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Surface Measurement of Seventy-Two Radii on the 140-ft Telescope by "Stepping-Bar-Method"

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(1) INTRODUCTION:

Test surveys by the "Stepping-Bar" method were performed on the indoor test stand and on the 140-ft telescope surface in the past two years. These tests were the forerunner of the complete surface measurement on the 140-ft telescope surface from October 9th thru 23rd, 1978.

The information following only describes the work performed on the telescope by telescope mechanics and engineering personnel during the 15 day scheduled down time. Details of data collection, data reduction and final output will be implemented by Dr. Findlay.

(2) CRITERIA AND SCHEDULE:

In July 1978 it was decided definitely to go ahead with the complete surface measurement. A total of seventy-two radii was decided upon with one radii through the center of the outer panel, center of the intermediate panel, and close to the center of the inner panel. In order to accommodate for the center of panel radii the remaining radii were laid out in five degree increments. This provided equal weighted areas respectively for the outer, intermediate, and inner panels.

The month of October was chosen because of the maximum temperature range from day to night and also because of the normally good working conditions for either day or night survey.

See Figure "A" attached.

(3) PRE-SURVEY:

Preparation for the surface measurement accounted for the first eight of the 15 days scheduled down time. Three of the eight days it rained or snowed with no work performed. The following is the procedure closely followed during the "pre-survey" and "survey" with the intent of explaining how the "Stepping-Bar-Method" was adapted to measure the 140-ft surface panels.

(A) The center area of the declination shaft had originally been rigged with a fixed instrument mount in which the Hilger-Watts or Wilde T-2 theodolites are mounted. From this fixed mount the Hilger-Watts theodolite was planized to four hard points symmetrically located on rigid members of the super structure at approximately twenty feet from center and nearly 90^{0} apart from each other. The perpendicular axis of this plane represents the mechanical axis of the surface paraboloid. From this axis we monitored a target at the apex which represents the vertical axis and polarization axis of the Sterling Mount.

(B) With this vertical axis established a Wilde T-2 theodolite with wooden tripod was aligned directly over the Hilger-Watts and at an elevation where the partial radii could be laid out on the surface panels. Since we were working beneath the Cassegrain building eight of the seventy-two radii were blocked by support structure. Most of the surface was visible from this setup and all radii were scribed. The outer portion of each radii was scribed after the T-2 theodolite was lowered to where the perimeter of the outer panels were visible. This layout included pencil marks at 48" increments along the radius with the theodolite and then pencil scribed from each point with a metal straight edge. A 6-H lead was used to scribe with since we have experienced that a hard lead pencil line will stay visible for a couple years and it does no damage to the surface. A temporary wood platform was installed for the instrument work.

After the 72 radii were completely scribed we removed the T-2 theodolite and wood tripod.

(C) A vertex support frame was installed by C-clamping the four legs to the Cassegrain building supports. This frame was so designed that it supported an assembly which, when finally aligned on the mechanical axis via the Hilger-Watts theodolite, could be adjusted to represent the theoretical vertex of the surface paraboloid. Within the assembly a spherical bearing with a 1.000" hole now establishes a work point for setting the start points on each of 72 radii at a fixed distance. The fixed distance from the vertex (spherical bearing) to the start point is represented by an aluminum "T" bar of 62.038". The "T" bar is so designed that one end (vertex end) is represented by a 1.000 inch diameter rod to fit the spherical bearing hole and the other end is fixed with a micrometer set perpendicular to "T" bar. The micrometer has one inch of travel and is used in conjunction with a precision level mounted on the "T" bar. The level can be (mechanically) set to zero angular reading and for each start point the elevation is read from the micrometer. The end of the stem of the micrometer is fixed with a precision steel ball. The center line through the ball represents the start point which, when snugged against a V-notched target glued to surface panel and centered on a pencil scribed radius line, established a fixed start point. The "T" bar is used exactly the same way to set all visible 64 start points. The other eight start points were interpolated from adjacent points. Thus all start point targets are set the same distance from the vertex and the elevation is known with respect to the theoretical vertex. This frame and assembly remained intact throughout the survey for elevation monitor of the start points.

(D) With all start points installed we then started installing the remaining 32 V-notched targets at a fixed distance per step along the 72 radii. One radii was completed in approximately 20 minutes. The stepping bar with both precision balls, fixed in height and distance, was used to install the remaining targets. The rear precision ball was snuggly set in the start point V-notched target making sure that it rests on the surface. The front precision ball was then aligned on the pencil scribe line and the next V-notched target was set snuggly against the precision ball and resting on the surface. Finger pressure on the target glued it to the surface as the stepping bar was "stepped" out the radius to the next target area. This procedure was followed for all 2304 targets.

(E) An added feature that the stepping bar performs is to allow us to drill a hole, through a bushing, at the end of each radius. This hole is located on the scribed line and at a fixed distance from the last target. By installing a specially designed target in this hole we recorded the elevation of 72 points by reading with a precise optical level from atop the Cassegrain building. From a level plane these targets were all set within the reading tolerance of a 1-cm micrometer. These elevation readings were read within the reading tolerance of .001 cm, which is the reading tolerance of the N-3 level micrometer. The tripod set atop the Cassegrain building allowed us to monitor these readings throughout the survey.

(F) Four telescope mechanics were trained to use the stepping bar during the installation of targets so that during the actual survey they could use the stepping bar with precision and confidence. This allowed engineering personnel who are familiar with other instruments and special tooling to monitor the perimeter targets, start point targets and Sterling Mount target for tilt.

(4) SURVEY:

The actual survey started after the electronic interface check out. The interface consisted of setting up the HP 9825A computer in the control room and connecting its associated cables to the multi-conductor cable from the Cassegrain building bulkhead. From the Cassegrain building bulkhead the interface was to the stepping bar inclinometer and linear transducer which in turn are fixed to the stepping bar. The inclinometer measures the angles of each step and the linear transducer measures the finite change (due to temperature) from the fixed distance of each step between targets at the time of survey.

With intentions of only surveying at night or overcast days we started the surface measurements in daylight with overcast skies. Later in the evening frost had accumulated on the panels, completely stopping the survey. The next day we decided not to rely on good weather at night but to commence the survey during the daytime. We continued the day-night survey on the assumption that if we waited on good weather at night we might never get it done. Fortunately the weather held good at night and we did not experience any more frost. We completed the first survey in twenty-three hours during a three-day period with an average of 1/3 hour per radii.

Immediately after the first complete survey, Dr. Findlay checked the repeatability of three radii. Unfortunately the repeat surveys were not within expected tolerance. We were lost as to why the repeats were not acceptable so we commenced checking the complete electronics system, and found no problems. We then checked the mechanical functions of the stepping-bar concentrating on the adjustable front precision ball assembly. Although we confronted no known problems with the stepping bar we decided to change the adjustable precision ball assembly to the old assembly that was used during test period, knowing that the repeatability was acceptable then.

With the old assembly on the stepping bar we proceeded to measure a few radii and then repeat them. We found the repeatability acceptable and decided to make the complete survey again.

The criteria now is to compare these readings with the first readings and to be more careful in stepping from target to target. If the second reading had not compared with the first then a third or fourth reading would have been taken until two readings agreed. Only a nominal number of steps were repeated and most of those were in the location of targets that had been replaced or had been knocked off.

The second survey went much smoother due to being more familiar with the method and equipment. Also, each step measurement was checked against the printout of the first survey by the computer operator. This dimension allows continued repeatability before the next step is recorded.

(5) COMMENTS ON METHOD:

Adapting the Stepping-Bar-Method to measure the surface panels was very time consuming as described in Item (3) - "PRE-SURVEY". On any new instrument (such as the 25 meter-millimeter wave telescope) appropriate equipment should be designed into the telescope to initiate a measurement from the optimum. We should concentrate any further efforts on possibly new target design, target installation and the measurement of the targets for any future surface measurements on existing or new instruments.

The following items will be given further consideration for any future surface measurements.

(A) The weather is important for a good survey, so early fall or late spring should be considered to reduce the possibility of frost.

(B) With another stepping-bar designed purposely for installing targets we could possibly set the targets and measure the surface simultaneously. Spacing the targets on each radii with more accuracy would be included in the design. This might eliminate the linear transducer if tests prove conclusively.

(C) More concentration and accuracy of stepping the bar.

(6) MATERIAL AND EQUIPMENT:

The use and application of material and equipment has been documented in previous engineering memos and will only be listed in this report.

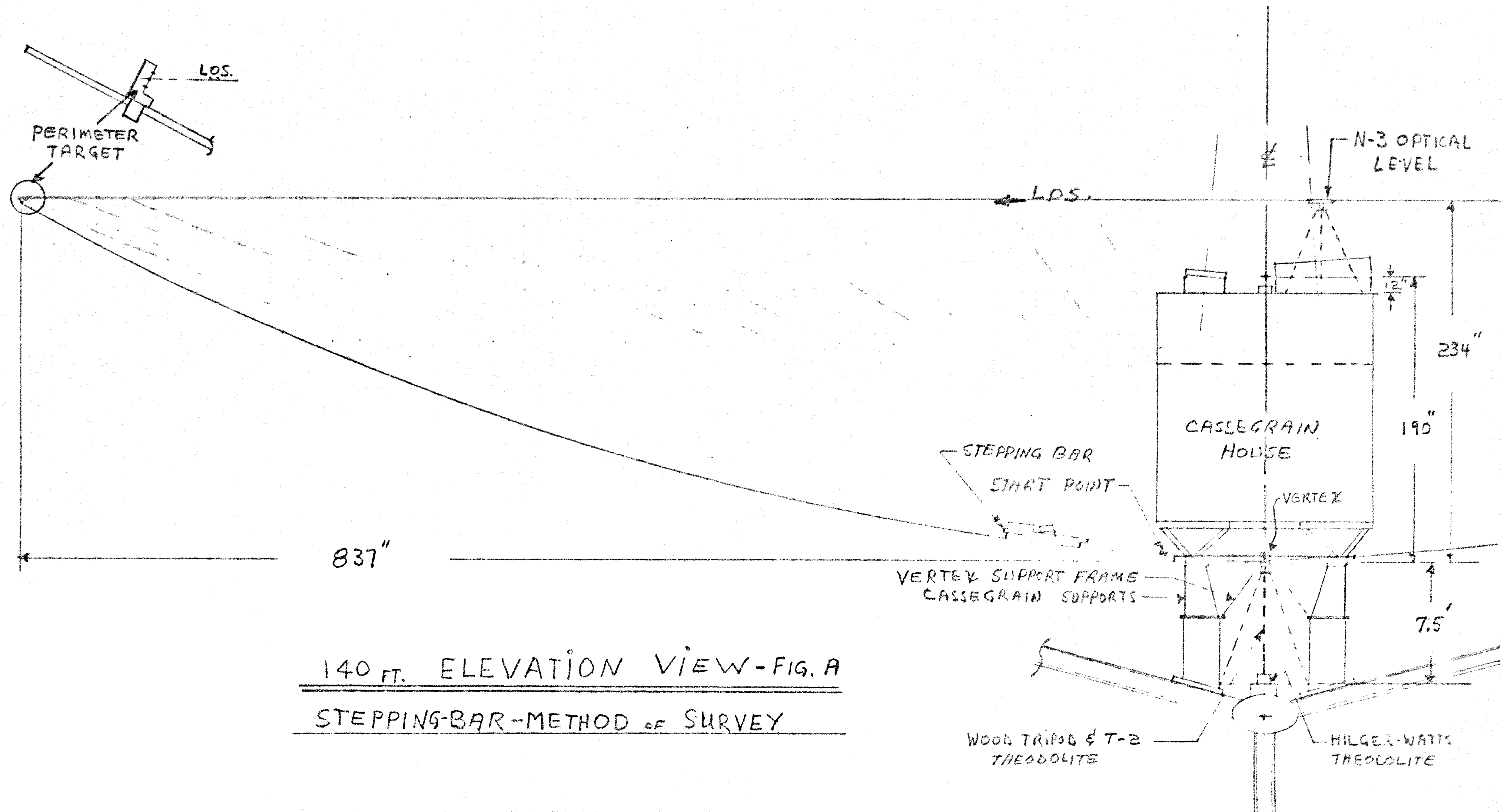
(A) Targets - Nylon adhesive-backed mounts; 1.3" x 1.3" x 0.156" thick specially V-notched in-house.

(B) Special Tooling - Vertex support frame; vertex bearing assembly and 64.038" stepping-bar for start points - all fabricated in-house.

(C) Instruments - Hilger-Watts theodolite, Wilde T-2 theodolite, Wilde N-3 level and mechanical inclinometer.

(D) Stepping-Bar - 650 mm long x 2.5" aluminum channel; machined and drilled for precision balls, inclinometer, linear transducer and electronic package with power and signal connectors assembled in one unit.

(E) Miscellaneous - Straight edges, hard lead pencils, targets and lighting equipment for night survey.



140 FT. ELEVATION VIEW - FIG. A

STEPPING-BAR-METHOD OF SURVEY