SPECIFICATION OF GEODETIC AND PHOTOGRAMMETRIC SURVEYING FOR OVERSEA

MARCH 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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SPECIFICATION

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Chapter 1 General

(Purpose)

Art. 1 The purpose of this specification is to define the method of the basic surveys which the Japan International Co-operation Agency (JICA) conducts in developing countries for making middle-scale maps as national base maps and for establishing control points as the basis of all other surveys.

(Relation to Other Specifications)

Art. 2 Surveying methods shall be in accordance with this specification except in the case of special specifications. When any other specifications are approved as equal or superior and permission to use these specifications are obtained in advance from JICA, they can be used.

(Range of Surveys)

Art. 3 "Surveys" in this specification means the control surveys and the preparation of topographic maps and photo maps.

2 Control surveys involve triangulation, traversing, astronomical observation, satellite observation, leveling (direct, indirect) and tidal observation.

Chapter 2 Standards of Surveying and Units to be used

(Standard)

Art. 4 Standards of surveying such as ellipsoid elements, etc., are provided in another specification.

(Units to be used)

Art. 5 Units of measurement provided by Japanese laws of measurement shall be used except in special cases.

Units of angle measurement shall be the degree, minute and second of arc.

Chapter 3 Process and Order of the Work

(Process and Order of the Work)

Art. 6 Process of the works and the order of carrying it out shall be as follows :

(1) Control Surveys
   a Reconnaissance
   b Monument construction for survey target and tower
   c Observation
   d Calculation and arrangement of the records, etc.

(2) Mapping

a Control surveying
b Establishment of air photo signal
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d Pricking
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a Map Manuscript

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(d) Plotting
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(f) Editing
b Rectification
(a) Classification
(b) Aerial triangulation
(c) Rectification
(d) Mosaic
(e) Editing

Chapter 4 Planning of Surveys

(Planning of Surveys)

Art. 7 Planning of surveys shall be drafted with the results of reconnaissance and the data collected in the field based on the scope of work (S/W) which is agreed by the two governments (Japan and the country concerned) and shall be admitted by JICA.

(Detailed Survey Plan)

Art. 8 Surveyor who executes the work must make a detailed survey plan and must get admission of this plan from JICA.

Chapter 5 Accuracy Control and Final Results etc.

(Accuracy Control)

Art. 9 The person responsible for the work must control all work to secure the required accuracy.

2 Table for "Accuracy Control" shall be prepared according to the form described in Table 3.

(Checking)

Art. 10 The person responsible for works must check the work at the time of middle and the end of each process.

(Results etc.)

Art. 11 In this specification, the term "Results, etc." implies the survey results, survey records and work data as follows:

(1) Survey results : final results

(2) Survey records : records obtained during each process

(3) Work data : every kind of data obtained in getting the survey records.

(Presentation of Results, etc.)

Art. 12 Results, etc. are required to be presented to JICA immediately after finishing all processes.

(2) In case that it is impossible to take out results, etc. from the country concerned, alternative instructions of JICA are required.

(Reports)

Art. 13 At the end of each process, report of work shall be submitted and at the end of all work general technical report shall be submitted to JICA.

Part 2 Control Surveys

Chapter 1 General

Section 1 General

(Control Surveys)

Art. 14 "Control surveys" in this specification means establishment of new control points or connecting new control points to existing control points and determining geodetic coordinates of the new points.

Section 2 Methods of Survey

(Methods of Survey)

Art. 15 Control survey implies several methods as follows.

(1) Traversing, Triangulation and Trilateration
(2) Astronomical Observations
(3) Satellite Observation (NNSS)
(4) Leveling

Section 3 Establishment of a Permanent Monument

(Permanent Monument)

Art. 16 Permanent monuments shall be made for newly established points.

(Establishment of monument)

Art. 17 Monumentation shall be performed according to the standard prescribed on other note except where there is special speculation about monumentation in the country concerned.

Section 4 Planning of Survey

(Selection of Survey Method)

Art. 18 Survey method shall be selected considering the purpose of survey, topography, vegetation, etc. in the area.

(Planning Report of Survey)

Art. 19 Planning report shall be made in accordance with the following items.

(1) Map of planned network at the scale 1/250,000~1/500,000
(2) Survey standard, geodetic coordinate system
(3) List of results, data, etc.
(4) Survey schedule
(5) List of survey party
(6) List of main surveying instruments

Chapter 2 Control Survey with Traverse, Triangulation and Trilateration

Section 1 General

(Purpose)

Art. 20 "Control Survey" in this specification means to newly establish control points based on national geodetic datum or existing control points.

(Methods of Survey)

Art. 21 Survey shall be carried out by one of the following methods : the traverse, triangulation and trilateration

(Classes of Control Points)

Art. 22 Control points are classified as follows :

(1) First class (order) control points are such points as are spaced about 30 km and are established forming the geodetic network.

(2) Second class (order) control point is established such that it is a point forming the network spaced about 10 km.

This network shall be made connecting to first order control points or existing more accurate points.

(3) Third class (order) control point is established such that it is a point forming the network with spaced about 4 km.

This network shall be made connecting to the 1st, 2nd or existing more accurate points.

(Accuracy of Control Point)

Art. 23 Accuracy of control point for traverse and triangulation shall be as follows :

(1) Relative accuracy of first class control point is better than 1/200,000.

(2) Relative accuracy of second class control point is better than 1/65,000.

(3) Relative accuracy of third class control point is better than 1/25,000.

(Main Instruments to be used)

Art. 24 Main instruments to be used for this work are theodolite and electromagnetic distance measurement equipment (EDME).

Section 2 Planning of Control Point Survey

(Planning of Network)

Art. 25 Location of the control points shall be at equal intervals and they shall be established in consideration of the utilization and conservation of the points.

2 Reconnaissance shall be performed in consideration of following conditions

(1) Traverse

a A loop traverse shall consist of 3 or 4 control points and minimum nodal points.

b Traverse network shall be composed of more than three polygons which adjoin each other.

c The connecting traverses can be used in case of 2nd or 3rd class control survey, if the topographic conditions do not permit the above method.

d Range of eccentric reduction shall be limited to 100 m.

(2) Triangulation

a An included angle of a triangle shall be more than 25° in principle. A regular triangle is desirable.

b Braced quadrilateral may be desirable for strengthening the figure. In this case, an included angle may be more than 15°.

c Control point forming the triangle network shall be the intersection point where more than 3 sides intersect.

d Base lines shall be selected from sides surrounding and within the triangle network and be measured directly.

e Numbers of base lines measured by EDME shall be 1 to 5 sides surrounding the network and within the networks, 1 to 8 sides.

f Base line shall be longer than mean length of sides.

g Distances of eccentricity (e) shall be less than 0.1S (S = side length).

(3) Trilateration

a An included angle of a triangle shall be more than 25° in principle.

b Measurements of common sides with adjacent triangle can be changed to the measurement of each opposite angle of common sides from which the common side length is to be calculated.

c Triangle network shall be consisted of single triangles.
In case that strengthening the figure is needed, braced quadrilaterals shall be established instead of triangles.

d Length of eccentricity (e) shall be less than 0.1S.

(Laplace Point)

Art. 26 Laplace point shall be established of the rate of 1 point per 200~300 Km, if necessary.

(Reconnaissance Map, Adjustment Plan and Description of Point)

Art. 27 Reconnaissance map shall be prepared when good sight between adjoining points has been verified and the selection of the point has been completed.

2 Adjustment plan must be made based on reconnaissance map.

3 Description of point shall be made for selected points.

(Setting of Permanent and Temporary Monuments and Targets)

Art. 28 Permanent monument shall be set at the selected location and target shall be built at exiting (given point) and new points. Method of setting, etc. are

specified in Art. 16 and 17.

Section 3 Observation

(Efficiency of Instrument)

Art. 29 Instruments to be used for survey shall have the following efficiency :

(1) Theodolite for 1st and 2nd classes survey must have minimum reading scale of 0.1 second of arc. The accuracy of EDME using microwave shall be better than 30 mm± 30 ppm×D and the accuracy of EDME using light wave shall be better than 10 mm± 2 ppm×D (D : Measured distance).

(2) Theodolite to be used for 3rd class survey must have minimum reading scale better than one second of arc. Distance measurement equipment for 3rd class shall be electro-optical one having the same accuracy as for 2nd class survey.

2 Calibration of instrument shall be conducted according to following items :

(1) Calibration of electro-optical distance measuring instrument.

a Check and adjustment of frequency.

Before the surveying, frequency of EDME shall be calibrated by an organization designated by JICA.

b Calibration with comparison method

No	Location	Allowance	Number of set	Remark
1	Geographical Survey Institute Local office of G.S.I. Murayama base line	30 mm	3	
2	A B C A~C 500 m~1000 m	30 mm	3	The difference between AC and AB+BC

(2) Calibration of Theodolite

a Check by horizontal angle observation

Minimum reading scale	Allowance of double angle difference	Allowance of difference of observation	Allowance of (T_1-T_2)
0.1″	8″	5″	3″
1″	15″	8″	6″

(a) Target suitable for observation such as tree, chimney so on shall be selected.

(b) Values of (T_1-T_2) are the difference between two mean values of sets at the position 0°, 60°, 120° and at the position 30°, 90°, 150°.

(c) (Double Angle Difference)

The double angle is the summation of the observed angles by telescope in the direct and the reverse.

The double angle difference is the difference between the maximum and minimum values of the double angles obtained by the observations in two or more sets of positions.

(d) (Difference of Observation)

The difference of observation is the difference of the observed angles with the telescope in the direct and the reverse.

When the observation is carried out in two or more sets of position, the difference of maximum and minimum values of "difference of observation" is also called "difference of observation".

b Check of vertical angle observation

Minimum reading scale	Allowance of constant of elevation
0.1″	8″
1″	10″

(a) Constant of elevation is the sum of the readings of vertical circle observed with the telescope in the direct and the reverse.

Table of Art. 29 shows the allowance of constant of elvation which is the difference between maximum and minimum value of the constants of elevation when two or more objects were observed from a station.

(Horizontal Angle Observation)

Art. 30 Horizontal angles shall be observed according to the following items:

(1) Direction method shall be adopted except for special specifications. One set observation shall consist of less than 4 directions.

(2) A pair of observation (1st) consists of two readings by telescope in the direct and in the reverse.

Allowance and others are as follows:

Class	Set numbers	Allowance of double angle	Allowance of differences of angle	Position
1 st	6	8″	5″	0°, 30°, 60°, 90° 120°, 150°
2 nd	3	12″	7″	0°, 60°, 120°
3 rd	2	20″	10″	0°, 90°

(Re-measurement)

Art. 31 In case that results of horizontal observation exceed the allowance in the table of Art. 30 at a position, all directions shall be observed with that position.

(Measurement of Eccentric Elements)

Art. 32 Measurement of eccentric elements shall be conducted according to the following tables.

(Measurement of Distance)

Art. 33 Distance shall be measured according to following items.

(1) In case of using electro-optical instrument. One set of observations consists of three readings for the direct reading instrument (digital count) and for the indirect reading instrument, one set consists of readings with all modulated frequencys.

(2) In the case of using electro-magnetic wave instrument.

Coarse readings shall be taken before and after the fine readings. One set of fine readings consists of 10 readings.

(3) Required set numbers and discrepancies between sets are shown in the following table.

Class	E.O.EDM		E.M.EDM		Remark
	Set numbers	Discrepancies	Set numbers	Discrepancies	
1 st	3	1/200,000	3	1/200,000	
2 nd	3	1/75,000	2	1/75,000	
3 rd	2	1/40,000			

(4) Meteorological elements shall be observed according to the following table.

Instrument	Class	Temperature		Pressure		Humidity		Remark
		M.S.	R.S.	M.S.	R.S.	M.S.	R.S.	
E.O. EDM	1 st	○	○	○	○	○	○	○ : measure
	2 nd	○	○	○	○			
	3 rd	○		○				
E.M. EDM	1 st	○	○	○		○	○	
	2 nd	○	○	○		○	○	

M.S. : Master Station

R.S. : Remote Station

(5) Two set observations shall be separated in time by not less than 20 minutes except 3rd class.

For 3rd class, set intervals shall be more than 5 minutes in case of direct reading instruments.

(6) The air temperature shall be taken before and after each set observation.

The air pressure and the humidity shall be taken before and after all observations.

(7) Calibrated thermometer and barometer must be used.

Section 4 Calculation

(Calculation)

Art. 34 The place of figures to be used for calculation shall be according to following table.

Class		Place of figure	Remark
Distance	1 st 2 nd 3 rd	three places of meter	
Angle	1 st 2 nd	two places of second	
	3 rd	one place of second	
Coordinate	1 st 2 nd 3 rd	three places of meter	
Latitude Longitude	1 st 2 nd	four places of second	
	3 rd	three places of second	

(Calculation at Field)

Art. 35 Allowance of closure and closure ratio of the obtained results at field are shown in following table. If results exceed the allowance, re-observation shall be conducted after re-checking the results.

(1) Traversing

Class	Closure of bearing	Closure rate of coordinate	Remark
1 st	$1.5\sqrt{N}$	1/200,000	N: Numbers of inter-section angle
2 nd	$2.5\sqrt{N}$	1/ 65,000	
3 rd	$3.5\sqrt{N}$	1/ 25,000	

(2) Triangulation

Class	Closure of sum of interior angle	Closure of side length	Remark
1 st	3″	7.0cm × S(km)	
2 nd	7″	〃	
3 rd	10″	〃	

(3) Trilateration

a 1st and 2nd class control survey

(a) Discrepancy between the two calculated lengths of the common side defined in Art. 25 para. 2, (3), b shall be less than

$(m'\varphi_1 + m'\varphi_2)S$ km (Unit mm)

$m'\varphi_i$: S.D. of calculated distance

(b) Closure of central angle obtained after correcting the spherical excess shall be less than

$$0.''8\sqrt{\Sigma D^2\varphi} + 3.''0\sqrt{n}$$

n : Numbers of observed angle

$$D^2\varphi = 6\tan^2\frac{\varphi}{2}$$

φ : Included angle

b 3rd class control survey

(a) Discrepancy between the two lengths of the common side defined in Art. 25, para. 2, (3),b shall be within the allowance shown in other table.

(b) Closure of central angle shall be less than

$$2''\sqrt{\Sigma D^2\varphi} + 4''\sqrt{n}$$

n : Numbers of observed angles.

$$D^2\varphi = 6\tan^2\frac{\varphi}{2}$$

φ : Included angle

(Adjustment)

Art. 36 Residual errors of net adjustment for traverse and triangulation shall not exceed the values of the following tables.

Class	S.D. for a direction	Residual of angle	Residual of length	Remark
1 st	±1.5″	3″	0.4cm×S(km)	
2 nd	±2.5″	4″	1.0cm×S(km)	
3 rd	±3.5″	5″	2.0cm×S(km)	

(Coordinates)

Art. 37 Horizonal position shall be expressed with geodetic and plane rectangular coordinates.

Section 5 Results

(Results)

Art. 38 Results of surveying and records are as follows.

(1) Results of Surveying

Final results (latitude, longitude, X,Y coordinates, height, true bearing, adjustment angle and distance)

Index map of control point.

(2) Records of Surveying

Field notes, list of directions, calculation sheets, description of points and accuracy control table.

Chapter 3 Astronomical Observation

Section 1 General

(Purpose)

Art. 39 Astronomical observation is carried out to determine the astronomical latitude, longitude and azimuth with observing stars or satellites.

2 Astronomical observation shall be conducted in the region where there are no datum or any existing control points.

Astronomical observation is also carried out for the purpose of adjustment of network.

(Main Instrument)

Art. 40 Universal theodolite or astrolabe is used for astronomical observation. Main accessories to be used are time receiver and precise clock.

(Accuracy)

Art. 41 Results of astronomical observation shall be within ± 0.3 second of arc in standard deviation.

(Preparation of Star Catalogue)

Art. 42 Star catalogue shall be prepared with assumed latitude and longitude of the observing points.

2 Stars shall be selected according to the following items

(1) Latitude Observation

a Zenith distance of observing stars shall be less than 30 degrees.

b Differences of zenith distances of a pair of stars shall be within 20 minutes of arc and differences of right ascension shall be within 1 to 10 minutes.

c Time interval of the observation from one pair to another pair shall be more than two minutes.

(2) Longitude Observation

a Stars which are brighter than 7th magnitude shall be selected from Star Catalogue FK4.

b Time interval of meridian transit from one star to another one shall be more than 4 minutes.

c Stars of upper culmination shall be nearly equal to those of lower culmination.

d Each star must satisfy the following conditions :

$$A = \sin(\phi - \delta)\sec\delta < 0.6 \text{ and } \Sigma A < 1$$

ϕ : Assumed latitude, δ : Declination of observing star.

(3) Equal Altitude Method determing Latitude and Longitude simultaneously.

a Stars shall be selected from Star Catalogue FK4.

b Star observation in a zone within ± 20 degrees from meridian shall be avoided.

c Bright stars shall be selected and time interval between observations shall be more than 2 mintes.

d One set of observations consists of 20~24 stars and shall be uniformly distributed over each quadrant. Minimum number of stars for a quadrant are 4.

e In principle, stars shall be selected so as to finish the one set observation within 2.5 hours.

Section 2 Observation

(Preparation for Observation)

Art. 43 Theodolite or astrolabe shall be set on a tripod which is fixed on driven stakes and catwalks supported away from the tripod legs and shall be protected from vibration.

2 Reading of theodolite on the meridian plane shall be set within ±15″ from zero degree by preleminary observation for longitude and latitude observation.

3 Theodolite or astrolabe to be used for equal altitude method shall be inspected and adjusted before the observation according to the G.S.I. manual of astrolabe.

(Latitude Determination with Theodolite)

Art. 44 Horrebow-Talcott method shall be adopted for latitude determination by theodolite.

2 Standard numbers of a pair of stars are 16 per night.

3 Before and after observation, air temperature and pressure shall be observed for meteorological correction.

(Longitude Determination with Theodolite)

Art. 45 Meridian transit method shall be adopted for longitude determination by theodolite.

2 In principle, six sets of observations shall be carried out where one set consists of the observation of 6 stars.

3 Observation shall be carried out for two nights. Minimum number of observing sets for each night are 2 sets.

(Equal Altitude Method)

Art. 46 Three sets of observation are required to be carried out at a station when the equal altitude method is adopted.

2 To avoid atmospheric effect, observed stars shall be selected from the four quadrants alternately.

Section 3 Reduction

(Calculation)

Art. 47 Calculation consists of the rough calculation in the field for checking of quality of the observation and the final calculation in the office.

(Field Calculation)

Art. 48 Field calculatiin shall be performed according to the following items.

(1) Any star which has a much larger azimuth coefficient shall be eliminated from observation.

(2) Equal Altitude Method.

a Stars which have errors more than 2 seconds on the position circle shall be rejected.

b A set which include more than 5 rejected stars shall be eliminated from results.

(Final Calculation)

Art. 49 Final calculation shall be carried out according to following items:

(1) Latitude Observation

a Latitude shall be reduced from observation equation by the least square method.

b For each result, correction of polar motion and curvature correction shall be added.

(2) Longitude Observation

a Longitude shall be reduced from observation equation by least square method.

b For each result, correction of polar motion and UTC−UT 1 shall be added.

(3) Equal Altitude Method

a Latitude and longitude shall be calculated with observation equation by least square method.

b For each result, correction provided in G.S.I. specification such as polar motion shall be added. If there are differences more than 2 seconds of arc between sets, re-checking of the calculation process shall be required.

c Weighted mean shall be final result. Weight must be determined with the numbers of stars included in each set.

Section 4 Astronomical Azimuth Observation

(Main Instruments to be used)

Art. 50 The instrument to be used for this observation shall be Wild T_3 or the theodolite which has the same accuracy and performance as that of Wild T_3.

(Accuracy)

Art. 51 Standard deviation of result shall be within ± 0.3 second of arc.

(Observing Star)

Art. 52 In the northern hemisphere, over 15° latitude, Polaris shall be observed.

2 Where Polaris does not rise, a pair of stars located north and south of the zenith and satisfing the following condition shall be observed:

$$\cot Z_1 = 2 \tan\Phi + \cot Z_2$$

where $Z_2 \fallingdotseq 75°$

Z_1, Z_2···Zenith distance

Φ···Astronomical latitude

(Observation)

Art. 53 Observations at a station consist of two sets. A set of observations consists of 12 pairs (12 D&R).

2 Two nights of observations are desirable for eliminating the refractive effect.

(Field Calculation)

Art. 54 Observed results which differ more than 5 seconds of arc from mean value shall be rejected.

(Final Results)

Art. 55 Final results shall be the mean value of every set.

(Correction)

Art. 56 The following corrections shall be added for the final results.

(1) Correction of vertical axis inclination of theodolite.

(2) Correction of diurnal aberration.

(3) Correction of curvature of star pass.

Chapter 4 Control Survey with Navy Navigation Satellite System (NNSS)

Section 1 General

(Purpose)

Art. 57 Control survey by satellite means to get the geodetic position (latitude, longitude and height) by receiving doppler signal from USA's Navy Navigation Satellite.

(Method)

Art. 58 Observation method of satellite is divided into point positioning, translocation and short arc method respectively.

This specification prescribes only point positioning method.

(Accuracy)

Art. 59 Standard deviation of the results by point positioning method shall be within ±6 meters.

Section 2 Reconnaissance

(Reconnaissance)

Art. 60 At time of reconnaissance, the following conditions must be satisfied to eliminate the radio-interference of incoming signal.

(1) Antenna area of doppler survey station shall be unobstructed by radio interference and reflector for radio waves.

(2) Doppler survey stations shall have enough distance from the radio noise source.

(Setting of Permanent Monument)

Art. 61 Permanent mounments shall be established at the selected points.

Method and specfication are same as described in Chap. 1, Art. 16 and Art. 17.

2 Descriptions of points shall be prepared.

Section 3 Observation

(Observation)

Art. 62 Observation means to get data for determining the geodetic position of the electrical center of the receiving antenna at the survey station.

2 In case that the satellite survey point is located near or in the existing geodetic network, connection between them shall be required.

3 Number of observations (pass numbers) shall be more than 20 in case of using precise ephemeris and more than 45 for broadcast ephemeris.

(Calibration of Instruments)

Art. 63 Instruments to be used for satellite observation shall be calibrated at the existing station (set point of Baker-Nunn camera at Dodaira astronomical observatory) by comparison method.

2 Setting of instrument and method of calculation at time of calibration shall be same as field works.

3 All data of calibration works shall be submitted to JICA.

(Setting of Instrument)

Art. 64 Setting of observation instruments shall be performed in accordance with makers manual and guidance in consideration of followiing items.

(1) Antenna Installation

The electric center of antenna shall be over or near the station. When it is difficult to install antenna on the ground owing to topographic conditions, antenna shall be fixed to the pole or something like a tower.

(2) Setting of Receiver

Receiver shall be set near the antenna and at a place protected against mechanical vibration, direct radiation of sun, rain and wind.

Measurement of element of eccentricity shall be performed in accordance with

Chap. 2, Art. 32, Item 1, (2) .

(Observation)

Art. 65 Observation consists of preparatory observation and main observation.

(Preparatory Observation)

Art. 66 Preparatory observation shall be performed to provide following information for given dates and location; satellite identification, rising time, time of the closest approach, rise azimuth and elevation at the closest approach.

2 Observation schedule shall be made with preparatory observation data.

3 If preparatory observations are performed at a selected control point in the field, the data obtained can be included with results of main observation.

(Main Observation)

Art. 67 Main observation shall be performed according to the schedule made by preparatory observation.

2 For the observation of satellite, the following factors shall be considered.

There shall be no over-lap or least over-lap between the observation of satellites.

Elevation at closest approach of observing satellite shall be more than 15°–75°.

3 During main observation and preparatory observation to be included with main observation, meteorological elements shall be observed.

Number of meteorological observations depend on circumstances.

(Observing Data)

Art. 68 Attention shall be paid to changes in quality, wear and tear of tapes on which data were recorded.

2 Meteorological elements consist of air temperature, humidity (dry and wet bulb readings can be used) , air pressure (in mb) and weather etc. and shall be noted in format.

3 Point name, location, observed data, number of satellites, name of instrument, number of instruments etc. shall be recorded as data.

Section 4 Reduction

(Calculation)

Art. 69 Calculation is performed to get the latitude, longitude and height of observing stations or to get three dimensional coordinates of the stations refered to the gravity center of the earth.

2 Computer program for reduction shall be approved by JICA.

3 Units of the results shall be 0.001 seconds of arc in latitude, longitude and 0.1 meters in height.

(Coordinates Transformation)

Art. 70 Coordinate values obtained shall be transformed to the coordinate values corresponding to geodetic system (adopted reference ellipsoid) of the country

concerned.

Chapter 5 Leveling

Section 1 General

(Purpose)

Art. 71 Leveling in this specification means to determine the height of bench mark (B.M.) with level and staff.

2 Cross sea (river) leveling and trigonometric leveling are included in the specification.

(Category of Leveling)

Art. 72 Leveling is classified into 1st, 2nd and 3rd class, respectively.

(Leveling Route)

Art. 73 In principle, leveling route shall be established according to the following items. When there are existing bench marks near the route, connection shall be made if necessary.

(1) 1st class leveling

The 1st class leveling route shall start from national leveling datum, or local leveling datum or 1st class bench marks and return there.

(2) 2nd class leveling

The 2nd class leveling route is required to be connected to existing 1st or 2nd class bench marks.

(3) In principle, 3rd class leveling route shall be connected to existing points such as 1st, 2nd or 3rd bench marks.

If connection is difficult owing to the topographic conditions, loop leveling may be permissible for 2nd and 3rd class and open leveling for 3rd class too.

(Length of Route)

Art. 74 As a rule, length of the leveling route shall be according to the following table.

Class	1 st	2 nd	3 rd
Length	less than 400km	less than 200km	less than 50km

(Spacing of Bench Mark)

Art. 75 Spacing of bench marks are required to be based on the specifications of the country concerned.

However, if not, they shall be 2 km for 1st and 2nd class leveling. Spacing for 3rd class is then 4km.

Section 2 Accuracy

(Accuracy)

Art. 76 Accuracy of each class is as follows, unless the country concerned has a

special specification.

	Class	1 st	2 nd	3 rd	Remarks
Accuracy	Difference of double running	2.5mm $\sqrt{S}$	5mm $\sqrt{S}$	10mm $\sqrt{S}$	S: length of single running in km
	Closure of loop	2.0mm $\sqrt{S}$	5mm $\sqrt{S}$	10mm $\sqrt{S}$	

Section 3 Planning

(Planning)

Art. 77 Before surveying, datailed planning shall be made for performing the work smoothly.

To establish the new leveling route, locations of bench mark shall be selected on a topographic map, photo-map or road map before field reconnaissance.

Section 4 Reconnaissance

(Performance of Reconnaissance)

Art. 78 Bench marks shall be established on stable ground and at the place appropriate for conserving the bench mark as a permanent mounment.

(Selection Map and Description of Point)

Art. 79 After the selection of the points, a selection map and description of points shall be made.

(Establishing Permanent Monuments)

Art. 80 As a rule, permanent monuments shall be established at selected sites according to the specification of the country concerned.

2 Permission must be secured from property owners or managers for the establishment of monuments.

Section 5 Observation

(Instrument)

Art. 81 Instrument to be used shall be equal or better than those shown in the following table. They shall be clearly designated in the operation plan.

Class	1 st	2 nd	3 rd
Level	1 st class	2 nd class	2 nd or 3 rd class
Staff	1 st class	1 st class	Staff made with wood (except extension type)

(1) 1st class level: Sensitivity of spirit level shall be better than 10″/2 ㎜.

(2) 2nd class level: Sensitivity of spirit level shall be better than 20″/2 ㎜.

(3) 3rd class level: Sensitivity of spirit level shall be better than 40″/2 ㎜.

(Inspection and Adjustment of Instrument)

Art. 82 The level and staff shall be inspected and adjusted for the items shown in the following paragraphs before beginning observation and during the operations whenever appropriate.

(1) Inspection and adjustment of parallelism between the collimation axis and axis of main level tube and circular level.

(2) Inspection and adjustment of circular level for pendulum level.

(3) Inspection and adjustment of circular level attached to staff.

(Observation)

Art. 83 Observation shall comprise fore-and back-leveling (double running).

(1) Observation procedure for 1st and 2nd class leveling.

a Telescope to back-sight, read the left scale of staff.

b Telescope to fore-sight, read the left scale of staff.

c Then read the right side scale of staff.

d Telescope to back-sight, read the right side of staff.

(2) Observation procedure for 3rd class leveling.

a Telescope to back-sight, read the scale of staff.

b Telescope to fore-sight, read the scale of staff.

2 Sight length and units of reading shall satisfy the requirements shown in the table below.

Class	1 st	2 nd	3 rd
Sight distance	Max. 60m	Max. 70m	Max. 70m
Min. reading unit	0.1mm	1mm	1mm
Number of runnings	Double running	Double running	As a rule double running

In case of 3rd class leveling, maximum sight distances can be changed up to 100 m depending circumstances. In this case, observation procedures shall be those of 1st and 2nd class leveling.

3 A staff which is set at starting point shall then be set at final point, in another words, the number of settings of instrument during one-direction leveling between starting and final points must be even.

4 Level is required to be set up on a straight line between two staffs if possible.

5 The scale of staff from ground surface up to 10 cm shall not be read.

6 Sight distances of fore-and back-sights which are measured by stadia method shall be equal.

7 At the starting and ending point, leveling shall be carried out to the nearest existing bench mark for checking.

Section 6 Cross Sea (River) Leveling

(Cross Sea (River) Leveling)

Art. 84 When leveling with standard sight length is difficult owing to obstacles such as rivers or valleys, method of cross sea (river) leveling may be used (See trigonometric leveling. Refer to Chap. 5, Sec. 8).

2 Leveling by reciprocal method or tilting screw method shall be carried out in accordance with the following items.

(1) Observing distance is admissible to 500 m for reciprocal method and about 6 Km for tilting method respectively.

(2) Instrument to be used for reciprocal method is the one which has the coincidence system of bubble with the characteristics cited in Art. 85. Especially for the tilting screw method, level with tilting screw scale must be used.

(Number of Observations)

Art. 85 Number of observations to be carried out are shown in following table.

Class	Sensitivity of level	Numbers of observations from one side	Allowance
1 st	10″／2 mm	$28\,S^{1.7}$	$2.5\text{ mm}\sqrt{S}$
2 nd	10″／2 mm	$8\,S^{1.7}$	$5\text{ mm}\sqrt{S}$
3 rd	20″／2 mm	$2\,S^{1.7}$	$10\text{ mm}\sqrt{S}$

where S: cross distance of river (in km).

Section 7 Calculation

(Calculation)

Art. 86 Hight of bench marks shall be obtained from observed values after performing the staff correction, orthometric correction and if necessary, correction for bench mark movement due to the difference in observed times. Final results shall be obtained after performing adjustment for leveling net based upon those corrected values. For 3rd class leveling, the corrections mentioned above can be omitted.

2 Adjustment shall be performed with weights inversly proportinal to the length of routes using observation equation or condition equation.

Section 8 Determination of Height of Control Point

(Trigonometric Leveling)

Art. 87 Trigonometric leveling is the method to get height differences between two points by measuring vertical angles and distance between them.

2 Determination of height of 1st, 2nd and 3rd control points may be performed by trigonometric leveling.

When 1st and 2nd class control survey is carried out, direct leveling is required to be performed to determine height of those control points.

In case that direct leveling is difficult owing to topographic conditions, trigonometric leveling may be used.

(Base Height for Trigonometric Leveling)

Art. 88 Height of base point for trigonometric leveling must be determined by following method.

(1) Height of base point from which the height of unknown control points are determined by trigonometric leveling shall be determined with 3rd class direct leveling starting from 1, 2 or 3rd class bench mark.

In this case, allowance of discrepancy of double running is 20 mm S (S : distance of single running in km).

(2) When direct leveling is impossible in (1), trigonometric leveling can be used instead of direct leveling.

a For determination of height of base point, more than two bench-marks shall be used as starting points.

b Observation of vertical angles shall be simultaneous from both sides. Number of observing sets and allowances shall be made in accordance with Art. 91.

c One set distance measurement with electro-optical instruments is enough for required distances.

(3) Standard densities of the base points are two per 100 km^2.

(Reduction)

Art. 89 As a rule, simultaneous adjustment of all the surveyed areas or each divided block area shall be required.

If this is difficult, height may be determined from the trigonometric data from two known points.

2 When the order of the height point determined by the above method is the first, the permissible lowest order of leveling is 5th.

3 Height points which were determined by simultaneous adjustment have same order.

(Instrument)

Art. 90 The instrument to be used is one prescribed in Art. 29.

(Vertical Observation)

Art. 91 One set of vertical angle observations consists of observation by telescope direct and reverse.

Instrument, set number and so on, are shown in the following tables.

Class	Theodolite to be used	Set numbers	Allowance of vertical angle constant
3 rd class control survey	min. vertical scale unit 1″	1	10″
1 st and 2 nd control survey (trigonometric leveling in Art. 87, 2)	min. vertical scale unit 0.1″	4	10″
Trigonometric leveling in Art. 88	min. vertical scale unit 0.1″	4	10″

2 Trigonometric leveling in Art. 87, 3, Art. 88, 1, (2) and 2, (2) shall be simultaneous observations from both side. Distance between them is limited to less than 10 km.

3 When trigonometric leveling method is used for cross river survey in Chap. 5, Sec. 6, Art. 84 simultaneous method shall be adopted. Set numbers shall be refered to Art. 85.

(Measurement of Instrumental and Target Heights)

Art. 92 Instrument and target heights shall be measured in cm unit.

(Calculation)

Art. 93 Distances to be used for the calculation of height shall be those of final results of traverse or triangulation.

2 Units for calculation are cm.

3 Allowance etc. are shown in the following table.

(1) Allowance for field check

Class	Discrepancy for height from two directions	Closure of circuits	Remarks
1 st, 2 nd	30cm	$30\text{cm}\sqrt{\Sigma S^2}$	S : in km
3 rd	30 cm	$30\text{cm}\sqrt{\Sigma S^2}$	

(2) Allowance for final results

Class	Standard deviation of vertical angle for one direction	Residual	Remarks
1 st, 2 nd	4″	4″	
3 rd	4″	4″	

Section 9 Tidal Observation

(Tidal Observation)

Art. 94 Tidal observation is to get the mean sea level by continuous observation of sea levels.

(Method of Tidal Observation and Limit of Application)

Art. 95 Method of tidal observation and limit of its application shall be as follows,

(1) Method by tide pole : height base for lower class leveling such as civil engineering.

(2) Method by portable tide gauge : height base for 2nd class leveling. Used where no tidal stations are near.

(3) Method by fixed tide gauge : height base for 1st class leveling.

(Selection of Location for Tidal Station)

Art. 96 Selection of location for tidal station shall be performed in accordance with the following items.

(1) Location must be where sea level can represent the level of the coastal region (so places such as the mouth of a river or an estuary shall not be selected) .

(2) Tide gauge shall be set on a rock if possible.

(3) Location shall be where sand cannot be accumulated by current.

(4) The place where water surface is usually calm.

(5) The place not obstructing the navigation or anchorage of ships.

(6) Location shall be convenient to transportation.

(7) Location shall have leveling route run nearby.

(8) The place where sea-water is clear and the recording of tide is not hindered by marine plants.

(Construction of Tidal Station)

Art. 97 For the long period observation with a float type (Kelvin type) tide gauge, tidal station shall be constructed in accordance with the following items, as a rule.

(1) Tide well shall be dug at a place rising steeply from the sea level and as near to beach line as posible. The length of guide tube which guides the sea water from the sea to the well is limited to 20 m.

(2) Bottom of well shall be about 50 cm lower than the lowest sea level and top of well shall be 2-3 m higher than the highest sea level.

(3) Diameter of well shall be more than 1 m.

(4) At the top edge of well which can be seen from outside, brass-sphere shall be set into it as a bench mark of the station.

(5) Length and diameter of guide tube shall be the following values in case of 1 m diameter well.

Length (m)	5	15	20
Diameter (cm)	10	12	14

(6) Gradient of guide tube from well side is 1/20.

(7) Bench mark shall be set near the tidal station (attached bench mark).

(Period of Observation)

Art. 98 For determination of mean sea level, observed data for the following periods must be used.

Instrument	Tide pole	Portable tide gauge	Fixed tide gauge
Period	As a rule more than 1 week	As a rule more than 1 month	As a rule more than 5 years

(Observation)

Art. 99 Observation shall be performed every hour for tide pole method and continuously with automatic recording system for tide gauge method.

(Calculation)

Art. 100 Reduction of Mean Sea Level (MSL)

The mean sea level is reduced from the arithmetic mean of the daily mean values during the observation period.

(1) Tide Pole Method

Daily mean value is the mean of every hour's reading values on the tide pole.

(2) Tide gauge Method with Automatic Recording System.

Daily mean value is the mean of every hour's reading values on the recording paper after smoothing the recorded curve.

Part 3 Mapping

Chapter 1 General

Section 1 General

(Definition of Topographic Map)

Art. 101 In this specification, the term "topographic map" is used for the general map at a scale of 1/10,000 to 1/100,000.

(Map Symbols)

Art. 102 Map symbols are required to be based upon the specifications prepared by the country concerned. However, symbols and their application rules prepared by Geographical Survey Institute of Japan may be applied by mutual consent when the country concerned lacks specifications.

Section 2 Map Accuracy Criteria and Standards

(Projection of Map)

Art. 103 The projection is required to be based upon the specification prepared by the country concerned. However, in case of no specifications, Universal Transverse Mercator Projection (UTM) is used.

(Sheet Dimension and Contour Interval)

Art. 104 Sheet dimension and contour interval are required to be based upon the specifications prepared by the country concerned. However, in case of no specifications, the following table may be applied in agreement with the country concerned.

Scale	1/10,000	1/25,000	1/50,000	1/100,000
Difference of longitude	3.′0	7.′5	15.′0	30.′0
Difference of latitude	2.′0	5.′0	10.′0	20.′0
Contour interval	5 m	10 m	20 m	50m

(Categories of Map)

Art. 105 The map is divided into 3 categories according to the precision criterion (in standard deviation) as follows.

Category	Planimetry	Altitude	Contour line
A	0.5mm on the map	1/3 of contour interval	1/2 of contour interval
B	1.0 〃	2/3 〃	1/1 〃
C	2.0 〃	4/3 〃	2/1 〃

Chapter 2 Control Point Survey

Section 1 General

(Definition of Control Point Survey)

Art. 106 The control point survey is done to establish control points necessary for performing aerotriangulation and mapping.

(Categories of Control Points)

Art. 107 The control point is divided into 3 categories according to the kind of the topographic map (Art. 105) as seen in the following table.

Category	A	B	C
Planimetry Altitude	0.07mm/ploting scale 0.07mm×contour interval	0.15mm/ploting scale 0.15mm×contour interval	0.3mm/ploting scale 0.3mm×contour interval

(Method of Control Point Survey)

Art. 108 The control point survey is carried out by means of triangulation, traversing, combination thereof and satellite observation for planimetric positioning and spirit leveling, trigonometric leveling and any other methods satisfying the precision required in the preceding article for altitude.

(Marker)

Art. 109 A wooden pile is placed at the control point. However, stumps or rocks may be used in place of the wooden pile if local conditions warrant.

Section 2 Planning

(Establishment of Control Point)

Art. 110 The control point survey shall be planned considering distribution of existing triangulation points, control of aerotriangulation and planning for aerial photography.

(Traversing)

Art. 111 Traversing is required to be originated on an existing control point and closed to another one. However, when closing to another point is difficult, a closing traverse to the starting point followed by two or more azimuth observations may be admissible. The azimuth observation shall be carried out at points well distanced from each other on the route.

2 An open traversing with electro-magnetic distance measurment instrument may be allowable when there are less than 4 sides. In this case, azimuth observations shall be carried out at both ends of the route. When there are less than 2 sides, only one azimuth observation may be admissible.

3 The azimuth may be determined with gyro-theodolite or by astronomical observation of the sun.

(Leveling)

Art. 112 Leveling is required to be started from a existing bench mark or a control point and closed to another one. However, if absolutely necessary, closing traverse to the starting point may be admissible. If the route is very short, an

open leveling by duplicate measurement may be admitted.

2 Elevation is required to be determined by spirit leveling or trigonometric leveling. However, if these are difficult, another method may be taken provided that the same accuracy is expected.

Section 3 Execution of Work

(Execution of Control Point Survey)

Art. 113 The rules specified in part II of this specification is applies for control point survey apart from articles specified in this chapter.

2 Observation is carried out as follows, regardless of the category of control point (Art.106).

(1) Trigonometric Method

a) Instrument and specification of observation

	Horizontal angle	Vertical angle
Theodolite	min. reading 12″	min. reading 12″
Position	2	2
Double angle difference	36″	
Difference of observation	24″	
Constant of elevation		36″

b) Closing of a triangle shall be less than ± 40 sec.

c) In the case that the determination of geodetic azimuth is difficult, astronomical observation by the sun may be admissible according to the table (2)-d.

(2) Traversing Method

a) The above table for triangulation method is also applied for angle observation of traversing and Art. 33 of Part II for distance measurement.

b) Closure of azimuth shall be less than $30'' \sqrt{N}$ (N: number of included angle).

c) Closure of coordinates shall be done according to Art. 107.

d) Azimuth observation shall be carried out under the following table.

	Astronomical Observation	Gyro
Instrument	min. reading 12″	gyro theodolite
Position	more than 4	7
Difference of min. and max.	40″	4 0″
Observation time	2^h after or before culmination	
Accuracy of time determination	1 second	

(3) Leveling

Closure of leveling shall be done according to Art. 107.

Section 4 Accuracy Control

(Accuracy Control)

Art. 114 Accuracy control shall be carried out according to in forms 4 and 5.

Chapter 3 Airphoto Signal and Pricking

Section 1 Execution of Work

(Standards of Signal)

Art. 115 The signal shall have shape, size and color allowing it to be identified on the 4 time enlarged aerial photograph and for the position of its center to be accurately measured by plotting instrument.

(Establishment of Signal)

Art. 116 The signal shall be established strongly with materials good for long time.

(Eccentric Reduction of Signal)

Art. 117 Accuracy of eccentric reduction shall be less than a quarter of that of positioning.

(Verification of Signal on the Aerial Photograph)

Art. 118 Signals shall be verified on the aerial photograph immediately after photographying. Singnals not clearly identifiable on the photographs shall be pricked in the field.

(Pricking)

Art. 119 Pricking is required to be executed for planimetric features clearly identifiable on the aerial photographs and whose position can be exactly reduced from control point. However, direct pricking on the control point may be admitted where eccentric reduction is difficult.

2 Provision of Art. 117 may be applied to the eccentric work of pricking point.

Chapter 4 Aerial Photography

Section 1 General

(Aircraft)

Art. 120 Aerial photographying aircraft shall meet the following requirements:

(1) to be stable with full load while in flight to required height.

(2) to have unobstructed vision in all directions.

(3) to be able to install apparatus at a position where exhaust fumes will not effect the aerial photography.

(4) to have a navigation system suitable for local conditions.

(5) to have an undistorted and calibrated view-finder window glass if necessary.

(Camera)

Art. 121 Aerial camera shall be a wide angle camera of format 23cm × 23cm unless otherwise specified and have the following properties:

(1) minimum resolution power: 30 lines/mm
(2) maximum tangential distortion: 0.015mm
(3) maximum radial distortion: 0.01mm
(4) flatness of film: less than 0.01mm
(5) rotating inter-lens shutter
(6) calibration report within 3 years with the following items:
a) camera number and lens number
b) position of principal point relative to fiducial marks (in 0.01mm)
c) calibrated focal length (in 0.01mm)
d) radial distortion
e) observer's name and number of report

(Film)

Art. 122 Aerial negative film shall have following performance capabilities.

(1) After processing, ratio of differential change in dimension between longitudinal and lateral shall not exeed 0.01%.

(2) Ratio of differential change shall be also less than 0.001% per 1% relative humidity.

(3) The spectral sensitivity is panchromatic unless otherwise specified.

Section 2 Planning

(Flight Plan)

Art. 123 Flight plan shall be made in consideration the following items.

(1) The flight lines shall be straight and drawn in relation to aero-triangulation and mapping.

(2) The average overlap is 60% and sidelap 30%

Section 3 Execution

(Aerial Camera)

Art. 124 A projected area shall be photographed as a rule by a identical metric camera.

(Roll Film)

Art. 125 One meter of both sides of an aerial roll of film shall be left unexposed.

2 A roll of film shall not be spliced as a rule for reassembly.

(Data Record)

Art. 126 Name of area and date of photography shall be recorded legibly on the data recording area of film.

(Flight)

Art. 127 The flight shall satisfy the following items.

(1) There shall be adequate stereoscopic coverage in the photo-taking area.

(2) Overlap, sidelap, crab, tip and tilt shall be within the following tolerances:

Overlap: more than 55% and less than 65%

Sidelap: more than 10%

Crab: less than 10 degrees

Tip and tilt: less than 5 degrees

(3) The tone of photograph shall allow for details in the shade to be interpreted.

(4) When a flight line is broken, that part shall be covered by an overlap of more than 2 models.

(5) Photo images shall not be spoiled by cloud or mist. However, this may be permissible to the extent of 10% if they are covered by the photographs of adjucent strips.

(Flight Record)

Art. 128 The following information shall be written on the flight record.

(1) name of contract
(2) name of photographing organisation
(3) film number
(4) beginning and end times of flight
(5) date of flight
(6) camera number, lens number and magazine number
(7) calibrated focal length
(8) opening aperture, filter number and exposure time
(9) type of film
(10) type of aircraft
(11) flight altitude.

Section 4 Photo-Processing

(Negative Film)

Art. 129 Processing of negative film shall be carried out as follows:

(1) Developer specified by manufacturer's guidance, or one equal or superior, shall be used.

(2) Development shall be carried out in such a manner that the negative contains all highlight and shadow details and camera recording data is legible.

(3) Fixer shall be acidity and fixing shall be carried out well enough to remove unused silver halide.

(4) Washing shall be carried out to remove undesirable residues.

(5) In drying, distortions shall be avoided.

(6) Photo-images shall not be marred by scratches, fingerprints smudges,

pink marks or shrinkage in the photo-processing.

(Contact Print and Enlarged Photograph)

Art. 130 The preceding article is applied to the processing of paper prints.

(Mosaic)

Art. 131 Under specified instructions or in case of lack of topographic maps of the area, a photo mosaic shall be prepared by following steps.

(1) Mosaic shall be uncontrolled using contact prints.

(2) A 1/4 reduced print of the mosaic made.

(3) A positive film of the reduced print made. Standard size of the positive film is A2.

Section 5 Re-flight

(Re-flight)

Art. 132 Film shall be developed and contact prints shall be printed for inspection as soon as possible. When the film is rejected, a reflights shall be carried out immediately.

Section 6 Arrangement

(Editing of Negative Film)

Art. 133 The negative film shall be edited as follows, except if specified instruction are given.

(1) A leader and trailer of clear film 1 meter long shall be provided with all film rolls.

(2) Information to be recorded on negative film includes name of area, date of flight, mission number, strip number, photo number, flight height and name of photographying organisation.

All information shall be recorded on photographs of both sides of each strip. But on the other photographs only strip number and photo number recorded.

(Index Map)

Art. 134 Index map shall be made by using a map of appropriate scale. If no maps are usable, a photo-index shall be prepared.

(Negative Film and Contact Print)

Art. 135 Negative film shall be kept into a tin labeled "flight information" in each roll.

2 Contact prints shall be kept in sacks in each strip.

Section 7 Accuracy Control

(Accuracy Control)

Art. 136 Accuracy control is carried out according to form 7.

Chapter 5 Classification

Section 1 General

(Use of Aerial Photographs)

Art. 137 Aerial photographs enlarged on same scale as plotting are used for classification.

(Working Time)

Art. 138 The classification is carried out, as a rule, before mapping.

Section 2 Advanced Survey

(Advance Study)

Art. 139 Advance studies shall be carried out as follows with aerial photographs and reference data assembled beforehand.

(1) A pair of aerial photographs, on which neat lines of corresponding maps were indicated in red, shall be prepared for each map sheet.

(2) Another pair of aerial photographs shall be used for editing the data assembled by field classification.

Photographs may be prepared for every other one.

(3) Studies shall be carried out on the following subject.

a) the map symbols prepared by the country concerned.

b) quality of the reference data and possibility of its use.

c) uninterpretable objects on the photographs.

d) discrepancies between reference data.

Section 3 Execution of Work

(Execution)

Art. 140 Prior to execution of field classification, a deliberation has to be held with staff members of the country concerned relating to the map symbols and application rules.

The same may apply to the case that doubtful points have been arisen on surveying.

2 Field classification shall be carried out according to the map symbol application rule.

Section 4 Editing

(Editing)

Art. 141 The data gathered by the field classification shall be edited as follows on the aerial photographs defined in (2) of Art. 139.

(1) The data shall be edited according to the map symbol specifications with water-resistant ink.

(2) The geographic features shall be laid down precisely on the points.

(3) In case that density of detail does not permit type being placed precisely on the point, the point indicated by a spot and a leader arrow is required from the type to the spot.

2 An overlay may be used to lay down on photographs when density of details is high.

Section 5 Accuracy Control

(Accuracy Control)

Art. 142 Accuracy control shall be carried out on each provision of symbol specification and accuracy control table may be substituted by checking overlays or checking sheets.

Chapter 6 Aerial Triangulation

Section 1 General

(Aerial Triangulation)

Art. 143 *Analytical block adjustment method is required for aerial triangulation.*

Section 2 Planning of Aerial Triangulation

(Number and Distribution of Control Points)

Art. 144 Control points shall be distributed under the following rules.

(1) Planimetric Control

Control points shall be placed on every corner of the block. Others are distributed as follows according to map category.

a) Along peripheral block strips.

Class A: one point for every 3 ~ 6 models
Class B: 〃 〃 5 ~10 models
Class C: 〃 〃 10~20 models

b) Along both peripheries perpendicular to strips.

Class A: one point for every 2 ~ 4 strips
Class B: 〃 〃 3 ~ 6 strips
Class C: 〃 〃 5 ~10 strips

c) Inside of block

Class A: one point for every 5 ~ 8 models
Class B: 〃 〃 7 ~13 models
Class C: 1 ~ 2 points

(2) Altitude

Leveling route shall be established along peripheries of block. The rest are established as follows.

Class A: one route for 3 ~ 6 models in the block
Class B: 〃 6 ~12 models in the block
Class C: 〃 10~20 models in the block

Section 3 Determination of Pass Points

(Pass point and Tie Point)

Art. 145 Pass point and tie point are determined as follows.

(1) Pass Points

a) Pass point is fixed near the center of photograph and wing points on the line drawn through or near the center of photograph and perpendicular to the base line, except on water part.

b) Wing points are placed at a distance of 7 ~10cm from pass point.

c) Pass point and wing points are fixed on as flat an area as possible.

(2) Tie Points

a) More than one tie point shall be selected in a model.

b) They shall be identifiable on the photographs of both strips.

(3) Marking of Points

Pass points, wing points and tie point are enclosed with small red circle on the contact print.

Section 4 Execution

(Measurement of Photo Coordinates)

Art. 146 Measurements of coordinates of control points, pass points, tie points and fiducial marks shall be carried out twice by precise mono- or stereo-comparator. When the difference is less than 0.02mm the mean is adopted.

(Inner Orientation)

Art. 147 Effect of shrinkage of diapositive shall be considered for each photograph.

2 Distorsion of aerial camera is required to be corrected.

3 Measurement error of distance between fiducial marks shall be less than 0.03 mm.

(Relative Orientation)

Art. 148 All points of a model shall be used for relative orientation.

2 Effect of atmospheric refraction shall be considered.

3 Residual error of relative orientation shall be less than 0.03mm on the diapositive.

4 Discrepancies of model coordinates at a common point between successive models shall be less than 0.05% of flight height for planimetry and height.

(Transformation from Model Coordinates to Geodetic Coordinates)

Art. 149 Independent model method is required for block adjustment.

2 Effect of earth curvature shall be corrected.

3 Discrepancies of coordinates at a common point between adjucent models shall be less than 0.08% of flight height for the planimetry and the height.

4 Residuals at control points used for block adjustment shall be less than the values in the following table for flight height.

Class	A	B	C
Wide angle camera	0.8 ‰	1.6 ‰	3.2 ‰
Super wide angle camera	1.4 ‰	2.7 ‰	5.3 %

5 Residual at tie points between adjucent blocks shall be less than in the following table for planimetry and height.

Class	A	B	C
Wide angle camera	0.9 ‰	1.8 ‰	3.6 ‰
Super wide angle camera	1.5 ‰	3.0 ‰	6.0 ‰

Section 5 Accuracy Control

(Accuracy Control)

Art. 150 Accuracy control is carried out according to form 9.

Chapter 7 Mapping

Section 1 General

(Material)

Art. 151 Plotting sheet shall be polyester with a thickness over 0.12mm and its ratio of differentical change in dimesion between longitudinal and lateral less than 0.05 % in normal temperature and humidity.

(Plotting Scale)

Art. 152 Plotting scale is required to be same as the map scale.

Section 2 Plotting

(Plotting of Control Points)

Art. 153 Control points, grid line and neat line are plotted by using a coordinate-graph.

2 Plotting error shall be less than 0.2mm.

(Orientation)

Art. 154 The relative orientation is carried out by using 6 points on a model and absolute orientation by 6 points determined by aerotriangulation.

2 Control points in model, if exist, are used for checking the orientation.

3 Residuals of orientation are as follows

(1) Residual parallax of relative orientation shall not be exceed 0.02 mm.

(2) Scaling error of model orientation is less than

0.3mm on the map for class A

0.5 〃 〃 B

1.0 〃 〃 C

(3) Leveling error of model orientation is less than

1/4 of contour interval for class A

1/2 〃 〃 B

1/1 〃 〃 C

(4) Measurements of spot height shall be carried out twice and the difference between the measurements shall be less than 0.01mm.

(Plotting)

Art. 155 Plotting of geographic details is restricted to inside a limit obtained by connecting pass points.

2 Plotting shall be carried out as follows.

(1) Plotting error caused by height measurment error shall not occur.

(2) Topographic features for which distorted surface area symbol are not prepared shall be expressed by contour lines as much as possible.

(3) Height shall be checked at the top of mountain, bottom of depressions and passes etc., to prevent the dropping of contour lines in restitution.

(4) Matching of Map Sheets

a) Continuity shall be established with adjoining sheets when it is less than 1 mm.

b) When no adjoining maps exist, geographic features shall be plotted to the extent of 1 cm outside of lines.

(Spot Height)

Art. 156 Spot height shall be measured at the following points distributed as uniformely as possible on the map.

(1) main top of mountains

(2) main fork of roads

(3) mouth of a valley, junction of river, riverbed

(4) main changes of slopes

(5) center of local plains

(6) most lowest part of depression

2 Independent measurements shall be carried out twice and the mean shall be adopted.

3 Spot height measurment may be omitted for the class C maps.

4 Earth curvature correction shall be applied when it exceeds the following limits

Class A 1/4 of contour interval

Class B 1/2 〃

Section 3 Accuracy Control

(Accuracy Control)

Art. 157 Accuracy control table may be substituted by checking sheets and orientation records.

Chapter 8 Compilation

Section 1 Compilation

(Material)

Art. 158 Compiled sheet shall be same standard as one for plotting.

(Plotting of Control Point)

Art. 159 Plotting of control points is carried out according to the rule of Art. 153.

(Matching)

Art. 160 Continiuity shall be established with adjoining sheets. However, if great mismatching with old maps caused by annual variations exist, this rule is not required to be applied.

Section 2 Accuracy Control

(Accuracy Control)

Art. 161 The provision of Art. 142 is applied to the accuracy control of compilation.

Chapter 9 Field Editing

Section 1 Field Editing

(Field Editing)

Art. 162 Field editing is carried out with field sheets (copies in polyester) and ozalide copies from compiled sheets and other data.

Section 2 Working

(Working)

Art. 163 Field editing is carried out as follows.

(1) Boundaries, place names and others are laid down on the basis of data supplied from the country concerned.

(2) Investigation of doubtful points

(3) Field survey if necessary

(4) A survey for checking the mapping accuracy is carried out if necessary.

2 The checking survey is carried out as follows:

(1) Checking survey is carried out at a point whose planimetric feature is clearly identifiable on the compiled sheet and not displaced by exaggerated size of symbols.

(2) Checking point is normally one for every five sheets.

3 A responsible person of the country concerned is required to sign agreement on every sheet completed by field editing.

Section 3 Accuracy Control

(Accuracy Control)

Art. 164 The provision of Art. 141 is applied to the accuracy control of field editing.

Part 4 Scribing

Chapter 1 General

Section 1 Accuracy of Scribing

(Accuracy of Scribing)

Art. 165 Scribed lines shall not be shifted more than 0.1mm refering to symbol lines drawn on scribing sheet.

Chapter 2 Scribing

Section 1 Scribing

(Scribing Manuscript)

Art. 166 A Map manuscript is a set of colour-separated scribed sheets including masks and a names film.

(Standard of Scribing Sheet)

Art. 167 Article 150 of Chapter 7, Part 3 is applied to scribing sheet.

(Preparation of Scribing Sheet)

Art. 168 Scribing sheet is prepared according to the following:

(1) Scribing is carried out on the basis of a punching system.

(2) When the length of the sheet line drawn on the scribing sheet is more than 0.2mm compared with the original stereocompilation, the later shall be printed again on the scribing sheet.

(3) The transparent film base shall not be scratched by the scribing and coating shall be removed perfectly.

(Matching)

Art. 169 Scribing is required to be carried out establishing direct continuity to adjoining sheets.

Part 5 Reproduction

Chapter 1 General

Section 1 Platemaking

(Accuracy of Platemaking)

Art. 170 Accuracy of making the process film and printing plate is less than 0.3mm refering to the sheet line compared with original plates.

(Making of Printing Plate)

Art. 171 Printing plate is made by means of photo-lithography.

Chapter 2 Printing

Section 1 General

(Standard of Printing Paper)

Art. 172 The standard of printing paper is as follows.

Sheet sizes		Basis weight (g/m^2)
Popular name		80, 90, 100
A 0	625mm× 880mm	
B 0	765mm×1085mm	
4 — 6	788mm×1091mm	
Kiku	636mm× 939mm	

Section 2 Printing

(Material)

Art. 173 Paper for printing shall be dimentionally stable, durable (tensional strength, internal tearing strength, water resistance) and demands good printability (reproducing ability for an image).

Printing ink shall have good hue, fastness and light resistance. And it shall not leak through paper to the back side.

Part 6 Photomap

Chapter 1 General

Section 1 General

(Definition of Photomap)

Art. 174 The term "photomap" is defined, in this specification, as the mosaic photograph rectified or differentially rectified upon which marginal data, names, etc., have been added.

2 Contour lines shall be drawn for the orthophotomap as follows.

Scale	1/25,000	1/50,000	1/100,000
Contour interval	20m	50m	100m
Spot height	one spot for every 5cm		

(Relation to other Provision)

Art. 175 Photomap making shall be carried out according to the provision of Part 3 except for the items specified here.

Section 2 Accuracy

(Map Accuracy)

Art. 176 Planimetric accuracy of photomap shall be less than ±1.0mm in standard deviation for clearly identifiable features on the photomap except high towers, buildings, and so on.

Chapter 2 Orthophoto Mapping

Section 1 Working

(Diapositive)

Art. 177 Diapositives used for orthophoto mapping are also used for aerotriangulation.

2 The diapositives used for orthophoto mapping shall not be scratched.

(Slot Width)

Art. 178 Width of aperture slot is determined in consideration of the slope of terrain.

(Scanning Speed)

Art. 179 Scanning speed shall be regulated so that floating mark is able to follow the undulation of the terrain well.

(Scale of Photo Map)

Art. 180 Scale of the differentially rectified photograph is required to be same as the final photomap.

Chapter 3 Rectification

Section 1 Rectification

(Rectification)

Art. 181 Orientation is carried out at 4 or more points and error shall be less than 1.0mm.

(Reference Plan of Rectification)

Art. 182 Reference plan is placed at a mean height of terrain in the photograph.

Chapter 4 Mosaic

Section 1 Mosaic

(Mosaic of Film)

Art. 183 Mosaic is carried out on the basis of control points plotted on a sheet.

2 Orientation error at the control points is less than 0.3mm for mosaic of film.

(Matching)

Art. 184 The discontinuity of photographic images between adjoining photographs shall be less than 1.0mm.

(Compiled Sheets)

Art. 185 Compiled sheets are made according to the following.

(1) Contour values are required to be put on compiled sheets at 20cm intervals.

(2) Symbols and type are required to be labeled in black.

(3) Type is positioned at highlight of image.

(4) The film for contour line and marginal information shall be stable and lithofilm 0.1mm in thickness and stable.

Chapter 5 Reproduction

Section 1 Reproduction

(Halftone Negative)

Art. 186 A halftone negative shall be produced according to the following items.

(1) It is produced by photographing a mosaic photo.

(2) A 150L/inch, positive type, magenta contact screen is used for screening.

(3) The scale of the halftone negative is the same scale as that of the original photomap.

(Production of a final Positive and a final Negetive for a Photomap)

Art. 187 A final positive and a final negative for a photomap shall be produced according to the following items.

(1) The final positive of the photomap is produced by multi-exposure from the halftone negative, contour negative and the marginal design negative.

(2) Dimentional tolerance of the multi-exposure is 0.2mm.

(3) The final negative is produced from the final positive of the photomap.

(4) The dimensional tolerance for a border line of the positive or the negative shall be 0.4mm from the prescribed length.

(Photographic Processing)

Art. 188 Photographic processing for positives, negatives and photographic paper shall be done in the manner described in Article 148.

ATTACHED TABLE AND CHART

TABLE 1 DESCRIPTION OF AIR PHOTO SIGNAL

STATION NO		OPERATED BY	
		CHECKED BY	
		DATE	

ZONE NO.	COORDINATES OF STATION		
	N	E	H
MAIN POINT	— —	— —	
ECCENTRIC POINT	— —	— —	
SUPPLEMENTARY POINT	— —	— —	

SKETCH	PHOTOGRAPH OF STATION

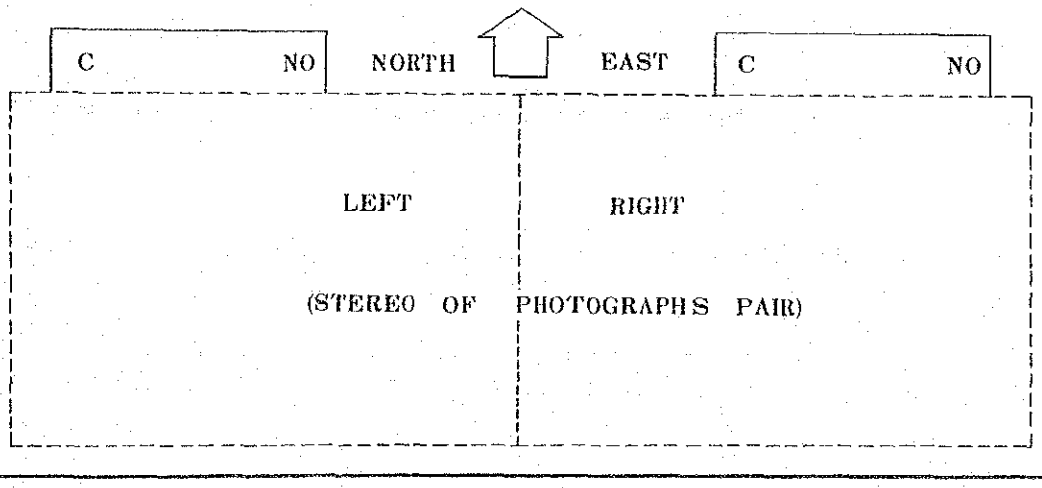
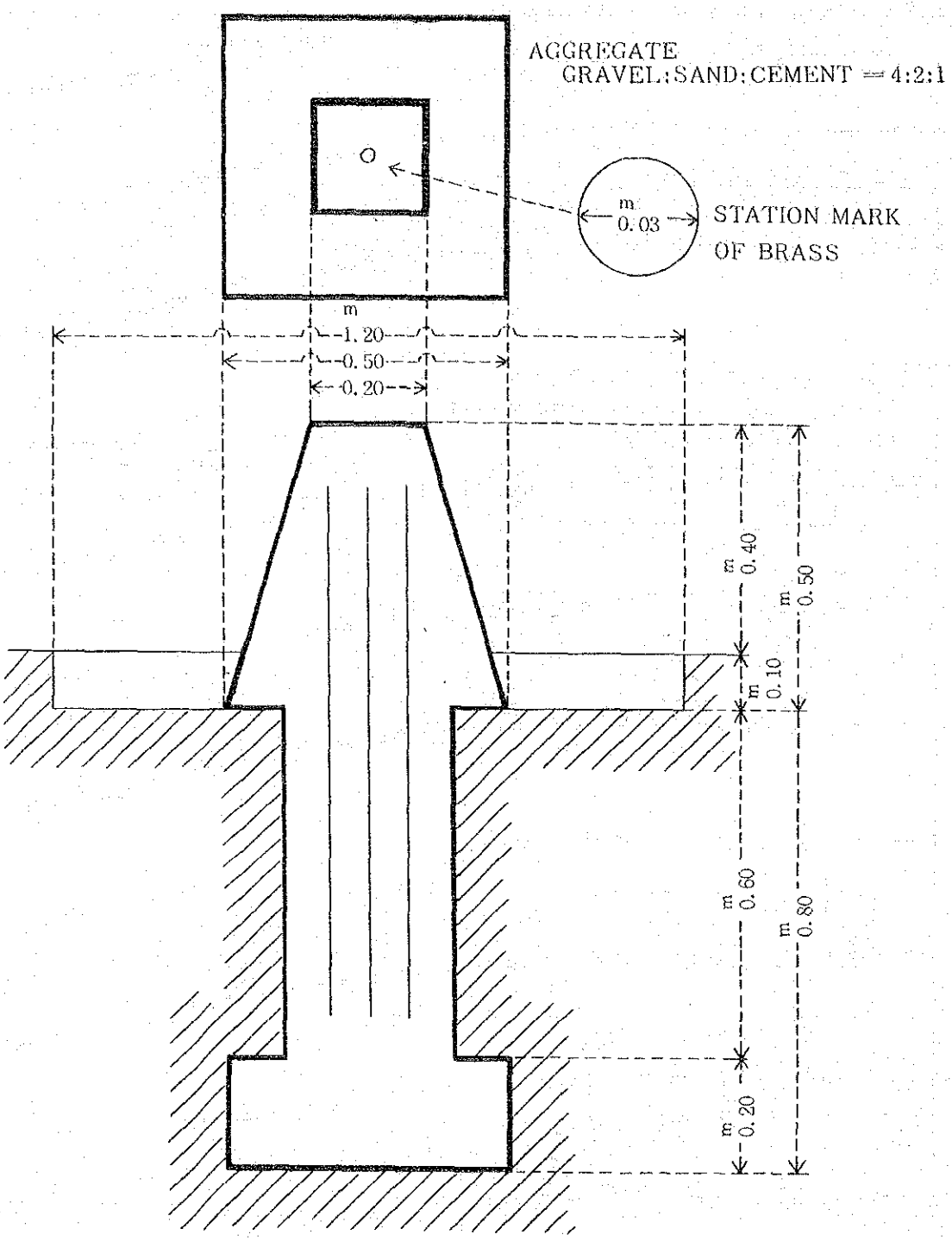


FIGURE 1 MONUMENT CONSTRUCTION



ACCURACY CONTROL TABLE

FORM 1

TRIANGULATION

MISSION:	AREA:	NAME:
PERIOD:	NUMBERS OF POINTS:	

NUMBER OF POINT AND POINT NAME	CLOSURE OF TRIANGLE	DISCREPANCIES				REMARKS
		LENGTH	Δ X	Δ Y	HEIGHT	
MEAN SQUARE ERROR						

REOBSERVATION	
	TIMES
DIFFERENCE OF OBSERVATION *DOUBLE ANGLE DIFFERENCE*	
ALTITUDE CONSTANT	
OTHERS	

REMARKS:

FORM 2

TRAVERSING

MISSION:	AREA:	NAME:
PERIOD:	NUMBERS OF POINTS:	

OBS:OBSERVATION
RES:RESTRICTION

NO.OF ROUTE	ROUTE LENGTH	CLOSURE		AZIMUTH		COORDINATES		ALTITTUDE		REMARKS
		OBS.	RES.	CLOSURE	RESTRICTION	CLOSURE	RESTRICTION	CLOSURE	RESTRICTION	

REOBSERVATION	
	TIMES
DIFFERENCE OF OBSERVATION DOUBLE ANGLE DIFFERENCE	
ALTITUDE CONSTANT	
OTHERS	

REMARKS:

FORM 3

LEVELING

MISSION:	AREA:	NAME:
PERIOD:	TOTAL LENGTH OF THE ROUTES:	

NO. OF ROUTE	DISTANCE	CLOSURE	RESTRICTION	REMARKS	NO. OF ROUTE	DISTANCE	CLOSURE	RESTRICTION	REMARKS

NUMBERS OF REOBSERVATIONS:	REMARKS:
MEAN SQUARE ERROR:	

FORM 7

PHOTOGRAPH

MISSION:	AREA:	NAME:
CAMERA NO.:	STRIP NO.:	DATE OF FLIGHT:
PHOTO SCALE:	FLIGHT HEIGHT:	REFERENCE PLANE:
MINIMUM OVERLAP:	MINIMUM SIDELAP:	
MAXIMUM K:	MAXIMUM φ, ω:	

PHOTO NO.	TONE	HALATION	SHADOW	DEVELOPING MARK	SCRATCH	CLOUD ITS SHADOW	MIST	REMARKS:

FORM 9

AERIAL TRIANGULATION

MISSION:	AREA:	NAME:
PERIOD:	NUMBERS OF STRIP:	NUMBERS OF MODELS:

STRIP NUMBER	PHOTO NUMBER	NUMBERS OF MODELS	MAXIMUM RESIDUALS(CONTROL POINTS)		MAXIMUM DISCREPANCIES(TIE POINTS)	
			PLANIMETRY	ALTITUDE	PLANIMETRY	ALTITUDE
	~					
	~					
	~					
	~					
	~					
	~					
	~					
	~					
	~					
	~					

MEAN SQUARE ERROR				REMARKS:
	CON-TROL POINT	PLANIMETRY		
		ALTITUDE		
	TIE POINT	PLANIMETRY		
		ALTITUDE		

CULCULATION FORMULA

CONTENTS

1. CALCULATION OF DISTANCE

(1) Calculation of meteorological correction

$$D = D_s \frac{n_s}{n} = D_s + (\Delta s - \Delta n)\, D_s$$

where

$n_s = (1 + \Delta s)$: Standard refractive index of air adopted forEDM

$n = (1 + \Delta n)$: Refractive index of air by observation

$$\Delta n = \frac{273.2(n_g - 1)}{273.2 + t} \frac{P}{760} - \frac{15.0e}{273.2 + t} \cdot 10^{-6}$$

$$n_g - 1 = (287.604 + \frac{4.8864}{\lambda^2} + \frac{0.0680}{\lambda^4}) \quad 10^{-6}$$

$P = \frac{P_1 + P_2}{2}$: Mean air pressure during observation

$t = \frac{t_1 + t_2}{2}$: Mean air temperature during observation

λ : Wave length of light in μm

e : Mean water vapour pressure in mmIlg

suffix 1 : Master station

suffix 2 : Remote station

Pressure(P_2) at remote station can be calculated with following formula

$$P_2 = P_1 \cdot 10^{-h/18464(1+0.003665t)}$$

P_1 : Pressure at master station

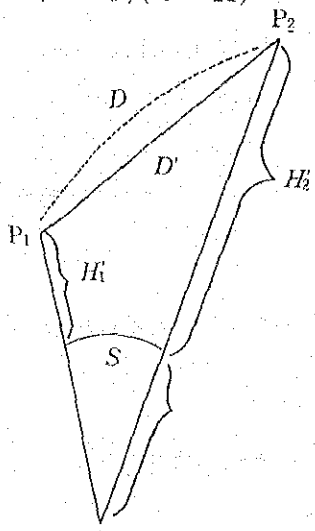
$h = H_2' - H_1'$(m) : Height difference in m.

suffix 1 : Master station

formula $P_2 = P_1 - 0.09\,h$($in\ m$)mmIlg may be used for field calculation and Δn may be read from nomogram.

(2) Reduction formula to sea level

$$S = D\left\{1-(h/D)^2/(1+H_1'/R_a)(1+H_2'/R_a)\right\}^{\frac{1}{2}} + (D^3/24R_a^2)(1-K)^2$$



where

R_a = Radius of curvature for azimuth α

R : Radius of curvature in meridian

N : Radius of curvature in prime vertical

H_1' : Height of master station····· $H_1' = H_1 + (G)$

H_2' : Height of remote station····· $H_2' = H_2 + (R)$

h : Height difference····· $h = H_2' - H_1'$

K : Refractive index····· K = 0.2

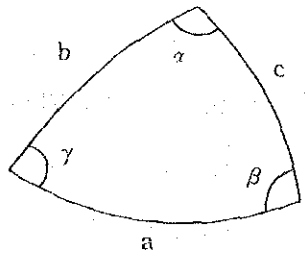
$(G)(R)$: Instrument height at two stations

For rough calculation at field, $R_a = \sqrt{RN}$ may be used.

(3) Side length calculation of a triangle

1) $a = \sqrt{b^2 + c^2 - 2bc\cos A}$

2) $a = (b+c)\dfrac{\sin\dfrac{A}{2}}{\cos\dfrac{B-C}{2}}$



where

$$\tan\frac{B-C}{2} = \frac{b-c}{b+c}\cot\frac{A}{2}$$

$$\frac{B+C}{2} = 90^\circ - \frac{A}{2}$$

$$A = \alpha - \frac{\varepsilon}{3},\quad B = \beta - \frac{\varepsilon}{3},\quad C = \gamma - \frac{\varepsilon}{3}$$

α, β, γ : Spherical angle

A, B, C : Plane angle

a, b, c : Spherical distance

$\varepsilon = (\rho''/2R^2)\,b\cdot c\,\sin\alpha \fallingdotseq 0''.00254\ b\cdot c\,\sin\alpha$ (b,c in km)(spherical excess)

2. INCLUDED ANGLE CALCULATION OF A TRIANGLE

$$\alpha = \cos^{-1}\{(b^2 + c^2 - a^2)/2bc\} + \varepsilon/3$$

$$\beta = \cos^{-1}\{(c^2 + a^2 - b^2)/2ca\} + \varepsilon/3$$

$$\gamma = \cos^{-1}\{(a^2 + b^2 - c^2)/2ab\} + \varepsilon/3$$

or

$$\alpha = 2\tan^{-1}\{(s-b)(s-c)/s(s-a)\}^{\frac{1}{2}} + \varepsilon/3$$

$$\beta = 2\tan^{-1}\{(s-c)(s-a)/s(s-b)\}^{\frac{1}{2}} + \varepsilon/3$$

$$\gamma = 2\tan^{-1}\{(s-a)(s-b)/s(s-c)\}^{\frac{1}{2}} + \varepsilon/3$$

where, ε : Spherical excess

$s = (a + b + c)/2$

α, β, γ : Spherical angle

3. CALCULATION OF ECCENTRICITY

(1) Eccentricity of angle

1) Method with sine formula

$$\sin x = (e/s_0)\sin\alpha$$

where

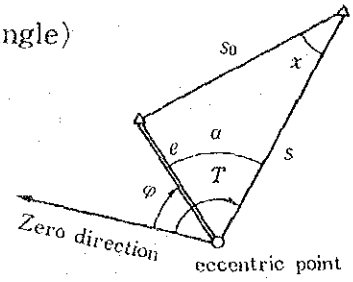
s_0 : Distance between trianglation points

$\alpha = 360° - \varphi + T$ (observed angle)

e : Distance of eccentricity

φ : Angle of eccentricity

s : Observed distance



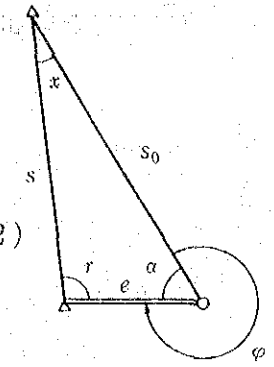
where

for 1st and 2nd class control survery, s may be used instead of s_0 it $e < (s_0$ it $s_0/2000)$.

For 3rd class control survey, s may be used intead of s_0 if

$e < (s_0/650)$.

2) Method with two sides and included angle



(a) $\tan x = e\sin\alpha/(s_0 - e\cos\alpha)$

(b) $(\gamma + x)/2 = 90° - \alpha/2$

$\tan\{(\gamma - x)/2\} = \tan(\lambda - 45°)\tan(90° - \alpha/2)$

$\tan\lambda = s/e$

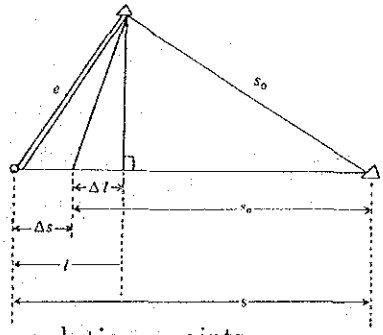
$x = (\gamma + x)/2 - (\gamma - x)/2$

3) The sign of x for the eccentricity of angle are shown in following table

position of theodolite (φ) / eccentricity	at B	at C	at P
(B=P)≒C	fore direction $+x''$ back direction $+x''$	fore direction $-x''$ back direction $-x''$	fore direction $+x''$ back direction $+x''$
(B=C)≒P	back direction $-x''$	back direction $-x''$	back direction $+x''$
B≒(P=C)	fore direction $+x''$	fore direction $-x''$	fore direction $-x''$
B≒C≒P	correction for fore direction (B≒C) $+x''$	correction for fore direction(B≒C) $-x''$ correction for back direction(C≒P) $-x''$	correction for back direction(C≒P) $\pm x''$

where B: Instrument station, P: Target station, C: Center of monument.

(2) Eccentricity of distance



1) case 1

$s_0 = s - \Delta s$

$\Delta s = l - \Delta l = e\cos\alpha - e\sin\alpha\tan(x/2)$

where

s, s_0 :Observed distance between triangulation points

φ, e :Eccentric angle, distance of eccentricity

$\alpha = 360° - \varphi + T$(observed angle)

2) case 2

$s_0 = (s^2 + e^2 - 2se\cos\alpha)^{\frac{1}{2}}$

where

s, s_0 : Observed distance between triangulation points

φ, e : Eccentric angle, distance of eccentricity

$\alpha = 360^\circ - \varphi + T$ (observed angle)

4. NET ADJUSTMENT OF X,Y COORDINATES

(1) Observation equation of distance

$$V''(s_{ij}) / s'_{ij} = b_i \Delta x_i - a_i \Delta y_i + b_i \Delta x_j + a_i \Delta y_j - \rho''(s'_{ij} - s_{ij}) / s'_{ij}$$

(2) Observation equation of direction

$$V(t_{ij}) = -\Delta Z_i + a_i \Delta x_i - b_i \Delta y_i - a_i \Delta x_j + b_i \Delta y_j - l_{ij}$$

$$X_i = X'_i + \Delta x_i \qquad Y_i = Y'_i + \Delta y_i$$

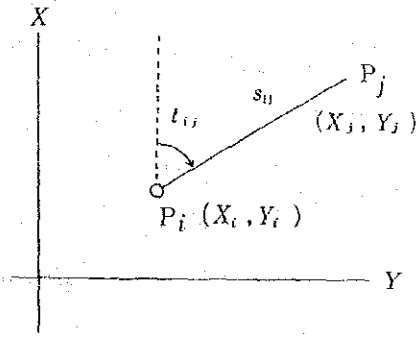
$$X_j = X'_j + \Delta x_j \qquad Y_j = Y'_j + \Delta y_j$$

$$s_{ij} = S_{ij} + C_m$$

$$s'_{ij} = \{(X'_j - X'_i)^2 + (Y'_j - Y'_i)^2\}^{\frac{1}{2}}$$

$$t'_{ij} = \tan^{-1}\{(Y'_j + Y'_i) / (X'_j - X'_i)\}$$

$$l_{ij} = Z_i + U_{ij} - t'_{ij}$$



$$a_i = (Y'_j - Y'_i)\,\rho'' / s'^2_{ij}$$

$$b_i = (X'_j - X'_i)\,\rho'' / s'^2_{ij}$$

where

$(X_i, Y_i)(X_j, Y_j)$: Final X,Y coordinate values of two points (i, j)

$(X'_i, Y'_i)(X'_j, Y'_j)$: Assumed X,Y coordinate values of two points (i, j)

$(\Delta x_i, \Delta y_i)(\Delta x_j, \Delta y_j)$: Correction for assumed value

S_{ij} : Distance on sea level between two points

s_{ij} : Distance on plane between two points

s'_{ij} : Distance on plane between assumed two points

C_m : Transform factor from S to s_i

Z_i : Approximate orientation angle at i point

ΔZ_i : Correction value for approximate orientation angle

U_{ij} : Observed direction angle

t'_{ij} : Direction angle from assumed i point to assumed j point

(3) Weight of observation equation

1) Weight of direction angle (observation equation) are 1 for two sets observation, 2 for 4 sets observation respectively. Weight for(observation equation) fixed direction is 1.

2) Weight of observation equation of distance

$$P_s = m_t^2 S_{ij}^2 / (m_s^2 + r^2 S_{ij}^2) \rho''^2$$

where

m_s : S.D. of distance measurement not proportional to length

γ : Coefficient of distance measurement proportional to length

m_t : S.D. of direction angle observation for 1 direction

(4) Correction of direction angle and distance

Reduction from spherical angle to plane angle and from spherical distance to plane distance

1)

$$t_{ij} - T_{ij} = -(1/4\gamma_0^2)(Y'_i + Y'_j)(X'_j - X'_i)\rho'' + (1/12\gamma_0^2)(X_j - X_i)(Y_j - Y_i)\rho''$$

$$t_{ji} - T_{ji} = +(1/4\gamma_0)(Y'_i + Y'_j)(X'_j - X'_i)\rho'' + (1/12\gamma_0^2)(X'_j - X'_i)(Y'_j - Y'_i)\rho''$$

or

$$t_{ij} - T_{ij} = -(1/6\gamma_0^2)(X'_j - X'_i)(2Y'_i + Y'_j)\rho''$$

$$t_{ji} - T_{ji} = +(1/6\gamma_0^2)(X'_j - X'_i)(Y'_i + 2Y'_j)\rho''$$

where

γ_0 : Mean radius of curvature at origin on the central meridian

t_{ij}, t_{ji} : Plane direction angle from i point to j point and from j to i

T_{ij}, T_{ji} : Spherical direction angle from i point to j point and from j to i

2) $(s/S)_{ij} = m_o\{1+(1/6\,\gamma_o^2 m_o^2)(Y_i^2 + Y_iY_j + Y_j^2)\}$

where

m_o : Scale factor at central meridian

γ_c : Mean radius of curvature at origin of plane rectangular coordinate system

S : Distance on spherical

s : Distance on plane

(5) Standard deviation (S.D.) of observations

1) S.D. of single observation

$$M = \sqrt{\Sigma P_i V_i^2/(m-\gamma)}$$

where

m : Numbers of observation equations

γ : Numbers of unknowns ($2n$ + number of correction value for approximate orentation angle)

n : Numbers of observation points

2) S.D. of X,Y

$$M_x = M/\sqrt{P_{xi}} \qquad M_y = M/\sqrt{P_{yi}}$$

where P_{xi}, P_{yi} : Weight of X,Y

5. TRANSFORMATION FORMULA FROM PLANE RECTANGULAR COORDINATES(X,Y) TO GEODETIC COORDINATES(B,L)

$$(B/\rho'') = (B_1/\rho'') - (\tan B_1/2R_1N_1)(Y/m_o)^2 + (\tan B_1/24R_1N_1^3)(5+3\tan^2 B_1 + \eta_1^2 - 9\eta_1^2\tan^2 B_1 - 4\eta_1^4)(Y/m_o)^4 - (\tan B_1/720N_1^5R_1)(61+90\tan^2 B_1 + 45\tan^4 B_1)(Y/m_o)^6 + \cdots$$

$$(\Delta L/\rho'')= (1/N_1\cos B_1)(Y/m_o) - \{(1+2\tan^2 B_1+\eta_1^2)/6N_1^3\cos B_1\}(Y/m_o)^3$$
$$+ \{(5+28\tan^2 B_1+24\tan^4 B_1)/120N_1^5\cos B_1\}(Y/m_o)^5+\cdots\cdots$$
$$(\gamma/\rho'')= (\tan B_1/N_1)(Y/m_o)-(\tan B_1/3N_1^3)(1+\tan^2 B_1-\eta_1^2)(Y/m_o)^3$$
$$+(\tan B_1/15N_1^3)(2+5\tan^2 B_1+3\tan^4 B_1)(Y/m_o)^5+\cdots\cdots$$

$$m = m_o\{1+(Y^2/2RNm_o^2)+(Y^4/24R^2N^2m_o^4)+\cdots\cdots\}$$

where B, L : Latitude and longitude of proposed point

P_1 : Foot of the perpendicular from P to the central meridian

B_1 : Latitude of P_1 point

m_o : Central scale factor

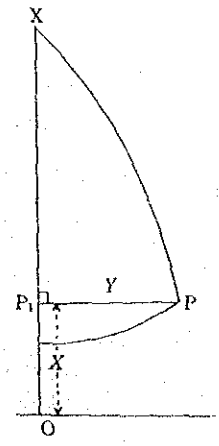
ΔL : Difference of longitude from the central meridian

m : Scale factor at ponit P

R_1, N_1 : Radius of curvature in meridian and in prime vertical at P_1

R, N : Radius of curvature in meridian and in prime vertical at P

$L = L_o + \Delta L$ $\qquad \eta_1^2 = \{e^2/(1-e^2)\}\cos B_1$



Formula used for calculation of B_1

$$B_1 = \{A_1\theta + A_2\sin 2\theta + A_3\sin 4\theta + A_4\theta\cos 2\theta + A_5\sin 6\theta$$
$$+ A_6\theta\cos 4\theta + A_7\theta^2\sin 2\theta + A_8\sin 2\theta\cos 4\theta\cos 4\theta + A_9\sin 8\theta$$
$$+ A_{10}\theta\cos 6\theta + A_{11}\theta\sin 2\theta\sin 4\theta + A_{12}\theta^2\sin 4\theta$$
$$+ A_{13}\theta^3\cos 2\theta + A_{14}\sin 6\theta\cos 2\theta + \cdots\cdots\}\rho''$$

where $\theta = M/a$

M : True meridian distance of point P from the equator

a : Equatorial radius

e : Eccentricity of ellipse

$$A_1 = 1 + \frac{1}{4}e^2 + \frac{7}{64}e^4 + \frac{15}{256}e^6 + \frac{579}{16384}e^8$$

$$A_2 = \frac{3}{8}e^2 + \frac{3}{16}e^4 + \frac{93}{1024}e^6 + \frac{87}{2048}e^8$$

$$A_3 = \frac{21}{256}e^4 + \frac{21}{256}e^6 + \frac{261}{4096}e^8$$

$$A_4 = \frac{3}{16}e^4 + \frac{45}{256}e^6 + \frac{285}{2048}e^8$$

$$A_5 = \frac{29}{3.256}e^6 + \frac{231}{4096}e^8$$

$$A_6 = \frac{21}{256}e^6 + \frac{483}{4096}e^8$$

$$A_7 = -\frac{3}{64}e^6 + \frac{33}{512}e^8$$

$$A_8 = -\frac{27}{1024}e^6 - \frac{81}{2048}e^8$$

$$A_9 = \frac{921}{131072}e^8$$

$$A_{10} = \frac{71}{2048}e^8$$

$$A_{11} = -\frac{27}{1024}e^8$$

$$A_{12} = -\frac{21}{512}e^8$$

$$A_{13} = -\frac{1}{128}e^8$$

$$A_{14} = \frac{11}{1024}e^8$$

$$\rho'' = 206264.806247$$

6. CALCULATION OF LATITUDE AND LONGITUDE

(1) Formula used for 1st class control survey

$$B_2 = B_1 + b - d$$

$$L_2 = L_1 + l$$

$$T_2 = T_1 \pm 180^\circ + t - \varepsilon$$

$$b = (B_1' - B_1) = (\rho u / R_1)\{1 + (v^2/3R_1N_1)\}\{1 - (3e^2 u \sin 2B_1/4R_1W_1^2)\} \times \{1 - (e^2u^2\cos 2B_1/2a^2)\}$$

$$l = c\sec B_1'\{1 - (c^2\tan^2 B_1'/3\rho''^2) + (c^4\tan^2 B_1'/15\rho''^4)(1 + 3\tan^2 B_1')\}$$

$$d = (B_1' - B_2) = (V_1'^2 cr/2\rho'')[1 - \{\lambda^2/12(1-e^2)\rho''^2\} - \{\tau^2/6(1-e^2)\rho''^2\} + \{e^2\tau^2/12(1-e^2)\rho''^2\}(13 - 10\sin^2 B_1')]$$

$$t = \tau[1 - \{\lambda^2/6(1-e^2)\rho''^2\} - \{\tau^2/6(1-e^2)\rho''^2\} + \{\tau^2 e^2/6(1-e^2)\rho''^2\}(3 - \sin^2 B_1')]$$

$$c = (v/N_1')\{1 - (u^2/6R_1'N_1')\} \qquad \lambda = c\sec B_1' \qquad \tau = c\tan B_1'$$

$$u = S\cos T_1 \qquad v = S\sin T_1 \qquad V_1'^2 = \frac{N_1'}{R_1'} \qquad \varepsilon = bc/2\rho''$$

$$R_1 = a(1-e^2)/W_1^3 \qquad N_1 = a/W_1 \qquad W_1 = (1 - e^2\sin^2 B_1)^{\frac{1}{2}}$$

where P_1, P_2 : Given point and proposed point

P_1' : Foot of the perpendicular from P_2 to the meridian which pass through P_1

B_1, L_1 : Latitude and longitude at given point

B_2, L_2 : Latitude and longitude at given point

B_1' : Latitude of P_1'

R_1, N_1: Radius of curvature in meridian and in prime vertical at given point respectively

R_1', N_1' : Radius of curvature in meridian and in prime vertical at P_1' respectively

T_1, T_2 : Azimuth from given point to proposed point and from proposed point to given point respectively

7. NET ADJUSTMENT OF GEODETIC COORDINATES

(1) Observation equation of distance

$$V_{(s)}/S_{ad} = -(N/S_{ad})\cos B \sin T\, dL_1 - \{(R/S_{ad})\cos T + (N/2S_{ad})\sin B \times \sin T \Delta L\}\, dB_1 + (N - S_{ad})\cos B \sin T\, dL_2 + \{(R/S_{ad})\cos T - (N/2S_{ad})\sin B \sin T \Delta L\}\, dB_2 + (S_{ad} - S_{ob})/S_{ad}$$

(2) Observation equation of azimuth

$$V_{(r)} = -\cos B\{(N/S_{ad})\cos T - (1/2)\tan B\}\, dL_1 + \{(R/S_{ad})\sin T - (N/2S_{ad}) \times \sin B \cos T \Delta L\}\, dB_1 + \cos B\{(N/S_{ad})\cos T - (1/2)\tan B\}\, dL_2 - \{(R/S_{ad})\sin T + (N/2S_{ad})\sin B \cos T \Delta L\}\, dB_2 + (T_{ad} - T_{ob})$$

where

(B_1, L_1), (B_2, L_2) :Final B, L coordinate values of two points (1, 2)

(B_1', L_1'), (B_2', L_2'): Assumed B, L coordinate values of two points (1, 2)

(dB_1, dL_1), (dB_2, dL_2) : Correction for assumed values

R, N :Radius of curvature in meridian and in prime vertical at latitude B

S_{ad}, T_{ad}: Distance and azimuth between assumed two points

S_{ob}, T_{ob} : Observed distance and azimuth

$$B=(1/2)(B_1'+B_2') \qquad \Delta L=L_2'-L_1' \qquad T=(1/2)(T_1+T_2)$$

$$dL_1=L_1-L_1' \qquad dB_1=B_1-B_1' \qquad dL_2=L_2-L_2' \qquad dB_2=B_2-B_2'$$

(3) Calculation of assumed values

1) Assumed values of latitude, longitude

Formula used for 3rd class or the following formula

$$B_2'=B_1'+S\cos T_1'/R_1$$

$$L_2'=L_1'+S\sin T_1'/(N_1\cos B_1')$$

2) Assumed values of distance, azimuth

$$S\sin T=(\Delta L\cos B)(N/\rho)\{1-(1/24\rho^2)\Delta L^2\sin^2 B+b^2/24\rho^2)$$
$$(1+\eta^2-9\eta^2\tan^2 B)/V^4\}$$

$$S\cos T=(bR/\rho)\{1-(1/24\rho^2)\Delta L^2\cos^2 B(2+3\tan^2 B+2\eta^2)-(b^2\eta^2/8\rho^2)$$
$$(\tan^2 B-1-\eta^2-4\eta^2\tan^2 B)/V^4)$$

$$\Delta T=\Delta L\sin B\{1+(1/12\rho^2)V^2\Delta L_2\cos^2 B+(b^2/24\rho^2)(3+8\eta^2+5\eta^4)/V^4\}$$

$$T_1=T-\Delta T/2 \qquad T_2=T+\Delta T/2\pm 180$$

$$B=(1/2)(B_1'+B_2') \qquad \Delta L=L_2'-L_1' \qquad b=B_2'-B_1'$$

$$\eta^2=\{e^2/(1-e^2)\}\cos^2 B \qquad V^2=(1-e^2\sin^2 B)/(1-e^2)$$

(4) Weight of observation equation

1) Weight of direction angle (observation equation) are 1 for 2 sets observation.

Weight (observation equation) for fixed direction is 1.

2) Weight of observation equation of distance

$$P_s=(m_i^2\cdot S_{ij}^2)/(m_s^2+\gamma^2 S_{ij}^2)\rho''^2$$

where m_s : S.D. of distance measurement not proportional to length

γ : Coefficient of distance measurement proportional to length

m_i : S.D. of direction angle observation for 1 direction

8. TRANSFORMATION FORMULA FROM GEODETIC COORDINATES (B, L) TO PLANE RECTANGULAR COODINATES(X, Y)

$$X/m_0 = M + (N/2)\sin B\cos B(\Delta L/\rho'')^2 + (N/24)\sin B\cos^3 B(5-\tan^2 B+9\eta^2 + 4\eta^4)(\Delta L/\rho'')^4 + (N/720)\sin B\cos^5 B(61-58\tan^2 B+\tan^4 B+270\eta^2 - 330\tan^2 B\cdot\eta)(\Delta L/\rho'')^6 + \cdots\cdots$$

$$Y/m_0 = N\cos B(\Delta L/\rho'') + (N/6)\cos^3 B(1-\tan^2 B-\eta^2)(\Delta L/\rho'')^3 + (N/120)\cos^5 B(5-18\tan^2 B+\tan^4 B+14\eta^2-58\tan^2 B\eta^2)(\Delta L/\rho'')^5 + \cdots\cdots$$

$$\gamma/\rho = \Delta L\sin B + (1/3)\sin B\cos^2 B(1+3\eta^2+2\eta^4)(\Delta L/\rho'')^3 + (1/15)\sin B\cos^4 B(2-\tan^2 B)(\Delta L/\rho'')^5 + \cdots\cdots$$

$$M = a\{\{1-(1/4)e^2-(3/64)e^4-(5/256)e^6-(175/16384)e^8\}(B/\rho'') - \{(3/8)e^2+(3/32)e^4+(45/1024)e^6+(105/4096)e^8\}\sin 2B + \{(15/256)e^4+(45/1024)e^6+(525/16384)e^8\}\sin 4B - \{(35/3072)e^6+(175/12288)e^8\}\sin 6B + \{(315/131072)e^8\}\sin 8B\}$$

B : Latitude of transformation point

N : Radius of curvature in prime vertical at latitude B

ΔL : Difference of longitude from the central meridian

M : True meridian distance of a point on the parallel of lutitude B from equator

$\eta^2 = \{e^2/(1-e^2)\}\cos^2 B$

$e^2 = (a^2-b^2)/a^2$

9. CALCULATION OF HEIGHT AND NET ADJUSTMENT

(1) Calculation of height difference

$$h = H_2 - H_1 = S \tan\{(1/2)(Z_2 - Z_1)\}\{1 + (H_1 + H_2)/2\gamma\}$$
$$= S\{\tan(1/2)(\alpha_1 - \alpha_2)\}\{1 + (H_1 + H_2)/2\gamma\}$$
$$\alpha_1 = 90^\circ - Z_1$$

where H_1, H_2 : Height of given and proposed point

h : Height difference

Z_1, α_1 : Zenith distance and vertical angle (altitude) at given point

Z_2, α_2 : Zenith distance and vertical angle (altitude) at proposed point

γ : Mean radius of curvature at mean position

(2) Adjustment computation of elevation

1) Observation equation

$$V = [\rho''\cos^2\{(1/2)(\alpha_1' - \alpha_2')\}/s][dh_2\{1 - (H_2'/\gamma)\} - dh_1\{1 - (H_1'/\gamma)\}]$$
$$+ \{(1/2)(\alpha_1' - \alpha_2') - (1/2)(\alpha_1 - \alpha_2)\}$$

where H_1, H_2 : Most provable height values of two points (1, 2)

H_1', H_2' : Assumed height values of two points (1, 2)

dh_1, dh_2 : Correction for assumed values

α_1', α_2' : Vertical angle between assumed two points

α_1, α_2 : Observed vertical angle between two points reduced to center of monument

2) Calculation of assumed values of vertical angle

$$(1/2)(\alpha_1' - \alpha_2') = \tan^{-1}[\{(H_2' - H_1')/S\}\{1 - (H_1' + H_2')/2\gamma\}]$$

10. LEVELING COMPUTATION

(1) Computation of orthometric correction

$$K = 5.30 \sin 2B \frac{B_1 - B_2}{\rho'} H$$

where K : Orthometric correction value in mm

B_1, B_2 : Latitude of beginning point and arrival point in minute

B : $(B_1 + B_2)/2$

H : Mean height of leveling route in m

(2) S.D. of leveling

$$m = \pm\sqrt{\frac{1}{4}\left[\frac{U_i^2}{S_i}\right]\frac{1}{n}}$$

where

m : S.D. of observation per km

U_i : Discrepancies of double running between each route (BM to BM)

S_i : Distance of each route (BM to BM)

n : Numbers of routes

(3) Net adjustment of leveling by mean of observation equation

1) Observation equation

$V(h) = -x_i + x_j - (h_i - h_j + \Delta h) \cdots\cdots$ Weight P

where h_i, h_j : Assumed height of B.M (i, j)

x_i, x_j : Correction for assumed value

Δh : Height difference between two B.M (i, j)

Weight $(P) = 1/S$ S : in km

2) S.D. of observation of unit weight

$$M = \pm\sqrt{[Pvv]/(m-n)}$$

3) S.D. of junction point (unknown point x_i)

$$M_{xi} = M/\sqrt{P_{xi}}$$

where m : Numbers of observation equation

n : Numbers of unknown

v : Residual by least square solution

11. CALCULATION OF CROSS SEA (RIVER) LEVELING

(1) Reciprocal leveling computation

$$\frac{\sum_1^n a}{n} - \frac{\sum_1^n b}{n} = \Delta H$$

where a: Reading value at instrument side

b: Reading value at staff side

n: Number of measures

ΔH: Height difference

(2) Tilting screw method with level computation

$$\Delta H = l - l_0$$

$$l_0 = l_1 + (l_2 - l_1)\frac{m_0 - m_1}{m_2 - m_1}$$

where

l_1, l_2 : Reading of staff of position of lower and topper target plate

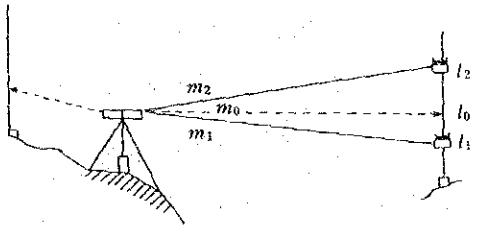
m_1, m_2 : Reading of tilting micrometer for two target

m_0 : Reading of tilting micrometer at coincidence of bubble

l : Reading of back sight staff (instrument side) at coincidence of bubble

l_0 : Reading of fore sight staff (staff side) at coincidence of bubble (m_0)

ΔH : Height difference



12. CALCULATION FORMULA FOR ASTRONOMICAL LATITUDE, LONGITUDE AND AZIMUTH

(1) Calculation of latitude and longitude (by Astrolabe)

$$\sin H = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos h$$

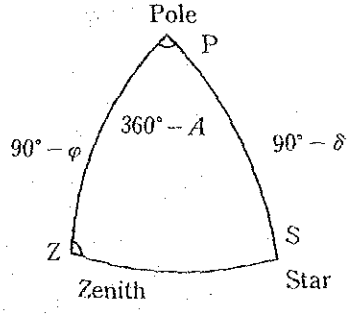
$$\cos H \cos A = \sin\delta \cos\varphi - \sin\varphi \cos\delta \cos h$$

$$\sin A \cos H + \cos\delta \sin h = 0$$

H : Altitude of star

δ : Right ascension of star

φ : Latitude of observation



h :Hour angle of star

$h = Ⓗ - \alpha$

Ⓗ :Local sidereal time

α : Declination of star

$Ⓗ = Ⓗ_0 + \lambda + (T - \triangle t) + m + S$

$Ⓗ_0$: Greenwich local siderial time of UT = 0

T : Observed time (local standard time)

m :Correction for sidereal time (hour, minute)

S :Correction for sidereal time (second)

λ : Longitude of observation station

$\triangle t$:The difference between Greenwich standard time and local standard time

(2) Latitude observation (by universal theodolite)

$\cos Z = \sin\delta \sin\varphi + \cos\delta \cos h \cos\varphi$

Z : Zenith distance of star

δ : Right ascension of star

h :Hour angle of star

φ : Latitude of observation station

(3) Longitude observation (by universal theodolite)

$\lambda = Ⓗ - Ⓗ_G$

$Ⓗ = \alpha + h$

$Ⓗ_G = Ⓗ_0 + (T - \triangle t) + m + S$

λ : Longitude of observation station

Ⓗ : Local sidereal time

$Ⓗ_G$: Greenwich sidereal time

α : Right ascension of star

h :Hour angle of star

$\textcircled{H}_0$: Greenwich sidereal time at UT = 0

T: Local standard time at observation

Δt : The difference between Greenwich standard time and local standard time

m : Correction for sidereal time (hour, minute)

S : Correction for sidereal time (hour, sec)

(4) Azimuth computation (by Polaris observation)

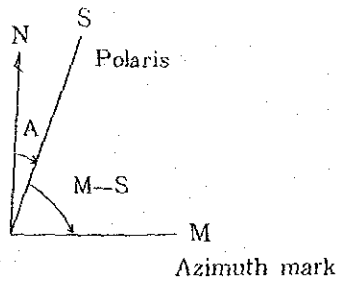
$$\cot A = \sin\varphi \cot h - \cos\varphi \operatorname{cosec} h \tan\delta$$

A : Azimuth of Polaris

φ : Latitude of observation station

h : Hour angle of Polaris

δ : Right ascension



$$A_m = A + (M - S)$$

A_m : Azimuth of azimuth mark

$(M-S)$: Horizontal angle between Polaris and azimuth mark

(5) Azimuth computation (by two stars observation)

$$\cot A_1 = \sin\varphi \cot h_1 - \cos\varphi \operatorname{cosec} h_1 \tan\delta_2$$

$$\cot A_2 = \sin\varphi \cot h_2 - \cos\varphi \operatorname{cosec} h_2 \tan\delta_2$$

$$A_{m_1} = A_1 + (M - S_1)$$

$$A_{m_2} = A_2 - (S_2 - M)$$

$$A_m = \frac{1}{2}(Am_1 + Am_2)$$

A_1, A_2 : Azimuth of two stars (1, 2)

φ : Latitude of observation station

h_1, h_2 : Hour angle of two stars (1, 2)

δ_1, δ_2 : Right ascension of two stars (1, 2)

A_{m_1}, A_{m_2} : Azimuth of azimuth mark

$(M-S_1)$: Horizontal angle between mark and star (1)

$(S_2 - M)$: Horizontal angle between mark and star (2)

A_m : Azimuth of azimuth mark by two stars observation