha} \ge \left\{ \left[1 - \left(e^{\mu_2 \beta} \right)^{-1} \right] \cdot \frac{r}{\rho} \right\}^{-1} \qquad (4)$$

It is clear from (4) that the maximum angle of contact of the rope with the sheave 5 is needed for $\rho = R$ (i.e. for the top position of the probe) and it will be equal to:

$$\alpha \ge \frac{1}{\mu_1} \ln \left\{ \left[1 - \left(e^{\mu_2 \beta} \right)^{-1} \right] \cdot \frac{r}{R} \right\}^{-1} \qquad (5)$$

Frictional feedback with the rope sheaves 7 and 5 must be such that at $\rho = R$ (rope reeled on the rope sheave in the last layer) no gliding of the rope with regard to the rope sheave 5 occurs. This condition is fulfilled when formula (4) holds true for parameters of frictional feedback between the rope and sheaves 5 and 7 through the factors $e^{\mu_1 \alpha}$ and $e^{\mu_2 \beta}$. The values $\mu\alpha$ and $e^{\mu\alpha}$ are given in Table 1. The maximum radius R of rope reeling on the drum with known length B and outer diameter
$D = 2r$, will depend on the length L of the reeled rope (depth of the hole) and its diameter d.

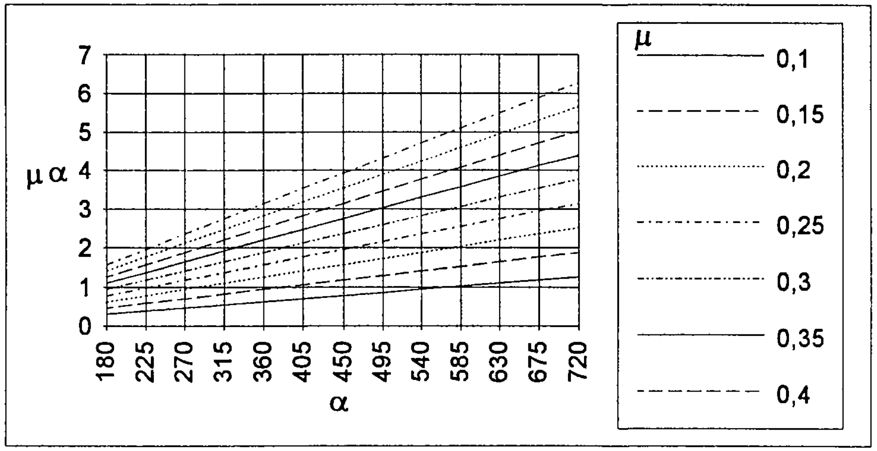
The number of reels in the first layer will be:

$$i = \frac{B}{d} \varphi \qquad (6)$$

where: φ - filling coefficient of the rope drum ($\varphi = 0.95$).

Table 1

μ \ α	180	225	270	315	360	405	450	495	540	585	630	675	720
0,1	0,31416	0,392699	0,471239	0,549779	0,628319	0,706858	0,785398	0,863938	0,942478	1,021018	1,099557	1,178097	1,256637
0,15	0,47124	0,589049	0,706858	0,824668	0,942478	1,060288	1,178097	1,295907	1,413717	1,531526	1,649336	1,767146	1,884956
0,2	0,62832	0,785398	0,942478	1,099557	1,256637	1,413717	1,570796	1,727876	1,884956	2,042035	2,199115	2,356194	2,513274
0,25	0,7854	0,981748	1,178097	1,374447	1,570796	1,767146	1,963495	2,159845	2,356194	2,552544	2,748894	2,945243	3,141593
0,3	0,94248	1,178097	1,413717	1,649336	1,884956	2,120575	2,356194	2,591814	2,827433	3,063053	3,298672	3,534292	3,769911
0,35	1,09956	1,374447	1,649336	1,924226	2,199115	2,474004	2,748894	3,023783	3,298672	3,573562	3,848451	4,12334	4,39823
0,4	1,25664	1,570796	1,884956	2,199115	2,513274	2,827433	3,141593	3,455752	3,769911	4,08407	4,39823	4,712389	5,026548
0,45	1,41372	1,767146	2,120575	2,474004	2,827433	3,180863	3,534292	3,887721	4,24115	4,594579	4,948008	5,301438	5,654867
0,5	1,5708	1,963495	2,356194	2,748894	3,141593	3,534292	3,926991	4,31969	4,712389	5,105088	5,497787	5,890486	6,283185
μ \ α	180	225	270	315	360	405	450	495	540	585	630	675	720
0,1	1,36911	1,480973	1,601978	1,73287	1,874456	2,027611	2,19328	2,372485	2,566332	2,776018	3,002837	3,248188	3,513586
0,15	1,60198	1,802273	2,027611	2,281123	2,566332	2,887201	3,248188	3,654309	4,111207	4,625231	5,203524	5,854121	6,586062
0,2	1,87446	2,19328	2,566332	3,002837	3,513586	4,111207	4,810477	5,628686	6,586062	7,706277	9,017029	10,55072	12,34528
0,25	2,19328	2,669117	3,248188	3,952889	4,810477	5,854121	7,124186	8,669793	10,55072	12,83973	15,62533	19,01528	23,14069
0,3	2,56633	3,248188	4,111207	5,203524	6,586062	8,33593	10,55072	13,35397	16,90202	21,39277	27,07666	34,27073	43,37621
0,35	3,00284	3,952889	5,203524	6,849841	9,017029	11,86988	15,62533	20,56896	27,07666	35,64332	46,92033	61,76522	81,3068
0,4	3,51359	4,810477	6,586062	9,017029	12,34528	16,90202	23,14069	31,6821	43,37621	59,38671	81,3068	111,3178	152,406
0,45	4,11121	5,854121	8,33593	11,86988	16,90202	24,0675	34,27073	48,79954	69,48772	98,9465	140,8941	200,625	285,6784
0,5	4,81048	7,124186	10,55072	15,62533	23,14069	34,27073	50,75402	75,16532	111,3178	164,8586	244,1511	361,5811	535,4917



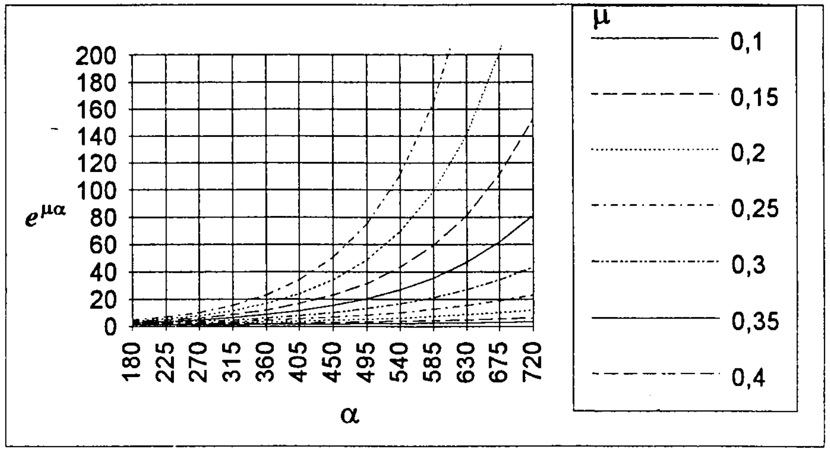


Table 1. Values $\mu\alpha$ and $e^{\mu\alpha}$ for μ = 0.1 ÷ 0.6 and α = 180° ÷ 720°.

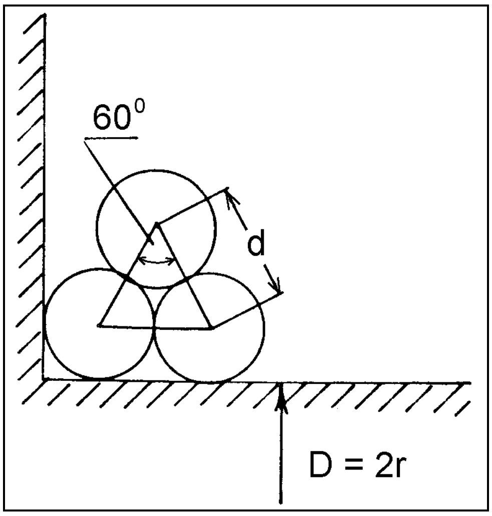


Fig. 3. Scheme of rope reeling on the drum.

When n denotes a number of layers reeled on the drum, then:

- a rope section of an approximate length 1 will be reeled on the first layer:

$$l_1 = \pi(D+d)\cdot i \tag{7}$$

- on the *n*-th layer (Fig. 3):

$$l_n = \pi\left[D+d+(n-1)\sqrt{3}\cdot d\right]\cdot i \tag{8}$$

For the *L* long rope reeled on the drum the following is valid:

$$L = \sum_{j=1}^{n} l_j = \pi n i\left\{D + d\left[1+\frac{\sqrt{3}}{2}(n-1)\right]\right\} \tag{9}$$

and the maximum radius *R* of rope reeling will be:

$$R = r + \frac{d}{2}\left[1+\sqrt{3}(n-1)\right] \tag{10}$$

On the introduction of the following denotations:

$$L/B = k \quad \text{oraz} \quad D/d = s \tag{11}$$

to equation (9) we can determine the number of layers *n* of the rope reeled on the rope drum from the formula:

$$n^2\frac{\sqrt{3}}{2} + n\left(s+1-\frac{\sqrt{3}}{2}\right) - \frac{k}{\pi\varphi} = 0 \tag{12}$$

obtaining the solution:

$$n = \frac{1}{\sqrt{3}}\left[\frac{\sqrt{3}}{2} - 1 - s + \sqrt{\left(s+1-\frac{\sqrt{3}}{2}\right)^2 + 2\sqrt{3}\frac{k}{\pi\varphi}}\right] \tag{13}$$

which, after taking into account equations (11), can be rewritten:

$$n = \frac{1}{\sqrt{3}}\left[\frac{\sqrt{3}}{2} - 1 - \frac{D}{d} + \sqrt{\left(\frac{D}{d}+1-\frac{\sqrt{3}}{2}\right)^2 + 2\sqrt{3}\frac{(L/B)}{\pi\varphi}}\right] \tag{14}$$

From the above relations basic parameters of the unit can be determined. Taking the following input data:

- rope length *L*,
- outside diameter of the rope drum *D = 2r*,
- coefficients of frictional feedback of the rope with rope sheaves μ_1, μ_2,
- angle of contact of the rope with one of the rope sheaves, e.g. β

it is possible to calculate the number of layers n of the rope reeled on the rope sheave from equation (13), then maximum radius *R* of rope reeling from equation (10), and α from dependence (5).

For the sake of exemplary calculations, data were taken from Table 2 and the following was obtained:

$$k = L/B = 1666{,}7; \quad s = D/d = 16.3 \approx 17; \quad R = 71.3 \text{ mm}; \quad \alpha \approx 312.^{\circ}$$

No	Parameters	Dimension	Value
1	Rope lenght L	m	500
2	Rope diameter d	mm	3
3	Drum diameter D	mm	60
4	Drum lenght B	mm	300
5	Angle β	°	90
6	Coefficients: μ_1 / μ_2	-	0.4/0.2

Table 2. Geometrical parameters of the hoist .

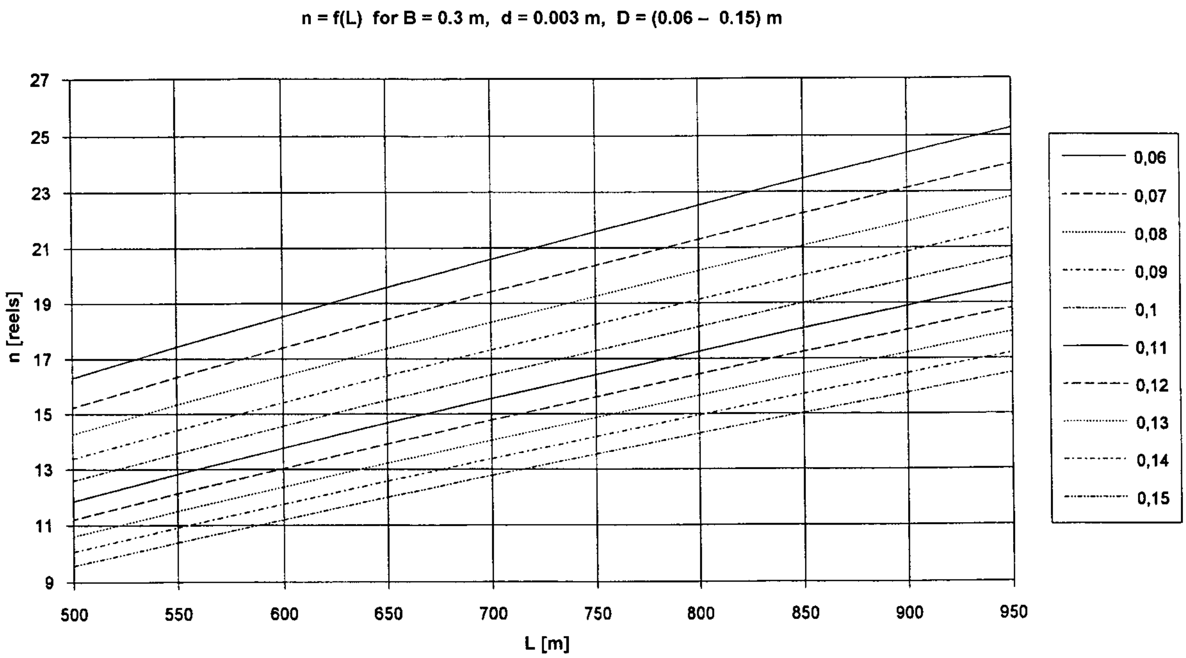


Fig. 4. Graph of relation n = f(L).

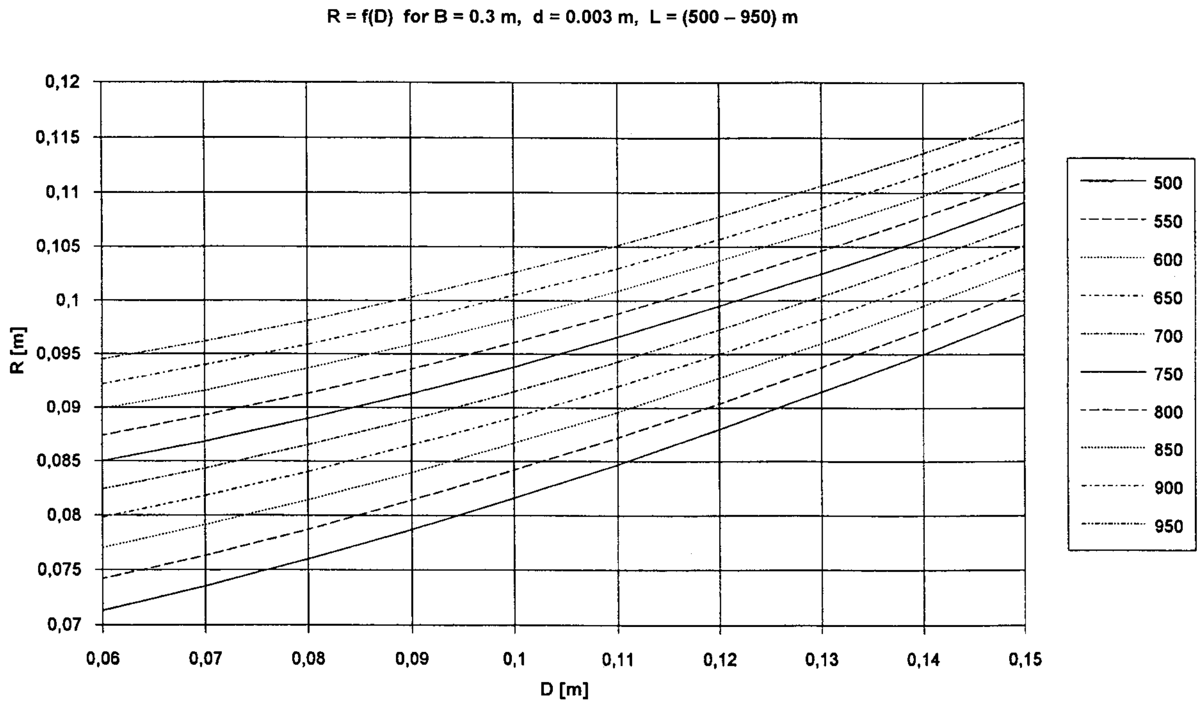


Fig. 5. Graph of relation R = f(D).

For design purposes, graphs based on the above relations may be useful for a quick determination of values of basic parameters of the unit. They were presented in Figs. 4, 5, and 6.

The Authors have a software for a complex determination of all necessary parameters of the unit (e.g. diameters of rope sheaves, power of motors, etc.).

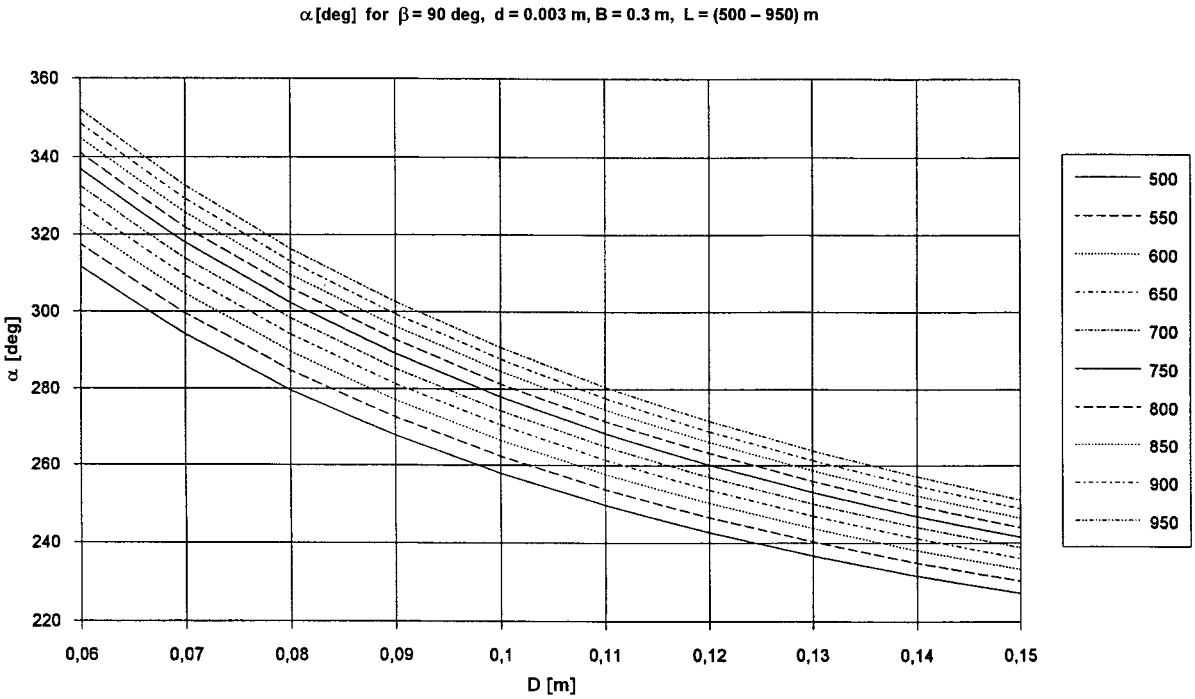


Fig. 6. Graph of relation α = f(D).

Resume

The accuracy of well logging depends, among others, on the possibility to maintain a constant velocity of motion of the probe throughout the hole (that is why the condition is so important).
The suggested hoist drive system secures a constant velocity of the rope motion; it has a simple construction employing typical constituent elements.

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