Reprinted from the
Journal of Scientific & Industrial Research, 1958, Vol. 17A, No. 12, Supplement, pp. 88, 90

Photographic Observation of the Moon's Position

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IT has long been realized that the photographic method, as applied to the problem of determination of the moon's position, would prove to be more flexible and accurate than the classical methods. The first efforts in this direction were made by King at Harvard almost four decades ago. A snapshot of the moon was taken in the middle of a 10 min. exposure. Despite the several factors that have to be corrected for to attain a reliable measure of position, these plates indicated well the reliability of the photographic method.

In recent years, with the development of the Markowitz camera, the problem of moon photography for positions has received considerable stimulus, and we now have a reliable technique which has numerous applications in the fields of time determination and geodesy. Photographic positional determinations with the Markowitz camera have been included in the list of programmes to be worked on during the International Geophysical Year. The cameras have all been made at the U.S. Naval Observatory in Washington and distributed to about twenty

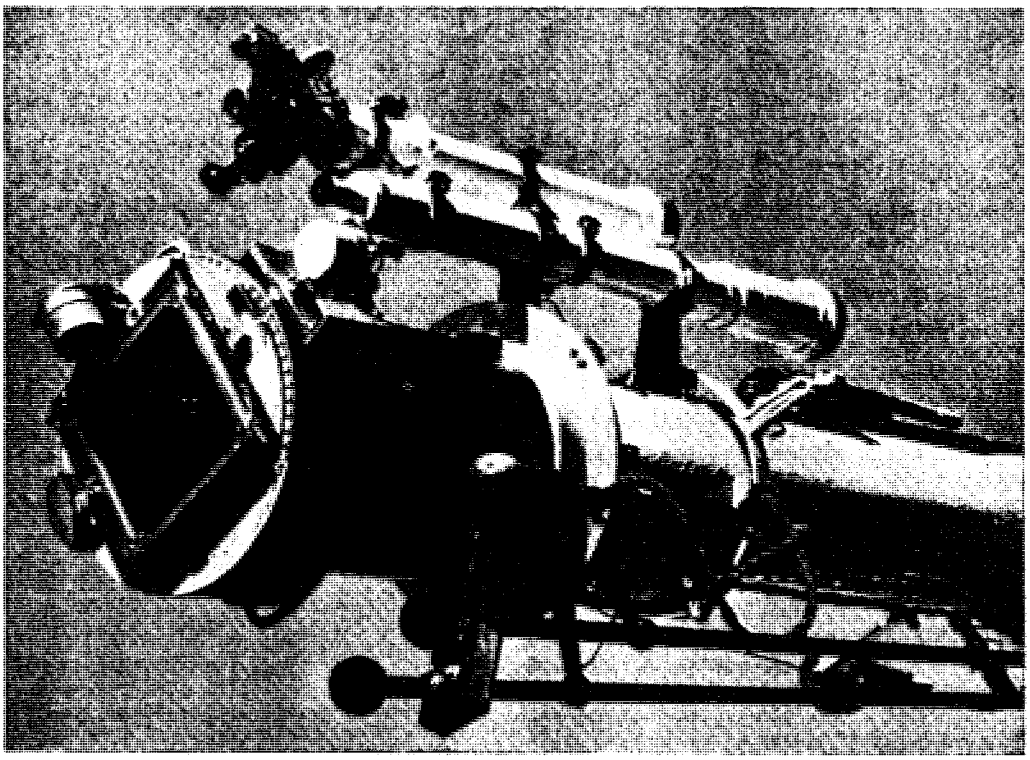

FIG. 1 — VIEW OF THE MARKOWITZ CAMERA ATTACHED TO THE 10 IN. REFRACTOR

different countries all over the world so as to have a good distribution in longitude. India received one camera and this was allotted by the Indian National Committee to the Uttar Pradesh State Observatory at Naini Tal.

Fig. 1 shows the camera mounted at the eye end of the 10 in. Cooke refractor. The camera, in principle, is a means of exposing simultaneously on both moon and stars for a duration not exceeding 20 sec. During this period the moon's image on the plate is held fixed relative to the stars. The epoch of the exposure is the instant when the moon's actual position in the sky relative to the stars is the same as that on the plate. A photograph of the moon taken at Naini Tal with the moon camera on 7 May 1957 is shown in Fig. 2.

All these are accomplished in the following way. Since the moon is exposed continuously for the entire 20 sec. duration, its light will have to be cut down considerably. Just before the focal plane a small circular plane parallel dark glass filter intercepts the moon's light. The dark glass reduces the moon's intensity by a factor of a thousand so that a properly exposed image can be obtained on the plate. During the entire exposure the clock drive is not used. Instead, the diurnal motion is corrected for by driving the entire plate holder in an east-west direction at the required rate by a small synchronous motor. This rate depends on the moon's declination and can be preset in the driving unit. The dark glass filter is held from the camera periphery by a slender rod and drive assembly. The rod forms the axis about which the dark glass filter is rotated at a known rate. This tilt of the filter by a known amount compensates the moon's motion against the starry background during the duration of the exposure. The position angle and actual value of drift motion are known prior to the night's work and the driving rate of the assembly adjusted accordingly. Since the photographs are all made with a visual refractor, a yellow filter of thickness equal to the dark glass filter lies ahead of the focal plane to absorb the steep portions of the colour curve of the telescope. The yellow filter has a hole in the centre so that the optical paths of both stars and moon before reaching the emulsion are the same.

An operation procedure for a night is as follows. The sidereal rate corresponding to the moon's declination, the speed of drift of the moon and the position angle of the axis of tilt are known and are set accordingly. The exposure is timed by an electrical timer which automatically opens and closes the shutter. Exposures of 10 sec. on II-G plates are employed near full moon phase. At other phases, when the moon is faint, 103-G plates and a 20 sec. exposure are used. The epoch of the exposure is when the dark glass filter is parallel to the focal plane. At this instant an electrical contact is made which actuates one of the pens of a chronograph. The chronograph is fed with time from the observatory's quartz clocks in order to interpolate the epoch of the photograph to better than 1/100 sec. After one plate has been taken the camera assembly is rotated through 180° and another plate taken. Four plates taken this way in a span of about 6 min. constitute a set taken for a particular hour angle of the moon on any night. A similar set is taken about 4 hr later. Photographs of the moon are taken usually during the period between the end of the first quarter until the beginning of the last quarter. The plates are processed and stars identified on them. The chronograph times are determined and the plates shipped to the measuring centre. Four such centres having similar specially made measuring engines are located at Greenwich, Paris, Washington and Cape Town. These measuring engines have been well investigated for errors so that

FIG. 2 — A PHOTOGRAPH OF THE MOON TAKEN AT NAINI TAL WITH THE MOON CAMERA ON 7 MAY 1958

efforts on the position determinations during the IGY may have as few intrinsic and systematic errors as possible.

The moon camera has several applications in geodetic measures. The size and shape of the earth and intercontinental distances can be measured to a high order of accuracy when the data received from various observatories are considered. The distances between observing locations can be determined with an uncertainty of a hundred feet or less when positions of the moon can be determined with high accuracy. A position measured at an observatory represents the line passing through the telescope and connecting the centre of the earth and that of the moon. It is obvious, therefore, that the geodetic distances emerge from the solutions when the errors of measurement are minimized. Observations of the moon are also bound to lead to a more exact determination of the constants in the theory of the motion of the moon as developed by Brown.

The moon camera will also provide a means of determination of absolute frequency accurate to about 1 to 2 parts in 10^9. This is possible by determining the correction to the mean longitude of the moon as given by the new lunar ephemeris. If ΔL is the longitude correction, then ΔT, which is the difference between Ephemeris Time (uniform) and Universal Time (non-uniform) becomes

$$\Delta T = 1{\cdot}821\ \Delta L$$

where ΔT is in seconds of time and ΔL in seconds of arc. ΔT can thus be determined at any one station and in the course of a year it should be possible to determine absolute frequency to about 3 parts in 10^9, since the probable error in ΔT during one lunation is of the order of 0·1 sec. When results from different observatories are taken together, it should be possible to determine absolute frequency to within 1 part in 10^9.