

ASSOCIATION INTERNATIONALE DE GÉODÉSIE

**BUREAU GRAVIMÉTRIQUE
INTERNATIONAL**

N° 17

Bulletin d'Information

Décembre 1967

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I N T E R N A T I O N A L

Paris

B U L L E T I N D ' I N F O R M A T I O N

Décembre 1967

N°17

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ERRATUM : p.9, 2nd line, read p.11 instead of p.6,

Compte-Rendu des séances de la Section IV : GRAVIMETRIE
de l'A.I.G.

Lucerne, 25 Septembre - 7 Octobre 1967

La XIVème Assemblée Générale de l'U.G.G.I. s'est tenue en Suisse, dans différentes localités : Zurich, Berne, Lucerne et St-Gall.

L'Association Internationale de Géodésie (A.I.G.) s'est réunie à Lucerne ; toutes les séances ont eu lieu à l'Ecole Cantonale, Alpen Quai 46.

La Section IV a tenu 7 réunions auxquelles il faut joindre quelques réunions de groupes d'études pour l'établissement du Réseau Gravimétrique Mondial.

Bureau de la Section IV :

Président : Dr. D.A. RICE
Secrétaires : Prof. W. GROSSMANN
Dr. S. CORON

Ordre du jour

Mardi 26 Septembre : 15.50 - 17.15

Adresse présidentielle ; programme :	D. A. RICE
A propos du "Rapport Général des mesures relatives de la pesanteur" :	S. CORON
Activité du Bureau Grav. Int., Paris :	

Mesures absolues de la pesanteur (I), Président : Dr. A.H. COOK

Détails sur les appareils et les résultats : SAKUMA, HYTONEN

Formule Internationale de la Pesanteur et	
Système de Potsdam, exposé du problème :	COOK

Mercredi 27 Septembre : 9.15 - 10.40

Mesures absolues de la pesanteur (II)

Discussion sur la Formule Internationale... :

COOK, TERRIEN, UOTILA, BUSCHMANN, HIRVONEN, SZABO, LEVALLOIS, VEIS, KOVALEVSKY, BJERHAMMAR, CULLEY, CORON, MARUSSI, PELLINEN, WHALEN.

Quelques détails sur les expériences en cours : BUSCHMANN, ROSE.

Jeudi 28 Septembre : 9.15 - 10.40

Réseau Gravimétrique Mondial (I), Président : Prof. C. MORELLI
 Mesures pendulaires... :
 HONKASALO, BROWNE, OKUDA, BUSCHMANN, HEIFETZ.

Vendredi 29 Septembre : 9.15 - 10.40

Réseau Gravimétrique Mondial (II)
 Mesures pendulaires... : BOULANGER
 Mesures au gravimètre... : MORELLI, WHALEN, McCONNEL,
 McCAHAN, RICE, CORON.
 Lignes d'étalonnage, Europe - Afrique : SOLAINI
 Ouest - Pacifique: OKUDA

Lundi 2 Octobre : 10.50 - 12.15 et 15.50 - 17.15

Mesures de pesanteur en mer (I), Président : Dr. J.L. WORZEL
 Appareils et résultats : HAYWORTH, FLEISCHER, TALWANI,
 BROWNE, HENDERSON, McCAHAN, HEIFETZ.
Mesures de pesanteur en mer (II)
 Appareils et résultats (suite) : VESELEV, WING, TSUBOKAWA,
 COLLETTE (LAGAAY), CERRATO, TANNER, MORELLI, STRANG van HEES, MURT.

Mercredi 4 Octobre : 9.15 - 10.40

Réseau Gravimétrique Mondial (III) : MORELLI
 Compensation
 Résolutions : COOK, BOULANGER
 Variation de pesanteur en Scandinavie : HONKASALO
 Quelques vues sur l'équipement de campagne (APCS) : WHALEN

Mercredi 4 Octobre : 15.50 - 17.15

Mesures de pesanteur en avion, Président : Dr. O WILLIAMS
 Problèmes techniques... : SZABO, MORITZ, ANTHONY, TAYLOR
 Conclusion... : RICE

Le Compte-Rendu détaillé, relatif à chacun des groupes d'études énumérés ci-dessus, est donné dans les pages suivantes. La liste des communications présentées ou distribuées n'a pas été mentionnée à nouveau ; on se reportera soit au Bull. Inf. n°16, soit à la publication spéciale du Bureau Central de l'A.I.G. où ont été résumées toutes les communications annoncées.

- I -

VUES D'ENSEMBLE

Au début de la 1ère séance, le Dr.D. RICE, Président de la Section IV, adresse un mot de bienvenue aux délégués et indique les grandes lignes de l'ordre du jour.

Dr. S. CORON qui avait été chargée antérieurement d'établir le "Rapport général sur les mesures relatives de l'intensité de la pesanteur sur terre", fait un bref commentaire à ce sujet.

Elle souligne que ce rapport ne peut plus être comme à l'origine une suite de tableaux d'observations, mais un rapport de synthèse qui a pour but de servir d'introduction à l'ensemble des Rapports Nationaux*, de souligner les travaux d'intérêt général ou de conception nouvelle. Malheureusement, avant la réunion de l'UGGI, elle a reçu trop peu de réponses et souvent des renseignements trop incomplets pour lui permettre de donner une vue générale des travaux réalisés durant la période 1963-1967.

Elle précise d'autre part, qu'une circulaire avait été envoyée à une centaine de personnes pour leur demander si l'établissement d'un tel rapport présentait toujours un intérêt et si sa publication devait être maintenue telle qu'elle. D'après les réponses, il semble que ce rapport doive être abandonné.

Dr. S. CORON, à la place du Prof. P. TARDI, Directeur du Bureau Gravimétrique International, résume rapidement l'activité de ce Bureau.

En particulier, elle présente la carte des Anomalies de Bouguer Europe - Afrique récemment mise à jour ainsi que les Bulletins d'Information établis au BGI.

Elle remercie tous ceux qui apportent leur collaboration au BGI en vue du rassemblement ou de la diffusion des résultats gravimétriques et insiste sur la nécessité d'une meilleure uniformité dans la publication des données.

A la fin de ce compte rendu Dr. D. RICE demande que ce Rapport d'activité soit publié dans le Bulletin Géodésique (voir ci-après le texte français).

La 2ème partie de la séance est consacrée aux Mesures Absolues (voir p. 12).

* RAPPORTS NATIONAUX distribués à Lucerne

Allemagne Démocratique	Grande-Bretagne	Roumanie
Allemagne Fédérale	Grèce	Suède
Argentine	Iran	Suisse
Autriche	Irlande	Tchécoslovaquie
Belgique	Israël	Thaïlande
Canada	Japon	Turquie
Espagne	Nouvelle-Zélande	URSS
Etats-Unis	Pays-Bas	Yougoslavie
France	Pologne	

Activité du
BUREAU GRAVIMÉTRIQUE INTERNATIONAL - PARIS -

1963 - 1967

Au cours de ces dernières années, le Bureau Gravimétrique International (B.G.I.) s'est efforcé d'être un organisme de liaison entre les gravimétristes du monde entier, en essayant de rassembler tous les articles concernant l'étude de la pesanteur et de diffuser au mieux et le plus rapidement possible les informations reçues. Son activité peut se résumer sous les 2 rubriques suivantes :

- A - Centralisation des données gravimétriques
- B - Information et distribution

A - CENTRALISATION DES DONNEES GRAVIMÉTRIQUES

1) CARTES PERFOREES (voir Bull. Inf. n°5 et 11)

En 1962 (Paris, voeu n°14) la Commission Gravimétrique Internationale avait chargé le B.G.I. d'établir un modèle de cartes perforées destinées à l'archivage des données gravimétriques.

La Commission souhaitait :

- que le plus grand nombre de renseignements soient indiqués sur ces cartes,
- que le relevé puisse être fait simplement.

Afin de remplir ces conditions, deux cartes ont été adoptées pour chaque observation gravimétrique (carte Index et carte Complémentaire).

En 1963 (Berkeley, voeu n°26) l'A.I.G. approuva les 2 modèles proposés en réservant une décision ultérieure sur quelques détails de la carte complémentaire dont certaines colonnes devaient être revues et complétées.

Ces compléments n'ont pas encore été apportés : il reste 6 colonnes inutilisées (col. 27 - 32) dont 4 destinées à une information géologique. Il n'a pas encore été possible de faire l'unanimité sur la classification des données géologiques à mettre sous cette rubrique. Cette question devra être reconsidérée.

Nombre de cartes perforées :

A l'heure actuelle, le B.G.I. possède :

	"Index cards"	"Complementary cards"
Mesures en mer	26.883	6.883
Mesures continentales	79.730	38.334

Ces dernières mesures s'étendent sur 28 pays.

Les sources de ces données gravimétriques sont les suivantes :

- publications : jusqu'à ce jour, 645 publications ont été dépouillées; 157 ont fourni des listes de stations, les autres ont permis d'obtenir des informations concernant les bases des réseaux nationaux, l'homogénéité des réseaux dans un système mondial uniforme (mesures et réductions à un système de référence unique),
- listes de données communiquées personnellement par les Services Nationaux,
- duplicata de cartes perforées.

Nous tenons à remercier tous les Pays ou Services qui ont bien voulu aider le B.G.I. en lui donnant des détails sur les publications ou en lui communiquant des résultats non encore publiés (listes ou cartes perforées) ; ce sont en particulier : l'Argentine, le Canada, le Danemark, les Etats-Unis, la Grande-Bretagne, l'Irlande, l'Islande, la Norvège, la Nouvelle-Zélande.

Code des "stations spéciales"

Comme on l'a écrit dans le Bull. Inf. n°11 (p.26)

- les colonnes 40 - 46 (Index card) sont réservées pour donner une information (emplacement et valeur de g) sur la station de référence à laquelle se rattache la station considérée,
- les colonnes 47 - 53 (Index card) sont réservées pour donner une information sur l'étalonnage, c'est-à-dire, sur une autre station présentant une différence de g assez grande par rapport à la station précédente (ou sur une chaîne d'étalonnage).

Le code de ces "stations spéciales" a été fait en collaboration avec les Services Géodésiques Nationaux qui ont bien voulu choisir eux-mêmes les normes du code, et en collaboration avec le Groupe d'Etudes n°5.

La liste de ces différents codes paraîtra dans un prochain Bulletin.

- (Le B.G.I. attire l'attention sur le fait qu'il est parfois très
 (difficile de découvrir dans les publications les données de ces "stations
 (spéciales", aussi il souhaite qu'avant chaque liste de résultats gravi-
 (métriques soient clairement indiquées :
- (- la station de référence, avec la valeur de g adoptée en ce point,
 - (- une station pouvant servir comme information d'étalonnage.

Uniformité des données gravimétriques

- Afin d'éviter un travail long et fastidieux, le B.G.I. recommande :
- que toutes les mesures de longueur soient exprimées en mètres,
 - que les coordonnées soient exprimées en degrés, minutes sexagésimales et fractions de minutes (au lieu de secondes),
 - qu'enfin, seul le méridien international de Greenwich soit utilisé.

Echange de données

Le B.G.I. peut, en principe, reproduire et fournir aux pays qui en font la demande, les données mises sur cartes perforées dans la mesure de ses possibilités (et après remboursement des frais engagés par lui pour ce travail de reproduction).

Cependant, les données non encore publiées officiellement par certains pays ne seront reproduites et fournies qu'avec l'accord du Pays (ou du Service) intéressé.

2) BIBLIOTHEQUE

Le B.G.I. continue l'archivage des publications sous la forme classique de fiches ; plus de 3.500 articles sont classés par auteur et discipline. La bibliothèque comprend aussi :

- une "cartothèque" où sont classées des cartes d'anomalies par espèce et par pays,
- et une "schématèque" qui rassemble les schémas des emplacements gravimétriques. Ces schémas sont rangés suivant la classification du B.G.I., par carreau de 10° x 10° et à l'intérieur par degré de latitude et de longitude (code p.32 du Bull. Inf. n°5).

A l'heure actuelle, il y a environ 2.600 schémas ainsi classés, avec différenciation pour les ports et les aéroports.

La liste de ces schémas a fait l'objet d'une publication spéciale (Bulletin d'Information n°15) ; étant donné l'intérêt porté à cette liste, le B.G.I. a publié sans attendre un 1er additif (Bull. Inf. n°16) pour faciliter la coordination entre les codes utilisés par les observateurs. Il est prévu de publier régulièrement des additifs et rectificatifs.

B - INFORMATION ET DISTRIBUTION

- 1) Le B.G.I. a poursuivi la publication du Bulletin d'Information. Depuis 1963, 12 Bulletins ont paru (voir annexe p.6).

En outre, à l'occasion de la réunion de la Commission Gravimétrique Internationale (Paris, Septembre 1965) on a établi une "Bibliographie relative aux problèmes d'étalonnage des gravimètres et au Réseau International de 1er Ordre" (20 p., 198 articles).

- 2) Le B.G.I. a publié quelques cartes d'anomalies de la pesanteur suivant le mode de présentation antérieurement adopté. Toutefois, ce travail d'ensemble n'a pas été très poussé car la collection des cartes au 1/1.000.000 peut difficilement être étendue aux régions de l'Europe Orientale et il a semblé préférable d'attendre encore quelques mois avant de publier les cartes générales de l'Océan Atlantique, étant donné les nombreuses croisières gravimétriques faites durant ces dernières années.

- Cartes au 1/1.000.000 (anomalies de Bouguer)
 - Feuilles de Berlin et Vienne (1963), Bull. n°6
 - Feuilles d'Oslo et de Budapest (1964-65), Bul. n°10
 - Feuilles de Rabat et Laghouat (en préparation)

- Cartes à l'échelle approximative du 1/10.000.000
 - Carte des anomalies de Bouguer (Europe - Afrique)
 - 1ère édition 1964, Bull. n°7
 - 2ème édition 1967

- Cartes des anomalies en mer (Océan Atlantique)

anomalies à l'air libre	)	en préparation
anomalies de Bouguer (non "modifiées")	)	

Ces dernières cartes ont été préparées conformément au désir exprimé à la C.G.I. (1965) : une carte pour chaque sorte d'anomalie. Pour les mesures pendulaires, on a indiqué les valeurs des anomalies à chaque point, sur les profils des mesures en surface, on a seulement différencié les zones d'anomalies positives et négatives en indiquant les valeurs relatives maximales et minimales. Les courbes isanomales sont tracées dans les régions où les résultats sont suffisamment nombreux.

- 3) Le B.G.I. a envisagé la préparation de cartes générales (ou tableaux) de valeurs moyennes des anomalies de la pesanteur.

Les 3 séries de cartes envisagées sont les suivantes :

- a - cartes d'anomalies moyennes de Bouguer
- b - cartes d'anomalies moyennes à l'air libre
- c - cartes d'altitudes moyennes.

D'une manière générale, ces valeurs moyennes sont reportées par degré carré (ou 1/4 de degré lorsque la précision des documents le permet et à l'exception des latitudes élevées) sur les feuilles de la Carte Générale du Monde (tirée de la carte générale bathymétrique de Monaco), carte à l'échelle approximative de 1/10.000.000 à l'équateur déjà utilisée comme support pour les cartes d'isanomales.

Les valeurs moyennes de Bouguer sont la reproduction de valeurs moyennes déjà calculées par les Services Géodésiques Nationaux ou sont extraites de cartes avec courbes isanomales.

Les valeurs moyennes à l'air libre sont évaluées pour chaque carreau indirectement à partir des valeurs moyennes de Bouguer et des altitudes moyennes. C'est pour cette raison que la série des cartes c - a été considérée. En dehors des cartes nationales existantes (voir liste Bull. Inf. n°5), les évaluations sont faites sur des cartes géographiques au 1/1.000.000 et en mer sur les "plotting sheet" de la même échelle.

(Mais ce dernier travail nécessite pour le calcul indirect des
(anomalies à l'air libre reste en dehors de l'activité normale du B.G.I.
(et fait peut-être double emploi avec des cartes déjà existantes, non
(publiées. Il est donc demandé que les cartes d'altitudes moyennes qui
(auraient pu être établies par d'autres Services, soient portées à la
(connaissance du B.G.I. L'établissement de telles cartes a d'ailleurs
(été recommandé à la dernière Assemblée Générale (Berkeley, vœu n°31).

Une première carte provisoire s'étendant sur l'Europe, le Nord de l'Afrique et l'Océan Atlantique (28°-65°N - 25°E.G. - 33°W.G. environ) a été commencée respectivement pour les anomalies moyennes de Bouguer et les anomalies moyennes à l'air libre. Toutefois, elle ne pourra être publiée que lorsque les récentes mesures de pesanteur en mer auront pu être incluses.

Le B.G.I. tient à remercier tous les Géodésiens et Géophysiciens qui lui communiquent rapidement les résultats de leurs travaux gravimétriques ou qui lui font part de leurs projets ou de toute information d'intérêt général. Il ne peut évidemment utiliser, classer et diffuser que les données qui lui sont fournies par les différents pays appartenant à l'A.I.G. il y a pour chacun d'eux un devoir de collaboration dans l'intérêt général qui ne doit pas être perdu de vue.

Le B.G.I. est à la disposition de la Commission Gravimétrique Internationale pour exécuter les travaux que les délégués signaleraient comme utiles ou les plus urgents : aussi, il serait heureux de connaître toutes suggestions des délégués.

Prof. P. TARDI

Dr. S. CORON

BULLETINS D'INFORMATION

N°5, Décembre 1963, 56 p.

- Compte-rendu de la XIIIème Assemblée Générale de l'U.G.G.I.
Berkeley 1963.
- Texte définitif relatif à l'archivage des données gravimétriques.
- Liste des cartes d'altitudes moyennes d'Europe et d'Afrique

N°6 et 7, cartes (voir par. B.2)

N°8, Février 1965, 59 p.

- Préparation de la Commission Gravimétrique, Paris 1965.
- Bibliographie : Mesures en mer.

N°9, Juillet 1965, 67 p.

- Bibliographie : Mesures absolues de la pesanteur
 - : Problèmes d'étalonnage des gravimètres,
 - : Réseau International de Premier Ordre
 - : Variation séculaire de la pesanteur
 - : Mesures du gradient vertical de la pesanteur.
- Traduction d'un article russe "Etalonnage des gravimètres à quartz".
(1ère partie)

N°10, cartes (voir par. B.2)

N°11, 12 et 13, Novembre 1965 (76 p.), Février 1966 (72 p.), Juin 1966 (80 p.)

- Compte-rendu de la Commission Gravimétrique, Paris, Septembre 1965.
- Dans le Bull. Inf. n°12, fin de la traduction de l'article russe.

N°14, Novembre 1966, 70 p.

- Bibliographie : Mesures en mer.
- Carte récapitulative de mesures récentes.

N°15, Février 1967, 128 p.

- Répertoire des stations gravimétriques, "schémathèque" B.G.I.

N°16, Juin 1967, 71 p.

- Informations diverses concernant l'Assemblée Générale de l'U.G.G.I.,
(Section IV de l'A.I.G., Lucerne, Septembre 1967).
- Premier additif au Bull. Inf. n°15.

- II -

ABSOLUTE GRAVITY MEASUREMENTS

Two meetings were held on :

- Tuesday, September 26th at 3.50 p.m.
- Wednesday, September 27th at 9.15 a.m.

FIRST MEETING

Dr. A.H. COOK, Chairman of Special Study Group n°4.18 "Absolute Gravity Measurements" summarized his General Report which was distributed at each delegate.*

He reminded absolute determinations completed since 1940 or in progress (see p.19) and called particular attention on the last completed determinations :

- National Bureau of Standards, Washington, D.C.
- National Physical Laboratory, Teddington (NPL)
- Bureau International des Poids et Mesures, Sèvres (BIPM)

He emphasized the particular advantages of the symmetrical free motion determination in which an object is thrown up vertically and is timed at its successive crossings of 2 horizontal planes separated by a distance H. Let the time interval between the upward and downward passages across the lower plane Δt_1 and let that between the corresponding passages across the upper plane be Δt_2 :

$$g = \frac{8 H}{(\Delta t_1)^2 - (\Delta t_2)^2}$$

- The time intervals are between passages across the same planes and therefore at the same velocities so that the duration of the 2 signals that define a time interval are the same ; in consequence the time constants of the apparatus are only required to remain unchanged during the flight of the object.
- The measured acceleration is independant of resistive forces to first order, provided that forces are proportional to the velocity of the moving body (this has been verified over a large wide range of air pressure).

It is now possible to think of results with uncertainties of about 0.1 mgal only.

Dr. A.H. COOK mentioned the recent value obtained in the NPL, (reduced to the British Fundamental Gravity Station) :

981.181,75 mgal with a standard deviation of ± 0.13 mgal

*This Report will be fully published in "Travaux de l'Association Internationale de Géodésie, t.23".

Then, he pointed out that "the most satisfactory feature of the recent observations is the good agreement between the results obtained at the NPL and at the BIPM. It is unfortunately still difficult to make reliable comparisons between Europe and America but it seems that FALLER's result agrees with COOK and SAKUMA while TATE's is somewhat higher. It may be that there is a systematic feature of the experiments in that those free-fall experiments made with rods (THULIN, PRESTON-THOMAS, TATE) give results significantly above those made with moving bodies that optically are effectively points (FALLER, COOK, SAKUMA). The former group gives for the mean difference from Potsdam $-12,7 \pm 0,6$ mgal while the latter gives $-13,8 \pm 0,04$ mgal". (see p. 20).

Dr. A. SAKUMA a présenté une note sur : NOUVELLE VALEUR PROVISOIRE
DE LA PESANTEUR AU BUREAU INTERNATIONAL DES POIDS ET MESURES,
SEVRES

"Une cinquantaine de mesures absolues de g ont été effectuées en août et septembre 1967, dans des conditions de mesure variées pour déceler les causes d'erreurs systématiques éventuelles. Aucun effet important n'a pu être mis en évidence.

La valeur la plus probable résultant de ces mesures est :
 $g_{A2} = 9,809\,256\,75 \text{ m/s}^2$ au point de mesure dit "Point A2" déterminé par rapport à SEVRES Point "A", sa cote est $+1,02 \text{ m}$ et sa distance $5,5 \text{ m}$ à l'ouest dans la salle de gravimétrie. La dispersion relative maximale a été de $\pm 1 \times 10^{-8}$ pendant le mois d'août, période la plus favorable quant à l'agitation du sol.

En admettant, pour le moment, une différence de g entre Point A2 et Point A de $3,00 \times 10^{-6} \text{ m/s}^2$, on obtient comme nouvelle valeur provisoire :

$$g_{\text{SEVRES POINT A}} = 9,809\,259\,75 \text{ m/s}^2$$

avec une incertitude estimée à $\pm 3 \times 10^{-7} \text{ m/s}^2$, la partie principale de cette incertitude provient actuellement de la liaison gravimétrique entre ces deux points.

Cette valeur de g est inférieure à celle admise dans le système de Potsdam (A.H. COOK, Metrologia, v.1, n°3, p.113) de $13,785 \times 10^{-5} \text{ m/s}^2$.

Les causes principales d'erreurs systématiques suivantes ont été étudiées :

a) Freinage par l'air résiduel :

On a étudié cet effet par comparaison des durées de montée : T_m , et de descente : T_d ($0,2 \text{ s}$ environ) du trièdre lancé en parcourant "deux stations". La différence : $\Delta T = T_d - T_m$ a été trouvée fonction linéaire de la pression dans le domaine exploré de $P = 4 \times 10^{-4} \text{ N/m}^2$ à $0,1 \text{ N/m}^2$.

On a trouvé :

$$(\Delta T_p - \Delta T_o)(\text{ns}) = 1,3_2 \times 10^4 P(\text{N/m}^2)$$

ΔT_o , obtenu par extrapolation à la pression nulle, sur 25 mesures, s'est avéré égal à $5,3 \text{ ns} \pm 0,5 \text{ ns}$ (écart quadratique moyen). ΔT_o peut donc être attribué à la vitesse de la lumière parcourant une distance de $4 l = 1,6 \text{ m}$ * (1 : distance entre les deux stations). Ceci nous permet de penser que le freinage par courants de Foucault induits dans le bâti métallique du trièdre dû aux inhomogénéités du champ magnétique terrestre ou du champ produit par les appareils de mesure, est ici négligeable.

Dans tout le domaine de pression exploré, la valeur de g déduite des mesures reste indépendante de la pression grâce à l'observation symétrique (montée et descente) du trièdre lancé, bien que le freinage par l'air introduise une accélération parasite pouvant atteindre, sur notre montage, environ $5 \times 10^{-5} \text{ m/s}^2$ pour $P = 0,1 \text{ N/m}^2$ lorsque le trièdre a une vitesse de 1 m/s qui est celle du corps après 5 cm de chute libre.

b) Distance entre deux stations

Cette distance (40 cm environ) est déterminée comme la moitié exacte de la longueur d'un des deux étalons de référence en silice fondue qui sont placés dans un caisson à vide. Ces étalons sont mesurés directement par la raie étalon primaire du krypton 86, avant et après la mesure de g . La précision de ces mesures est considérée comme supérieure à 5×10^{-9} en valeur relative et aucune différence significative n'a été observée entre les valeurs de g obtenues avec ces deux étalons de longueur. Une erreur d'une unité sur l'ordre d'interférence pour un des étalons aurait fait apparaître une différence d'environ $3 \times 10^{-6} \text{ m/s}^2$ sur la valeur de g . Ainsi une telle erreur de la détermination de la longueur semble extrêmement peu probable.

c) Charge électrostatique

Cette étude n'est pas encore terminée mais on a déjà constaté qu'il n'y a pas sur le trièdre tombant dans le vide de charges électrostatiques dépassant quelques 10^{-11} C et que la capacité électrique du trièdre par rapport à la terre est d'environ 20 pF et reste constante à 1% près sur toute la longueur de la trajectoire. Par conséquent, cet effet de la charge semble devoir être négligeable. Des essais seront entrepris prochainement, en chargeant électriquement le trièdre dans sa course, pour s'assurer de ce point.

On peut espérer que la première étape de cette détermination absolue de g sera achevée à la fin de l'année 1968, avec une précision très voisine de celle de la détermination interférentielle de la longueur, et on envisage de poursuivre cette mesure comme "routine périodique" afin d'étudier la constance à long terme de g et ses variations séculaires éventuelles.

Nous ajoutons ici que l'unification du réseau gravimétrique mondial, qui est un problème très important, pourrait, semble-t-il, être réalisé avec le maximum de sécurité au moyen d'un appareil semblable à celui du BIPM et avec la collaboration et l'appui financier d'Organisations scientifiques nationales ou internationales".

* Une estimation précédente de ΔT_o : $\Delta T_o = 8 l/c = 10,7 \text{ ns}$ (Bull. Inf. n°16, p.I-6) s'est avérée inexacte, ΔT_o soit $4 l/c = 5,3 \text{ ns}$ dans le cas idéal.

Mr.E. HYTÖNEN presented a note on : PROGRESS OF THE ABSOLUTE
GRAVITY MEASUREMENT WITH LONG WIRE PENDULUM, AT THE FINNISH
GEODETTIC INSTITUTE, HELSINKI.

"Test measurements to determine the absolute gravity by the aid of a long wire pendulum have been continued. (cf. T.J. KUKKAMÄKI : Two hundred meter pendulum (Bull. Géod. 1959, n°51, p.103). The pendulum of 8 meters is installed on a wall of reinforced concrete on a rock. In order to investigate the moving of the wall caused by the temperature changes, the invar wires of 8 and 4 meters have been suspended near the fixing devices of the pendulums. The positions of the fixing device in respect to the wall are determined by means of a screw micrometer. The pendulum is mounted in a plastic tube, in which a vacuum of 1-3 torrs exists. The amplitude is read on the scale with the aid of the wire's shadow. A microscope is used for measuring the variations in length of the wire. The vertical component of terrestrial magnetism is eliminated by the Helmholtz coil. The swinging wire cuts a light beam and generates so a pulse to the electronic counter through the photomultiplier.

The swinging period has been obtained from a series taking about half an hour. Owing to the Foucault-effect and to the imperfection of the release of the body, the projection of the movement of the swinging body on the horizontal plane is an ellipse. This elliptic movement, increasing during the series, restricts the number of the oscillations of one series. The effects of torsion, of vertical vibration and of oscillation motion of the body around its suspension point are eliminated by using whole periods of these oscillations. The magnitude of the elliptic movement is measured by observing its minor axis by means of a theodolite. The amplitude decreases due to the damping of about 1 mm within 30 minutes. The observation of the microscope is made when the pendulum is swinging. The form of the pulse is observed before and after the series.

The internal accuracy of the acceleration of the gravity computed from single series was in the last experiments 3 mgal. The difference of the lengths of two pendulums determined only by a steel tape and thus the obtained gravity value is not an absolute one. In the computing of the results the following reductions have been used :

- Amplitude correction.
- Correction caused by the variation in length of wire.
- Corrections owing to inclination of the microscope and due to variations in length of its support.
- Corrections depending on the positions of the fixing device and on the movement of the wall.
- Air density correction.
- Correction due to elliptic movement.
- Correction arising from changes in direction of light beam.
- Corrections arising from conical form of the light beam directed into the photomultiplier.
- Correction due to bending moment of wire.

Many other possible sources of errors have been investigated. E.g., the form of the swinging wire deviates from a straight line, the value of the

gravity varies with height, and the pendulum is, in fact, spherical one due to the elliptic movement. The errors caused by these factors are negligible.

There are, however, some questions still partly unsolved, except ones appearing in connection with the measurement of length :

- Measurements of the swaying of the support and the effect of microseisms.
- The influence caused by the eddy-currents.
- Effect of the double pendulum.
- The rise time of the pulse increases when the pendulum becomes longer.

To get a sharp pulse the use of LASER has been planned.

The next stage will be test measurements of the length by the aid of the Vaisala-comparator. A longer pendulum will be used in the final observations, because the relative effects nearly of all errors decrease. However, the error, caused by the variations in the wire's thickness increases and has to be taken into consideration when selecting the length of the pendulum".

At the end of the first meeting Dr.A.H. COOK explained the situation concerning the problem of the International Gravity Formula and the Potsdam system (see p.21).

Some complementary details were given on the absolute determination in progress at the end of the second meeting : we mention them hereafter :

Dr. E. BUSCHMANN spoke about : ABSOLUTE GRAVITY MEASUREMENTS WHICH ARE UNDER WORK AT THE GEODETIC INSTITUTE, POTSDAM, WITH TWO APPARATUS, BOTH USING REVERSIBLE PENDULUMS.

"With the first apparatus, using pendulums of 25 cm length made of brass, continuous measurements are made since the end of 1966. The internal mean square error was found to about 2 mgal. Some systematic error occurred which are assumed to depend on different material used for the bearings and the edges, for instance, apphire, steal, glass, agate.

The second apparatus is nearly built up completely, including the device for interferometrical length measurement. Three pairs of pendulums are used made of quartz with different lengths of 37.5, 50 and 75 cm but the same mass. The vacuum was checked to be better than 10^{-4} mm mercury. Times of oscillation, phases and amplitudes will be measured by electronic devices. It is expected that the first complete test measurement can be made at the end of this year".

Dr.J.C. ROSE gave some details concerning THE ABSOLUTE GRAVITY EXPERIMENT AT THE HAWAII, INSTITUTE OF GEOPHYSICS.

"The portable absolute gravity equipment being developed, measures the acceleration due to gravity by employing a retrodirective reflector falling through a distance of 2 m.

Two methods are used for determining the rate of fall. One depends on the velocity of light and consists of a pulse recycle oscillator. A pulse of light reflected from a corner-cube and detected by a photomultiplier. The resulting electrical pulse is re-shaped by a pulse generator and returned to the light source where a new pulse of light is generated. The light source is a Gallium Arsenide semiconductor device. The recycle frequency changes from 7 to 8 Mhz during the drop. The timing system accepts the system pulses divided by 1024 and compares their occurrence with a continuously running 5 Mhz crystal clock. Approximately 4 thousand samples are obtained for each drop. These are processed by computer. The drop-tube rests on the floor of the Laboratory and the transducer assembly rests on an isolated pier flush with the floor. The gravity result is calculated from the relation :

$$g = \frac{C (T_3 - T_2) (T_3 - T_1) - (T_2 - T_1) (T_4 - T_2)}{(T_3 + T_1) (T_3 - T_1)^2 + (T_3 + T_1) (T_3 - T_2)^2 + (T_2 + T_1) (T_2 - T_1)^2}$$

where C is the velocity of light and each T is a time interval relative to some initial time and corresponding to an integral number of system recycle pulses.

The mechanical system will also be used with a second method which depends on the wavelength of a single-mode Helium-Neon gas laser operating in an unequal-arm Michelson interferometer. The fringe-shift frequency change is from 22 to 28 Mhz during the drop. By dividing this frequency by 4, the data handling process becomes identical with the one for the pulse recycle system. The gravity result can be obtained by using the relation :

$$g = \frac{\lambda (t_j N_k - t_k N_j)}{t_j t_k (t_k - t_j)} \left(1 - \frac{v_j + v_k}{2 C} \right)$$

where $\lambda = 6329.911 \text{ \AA}$ in vacuum, t_j and t_k are total elapsed times corresponding to integral numbers of fringe shifts N_j and N_k respectively. v_j and v_k are the instantaneous velocities of the projectile at time t_j and t_k respectively.

The drop-tube is 2.5 m. long and is made of aluminium alloy. The diameter of the tube is 15 cm and the release and catching devices are entirely mechanical. The mechanical system has been completed and preliminary pressures of 0.05 micron have been obtained with 24 hours of pumping. All units can be readily dis-assembled and the estimated transportation weight is 500 kg.

A short note by Mr. T. KITSUNEZAKI on : THE FREE-FALL EXPERIMENT
AT THE NATIONAL RESEARCH LABORATORY OF METROLOGY (NRLM, Japan)
is reported here :

..."The NRLM finished the sequence of the measurements, and the data are under final verifications and treatments. According to a preliminary treatment of the data, the acceleration due to gravity at NRLM "g" point at Kakioka* is $979\,965.8 \pm 2.13$ mgal. This value of "g" shows a decrease of 14.2 mgal compared with the value of the Potsdam system at the same point (979 980.0 mgal). The value is based on that of Tokyo (979 801.00 mgal) which was calculated by E. BORRASS in 1911 ; and a comparison between Tokyo and NRLM "g" point was done by the Geographical Survey Institute in 1963.

The value of acceleration due to gravity measured by the NRLM method is derived at a point about 80 cm higher than the ground level, and the correction for the height difference based on $dg/dz = -0.3$ mgal per metre is applied to the value. Both 15 observations with a fused quartz scale at the falling body and 23 observations with an invar scale have been performed by the NRLM from 1965 to 1967. Each observation produces 97 to 98 timedisplacement relations corresponding to graduation lines ruled on scale surfaces over nearly one metre. The standard deviation of acceleration in single observation (about 97 to 98 lines) is 0.5 to 2 mgal.

The preliminary value mentioned in this note is derived dealing with a part of the data of 15 observations of falling motion of fused quartz scale. The data for only fifty graduation lines in beginning half, from 2nd to 51st (from 1 cm to 50 cm) among 98 graduation lines, are used, because some retarding force appears growing with the increase of the falling velocity. It is supposed that the force would be an effect of electric charge induced on the surface of the fused quartz scale, and that a kind of dynamic braking between the slightly magnetized falling invar scale and the surrounding metal cylinder.

Another defect of this method is the vibration of observing point ; just after the scale hung at the top of evacuated cylinder starts to fall, the cylinder stretches and the observing optical device mounted on it begins to vibrate. The elimination of this effect is difficult and under examination".

* NRLM gravity station in the yard of Kakioka Geophysical Observatory of Tokyo University, Ibaraki prefecture, Japan (Lat. $36^{\circ}13'8$ N, long. $14^{\circ}11'5$ E H = 32.17 m).

LIST OF ABSOLUTE DETERMINATIONS COMPLETED SINCE 1940,
OR IN PROGRESS

Laboratory	Author	Date of publication	Method
Bureau International des Poids & Mesures, Sèvres	A. Thulin	1961	Photography of freely falling scale
	A. Sakuma	provisional result	Free rise & fall of interferometer reflector
National Bureau of Standards, Gaithersburg	D.R. Tate	1966	Photoelectric timing of free fall in falling enclosure
National Physical Laboratory, Teddington	A.H. Cook	1967	Photoelectric timing of free rise and fall
Mendeleev Institute of Metrology, Leningrad	P.N. Agaetskii & K.N. Egorov	1956	Reversible pendulum
		1956	Free fall in falling enclosure
	A.I. Martsinyak	1956	Free fall of emulsion coated rod
National Research Council, Ottawa	H. Preston-Thomas	1960	Photography of freely falling scale
Palmer Physical Laboratory, Princeton	J.A. Faller	1963	Free fall of interferometer reflector
Physikalisch-Technische Bundesanstalt, Braunschweig	German	in progress	Free fall of emulsion coated rod
Geodetic Institute, Potsdam	Reicheneder & Schuler	in progress	Two reversible pendulums in anti-phase
Deutsches Amt für Messwesen	M. Dietrich & G. Harnisch	in progress	Photoelectric timing of small object
Faculty of Engineering, University of Buenos Aires	A.A. Cerrato	in progress	Reversible pendulum
National Research Laboratory of Metrology, Tokyo	M. Tomonaya	in progress	Photoelectric timing of freely falling scale
Air Force Cambridge Research Directorate		in progress	Reversible pendulum
Finnish Geodetic Institute	T.J. Kukkamäki	in progress	200 m pendulum
National Standards Laboratory, Sydney	Bell	in progress	Free rise and fall of interferometer reflector
Wesleyan University Connecticut	J.A. Faller	in progress	Free fall of interferometer reflector
Institute Geophysics Hawaii.	J.C. ROSE	in progress	Fall in reflector

RESULTS OF ABSOLUTE DETERMINATIONS OF GRAVITY (from Dr. A.H. COOK)

Laboratory	Author Date	Method	Result mgal	Value at site in Potsdam system	Observed- Potsdam
National Bureau of Standards, Washington	Heyl & Cook 1936	Reversible pendulum	980 082.3 ±1.2	980 098.1 ± 0.3	- 15.8
National Bureau of Standards, Gaithersberg	Tate 1966	Falling bar in enclosure	980 101.8 ±0.3	980 114.6	- 12.8
National Physical Laboratory, Teddington	Clark 1939	Reversible pendulum	981 183.2	980 195.47	- 12.3
	Cook 1967	Symmetrical rise & fall	981 181.75 ±0.13		- 13.7
Mendeleev Institute of Metrology, Leningrad	Agaletskii & Egorov 1956	Reversible pendulum	981 918.6 ±0.4		- 12.2
		Falling bar in enclosure	981 921.5 ±1.6		- 9.3
	Martsinyak 1956	Free fall	981 922.4 ±2.0	981 930.8	- 8.4
International Bureau of Weights & Measures, Sèvres, A	Thulin 1961	Free fall	980 928.0 ±0.7	980 939.76	- 11.8
	Sakuma 1967	Symmetrical rise & fall	980 926.0 ±0.1		- 13.8
National Research Council, Ottawa	Preston-Thomas & others, 1960	Free fall	980 613.2 ±1.5	980 626.3	- 13.1
Dept. of Physics, Princeton	Faller 1963	Free fall	980 160.4 ±0.7	980 174.1	- 13.7

Notes : 1) The Potsdam values are based on Cook (1965) except that, following Tate (private communication), the difference between Commerce Base (Washington) and the Gaithersberg site is taken to be - 19.5 mgal.

2) The correction applied by Cook (1965) to Faller's result for eddy current damping was wrong.

- II - (following)

SECOND MEETING

about the International Gravity Formula and Potsdam Absolute Value.

In the opening of this meeting Dr. A.H. COOK reminded that the International Astronomical Union (IAU) adopted in 1964 new fundamental constants, including the equatorial radius of the Earth and the value of the flattening. He indicated the position of the International Gravity Formula and the Potsdam system ; and invited each delegate to express his opinion on the adoption of a new gravity formula.

We are printing hereafter the note of Dr. A.H. COOK and the comments of each delegate on this subject.

Dr. A.H. COOK : REFERENCE GRAVITY VALUES AND FORMULAE

The International Gravity Formula, consistent with the International Spheroid, is :

$$g = 978\ 049.0 + 5\ 172.31 \sin^2 \phi - 5.77 \sin^2 2\phi \text{ mgal}$$

(ϕ is the geographical latitude).

The constant value is based on the absolute determination of $g = 981.274$ mgal at Potsdam by Kühnen and Fürtwangler and is shown by recent absolute determinations to be about 14 mgal too great. The coefficient of $\sin^2 \phi$ is also inconsistent with the values of the flattening found from observations of artificial satellites.

The IAU, at its XII General Assembly in 1964, adopted a new set of fundamental constants to describe the dynamics of the solar system ; among other observations they are based on satellite values of the dynamical form factor of the Earth, J_2 , radar measurements of the distance of the Moon, and satellite and space probe values for the product $G \times$ mass of Earth. The constants include the values :

equatorial radius of the Earth	6378 160 m
form factor J_2	1.0827×10^{-3}
$G \times$ mass of Earth	$398\ 603 \times 10^9 \text{ m}^3 \text{ s}^{-2}$

They imply a formula for surface gravity in which the constant term has been established independently of absolute measurements of gravity at sites on the surface ; the formula is :

$$978\ 030.9 + 5185.52 \sin^2 \phi - 5.70 \sin^2 2\phi \text{ mgal}$$

(the mass of the atmosphere has been taken to be 1×10^{-6} of the mass of Earth)

The constant term in this formula is 18.1 mgal less than that in the International Formula and thus about 4 mgal less than that indicated by recent absolute determinations.

Helmert's formula is :

$$978\ 030.0 + 5185.52 \sin^2 \phi - 6.85 \sin^2 2\phi \text{ mgal.}$$

The IAG may well adopt for geodetic surveys a reference spheroid having the IAU parameters. This fact, the clear discordance between the International

Gravity Formula and current estimates of the constant term and of the coefficient of $\sin^2 \phi$, and the desirability of having, if possible, a formula consistent with constants adopted by other international bodies, make it desirable to discuss possible changes in the gravity formula.

The coefficient of $\sin^2 \phi$

The issue here is clear-cut. The value in the International Formula is wrong by $13.2 \sin^2 \phi$ mgal. A change in the formula would alter gravity anomalies by amounts which would be significant almost everywhere. The choice is thus clearly between consistency with the best value of J_2 and the inconvenience of changes in all existing gravity anomalies.

The discrepancy between the formula and the satellite values of J_2 is significant only for studies of the comparison between satellite and surface measurements of the potential, studies which are in any case bedevilled by the considerable theoretical and statistical problems.

The constant term

The issues are less straightforward than for the coefficient of $\sin^2 \phi$. Whereas the satellite value of J_2 is well established independently of surface measurements, the observational value for the constant term is less secure. On the one hand, the value derived from observations of the radius of the Earth, the distance of the Moon and satellite observations of the mass of the Earth, has an uncertainty of 3 to 4 mgal. On the other hand, while recent absolute determinations have uncertainties of about 0.1 mgal, they relate to isolated points and the uncertainty of the mean value over the Earth, represented by the constant term in the gravity formula, will be a few milligals on account of the errors due to poor sampling that affect the mean value of surface gravity. The fact that the difference of the two constant terms (18 mgal) is not equal to the 14 mgal departure of the recent observations from the Potsdam standard, is thus not significant. I conclude that the material is not adequate to fix a value of the constant term in the formula correct to 1 mgal.

The base value in the Potsdam system of gravity measurement (as distinct from the reference formula) could be reduced, on the basis of absolute determinations at Sèvres and Teddington, by 14 mgal to 981 260 mgal. Anomalies would not be altered if the constant in the gravity formula were correspondingly taken to be 978 035.0 mgal but this value is not of course consistent with the IAU constants.

My tentative conclusions are :

- 1) That when actual values of gravity in absolute terms are required, they should be based on a value of 981 260 mgal at Potsdam.
- 2) No change should be made in the gravity formula, nor in the existing method of expressing relative values of gravity in the Potsdam system until
 - a - the relations between absolute determinations of gravity at European and other sites are better established, and
 - b - the relation between the mean surface value of gravity and individual absolute determinations is better established".

Mr. TERRIEN, Directeur du Bureau International des Poids et Mesures, Sèvres, rappelle la lettre envoyée par le Comité International des Poids et Mesures (CIPM) au Président de l'UGGI (Bull. Inf. n°16, p.I-8) et conclut ainsi :

- le CIPM souhaite remplacer le système de Potsdam ;
- toutefois, il serait désirable que ce changement ne soit pas immédiat, en raison des progrès en cours dans l'exactitude des mesures absolues de g.

Prof. U. UOTILA (Ohio State University, Columbus) :

"If we trace back the origin of the equatorial value 978 049, we find that it was derived from observed gravity data available at that time. The material was very poorly distributed over the world. I have used material available in 1962 and made similar determinations of equatorial value. If we take into account - 14 mgal correction to Potsdam system and flattening 1/298.3, the result was 978.0315.

Distribution of observed data is still very poor. We can expect that large unsurveyed Ocean areas will leave considerable effect to the value. In order to decrease this I made an other computation in which I used differences between so called model-earth anomalies and observed anomalies. The result was 978.0284.

Professor KAULA has given 978.0296 and Professor RAPP will present a paper in which he gives a value 978.0326.

From the above values we can see that uncertainty is large, therefore I suggest, for uniformity that we recommend temporarily a correction to the equatorial value, which will be in the agreement with the value adopted by IAU".

Mr. E. BUSCHMANN (Geodetic Institute, Potsdam)

"About the question whether it is the right time or it is premature to change the Potsdam absolute standard, our opinion is :

More absolute gravity measurements should be ready at more stations all over the world, using different methods.

More relative gravity measurements of high precision should be made between the most important absolute stations, especially connecting these stations with Potsdam.

If anybody needs to use a new gravity reference system or a new gravity formula, he may do so for his special purposes and quote it in all his papers exactly. But to confirm a definite change by IAG, it seems us to be too early".

Dr. R.A. HIRVONEN (Institute of Technology, Helsinki) :

"Replace the old series form by the well-known closed formula because very soon we need more terms and more decimal places ;

Change the equatorial value as well as it can be done today, without waiting some more definite values".

Dr. B. SZABO (USAF, Cambridge Research Laboratories, Bedford) :

"At the present time a portable absolute gravity measuring experiment has been developed by Dr. FALLER of Wessleyan University. This experiment will be repeated at Teddington and Sèvres in 1967. Therefore it is recommended to delay the revision of the Potsdam system until more direct comparisons between the various modern absolute measurements will be available. This could be achieved within a time period of one year".

Prof. J.J. LEVALLOIS, Secrétaire Général de l'AIG :

"1) Il y a d'abord un problème de compétence : l'apparition des satellites artificiels suivie de l'adoption par l'UAI d'une valeur 1/298.25 a montré que les valeurs auxquelles l'AIG a toujours recours sont périmées. Quelle que soit l'importance ou la facilité qu'offrirait leur conservation, l'AIG ne peut indéfiniment conserver comme officielles des valeurs dont personne aujourd'hui ne peut soutenir la valeur.

Si l'AIG ne fait pas elle-même son choix, d'autres le feront à sa place dans n'importe quelles conditions.

2) La valeur 1/297 présente pour les calculs par la formule de Stokes des incohérences avec ce que donnerait un aplatissement 1/298.25 dans toutes les zones où l'on dispose d'anomalies provenant d'extrapolation mathématique au lieu d'anomalies mesurées et le géoïde obtenu ne peut être "correct", que si l'on part d'anomalies référées à une origine correcte, telle que celle que donnent les satellites.

3) Il est urgent de procéder à des changements : on oppose à leur éventualité la quantité du travail actuel pour passer de l'ancien système au nouveau, l'incertitude des données fondamentales etc... Ce ne sera pas résoudre le problème que de le retarder : dans 4 ans ou 8 ans, les données anciennes se seront amoncelées et leur transformation n'en sera que plus longue : c'est donc une solution sans intérêt que de s'y confiner jusqu'à plus tard. L'incertitude des données véritables n'est pas un obstacle insurmontable : mieux vaut une valeur erronée de ± 2 milligals que la valeur erronée de ± 14 milligals à laquelle on veut se cramponner. Il est d'ailleurs facile d'utiliser les vieux documents en en précisant le système et en y apportant les corrections adéquates. D'autre part, à l'âge des ordinateurs tout ceci est simplifié.

Pour toutes ces raisons je suis en faveur de l'adoption d'une formule nouvelle basée sur un aplatissement 1/298.25 (UAI), une constante γ_0 vraisemblable, par exemple, celle de l'UAI ou tout autre à préciser, et d'homogénéiser les données avec celles qu'adopterait la Section I (données géométriques)".

Dr. G. VEIS (Smithsonian Observatory in Cambridge, U.S.A.) :

"The determination of γ_e adopted by IAU was based on the best available data at that time for GM and a. More recent determinations of GM and a, although they change the values from those adopted by IAU, give essentially the same value for γ_e , namely 978 031.1 mgal. With the uncertainties associated with GM, and a, this value of γ_e is determined to ± 3 mgal.

Today a lot of the analysis of gravity data for the determination of the geoid is based on a combination of surface gravity with satellite data, and so it is very desirable that the same reference is used".

Dr. J. KOVALEVSKY (Bureau des Longitudes, Paris) :

"En tant que l'un des responsables du système UAI de constantes, je tiens à dire que ce système n'est pas destiné à être le meilleur possible, mais seulement une référence qui permette de ne pas introduire d'erreur dans les réductions des mesures.

Dans le cas présent, une erreur de 10 ou 20 mètres sur le rayon terrestre, une erreur de 1 milligal sur la formule de gravité ne peuvent pas introduire une telle erreur systématique dans la réduction des observations (ces erreurs sont faibles par rapport aux bosses du géoïde et aux anomalies de la pesanteur).

Il ne faut donc pas attendre que des valeurs meilleures obtenues par des mesures absolues de la gravité arrivent pour effectuer le changement car les améliorations apportées ne seront pas significatives au sens indiqué ci-dessus".

Dr. E.A. BJERHAMMAR (Kungl. Tekniska Högskolan, Stockholm) :

"In our studies we have found a solution of the flattening exclusively based on terrestrial gravity data which agrees almost exactly with the old value 1/297. Furthermore, we have found that forcing the satellite flattening into a solution with gravity data gives considerable bias for most of the lower order harmonics".

Mr. F.L. CULLEY (Army Map Service, Washington) :

"We should change to a new formula as soon as possible. The longer we wait, the more data we will accumulate that will have to be corrected. We have a great quantity of satellite data available now, and such data will increase tremendously.

We have reached a plateau in speed of electronic computers. Five or ten years ago, it would have paid to wait ; this is no longer so.

We should not be causing confusion by mixing gravity data from satellites using one set of ellipsoidal parameters with gravity data from other sources using other parameters.

It is the function of IAG to determine the ellipsoidal parameters and we should not accept those adopted by IAU".

Dr. S. CORON (Bur. Grav. Int., Paris) :

"En tant que représentant du B.G.I., j'attire l'attention sur le côté pratique et le risque de confusion qu'il y a à modifier souvent des systèmes de référence.

1) A l'heure actuelle tous les résultats gravimétriques sont donnés dans un système pratiquement homogène et il y a une grande quantité de données sur punched cards (plusieurs 100.000).

Il est plus rapide d'ajuster un programme de calculs que de rechercher et de savoir à quelle formule, à quel méridien etc... se rapporte telle ou telle station. Ceci pourrait encore être résolu, mais il existe une seconde raison beaucoup plus importante :

2) Les données gravimétriques sont fournies en grande partie par des services géophysiques et des services de prospection. Il est difficile de demander à ces services de changer leurs habitudes, aussi, il semble souhaitable que la résolution concernant un changement éventuel de la formule de pesanteur comprenne un paragraphe restrictif relatif aux mesures courantes de g , semblable à la résolution prise à Berkeley (1963).

Les résultats gravimétriques pourraient être publiés de 2 manières différentes : forme internationale et nouvelle formule. Il y a quelques années encore, de nombreux résultats étaient calculés par la formule d'Helmert et la formule internationale".

Remarque ultérieure, suggestion de Mr. B.C. BROWNE :

Pour éviter les confusions probables entre les différentes anomalies, on pourrait adopter une nouvelle dénomination pour les anomalies calculées avec la nouvelle formule.

Prof. A.E. MARUSSI (University of Trieste) :

"In the problem with which we are faced, I can see two aspects :

- the one which we may call "legal" and
- the second one which is purely technical.

As far as the first aspect is concerned, I feel that although the Association should recognize that the parameters of the International or Cassinis formula are superseded by better values, the old formula should be retained as a standard, but the best now available values should be indicated to all potential users.

As far as the second aspect is concerned, it is of utmost importance that the selection of the best 1967 values should be made in conjunction with Section I so as to produce consistent system of values".

Dr. L.P. PELLINEN (Soviet Geophysical Committee, Moscow) :

"There are two problems not exactly connected :

- 1 - The change of Potsdam gravity value
- 2 - The revision of normal gravity formula.

The first problem can be solved by absolute gravity measurements. We are able to recommend the most probable correction value to the Potsdam system nowadays. In the future it should be precised.

The second problem can be solved by detailed studying the gravity field. It is not possible to recommend the parameters of the IAU because the equatorial gravity value was obtained indirectly with insufficient accuracy".
($\Delta \gamma = \pm 3$ mgal when $\Delta a = \pm 10$ m.)

Dr. C.T. WHALEN (USAF, Coast & Geodetic Survey, Wyoming) :

"Contrary to Dr. A.H. COOK's statement of yesterday, there are many good relative gravity ties between the absolute sites in Europe and in the Americas.

My group has completed 22 direct LaCoste - Romberg ties between Princeton and Frankfurt. In Europe, Frankfurt is connected to Paris, Teddington and Potsdam by 8 or more direct or indirect ties. In the Americas, Ottawa, Princeton, Washington and Buenos-Aires are also connected by 8 or more direct or indirect ties. These ties have been used in an adjustment to obtain Potsdam datum gravity values for the primary bases near the absolute sites. The standard error terms with respect to Potsdam, for these bases are withing ± 0.5 mgal.

A simple mean of the differences between the Potsdam datum and absolute gravity values for Potsdam, Teddington, Paris, Ottawa, Princeton, Washington and Buenos-Aires gives a correction to the Potsdam datum of - 13.7 mgal which is in good agreement with Dr. A.H. COOK's value of 13.8. It should be pointed out that the simple mean is based on different types of absolute gravity measurements. The good agreement of the values based on the new absolute measurements by COOK, SAKUMA and TATE with the simple mean indicates that their measurements do not contain large "system" error".

At the end of this discussion Dr. A.H. COOK summarized the different opinions expressed by the delegates and pointed out that the audience seemed favourable for an immediate adoption of Potsdam correction.

He proposed that the Resolution Committee jointly with Section I and Section III (on the proposal of Prof. J.J. LEVALLOIS) prepare a resolution on this question.

The Resolution Committee included : Dr. A.H. COOK, Prof. A.E. MARUSSI and Dr. U.A. UOTILA.

During the last minutes of this meeting, Mr. E. BUSCHMANN and Dr. J.C. ROSE reported on the gravity absolute experiments in progress respectively in D.D.R. and in U.S.A., Honolulu. (See above p. 16 - 17).

- III -

FIRST ORDER WORLD GRAVITY NET - STANDARDIZATION PROBLEM

Three general meetings were held on these problems :

- Thursday, September 28th at 9.15 a.m.
- Friday, September 29th at 9.15 a.m.
- Wednesday, October 4th at 9.15 a.m.

and some special meetings of a working sub-group of Special Study Group 4.05.

FIRST MEETING

Prof. C. MORELLI, Chairman of the S.S.G. 4.05, presented the General Report of this Group, which was distributed to the concerned delegates. This provisional Report summarizes the situation concerning the gravity measurements made with pendulums and gravimeters for the solution of the First Order World Gravity (F.O.W.G.N.) and its standardization. It is the provisional scheme of the final one which will be made as soon as the missing Annexes will be presented.

Prof. C. MORELLI pointed out that the final step is approaching, due to the spirit of cooperation of all those members of the Group that have been active in pursuing theoretical improvements or in realizing the measurements or in studying new methods for their best utilization.

The Table of Contents is given again here, with the different Annexes.

GENERAL REPORT S.S.G. 4.05 - Table of Contents

- S.S.G. Members list
- Abstract
- List of abbreviations and symbols

1°) Introduction to the problems

- 1.1 - Foreword
- .2 - The FOWGN
- .3 - The Standardization Problem
- .4 - The Absolute Net
- .5 - The Adjustment Problem

2°) Pendulum measurements

- 2.1 - Advances
- .2 - Actual situation of pendulum observations
 - 2 - 1. Gulf pendulum measurements
 - 2. Cambridge pendulum measurements
 - 3. I.G.C. pendulum measurements
 - 4. U.S.C.G.S. pendulum measurements
 - 5. G.S.I. pendulum measurements
 - 6. G.I.P. pendulum measurements
 - 7. Other pendulum measurements
- 2.3 - Pendulum station descriptions

3°) Measurements with gravity meters

- 3.1 - Advances
- .2 - Actual situation of gravity meter measurements
 - 2 - 1. Woollard's group gravimeter measurements
 - 2. APCS 1381st GSS gravimeter measurements
 - 3. DO gravimeter measurements
 - 4. USNOO gravimeter measurements
 - 5. AMS (and USAMSFE) gravimeter measurements
 - 6. AFCRL gravimeter measurements
 - 7. IAGS gravimeter measurements
 - 8. GITH gravimeter measurements
 - 9. ITGTH gravimeter measurements
 - 10. EPF-ORSTOM gravimeter measurements
 - 11. OGST gravimeter measurements
 - 12. IGPM gravimeter measurements
 - 13. Various measurements with LCR meters
 - 14. Measurements with other gravimeters

4°) AdjustmentReferences2.4 - Annexes

- 4 - 1. Gulf pendulum measurements 1953-1966, G.P. WOOLLARD (in preparation)
- 2.a) Recomputation of Cambridge pendulum measurements from 1952 to 1960 (with Helmholtz coil), T. HONKASALO.
- 2.b) Gravity measurements in the First Order World Gravity Net with Cambridge pendulum apparatus in 1963-64, T. HONKASALO, J.E. JACKSON, D.I. GOUGH & B.C. BROWNE.
- 2.c) Gravity measurements made with the Cambridge pendulums at Teddington, Melbourne, Singapore, Tokyo and Fairbanks, April-August 1967, B.C. BROWNE.

- 3.a) Italian Geodetic Commission pendulum measurements from 1957 to 1963, C. MAZZON, L. PIERI.
- 3.b) Report about the pendular expeditions carried out by means of the italian three-pendulum apparatus C.G.I. n°1 and n°3 in Europe and Africa 1963-64, C. MAZZON.
- 3.c) Report about the relative gravity measurements carried out by means of the italian three-pendulum apparatus n°2 in Europe and America in 1965, V. TOMELLERI.
- 4. Gravity control measurements in North America, D.A. RICE.
- 5. Gravity observations along the Western Pacific Calibration Line during the periods from 1965 to 1967 with G.S.I. pendulums, Y. HARADA.
- 6.a) Results of relative pendulum measurements connecting Potsdam with Rome, C. ELSTNER.
- 6.b) Results of relative pendulum measurements connecting Potsdam with Mirny and Molodjoshnaja, C. ELSTNER.
- 6.c) Pendulum gravity measurements connecting Potsdam with Helsinki and Ivalo, Finland, C. ELSTNER.

3.3 - Annexes

- 3 - 1. University of Wisconsin and University of Hawaii Gravimeter measurements, G.P. WOOLLARD (in preparation).
- 2.a) 1381st GSS gravimeter measurements, C.T. WHALEN (in preparation).
- 2.b) The U.S. National Gravity Base Net (NGBN), D.A. RICE.
- 3. Dominion Observatory, Ottawa, Gravity measurements, A.C. HAMILTON, (in preparation).
- 4. U.S. Naval Oceanographic Office contribution to the World Gravity Net 1952-1967, C.GANTAR & A.L. McCAHAN.
- 5. A.M.S. contribution to FOWGN gravimeter measurements, R.M. IVERSON. (in preparation).
- 6. A.F.C.R.L. contributions to FOWGN gravimeter measurements, C. GANTAR & B. SZABO.
- 7. I.A.G.S. contribution to FOWGN gravimeter measurements (in preparation).
- 8. Remarks on the gravity measurements made by the Geodetic Institut, Hanover, on the Euro-African Net, C. GANTAR.
- 9. Gravity measurements made by Institut für Angewandte Geodäsie, Hannover, W. HOPCKE, (in preparation).
- 10. Note sur les résultats des grandes liaisons gravimétriques françaises, S. CORON.
- 11. Measurements with LaCoste and Romberg gravity-meters in 1963-64 by Osservatorio Geofisico Sperimentale, Trieste, C. GANTAR & C. MORELLI.

During these sessions, various Members of this Group drew attention on the particular points of this General Report or gave some complementary details on the apparatus, recent results... We reproduce them below .

First meeting : PENDULUM MEASUREMENTS

Dr. T. HONKASALO was charged of recomputing the Cambridge pendulum measurements from 1952 to 1960 (with Helmholtz coil) because it was stated that an accurate comparison of the results of different observers was not possible if all the pendulum measurements were not reduced in a similar manner.

He explained that the most important correction is the temperature correction since temperature differences in measurements from equator to pole areas can hardly be avoided. A 10° temperature difference causes a standard error of ± 0.4 mgal for the gravity differences when computed with the old correction formula.

He carried out observations at the station Helsinki, for new temperature correction formula. The pendulum periods were determined at temperature of + 10°, 20°, 30° and 40°C... The later experience has shown that each pendulum has a correction formula of its own and in addition to this, the correction is depending on the flat upon which the pendulum is swinging.

During these observations, it was stated that the pendulum sets clearly differ from each other in regard to thermal hysteresis ; on the other hand, it was proved that the delay of pendulum temperature from that of thermometer was very small.

(Annexe 2.4 - 2.a, 2.b)

Mr. B.C. BROWNE gave some details about the recent gravity measurements made with the Cambridge pendulums at Teddington, Melbourne, Singapore, Tokyo and Fairbanks, between April 17th and August 4th, 1967.

He pointed out that two sets (n°1 and VI), each consisting of 3 pendulums, (A,B and C) were swung at each site in pairs in the following order : IA and B, IB and C, IC and A, VI A and B, VIB and C, VIC and A.

At least 2 swings, of 4.000 seconds duration each, were made with each pair.

The preliminary results are :

	<u>Forward</u>	<u>Backward</u>	<u>Mean</u>
Teddington - Melbourne	1 216.81		
Teddington - Singapore	3 115.12	3 115.28	3 115.20 $\pm$ 0.06 mgal
Singapore - Tokyo	1 418.65	1 418.98	1 418.82 $\pm$ 0.1
Tokyo - Fairbanks Col.	1 050.01	1 048.94	1 049.48 $\pm$ 0.36

It is to be noted that the seismic disturbance can affect the observation at Tokyo and that there is a long time interval between the observations at Tokyo and Fairbanks.

(Annexe 2.4 - 2.c)

Prof. C. MORELLI indicated briefly the pendulum observations carried out by means of the Italian three-pendulum apparatuses C.G.I. in Europe from 1957 to 1963 (annexe 2.4 - 3.a), in Europe and Africa in 1963-64 (annexe 2.4 - 3.b) and in Europe and America in 1965 (annexe 2.4 - 3.c).

Then, he reminded also the USC and GS pendulum measurements (Brown apparatus with Helmholtz coil) carried out in North America 1952-53 (annexe 2.4 - 4.).

No complementary information was given on these individual Reports.

Dr. T. OKUDA described shortly gravity observations along the Western Pacific Calibration Line (W.P.C.L.) with G.S.I. pendulums, during the periods from 1965 to 1967. The occupied stations were : Tokyo, Honolulu, San Francisco, Denver, Fairbanks, Manila, Singapore, Sydney and Canberra (annexe 2.4 - 5.). *

Mr. E. BUSCHMANN presented the pendulum measurements carried out by the Geodetic Institut, Potsdam (G.I.P.) with two different four-pendulum apparatuses between :

Potsdam with Rome

" with Soviet Antarctic stations (Mirny - Molodjoshnaja)

" with Helsinki and Ivalo. ‡

All measurements were related to Potsdam G (pendulum cellar of GIP) i.e. to the value $g_p = 981\,275.39$ mgal, (annexe 2.4 - 6.a, 6.b, 6.c).

Dr. M.E. HEIFETZ reported on "Recent pendulum gravity measurements in the USSR".⁺

During 1965-66, the Gravimetric Laboratory of the Central Research Institute of Geodesy, Aerial Surveying and Cartography, had completed the elaboration and manufacture of the first set of automatized vacuum pendulum apparatuses (four two-pendulum apparatuses). All the new apparatuses called "OBM" set are identical, but differ in type of the quartz-metal pendulums used.

Five stations had been determined in 1966 and observations were repeated at 4 stations.

From the graphs, we can see that the drift of the periods of the pendulums is different with each apparatus ; this drift is accepted to be systematic and smoothing curve (a straight line or a parabola)...

From the results we have obtained :

rms. error of a single determination with the whole OBM set : ± 0.13 mgal
rms. error of the station which was repeated with the whole OBM set: ± 0.09 "

The comparison between pendulum results against gravimeter results shows a systematic discrepancy, although the gravimeters of GAE or GAG type do not require calibration and like the pendulums, provide the results in the system CGS.

* Summaries have been already published in Bull. Inf. n°16 p.I-10 and 11.

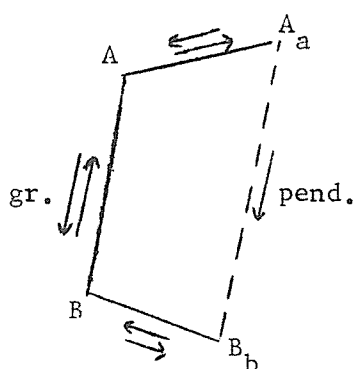
+ The integral text will be published in the next Bull. Inf. n°18, March 1968.

The measurements with such gravimeters had been made at all the "OBM" pendulum stations. The actual discrepancy is estimated about $4-5 \times 10^{-4}$, with a rms. error about 30%. According to a recent comparison the systematic discrepancy is considerably reduced ; it is only $1,1 \pm 0.3 \times 10^{-4}$. This question remains open.

SECOND MEETING : PENDULUM MEASUREMENTS AND GRAVIMETER MEASUREMENTS

(FOWGN)

The meeting was opened by Prof. Y.D. BOULANGER who reported on : numerical results obtained on a large difference of g with gravimeters and pendulums.



Δg (gravimeter)	Δg (pendulum)
$A_a - A = + 8.17 \pm 0.02$	
$B - A = - 2730.25 \pm 0.19$	
$B_b - B = - 6.40 \pm 0.02$	
$B_b - A_a = - 2728.48 \pm 0.20$	2728.40 ± 0.20
Then : $\frac{m \Delta g}{\Delta g} \hat{=} \pm 7 \times 10^{-5}$ about 0,05 mgal	

Secondly, he explained that he wished to extend gravity comparisons on the World Calibration System, and it seemed useful to him to make pendulum observations on the choosen stations of the FOWGN, for instance Potsdam, Tokyo, Sydney... These measurements could be carried out by USSR in 1969. In conclusion, he pointed out the interest of a large cooperation with the concerned Nations.

Prof. C. MORELLI summarized the actual situation of the gravity meter measurements concerning the standardization problem, and asked for each concerned Member of this Group to expose his particular problem.

Unfortunately, Prof. G.P. WOOLLARD could not attend this meeting and the Report on "University of Wisconsin and University of Hawaii, Gravimeter measurements" have not been sent. The observations made with LCR meters since 1960 are being reworked, particularly large periodic errors having been detected in the micrometer screw.

Dr. C.T. WHALEN reported on the APCS 1381st GSS gravimeter measurements (Air Photographic and Charting Service).

He indicated that the scheduled program for FOWGN purposes was realized between 1963 and 1967. The observations were carried out with 4 or more small geodetic model LCR gravimeters at approximately 270 cities. Measurements were made in ladder sequence along the American, American Secondary, Euro-African, Euro-African Secondary, West Pacific, and Central Asian Secondary Calibration Lines. (See fig.19, General Report of SSG 4.05).

The standard error terms for the adjusted values do not exceed ± 0.10 mgal with respect to Potsdam.

At the end, he thanked the IGB for giving details on gravity base stations and for its cooperation.

Prof. C. MORELLI drew attention on this important work which was realized in due time and summarized the contribution of Dominion Observatory to the establishment of the FOWGN. (See fig.20, General Report of SSG 4.05).

Dr. R.K. McCONNELL added that the Gravity Division of the Dominion Observatory has been involved in the establishment and adjustment of gravity control networks in Canada. As a result of requirements for processing some 8 000 control station observations in the Canada Net and FOWGN, the Dominion Observatory has developed a system of computer programs. These were described briefly.

Results of analysis of LaCoste and Romberg gravity meter performance on the Ottawa-Washington calibration line were given.

Dr. A.L. McCAHAN presented the contribution of the US Naval Oceanographic Office to the FOWGN started on 1962 in conjunction with the execution of the world-wide airborne geomagnetic survey called Project Magnet.

The complete list of the trips from 1962 to 1967 has been summarized and the gravity net of USNOO was shown.

(Annexe 3.2.4, fig.5)

Dr. D.A. RICE spoke about the U.S. National Gravity Base Net (NGBN) which was made by the major U.S. gravimetric organizations to provide a single system of gravity base values throughout the U.S. This project was realized from January 1966 to June 1967.

Stations were established at 54 cities and the adjusted gravity values are referred to 980.118 00 gal at Washington A (IGB, code : 11687 A).

The position of the station is shown.

(Annexe 3.2.2b).

Dr. S. CORON fait quelques remarques relatives aux liaisons gravimétriques effectuées par les observateurs français dans le cadre des Expéditions Polaires françaises et de l'Office de la Recherche Scientifique d'Outre Mer (ORSOM).

Ces mesures s'étendent à l'Europe, l'Afrique (2 campagnes de l'ORSOM), l'Asie, l'Australie et l'Antarctique.

Il faut signaler que tous ces résultats ont déjà été publiés et que les résultats tiennent compte des conditions expérimentales (dérive de repos, de transport, effet adiabatique...) ; les gravimètres utilisés furent des "Western" ou un "North American".

La comparaison de ces résultats avec différents réseaux régionaux montre que ce système gravimétrique (EPF-ORSOM) présente une certaine homogénéité, une bonne précision (supérieure à 0,1 mgal), mais que l'échelle d'étalonnage adoptée est inférieure d'environ 1,1 % à l'étalonnage moyen donné par les mesures pendulaires mondiales.

Dr. S. CORON signale enfin qu'une nouvelle Note, un peu plus complète que celle de l'Annexe 3.2.10 (Rapport Général du SSG 4.05) a été établie et qu'elle sera distribuée aux délégués intéressés.

Prof. C. MORELLI summarized also the contribution of other Organizations (see Table of Contents, p.29). He pointed out particularly the gravity measurements made by the Geodetic Institut, Hanover on the Euro-African Net with Askania gravimeters.

(Annexe 3.2.8.)

Then, he added some words about the measurements with LCR gravimeters in 1963-64 by Osservatorio Geofisico Sperimentale, Trieste.

(Annexe 3.2.11)

At the end of this meeting, Dr. T. OKUDA reminded the work executed on the West Pacific Calibration Line and Prof. L. SOLAINI made a brief Report on the work executed for IAG SSG 6, "Establishment of a European Gravimeter Calibration System and Unification of the European fundamental gravimeter networks".

1. General work

The state, and the activity scope of the Special Study Group n°6 has been newly settled during a special session on the 6th of March 1964 in Munich. This was necessary because the main task of the Special Study Group n°6 is preliminarily concluded, i.e. the adjustment of the European gravimeter calibration system.

The future working programme of our Special Study Group especially projects gravimetrical measurements on the European part of the meridian

line, further the establishment of a unified European gravity network satisfying to high precision requirements, and closely tied with the world gravity net.

On other sessions on the 6th and 18th of November 1963, detailed problems have been discussed, Prof. HONKASALO informed about the results of a new adjustment of the northern part of the European gravimeter calibration system. Measurements executed after 1962 have been included into this adjustment ; especially measurements executed via Helsinki, and not considered with the adjustment of 1962, have been employed.

2. Measurements

According to the recommendations adopted during the Munich session, several gravity meter measurements on the European calibration line, further gravimetric connexion measurements to Potsdam have been performed since 1963. Nearly for all measurements, LaCoste-Romberg gravimeters have been used which are better than other gravimeter types in many ways.

In 1963, detailed measurements have been executed over the total line Etna - Bodø with three LaCoste-Romberg gravimeters by the Air Force Research Laboratories in collaboration with the Osservatorio Geofisico Sperimentale in Trieste (OGST).

At the same time, the US Naval Oceanographic Office has made gravimeter measurements over the same line, and with a corresponding measuring programme, also with three LaCoste-Romberg gravimeters. A summarizing elaboration of these measuring series has been prepared and published by the OGST.

The 1st Department of the German Geodetic Research Institute has made gravimeter measurements with two LaCoste-Romberg gravimeters in the section Munich-Helsingør of the European calibration line in 1965. The results and a new catalogue of the German calibration line points have been published.

Since 1963, Hamilton, Morelli, the Geodetic Institute Potsdam, the Geodetic Institute Hannover, and the German Research Institute Munich, have performed direct gravimetric connexion measurements from Bad Harzburg to Potsdam. The discrepancies between the different results do not exceed 0,1 mgal ; thus the gravity difference between the absolute station Potsdam, and the reference station Bad Harzburg (important for the world gravity net) is determined with sufficient accuracy.

In the future the most important task of the Special Study Group n°6 should be to strengthen the gravimetric connexion measurements between the European stations of the world gravity net. Thus a test net could be made available to the Special Study Group n°5 in which all problems occurring with the future adjustment of the world gravity net could be studied. A uniform adjustment of the European gravimeter networks is to be postponed up to the completion of the world net. In order to prepare this adjustment, all European countries interested in a common adjustment should compile uniformly their gravimeter networks, divide them into order classes, check and complete them. Especially the boundary transitions have to be controlled, further eventually missing connexions should be established.

THIRD MEETING : ADJUSTMENT OF PENDULUM AND GRAVITY MEASUREMENTS.

Prof. C. MORELLI presented the general problem of adjustment.

He reminded the Cook's method, its application by Dr. K. MARZHAN in the adjustment of the European Calibration System, the trials of Prof. L. SOLAINI and Dr. G. TOGLIATTI in the research of systematic errors in gravity measurements...

The adjustment of the gravity measurements will be performed by successive steps as schematically suggested by Prof. H. WOLF, accordingly to the general proposed procedure (the Helmert's one)...

The computation will be made by different Centers.
(See conclusion below).

Prof. Y.D. BOULANGER recalled the proposition of USSR to participate at the International work, in carrying out direct connexions with USSR pendulums between Potsdam, Tokyo, Nairobi, Melbourne and Mexico or La Paz. (See resolution).

On the other hand, he proposed the names of 3 stations in USSR which could be international points occupied by foreign observers of the SSG 4.05 : MOURMENSK, ODESSA, NAHODKA (near Pacific Ocean).

Conclusion, future program (Prof. C. MORELLI)

The summary of the arguments discussed during special meetings of a working sub-group of SSG 4.05 is given below.

1. Distribution of observational material

It has been agreed that all the observational material will be distributed to following persons :

MORELLI - WOLF	BROWNE
TANNER	HONKASALO
WHALEN	SZABO
WOOLLARD	UOTILA

The interested material is :

Pendulums

- BROWNE : 1967 WPCL measurements
- CAMBRIDGE : 1952 & 1953 (GARLAND), 1957 (GOUGH) and 1958 (BROWNE), for which temperatures data are yet missing: by HONKASALO.
- WOOLLARD : final report, copies will be sent directly to the above mentioned persons by SZABO who will check if HONKASALO's correction is applied, otherwise WOOLLARD will be requested to complete the report.

HONKASALO's correction to the other pendulums measurements will be applied by HONKASALO himself.

Gravimeters

- WHALEN : final report will be distributed directly within 1967, in addition, the measurements will be sent in card's form to MORELLI, for distribution.
- TANNER : if not sent together with WHALEN's material, will be sent as above.
- WOOLLARD : as for the pendulums.
- MORELLI : two extra more copies in the report form have to be sent to SZABO & WOOLLARD, a complete set in card's form for all the interested ones.
- HÖPCKE : MORELLI will transfer in card format and distribute as above.
- CORON : will kindly complete the French measurements as agreed (Δ g, number of legs, etc...) and send to MORELLI. MORELLI will transfer in cards and distribute.

Time schedule

It has been agreed that the distribution of all the above indicated observational material will be done as first priority as soon as possible, and in any case completed not later than January 1968.

2. Adjustment

As it was agreed in Bedford (April 1967), the following groups would perform preliminary adjustments :

MORELLI - WOLF, UOTILA, WHALEN - TANNER, WOOLLARD.

In order to expedite the progress of the adjustment, it has been now agreed that all the information which could help for the advancement of this work will be exchanged immediately between the interested groups.

The best available status of the art will be utilized regarding the solution pertinent to the adjustments. Computer requirements and methods for solving the problems will be investigated and circulated immediately within the group.

Each group should inform periodically of the progresses MORELLI, who will then inform all the others.

According to the status of the program, MORELLI will set a due data for the submission of the primary adjustments, which will be distributed to all the interested persons for examination at least one month before the next Meeting of the Bedford Group (tentatively scheduled for June 1968).

- IV -

GRAVITY MEASUREMENTS AT SEA

Report of the Special Study Group n°4.20 made by Dr. J.L. WORZEL.*

This report covers the gravity measurements at sea since the fall of 1963, which have come to the attention of the writer, either by publication or by personal correspondence. Persons believed to have pertinent information for this report were contacted for additional information. The writer wishes to thank all contributors for their help.

Study meetings of SSG 4.20, Gravity Measurements at Sea, were held under the chairmanship of J.L. WORZEL in two sessions, one the morning and one in the afternoon of Monday October 2nd, 1967.

During the first session a moment of silence was observed for the passing of Dr. F.A. VENING MEINESZ, who had initiated the measurement of gravity at sea.

FIRST MEETING

The following papers were presented in the morning session :

AN ANALYSIS OF THE ERRORS IN GRAVITY MEASUREMENTS AT SEA
by R.T. HAYWORTH, (Dept. of Geodesy and Geophysics, Cambridge
University, U.K.).

"Two Askania GSS-2 sea gravimeters mounted antiparallel in tandem on separate gyrostabilized platforms were operated simultaneously for a period of two months aboard H.M.S. Hecate in order that an absolute determination might be made of the cross coupling errors experienced by HECLA class survey ships. This determination was used as the control against which the Cambridge analog cross coupling computer was tested. Errors of up to 35 mgal were encountered under normal survey conditions and the reliability of the cross coupling computer is discussed for a period when the errors were in the range from 5 to 10 mgal. The maximum error of the computer was 2 mgal, this figure including residual errors due to effects other than cross coupling. The mean output from the two gravimeters seemed to be accurate to one mgal, this figure being representative of the residual errors when cross coupling errors of ten mgal are present, and limited by the matching of the two gravimeter systems".

*Complementary details communicated by delegates have been sometimes added.

TEST OF GYROTABLES AND COMPARISON ON TWO SIMULTANEOUSLY
OPERATING SEAGRAVIMETERS by U. FLEISCHER, (German Hydrographic
Institute, Hamburg, Germany).

"Two complete seagravimeter devices were continuously operating for five months during two Atlantic expeditions of the German research vessel "METEOR" (2,700 tons). The behavior of the gyrotables were steadily observed by damped tubular levels. The oil erected gyro from Anschutz Company was reliable up to mean horizontal accelerations of $\pm 40,000$ mgal. The mean error on an equatorial cruise was two minutes of arc.

In rough sea on a North Atlantic cruise the electrically erected gyro was successfully used. In laboratory experiments on an escarpolette producing horizontal accelerations up to 125,000 mgal as well as at sea the maximum error was less than four minutes of arc.

Two Askania seagravimeters, type Gss-2, mounted antiparallel on separate platforms were operating simultaneously. The gravity results of the two instruments differ in dependence of the ship's course. The amplitude of that difference in moderate, uniform sea conditions, essentially resulting from cross coupling effects, was about 8 mgal. The behavior of the gravimeters in rough sea and a comparison with gravity at 30 submarine pendulum stations will be discussed".

ACCURACY TESTS OF GRAF ASKANIA SEA GRAVIMETER MADE ABOARD
USNS ELTANIN IN THE TASMAN SEA by M. TALWANI, (Lamont Geological
Observatory, Palisades, New York, U.S.A.).

"The Graf Askania sea gravimeter and the Anschutz gyrotable, including an electrically erected gyroscope, were installed aboard "ELTANIN" at Melbourne, Australia, in March 1967. Also installed were analog error correcting computers and electric table level monitors developed at Lamont.

The gravity equipment performed extremely well on cruise n° 28, 29 and 30 (March - September 1967) and data were obtained for all but two days during this period. A grid survey made in the Tasman Sea to check the accuracy of the gravity meter gave r.m.s. differences of about 3 mgal at track intersections. Navigation was based on navigational satellite fixes. Only one satellite was functional during this survey. If more satellites had been operating, the check at track intersections would most probably have been even better. The gravity meter, together with the error correction apparatus, is believed to be one of the most accurate at present operational in deep water areas.

Gravity measurements were made during cruises n° 28 and 29 in the South-East Pacific. These represent the first gravity measurements made south of 20°S between 170°W and 90°W. Measurements in this area are considered vital for the determination of the gravimetric geoid.

Free-air gravity anomalies obtained aboard surface ships and averaged over 5° squares in the Atlantic and Indian Oceans were compared with values obtained from satellite derived geopotential data. The agreement was good for the data representable by harmonics of low order and degree".

ERRORS CAUSED BY CONTINUOUS VIBRATION OF AN ASKANIA Gss-2
SEA GRAVIMETER by G.A. DAY (presented by B.C. BROWNE),
(Dept. of Geodesy and Geophysics, Cambridge University, U.K.).

"The Askania sea gravimeter was shown to have large errors when vibrated at certain frequencies below 200 Hz. The most important frequencies were isolated, and the errors associated with them measured for a vibration level of g-30 dB (peak) : these can be as large as 200 mgal. Vibrations at higher frequencies were also shown to produce errors in the gravimeter, but these are considered less important since they are much less common on board ship and because the method of mounting the gravimeter tends to dampen the vibrations at higher frequencies".

It seems worth pointing out briefly a further source of error to which the more recent models of the Askania gravimeter are prone. Disturbances of the photo cell signal have been produced by ship's radio transmitters broadcasting in the 4-8 MHz band. This interference can be removed by disconnecting the diode circuit which is introduced before the data amplifier.

A GRAVIMETER FOR MARINE, AIRBORNE, AND LUNAR SURFACE
MEASUREMENTS by G.C. HENDERSON, (General Dynamics,
Fort Worth, Texas, U.S.A.).

"State-of-the-art technology has supplied geophysicists with a single precision device to measure variations of the gravity field in the oceans, the atmosphere, and on extraterrestrial bodies. A sensor derived from an inertial grade, force rebalance accelerometer has been successfully tested in turboprop and rotary-wing aircraft. An extensive marine program has been conducted aboard the USNS "SHOUP".

With a range of 966-994 gal, this gravimeter system mounted on a stable platform has consistently exhibited a one-three milligal instrumental accuracy, excluding navigational errors, in dynamic conditions of up to seastates seven and eight. Static resolution is better than 0.1 mgal with a predictable drift rate of 1 mgal/month.

The basic system has been evaluated and found to be a strong contender for an earth-reference, lunar surface gravimeter. This wide dynamic range device can obtain a lunar base-station reading to within one milligal in terms of the absolute referenced to a terrestrial station. The possibility of improving system resolution is being investigated for the feasibility of obtaining tidal variations on the lunar surface".

DESIGN AND SEA PERFORMANCE OF THE BELL AEROSYSTEMS SEA
GRAVITY METER by A.L. McCAHAN, (U.S. Naval Oceanographic
Office, Washington, D.C., U.S.A.).

"The Bell gravity meter was designed to meet the specifications of the U.S. Navy Oceanographic Office. The specifications called for an accuracy of 0.2 mgal, drift less than 0.4 mgal/day and readings at 5 minute intervals. In tests, the meter operated 98 % of the time.

To mention problems encountered :

1) Fail-safe checks were too stringent in some places and needed to be relaxed.

2) Slip ring in the stabilized platform were damaged but were by passed to eliminate the problem.

3) The punched Mylar tape which introduces the forcing function to the digital filter tended to ship where spliced together.

The most annoying problem has been the lack of sufficient power on the ship and occasional surges which have required minor replacements".

PENDULUM MEASUREMENTS AT SEA by M.E. HEIFETZ,
(Geod. & Cartogr. Inst., Moscow).

"Pendulum gravity measurements on surface ships and submarines have been made in seas up to force 4 in the USSR. The first results have been published. Two pendulum apparatuses have been built, one with pendulums of 1/2 second period, the other with pendulums of a 1/4 second period. The 1/2 second pendulums show greater accuracy. Normally, these are only used in ports as controls for sea gravimeter data. They are mounted on gyro platforms and have been used at sea indicating an accuracy of 6.5 mgal.

In Winter 1964-65, an experiment of joint utilization of pendulums and gravimeters during a rather long sea expedition was undertaken. The reference station was Tokyo ; an estimation of stability of the half-second device could be made at the stations Colombo, Victoria and Perth by comparison of measurements made by other expeditions. The largest difference was at Colombo of about 1 mgal ; at Victoria and Perth, the differences were 0.5 and 0.1 mgal.

It is concluded that the use of pendulum in conjunction with gravity meters for sea observations is a useful technique".

OFFSHORE GRAVITY MEASUREMENTS FROM SMALL SHIPS
(100 to 400 tons) by K.E. VESELOV, L.P. SMIRNOV
& V.O. BAGRAMJANTS, (Moscow Inst. of Geophysics).

"Since 1964 VNII Geophysika has been conducting experimental offshore investigations to study an opportunity of using small ships (100 to 400 tons) for on-board gravity measurements. The experiments have been conducted on the Caspian and Black Seas.

Shipboard gravimeters with photographic and photoelectric recording developed in VNII Geophysika have been used. Elastic systems of gravimeters with a horizontal torsion wire are made of quartz glass and have supercritical damping. Gravimeters were mounted on a gyrostabilized platform. The same platform carried also two horizontal accelerometers and a photo-horizon to record residual tilting of the platform.

As a result of the analysis of the experimental data, it has been found that application of two gravimeters with elastic systems placed at an angle of 180° , makes it possible to eliminate systematical effects resulting from the total effect of horizontal and vertical accelerations (CC-effect), with an accuracy of $\pm 2 - 3$ gal with accelerations of up to $\pm 30 - 35$ mgal without using the results of measuring horizontal accelerations.

Errors due to the Harrison effect are not more than ± 2 mgal with similar accelerations.

The accuracy of an experiment with a gyroplatform amounted to $\pm 1' - 2'$, and a phase shift between the platform tilt and horizontal accelerations was close to 90° . A higher instrumental accuracy of the platform and a better phase relationship between the tilt and horizontal accelerations as compared with results obtained with large ships are due to a shorter period of rolling and pitching in case of small ships (3 - 4 sec. approximately).

A continuous gravity profile was run from a 100 ton ship with the gravity values known from bottom gravimeter measurements.

Measurements were made with the sea roughness of up to 3. The ship's position was continuously located by a radionavigational system with an accuracy of not more than ± 50 m.

Navigation data and the Eötvös effect were calculated using the digital computers.

Comparison of continuous Δg values obtained from small ships with bottom measurements has shown that the greatest errors of shipboard measurements (up to 10 mgal) are related to variations of the Eötvös effect. After making corrections for the Eötvös effect coincidence of the shipboard and bottom measurements with a root-mean-square error of about ± 3 mgal with the instrumental gravimeter accuracy of ± 2 mgal was obtained. Long period variations of horizontal accelerations and platform tilting due to an unstable ship course along the profile do not result in errors more than ± 2 mgal.

Further increase of an accuracy of shipboard measurements from small ships requires, in the first place, a higher instrumental accuracy of gravimeters and, in the second place, a higher accuracy of gyroplatform stabilization provided that the Eötvös correction is computed automatically".

SECOND MEETING

In the afternoon session, the following papers were presented :

VIBRATING STRING SEA GRAVIMETER by C.G. WING
(Massachusetts Institution of Technology, Cambridge, Mass.).

"A surface-ship gravimeter utilizing an inertial grade American Bosch Arma vibrating string accelerometer on a Sperry MK 19 mod 3C gyrocompass has been assembled at the Massachusetts Institute of Technology. A hybrid technique is employed to allow analog filtering of the sensor frequency output. All systematic error sources of greater than 0.1 mgal are compensated in real-time. In addition, the fishtail effect is compensated in real-time.

Preliminary results show a smoothness of ± 0.3 mgal in 20 gal seas. The systematic error is believed to be less than 1 mgal at accelerations of up to 100 gal and 15 second periods".

A NEW SURFACE SHIP GRAVITY METER USING THREE STRINGS
by I. TSUBOKAWA (Earth Res. Inst., University of Tokyo),
M. TAZIMA & T. SETO (Geograph. Surv. Inst., Ministry of
Construction, Japan).

"Since 1962, a new surface ship gravity meter has been developed, the principle of which uses three vibrating strings suspending one weight and intersecting at right angles to one another at the center of the weight in their extension. Pendulous motion of the weight owing to swells is damped magnetically. The gravity difference dg between a starting station and an observation station can be obtained by :

$$dg = g_0 \left[\frac{2}{3} \left(\frac{df_{1s}}{f_{1s}} + \frac{df_{2s}}{f_{2s}} + \frac{df_{3s}}{f_{3s}} \right) + \left(\frac{\overline{df_1}}{f_{1s}} \right)^2 + \left(\frac{\overline{df_2}}{f_{2s}} \right)^2 + \left(\frac{\overline{df_3}}{f_{3s}} \right)^2 - 2 \left(\frac{\overline{df_1 + df_2 + df_3}}{f_{1s} + f_{2s} + f_{3s}} \right)^2 \right]$$

$$- \frac{1}{2g_0} \overline{g_h^2} + 7.5 V \cos \varphi \sin A$$

where the frequency of each string is expressed by

$$f_1 = f_{1s} + df_1 = (f_{10} + df_{1s}) + df_1$$

$$\overline{f_1} = f_{10} + df_{1s}, \quad \overline{df_1} = 0,$$

the suffix o corresponding to the starting station and s the observation station,
 $\left. \begin{array}{l} V = \text{speed of the ship in knot} \\ \varphi \text{ and } A = \text{latitude and azimuth of the course.} \end{array} \right\}$

The second and third terms denote the correction of horizontal acceleration g_h and the Eötvös correction respectively. The frequencies f_1 , f_2 and f_3 are recorded with a standard frequency on a magnetic tape, the running mean of their sum being recorded on an analog recorder through 10 sets of counters for the purpose of obtaining the first approximation of observed values during a cruise. The second order corrections such as $(\frac{df_1}{f_{1s}})^2$ and $\frac{1}{2g_0} (\overline{g_h})^2$ are integrated and recorded by using watt hour meters and digital printers.

The results of the sea gravity survey made during the 8th Japanese Antarctic Research Expedition show that free-air anomalies along the ice edge in the Lutzow-Holm bay are positive more than a few tens of mgal, but there is a decreasing tendency toward the south up to nearly zero mgal at the Syowa Base.

A GRAVITY SECTION OVER THE NEGATIVE ANOMALY ZONE NORTH
OF CURACAO by R.A. LAGAAY (Vening Meinesz Laboratory,
Utrecht, Netherlands).

"A gravity map of local isostatic anomalies of the Netherlands Leeward Antilles area incorporating several new data is presented. This area is part of the "Meinesz Zone" ; (negative gravity anomaly zone) which here runs roughly parallel to the Venezuelan-Colombian coastline.

A N-S section across Curacao gives the crustal structure beneath the negative and the adjoining positive zone, and of the negative area south of the positive zone. This structure is best described as a wave-like deformation of the transitional region between the oceanic crust of the Venezuelan basin and the crust of the South American continent.

The crust under the negative zone north of the Leeward Antilles has been displaced downward at the amount of several kilometers, the crust under the islands upward and the crust under the region between the islands and the Venezuelan coast slightly downward.

The negative anomaly zone north of Curacao is not associated with a true bathymetric deep since a thick sedimentary and possibly volcanic fill obscures the downward displacement of the crust in this area. The presence of sediments appears from Hambleton's section at 68° W (Worzel 1965) which is based on gravity and seismic refraction data. Comparison of both sections shows that there is agreement on the essential point, viz. no appreciable crustal thickening is needed to explain the anomalies. If Hambleton's interpretation is slightly altered, complete agreement with the present section is obtained.

The absence of crustal thickening under the negative zone has an important consequence. Only a shallow submarine ridge would result if the crust would be allowed to reach isostatic equilibrium. This makes the concept that the present negative zones of island arcs are an early stage in mountain building doubtful".

UNDERWATER GRAVIMETRIC DETERMINATIONS BETWEEN BUENOS AIRES
AND MAR DEL PLATA by A.A. CERRATO (Instituto de Geodesia,
Universidad, Buenos Aires, Argentina).

"Forty two gravimeter stations were made on bottom with a North American Gravity Meter operated in a diving bell in the mouth of the Rio de la Plata and along the shore as far as Mar Del Plata. A maximum free-air anomaly of + 55 mgal was found off the Rio Salada and a minimum of 7 mgal off the Rio de la Plata".

GRAVITY MEASUREMENTS ALONG THE ARCTIC COAST OF CANADA
by J.G. TANNER (Dominion Observatory, Ottawa, Canada).

"Measurements were made with an underwater gravity meter along the Arctic Shelf of Canada to supplement the land gravity observations along the margin of Canada at the structural boundaries of the Pre-Cambrian Shield. Transponders on bottom supplied navigational control. Seismic refraction measurements were made as a part of this work also. Negative anomalies flank a central positive anomaly. From the data in hand it cannot be decided whether or not the source or sources of these anomalies are deep-seated".

PROGRESS REPORT ON SURFACE GRAVITY MEASUREMENTS WITH THE
SHIP "BANNOCK" IN THE MEDITERRANEAN SEA, 1965-1967,
by C. MORELLI (Osservatorio Geofisico Sperimentale,
Trieste, Italy).

"80,000 nautical miles have been steamed in the past three years, making surface ship gravity observations in the Mediterranean Sea using a Graf-Askania gravimeter. The geophysical tracks cover a quasi-rectangular grid of a mean spacing of 15' in latitude and longitude, with a closer grid in the seas immediately around Italy.

The recording system was changed from an analog system to a digital system. The data is being rapidly reduced and a detailed map of the Mediterranean Sea will be started soon". *

*Prof. C. MORELLI added that he hoped a better collaboration between the different Organizations and concerned Countries, specially for the study of Eastern part of the Mediterranean Sea.

GRAVITY MEASUREMENTS ON THE ATLANTIC : NAVADO III
by G.L. STRANG van HEES (Vening Meinesz Laboratory,
Utrecht, Netherlands).

"H. Neth. M.S. Snellius made ten crossings of the Atlantic on the Navado III operation making gravity observations with Graf-Askania Seagravimeters Gss 2 $\neq$ 11 and $\neq$ 19. Connections to the World System were made at Harbor stations. Continuous profiles of free-air anomalies are published with associated bathymetric and magnetic data. Mean values for each degree of longitude were compared with the gravity anomalies computed by U.A. UOTILA based on the development of the topography of the earth in spherical harmonics".

Then, G.E. MURT made some remarks about this work :

"He congratulated G.L. STRANG van HEES on the content of his paper and in the way he has presented his data. He had studied the gravity profiles published for the same project by the Netherlands Hydrographic Office and felt that G.L. STRANG van HEES' interpretation has brought this data to life and given it real meaning.

He added that this work was one result of a joint project between the Hydrographic Offices of the Netherlands and Great Britain, assisted by University bodies from both countries. The gravity work described by G.L. STRANG van HEES was complementary to similar work carried out by Great Britain, South of the Netherlands work to 10° North, and North of the Netherlands work to 64°N. Thus, lines at 3 degree spacing have now been completed from 10° North to 64° North.

In some ways it is unfortunate that this systematic survey was too early. Some of the British work for example was done in the Spring of 1964, long before the improved ocean position fixing techniques such as Omega or the satellite navigation were available, and long before the improved gravity meter instrumentation we have heard so much about today. Nevertheless the work filled a gap in on sea gravity knowledge and the results do have significance, particularly when presented as generalised or averaged values".

At the conclusion of the presentation of papers, a short meeting of the Special Study Group members present was held. It was decided :

- 1 - That the study groups work was valuable and that it should be continued,
- 2 - The meeting system is considered satisfactory and it will be continued,
- 3 - The chairman will continue his offices until the next IUGG meeting.

The Study Groups attention is called to the references about gravity measurements at sea which have been published by the Bureau Gravimétrique International in Bulletin d'Information n°12, February 1966 p. 15-17, and n°14, Novembre 1966, p. I-25 to I-48.

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- V -

AIRBORNE GRAVITY MEASUREMENTS

Meeting on Wednesday, October 4th at 5.15 p.m.

Dr. O. WILLIAMS, Chairman of the Study Group, opened the meeting with a brief joke for geodesists and pointed out the evolution in this research.

"During the past decade there have been numerous tests of airborne gravity measuring systems (including the LaCoste and Romberg, Askania-Graf, Worden, Bell accelerometer, PIGA-25, Pendulous Integrating Gyro Accelerometer) in propeller driven, turbo-propeller and jet aircraft).

Most of these tests have been conducted in the United States. These unique instrumentation techniques have required sound theoretical work as well as advanced instrumentation concepts. Many problems have been resolved and many remain before universal acceptance can be expected.

The session today will summarize some of these efforts.

- 1 - B. SZABO will discuss on :
"Recent development in aerial gravity measurements".
- 2 - H. MORITZ will discuss on :
"Optimum smoothing of aerial gravity measurements.
- 3 - D. ANTHONY will discuss on :
"Evaluation of aerial gravity measurements".
- 4 - P. TAYLOR will discuss on :
"Current U.S. Navy efforts to measure gravity from airborne platforms".

Dr. B. SZABO gave some details on the RECENT DEVELOPMENT IN AERIAL GRAVITY MEASUREMENTS (AFCRL, Bedford, Massachusetts).

"The processing of data recorded by airborne gravity measuring instrumentation is described. The methods for the elimination of non-gravitational accelerations and other errors are presented. Preliminary filtering methods are experimentally used for smoothing of navigation data and gravity sensor's outputs.

Results are evaluated by comparison with gravity values uplifted to flight altitudes from independent terrestrial gravity measurements,

Mean anomalies and their RMS errors for $5^\circ \times 5^\circ$ and $1^\circ \times 1^\circ$ blocks are computed from two symmetrically located East-West profiles across each block. The achieved accuracies were : ± 5 to 8 mgal RMS error for a $5^\circ \times 5^\circ$ block and ± 9 mgal for a $1^\circ \times 1^\circ$ block. The errors include measurement and representation errors. The major components of the measurement errors are from navigation parameters (velocity and azimuth errors)".

Dr. H. MORITZ reported on the OPTIMUM SMOOTHING OF AERIAL GRAVITY MEASUREMENTS (Techn. Univ. Berlin).

"The smoothing of aerial gravimeter records is investigated theoretically using the theory of stationary stochastic processes (time series). Two methods of optimum filtering are considered : first, least-squares filtering, due to Norbert Wiener, where the rms. error is minimized absolutely ; and second, equal-spectrum filtering, where the rms. error is minimized subject to the condition of least distortion as expressed by preservation of spectrum. The equal-spectrum method seems to be more appropriate for aerial gravimetry because of the high noise level and has a considerable practical advantage.

Emphasis is on digital computation, for which practical formulae are given, analog computation by means of electric networks is outlined

Advantages of digital filtering.

Numerical filtering using a digital computer has advantages over analog filtering by means of an electric network. Here are a few of them.

1 - Simplicity : The symmetry of past and present, essential for an optimum use of the data, is directly contained in the formulae for digital computation. Since physical systems such as electrical networks are essentially causal, that is, operating on the past only, this symmetry cannot be directly achieved here but must be approximated using a time lag. This fact heavily complicates formulae, so that complex electronic network is needed for their realization.

2 - Flexibility : Modifications in the spectra caused by changes in the measuring equipment, in the environment, etc... can easily be taken into account by the digital formulae, whereas in analog filtering they would involve expensive reconstruction of electric networks.

3 - Accuracy : After sampling, digital computation is errorless, and approximations such as spectrum smoothing are well under control. In analog filtering, additional errors are introduced during computation by the electric networks, and control of spectrum smoothing, etc... is limited".

M. D. ANTHONY discussed on the FILTERING AERIAL GRAVITY MEASUREMENTS (AFCRL, Bedford, Massachusetts).

"Five numerical filters designed for aerial gravity measurements are discussed. Three of the filters were obtained from a least squares approximation to a theoretical transfer function continued beyond the desired cutoff frequency by a sine function to allow a closer approximation. The cutoff frequencies for the three filters were zero, one cycle per twenty nautical miles, and one cycle per forty nautical miles. The remaining two are optimum filters derived by H. MORITZ. One is obtained by minimizing the filter error according to least squares, the other results from minimizing the filter error subject to the condition of least distortion of the data spectrum.

The least squares and equal spectrum filters of MORITZ are very similar in effect with the least squares producing slightly more smoothing. All three of the cutoff frequency filters smooth the data much more than the MORITZ filters. A conclusion as to the best filter must wait until more data has been filtered and analyzed".

M. P. TAYLOR reported on U.S. NAVY EFFORTS IN THE FIELD OF AIRBORNE GRAVITY MEASUREMENTS (U.S. Naval Oceanographic Office, Washington, D.C.).

"A triservice test of a helicopter used as a gravity measuring platform is planned for the first quarter of 1968.

A Bell sea type g meter will be obtained by the Army Map Service and used in an Air Force HH-3Fz helicopter.

The tests planned by the U.S. Navy Ocean. Off. will be conducted at the Naval Air Test Center at Patuxent River, Maryland and the NASA Wallops Island, Virginia".

In conclusion, the President said :

"I feel it is quite safe to conclude that much will be accomplished in this new field, of an operational nature during the next few years.

I also feel confident that these new gravity data gathering techniques will be universally accepted prior to our next Assembly".

- VI -

VARIOUS TOPICS

At the first meeting on Wednesday October 4th, Dr. HONKASALO reported on the "Variation of gravity caused by land uplift in FENNOSCANDIA". The text was distributed to each delegate :

"The secular variation of gravity has been an important problem especially for these gravimetrists who are working for the first order world gravity net...

Today we have anomaly maps over the whole Fennoscandia, but no clear correlation between the anomalies and the land uplift can be detected.

On the other hand, the land uplift changes the gravity differences between the central and the fringe areas of the rise. This change can be measured with modern technic in a reasonable time. The difference of land uplift between the western and the eastern Finland is about 5mm/year. We can estimate the effect of this on the gravity difference...

In Finland we have already made the first measurements of this program (1965-1966). In 1967, the program was extended over the Gulf of Bothnia in cooperation with Rikets allmänna kartverk (Dr. PETTERSSON), in Norway to the Atlantic coast.

We have planned to remeasure the gravity differences every 5-10 years".

See p. 55, the establishment of a new Study Group on this subject.

Then, C.T. WHALEN ended this meeting showing many slides on the field gravity equipment of Air Force Cambridge Research Laboratories.

To be noted the paper "On the needed density of gravimetric stations in geodetic nets" by Dr. P. BIRO (Tech. Univ., Budapest).

"In the first part, the problem is discussed in relation to the high precision levellings. The needed density of well chosen gravimetric stations are proposed.

In triangulation-nets anomaly maps are used for gravimetric interpolation of the deflection of the vertical. The accuracy of them can be approximately characterised by the "error of interpolation" of the anomalies.

This latter has been discussed in function of the density of gravimetric stations in different characters of topography.

The given formulae enable us to estimate the needed density of the gravimetric stations to a demanded accuracy of the gravimetric deflection of the vertical".

CONCLUDING REMARKS (Section IV)

The Officers of the Section IV were not reeligibile, a new Bureau was elected by the I.A.G.

New Bureau of the Section IV

Chairman : Prof. C. MORELLI (Italy)
Secretary: Dr. T. HONKASALO (Finland)

Special Study Groups

- n°4.05. First Order World Gravity Net (C. MORELLI)..... retain
- n°4.06. Establishment of Gravity Calibration Bases..... discontinue
- n°4.18. Methods of Absolute Gravity Determinations (A.H. COOK) retain
- n°4.20. Measurement of Gravity at Sea (J.L. WORZEL)..... retain
- n°4.21. Measurement Techniques for Determination of
Secular Gravity Variation
(Chairman : T. HONKASALO)..... New Special Study Group

These modifications were approved at the I.A.G. General Assembly on October 6th, 1967.

RESOLUTIONS

At the first meeting (October 4th), some resolutions were proposed and adopted :

- One double resolution (n°1 and 2) jointly with the Section I and III, which was discussed many times, specially at the Section IV (See p. 21-28).
- One third resolution discussed in the same time (n°22)
- Two resolutions proposed by Prof. Y.D. BOULANGER, concerning the First Order World Gravity Net and the Calibration Lines (n°23 and 24).

About the GEODETIC REFERENCE SYSTEM and POTSDAM

(Resolutions n°1, 2 and 22) :

Dr. A.H. COOK introduced two resolutions on a new geodetic reference system to replace the International ellipsoid (1924) and the International Gravity Formula (1930). He explained that these resolutions had been formulated by a working group of Section I in which were included the Members of the resolutions Committee of Section IV. The resolutions were in accordance with the views expressed by Section IV on September 27th and with a resolution passed by the International Gravity Commission (1962).

He explained that the proposals were in the form of 2 resolutions, one for the Union and one for the Association of Geodesy, because it was not possible, in the course of the Assembly, to check thoroughly the numerical values for the flattening and the gravity formula that followed from the defining constants, namely the values of a_e , G_E and J_2 contained in the IAU system of Astronomical constants, 1964.

He introduced a third resolution recommending a change in the value of gravity to be adopted at Potsdam. He suggested that this change, which concerned actual measured values, could be considered to be more transient than the change in the conventional reference system.

Some objections were made on the change of the Potsdam system, because now many absolute measurements are in progress, specially Prof. C. MORELLI would like to delay the change up to the achievement of the FOWGN and suggested a change only for metrological purposes.

In reply Dr. A.H. COOK said that it was not sufficient ; if the new geodetic reference system was adopted ; it was highly desirable to use the proposed new Potsdam value for expressing measured values of gravity.

N° 1 - On a new Geodetic Reference System

The IUGG,

recognizing that the International Ellipsoid adopted at Madrid in 1924 and the International Gravity Formula adopted at Stockholm in 1930 no longer represent the size, shape and gravity field of the Earth to adequate accuracy, although they may continue to be used as references for current work where a change would be disadvantageous and considering that :

a) for scientific uses more appropriate values are needed and are now available,

b) the IAU in consultation with the IUGG has adopted at its General Assembly in 1964, as part of a new set of astronomical constants, values that are far closer to those currently considered the best, and that :

c) the IAU and IUGG have adopted in 1967 a new Conventional International Origin for polar motion, and the BIH adopts conventional longitudes for the determination of UT 1, (and UT 2);

recommends that :

a) the following conventional set of constants define the Geodetic Reference System 1967 :

equatorial radius of the earth : $a_e = 6\,378\,160$ meters,

geocentric gravitational constant of the earth, including the atmosphere :

$$GM = 398\,603 \cdot 10^9 \text{ m}^3\text{s}^{-2},$$

dynamical form factor of the earth : $J_2 = 10\,827 \cdot 10^{-7}$;

b) the minor axis of the reference ellipsoid equipotential in the system defined above, be parallel to the conventional International Origin for polar motion, and the primary meridian be parallel to the zero meridian of the BIH adopted longitudes.

N° 2 - New Reference Ellipsoid (1967)

The IAG,

resolves that the parameters of the equipotential ellipsoid (Reference Ellipsoid 1967) that correspond to the Geodetic Reference System 1967 as well as the expression in series and in closed form of the corresponding gravity formula (Gravity Formula 1967), together with the derivations used will be published in the Bulletin Géodésique.

N°22 - The Potsdam System

The IAG,

considering that the value of gravity at Potsdam, namely 981 274 mgal, in terms of which all measured values of gravity are expressed, is known to be greatly in error, and that for scientific uses a more accurate value is needed and is available,

recommends that whenever improved absolute gravity values are required, in particular for metrological purposes and when anomalies are computed in the Geodetic Reference System 1967 as recommended by the IUGG, the value at Potsdam should be taken to be 981 260 mgal.

N°23 - First Order World Gravity Net

The IAG, to increase the rigidity of the International Gravimetric Network of the First Order,

recommends to realize direct pendulum ties of Potsdam with Tokyo, Nairobi, Melbourne and Mexico or La Paz, using pendulum instruments guaranteeing the realization of these ties in accordance with A-B-A program with the mean square error not exceeding ± 0.2 mgal and

requests the National Committees of the countries concerned to assist in these works.

N°24 - Gravimeter Calibration Lines

The IAG, to increase the accuracy of calibration bases for gravimeters

urges all nations to continue measurements on these bases possibly by means of instruments of different construction and

requests all the Nations Committees of the countries concerned to assist in these works.

VOEUX (texte français)

N° 1 - Sur un nouveau Système de Référence Géodésique

L'UGGI,

constatant que l'Ellipsoïde International adopté à Madrid en 1924 et que la Formule Internationale de Pesanteur adoptée à Stockholm en 1930 ne représentent plus les dimensions, la forme et le champ de pesanteur de la Terre avec une précision suffisante, bien qu'ils puissent encore servir de références pour des travaux courants dans lesquels un changement serait désavantageux et considérant

a) que des valeurs plus appropriées sont nécessaires et actuellement disponibles pour des besoins scientifiques,

b) que l'UAI après consultation de l'UGGI, a adopté au cours de son Assemblée Générale de 1964, comme partie d'un nouvel ensemble de constantes astronomiques, des valeurs beaucoup plus proches de celles couramment considérées comme les meilleures et,

c) que l'UAI et l'UGGI ont adopté en 1967 une nouvelle Origine Internationale conventionnelle pour le mouvement du pôle, et que le BIH adopte les longitudes conventionnelles pour la détermination de TU 1 (et TU 2),

recommande que

a) l'ensemble suivant de constantes conventionnelles définisse le Système de Référence Géodésique 1967 :

- rayon équatorial de la Terre..... $a_e = 6\,378\,160$ mètres
- constante géocentrique de gravitation
terrestre, y compris l'atmosphère..... $GM = 398\,603.10^9 \text{ m}^3 \text{ s}^{-2}$
- facteur d'ellipticité géopotentielle... $J_2 = 10\,827.10^{-7}$

b) le petit axe de l'ellipsoïde équipotentiel de référence dans le système décrit ci-dessus, soit parallèle à la direction définie par l'Origine Internationale conventionnelle pour le mouvement du pôle et le méridien Origine soit parallèle au méridien zéro des longitudes adoptées par le BIH.

N° 2 - Nouvel Ellipsoïde de Référence (1967)

L'AIG,

décide que les paramètres de l'ellipsoïde équipotentiel (Ellipsoïde de Référence 1967) qui correspond au Système de Référence Géodésique 1967 ainsi que l'expression en série et sous forme finie de la formule de pesanteur correspondante (Formule de Pesanteur 1967) avec les méthodes de calculs utilisées, soient publiés dans le Bulletin Géodésique.

N°22 - Système de Potsdam

L'AIG,

considérant que la valeur de la pesanteur à Potsdam, à savoir 981 274 mgal, en fonction de laquelle sont exprimées toutes les valeurs mesurées de la pesanteur, est affectée d'une erreur considérable, et qu'une valeur plus précise est nécessaire et disponible pour les usages scientifiques.

recommande que toutes les fois que de meilleures valeurs absolues de pesanteur sont nécessaires, en particulier en métrologie et dans le calcul des anomalies dans le Système de Référence Géodésique 1967, la valeur à Potsdam soit prise égale à 981 260 mgal.

N°23 - Réseau de 1er Ordre

L'AIG, pour accroître la rigidité du réseau gravimétrique international de premier ordre,

recommande des jonctions directes par pendule de Potsdam à Tokyo, Nairobi, Melbourne et Mexico ou La Paz, en utilisant des instruments à pendule garantissant la réalisation de ces jonctions suivant le mode opératoire A-B-A, avec une erreur moyenne quadratique n'excédant pas $\pm 0,2$ mgal

demande aux Comités Nationaux des pays concernés l'aide nécessaire à ces travaux.

N°24 - Chaînes d'Etalonnage pour Gravimètres

L'AIG, pour accroître la précision des bases d'étalonnage des gravimètres,

demande de façon pressante à toutes les nations de continuer les mesures sur ces bases, si possible au moyen d'instruments de construction différente, et

demande à tous les Comités Nationaux des pays concernés l'aide nécessaire à ces travaux.

RECENT INFORMATION
about GRAVITY MEASUREMENTS AT SEA

M.A.R.- 68 : Plans for BIO Cruise to Mid Atlantic Ridge in 1968
(Bedford, Inst. Ocean., Dartmouth, N.S., Canada)

"The proposed cruise to the Mid-Atlantic Ridge is a part of a continuing research investigation. The area to the north of 47° N was investigated by M.N. HILL in 1954 and 1956 and that around 46° N in 1960. CSS HUDSON started the present programme of detailed investigations in 1965. The location of the study area and the coverage to date is shown on the enclosed illustration.

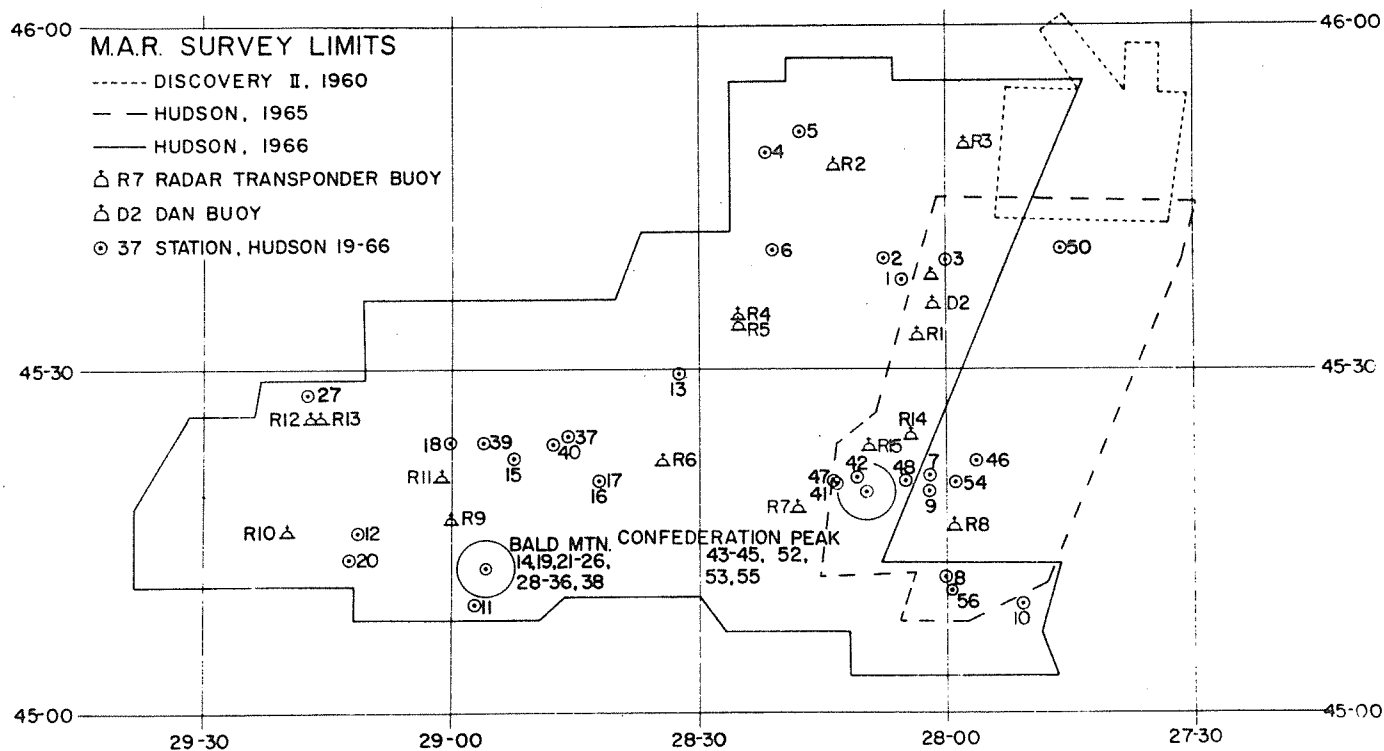
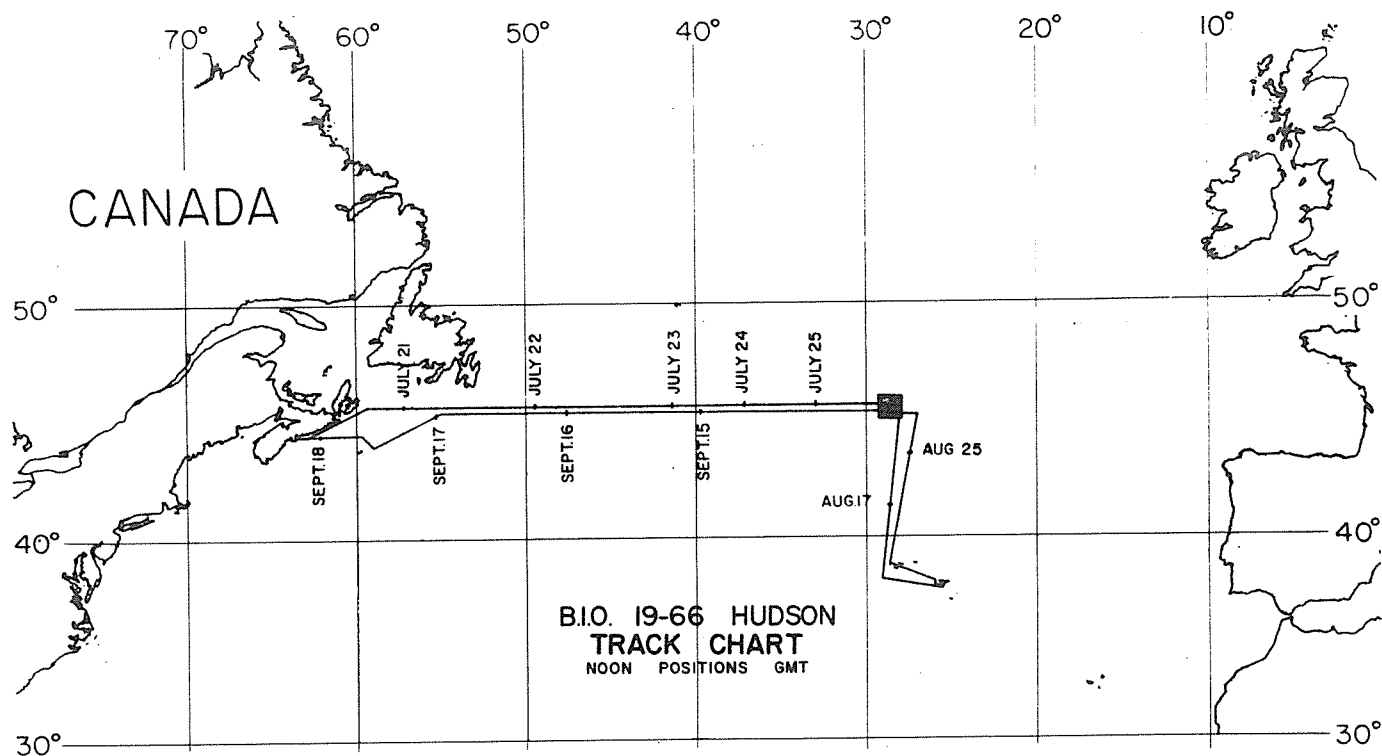
The purpose of the present investigations of the Mid-Atlantic Ridge is to study and describe in detail a representative area near the crest of the ridge at 45° N. The maximum density of observations compatible with the resolution of various geophysical techniques will be planned in order to obtain a sufficiently detailed picture. In addition to increasing our understanding of the structure of the ridge, the project is used to test and develop new methods of precision surveying and data collection in the deep ocean. Concentration on a small area in the Mid-Atlantic makes it possible to study time variations of various parameters in oceanography, meteorology and biology.

The Mid-Atlantic ridge study is a part of the Newfoundland geotraverse. Gravity, magnetic and bathymetry survey of the continental shelf section of this geotraverse was completed in 1967.

Two ships are scheduled for the 1968 expedition.

The following is the general outline of the proposed programme :

Phase	Dates	Activity	At Sea	Work	On Pas- sage	In Port
1	May 6-25	Shakedown-Metrology	20	16	4	-
	May 26-Jun.5	Load at BIO	-	-	-	11
2	Jun.6-Jul.2	Btmtry, Mag, Grav. Survey Based on moored buoys	23	16	7	4
3	Jul.3-28	As 2 until July 16. Seismic experiments afterwards	23	19	4	3
4	Jul.29-Aug.22	Seismic experiment	22	18	4	3
5	Aug.23- Sept.12	Detailed seismic & bathy- metry investigations, bottom sampling.	21	14	7	-
	Sept.12-18	Unload at BIO	-	-	-	6
Total cruise length : 136 days			109	83	26	27



On survey, main navigational control will be by means of radar transponder buoys, moored and serviced by second ship. CSS HUDSON will carry a satellite navigation system for absolute positioning and a single range Decca system for determining the distance between the two ships. Seismic experiment during phases 3 and 4 will be based on moored sonobuoys. A bottom seismometer and a multiple hydrophone seismic cable are also under development. All the survey data reduction will be performed on a PDP-3 computer in Real + 24 hrs. time. A LINC-8 will be used for signal correlation studies in reflection seismics.

Four meetings are scheduled for pre-cruise planning and discussion of proposed projects. The meetings will take place in mid-November, mid-January, mid-March and mid-April.

The first planning meeting will take place in BIO Conference Room at 1400 hrs. on Friday, November 17, 1967.

The following topics will be discussed :

- 1 - Overall programme and dates,
- 2 - Outside participation and project coordination,
- 3 - Major responsibility,
- 4 - Equipment requirements".

BIO 5250-6 (68)
October 30, 1967
First Circular.

B.D. LONCAREVIC
Senior Scientist
MAR-68 Expedition
