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Short Communication

Incidence factors of the tracking systems used in parabolic-cylindrical concentrators

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Abstract

Various orientation and tracking systems that can be adopted in parabolic-cylindrical concentrators are analysed and the one that is most suitable, with costs and efficiency in view, is recommended.

Key words : Incidence factor, tracking systems, polar axis.

1. Introduction

Parabolic-cylindrical concentrators are used for medium temperature applications (100° to 250° C). These concentrators focus the direct solar radiations on the absorber tubes through which the working fluids circulate and thus absorb heat. In addition to various factors, the efficiency of collection depends also on orientation and tracking systems employed in these concentrators. The primary objective of this note is to analyse the various orientation and tracking systems that are normally employed in parabolic-cylindrical concentrators and discuss their relative merits.

2. Orientation and tracking systems

The useful energy received by the absorber of a parabolic-cylindrical concentrator is represented by

$$Q_R = AP(\cos i)\,\rho\,\gamma\tau\alpha$$

where A = projected area of the collector

P = incident direct solar radiation

$\cos i$ = incidence factor

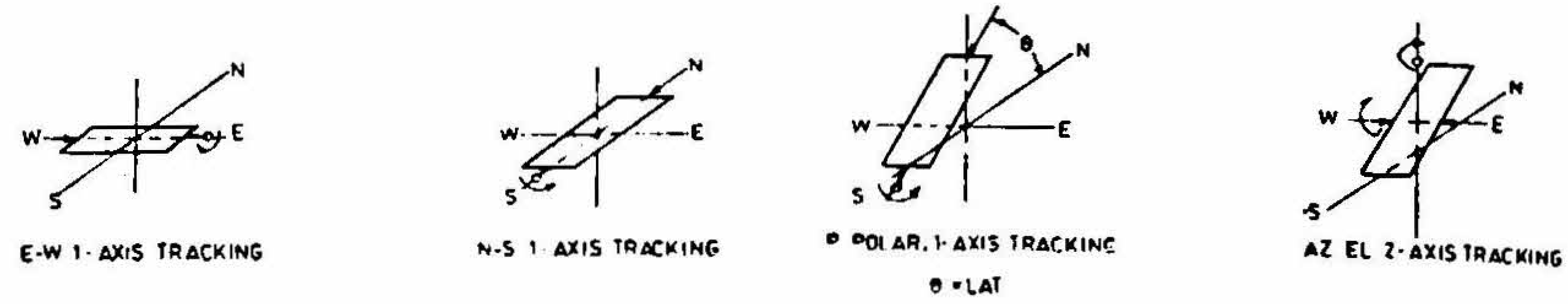

FIG. 1. Orientaion and tracking methods used in parabolic cylindrical concentrators.

ρ = specular reflectance of the reflector surface

γ = intercept factor

τ = transmittance of the glass cover tube

α = absorptance of the receiver tube for the incoming solar radiation.

The incident factor represents the angle of incidence of the solar beam radiation, incident on the reflecting surface of a parabolic-cylindrical concentrator. Duffie and Beckman[1] and Burges[2] have discussed the various orientation and tracking systems used in these concentrators. These are represented in Fig. 1. and the dependence of the incident factor on declination, hour angle and latitude are related and stated in

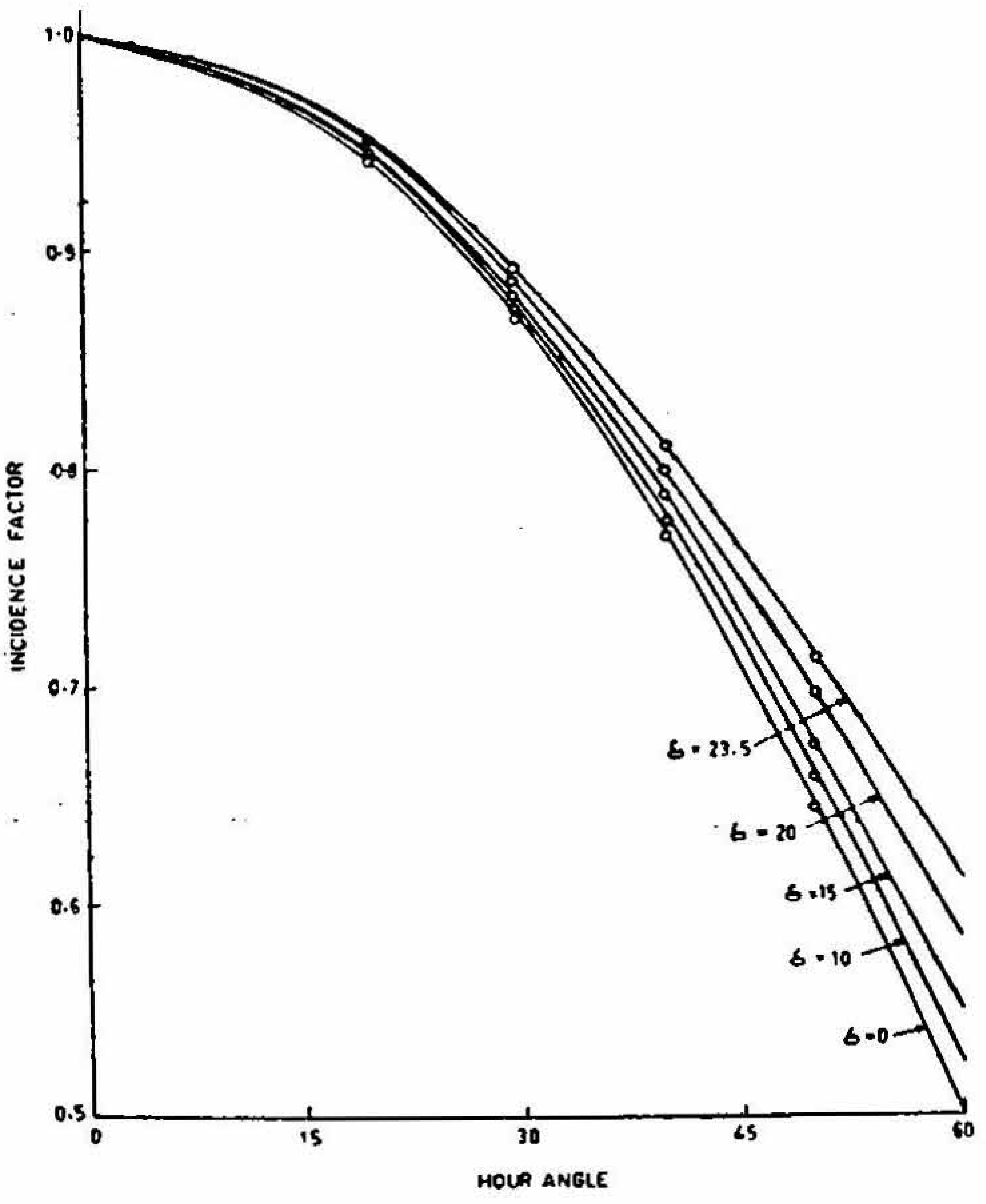

FIG. 2.

Table I

Sl. No.	Orientation of collector	Incidence factor ($\cos i$)
1.	Orientation along east-west axis and rotation about E–W axis with continuous adjustment to obtain maximum energy incidence	$(1-\cos^2\delta\sin^2\omega)^{\frac{1}{2}}$
2.	Orientation along north–south axis and rotation about N–S axis with continuous adjustment to obtain maximum energy incidence	$[(\sin\phi\sin\delta+\cos\phi\cos\delta\cos\omega)^2 + \cos^2\delta\sin^2\omega]^{\frac{1}{2}}$
3.	Orientation along polar axis and rotation about this axis with continuous adjustment to obtain maximum energy incidence	$\cos\delta$
4.	Rotation about two perpendicular axes with continuous adjustment to allow the surface normal to coincide with the solar beam at all times	1

δ = Declination (*i.e.*, the angular position of the sun at solar noon with respect to the plane of the equator);
ω = Hour angle, solar noon being zero and each hour equalling 15° of longitude with morning's positives and afternoon's negatives.
ϕ = Latitude.

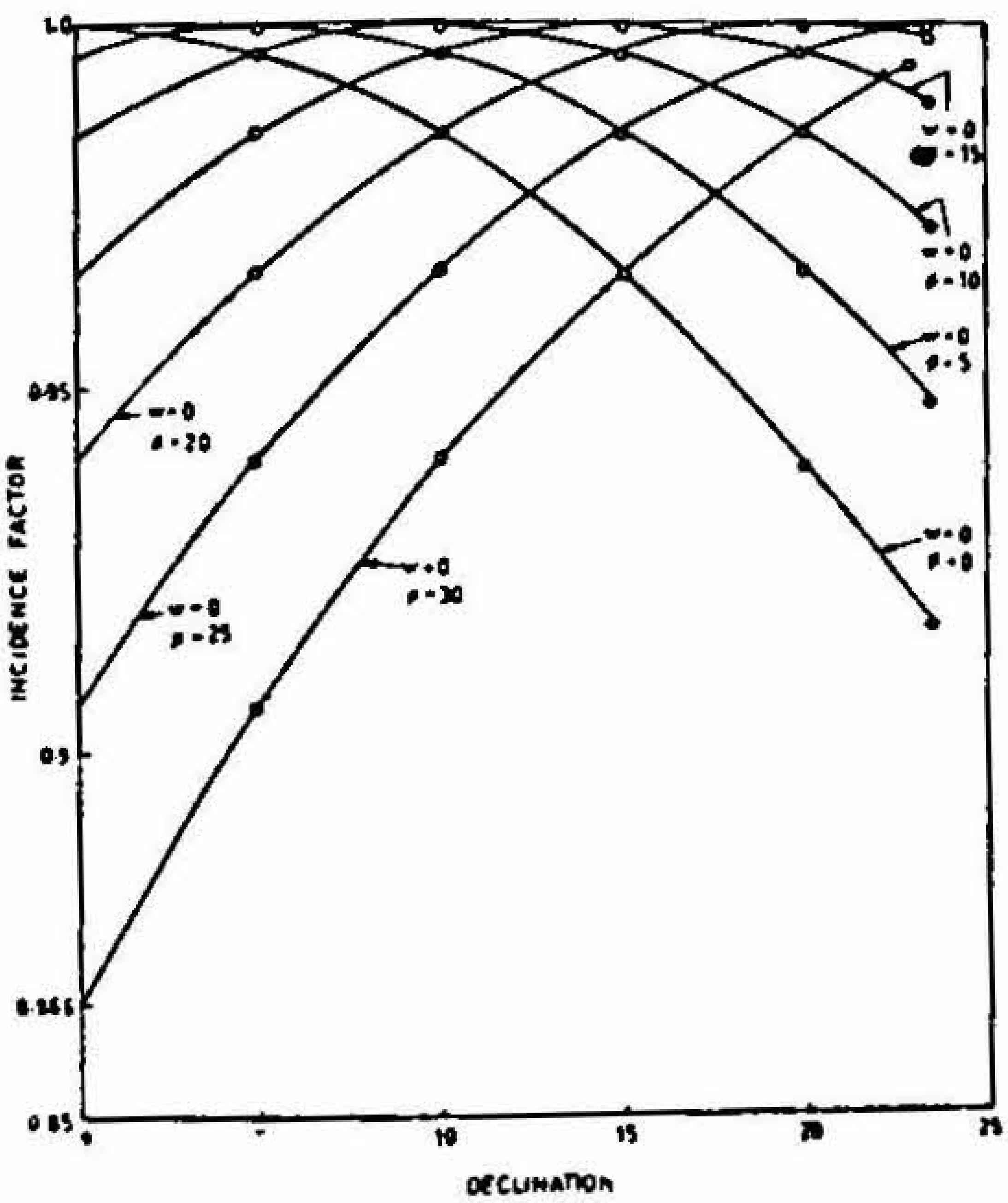

FIG. 3.1.

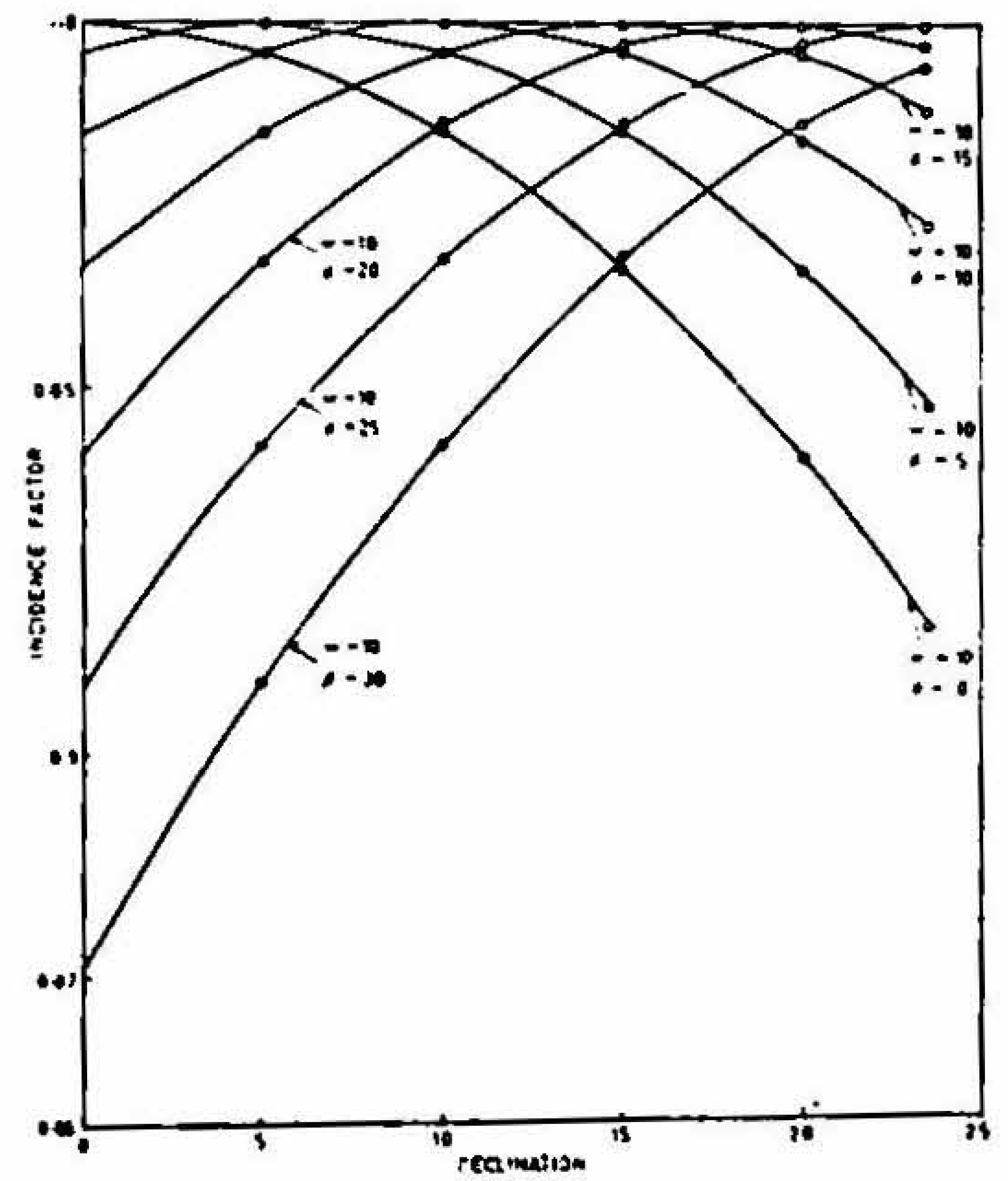

FIG. 3.2.

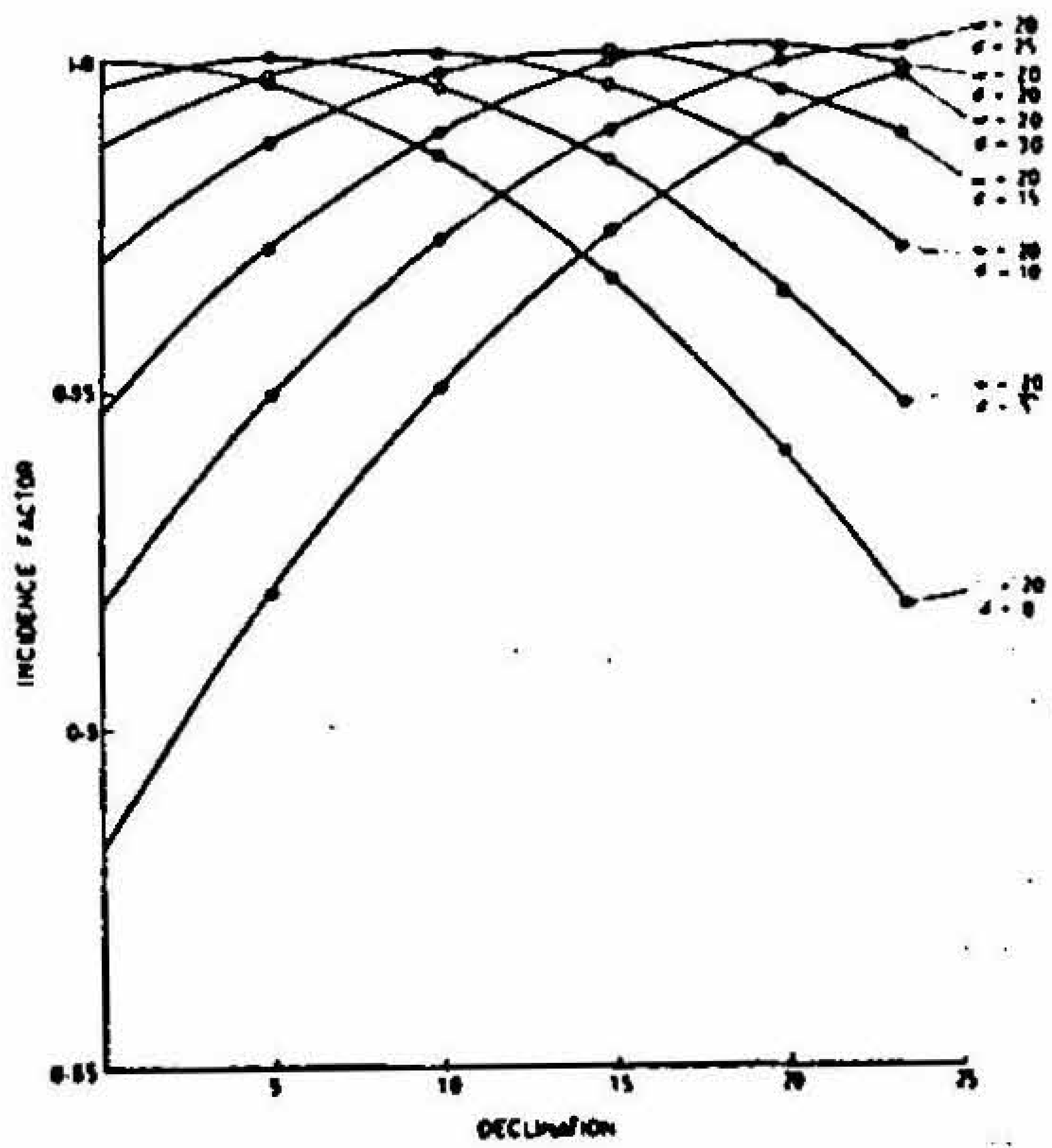

FIG. 3.3.

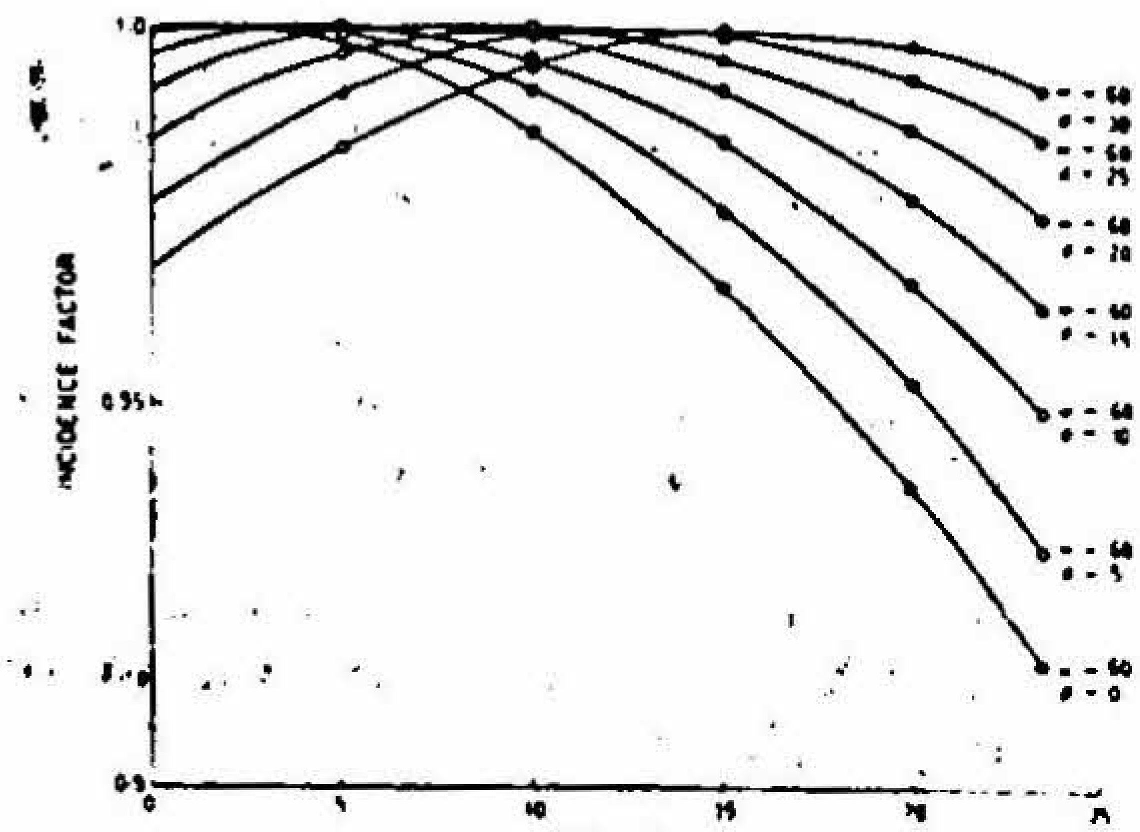

FIG. 3.4.

Table I. Using these relations, the incidence factors have been determined for various values of declination (0 to 23·5° in steps of 0·5°), hour angles (0 to 60° in steps of 1°) and latitudes (0 to 30° in steps 1°) with the help of a computer and the values are represented in Figs. 2–4.

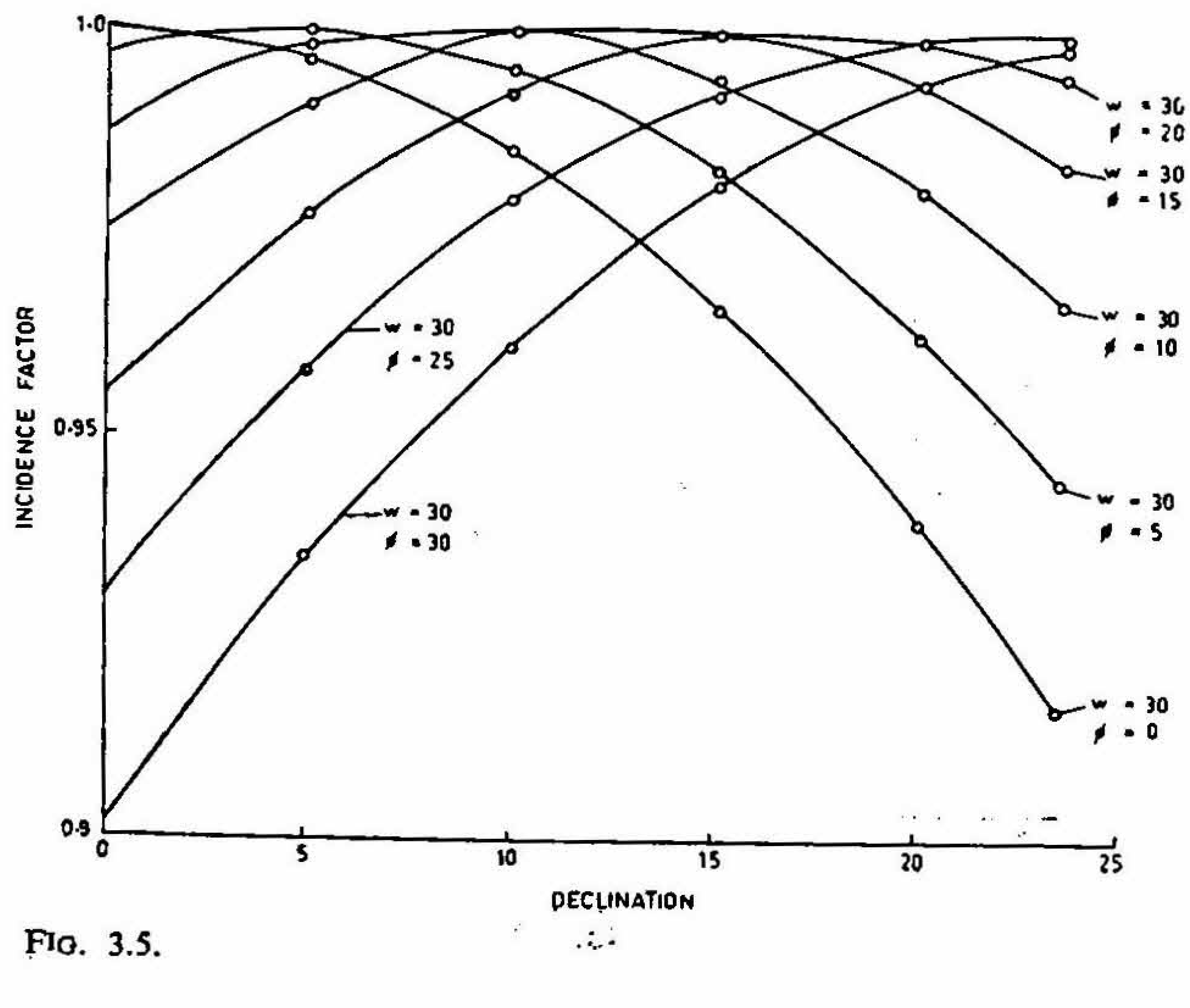

FIG. 3.5.

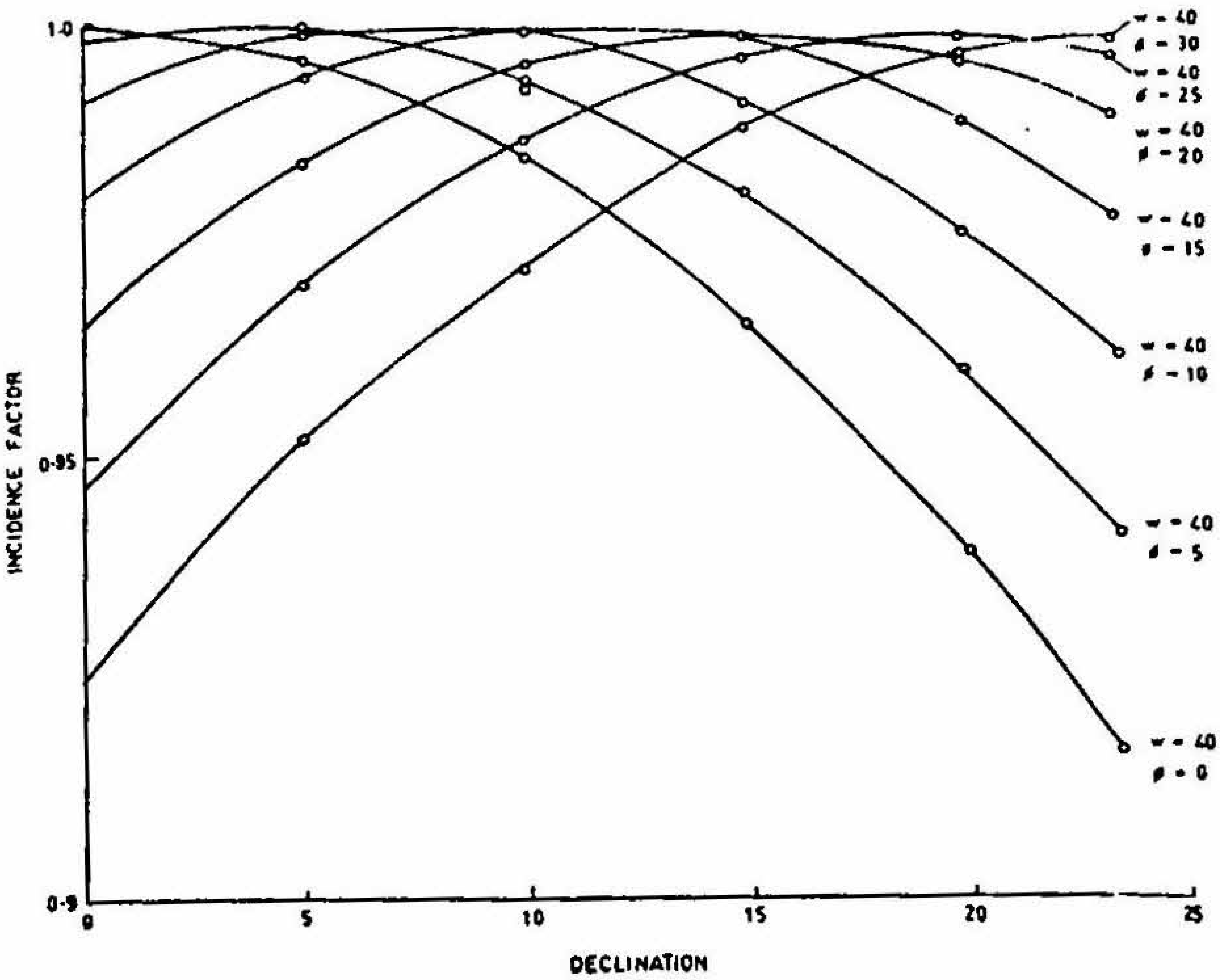
1·0
0·95
0·9
INCIDENCE FACTOR
0
5
10
15
20
25
DECLINATION
w = 40
ϕ = 30
w = 40
ϕ = 25
w = 40
ϕ = 20
w = 40
ϕ = 15
w = 40
ϕ = 10
w = 40
ϕ = 5
w = 40
ϕ = 0

FIG. 3.6.

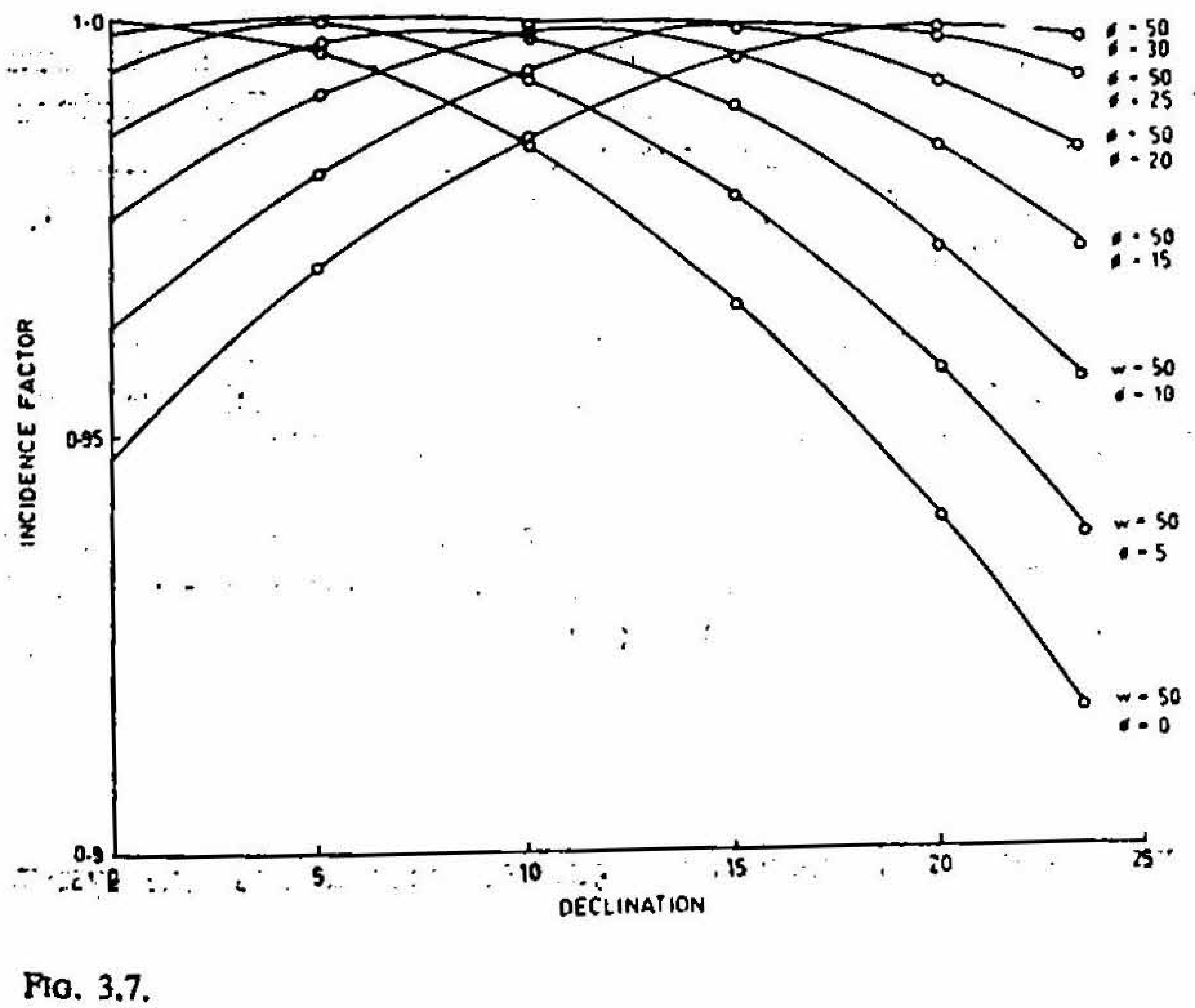
1·0
0·95
0·9
INCIDENCE FACTOR
0
5
10
15
20
25
DECLINATION
ϕ = 50
ϕ = 30
ϕ = 50
ϕ = 25
ϕ = 50
ϕ = 20
ϕ = 50
ϕ = 15
w = 50
ϕ = 10
w = 50
ϕ = 5
w = 50
ϕ = 0

FIG. 3.7.

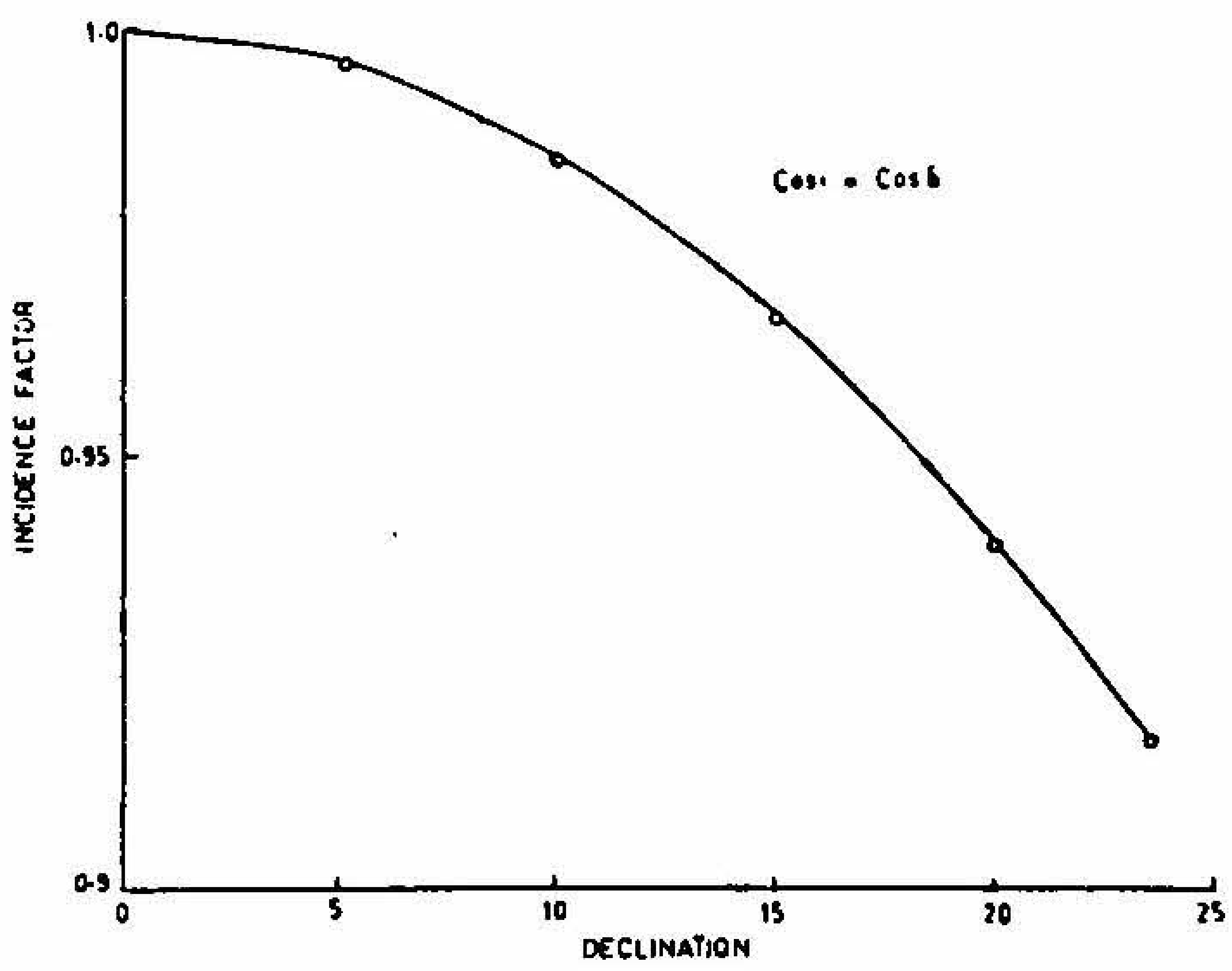

FIG. 4.

3. Analysis

The curves represented in Fig. 2 correspond to the case 1 of the table where the incidence factor is a function of declination and hour angle. The maximum variations of incidence factor from morning 8'o clock to noon is 0·5 at zero angle of declination. This improves with higher angle of declination, though not appreciably.

The curves represented in Figs. 3·1 to 3·7 correspond to the case 2 where the incidence factor is a function of declination, hour angle and latitude. The maximum variation of the incidence factor is 0·128 which occurs during noon at the latitude of 30°. This corresponds to a change of declination from 0 to 23·5°. The variations in the other cases are comparatively small.

The curve represented in Fig. 4 corresponds to the case 3 where the incidence factor is a function of declination only. The maximum variation of the incidence factor corresponding to the change in declination from 0 to 23·5° is 0·0758.

The incidence factor is one in the case 4, but it (tracking) requires two mutually perpendicular axes and complicated structures[3]. The gain is not appreciable compared to the cost of the structures and the cost of tracking system.

4. Conclusion

With costs and efficiency in view, this analysis in general recommends the system corresponding to case 3.

Acknowledgement

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