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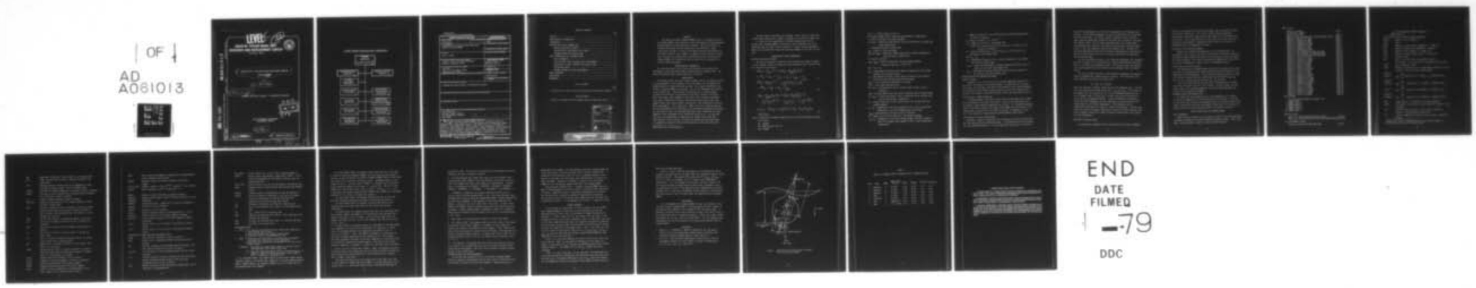

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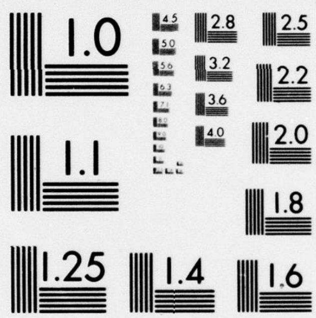

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

DESCRIPTION OF THE REVISED BUOY-CABLE-BODY COMPUTER PROGRAM CABMOD

by

Henry T. Wang

Final rept.

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SHIP PERFORMANCE DEPARTMENT
DEPARTMENTAL REPORT

20p.

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DTNSRDC/SPD-0633-02

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by Henry T. Wang
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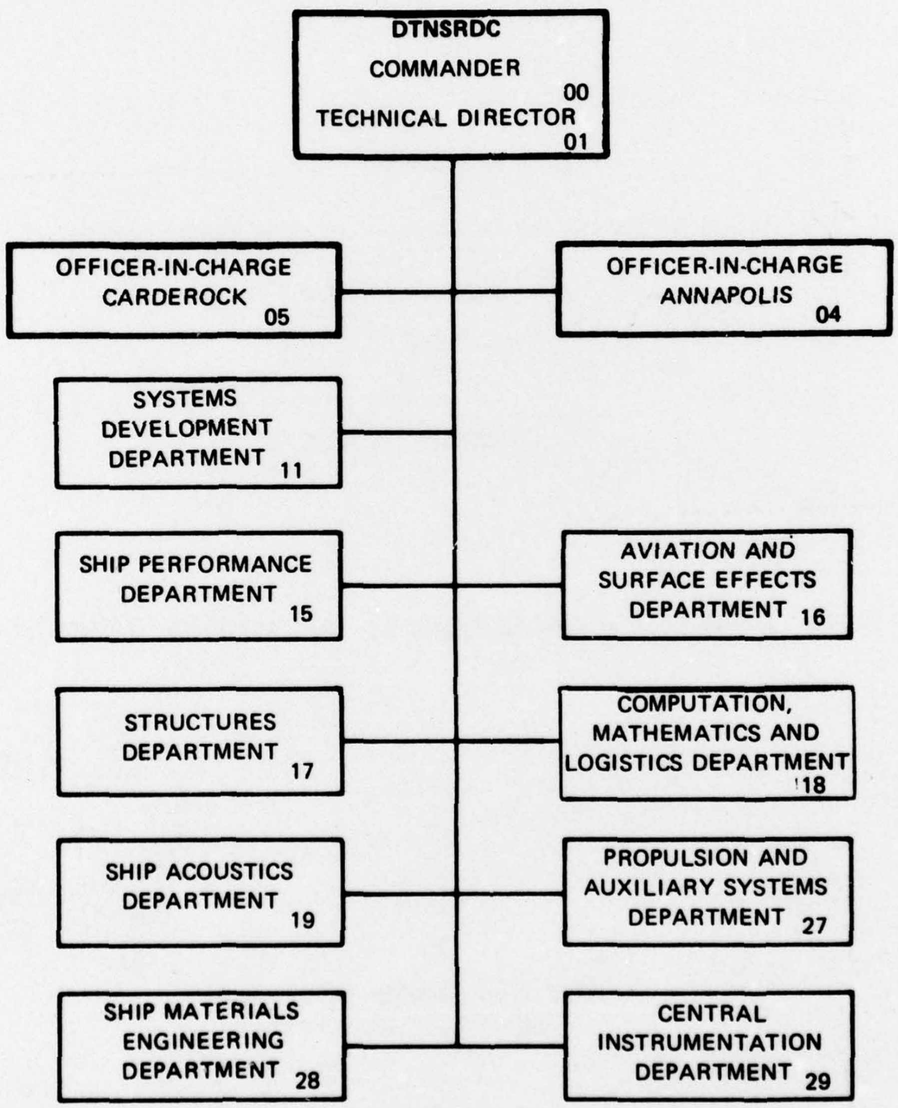

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The report describes Program CABMOD, which is an updated version of Program CABUOY, which analyzes in the time domain the two-dimensional dynamic behavior of buoy-cable-body systems. The new revisions, all of which are related to the surface buoy, are described. Input instructions include a listing of the READ statements, definitions of the input variables, and a number of comments on the entering of input data. Results are presented for seven different ways of exercising Program CABMOD for a spheroidal buoy of aspect ratio 10 moored in a typical ocean environment.

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ABSTRACT

The report describes Program CABMOD, which is an updated version of Program CABUOY, which analyzes in the time domain the two-dimensional dynamic behavior of buoy-cable-body systems. The new revisions, all of which are related to the surface buoy, are described. Input instructions include a listing of the READ statements, definitions of the input variables, and a number of comments on the entering of input data. Results are presented for seven different ways of exercising Program CABMOD for a spheroidal buoy of aspect ratio 10 moored in a typical ocean environment.

ADMINISTRATIVE INFORMATION

The work described in this report was authorized by the Naval Air Development Center under Work Request WR-00501 dated 1 February 1978. The work was performed under internal Work Unit 1-1552-147.

INTRODUCTION

The present report describes Program CABMOD, which is an updated version of Program CABUOY,[1] which analyzes in the time domain the two-dimensional dynamic behavior of buoy-cable-body systems. The various refinements contained in Program CABMOD are described. All of the refinements are related to the surface buoy. These include the presence of a surface package situated below the buoy, distribution of the forces acting on the upper half of the upper cable segment to the surface buoy instead of the upper cable node, calculation of inertia coefficients based on the actual submerged volume, and a more accurate formulation of the hydrostatic restoring forces and moments. Also, provision is made for directly entering inertia and forcing coefficients in addition to the internally-generated coefficients for spar buoys of any size and spheroidal buoys whose dimensions are small compared to the wavelength of the significant ocean waves. For the spar buoy case, the formulation is generalized to include cases where the cross section is not circular. Finally, the output for the surface buoy is expanded to include a statistical description of the draft and pitch.

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[1] References are listed on page 15.

Detailed input instructions are provided. These include a definition of each input variable and a number of comments on the entry of input data.

To illustrate the significance of the new formulations for the surface buoy, Program CABMOD is exercised in seven different ways for a spheroidal buoy of aspect ratio 10 moored in a typical ocean environment. Results are presented for the pitch and heave response of the buoy for each case.

DESCRIPTION OF BUOY FORMULATION

REVISED EQUATIONS OF MOTION

The revised equations of motion for the surface buoy shown in Figure 1 are as follows, where the underlined terms represent new or revised terms not contained in Reference 1:

$$(A_{\xi\xi} + \underline{A_{\xi SP}})\ddot{\xi} + (A_{\xi\psi} - \underline{A_{\xi SP} R_{SP}})\ddot{\psi}$$
$$= FK_x + D_x + \underline{D_{xSP}} + T_x + T_{IW_x} + \underline{F_{cx}} \qquad (1)$$

$$(A_{\eta\eta} + \underline{A_{\eta SP}})\ddot{\zeta} = \underline{-\rho g (V + V_{SP}) + W}$$
$$+ FK_y + D_y + T_y + \underline{F_{cy}} \qquad (2)$$

$$(A_{\xi\psi} - \underline{A_{\xi SP} R_{SP}})\ddot{\xi} + (A_{\psi\psi} + \underline{A_{\xi SP} R_{SP}^2})\ddot{\psi}$$
$$= \underline{-\rho g I_{SW} (\psi - \beta)} - \underline{R_{SP} D_{xSP}} + \rho g V \overline{BG} \psi$$
$$+ FK_\psi - \overline{BG} D_x + (-r_y \psi + r_x) T_y - (r_x \psi + r_y) T_x$$
$$- r_{Wy} T_{IW_x} \qquad (3)$$

where the subscript SP denotes quantities for the surface package attached to the buoy

$A_{\xi\xi} = m + K_S \rho V$

$A_{\xi\psi} = -\rho \int (y - y_G) k_s(y)\ S(y)\ dy$

$A_{\eta\eta} = m + K_H \rho V$

$A_{\psi\psi} = I + \rho\int (y-y_G)^2 k_s(y)\ S(y)\ dy$

ξ, ζ, and ψ = surge, heave, and pitch displacements, respectively,

m = mass of the buoy and surface package

K_S and K_H = added mass coefficients for the surface buoy for surge and heave, respectively.

V = submerged volume of surface buoy

V_{SP} = volume of surface package

K_{SSP} and K_{HSP} = added mass coefficients for the surface package for surge and heave, respectively

ρ = density of fluid

$A_{\xi SP}$, $A_{\eta SP}$ = inertia coefficients for the surface package $= K_{SSP}\rho V_{SP}$, $K_{HSP}\rho V_{SP}$, respectively

$R_{SP} = y_{SP} - y_G$

Y_{SP} = longitudinal distance of the center of buoyancy of the surface package from the buoy origin

y_G = longitudinal distance of the center of gravity of the surface buoy and surface package from the buoy origin

$k_s(y)$ = local added mass coefficient for surge

S(y) = local cross-sectional area

FK_x, FK_y = exciting forces due to surface waves in the x- and y-directions

FK_ψ = exciting moment about the center of gravity due to surface waves

D_x, D_{xSP} = viscous drag forces in the x-direction on the surface buoy and surface package, respectively

D_y = viscous drag force in the y-direction on the surface buoy and surface package

T_x, T_y = components of the cable tension in the x- and y-directions, respectively, at the attachment point to the buoy

T_{IWX} = wind loading on the buoy in the x-direction

W = weight in air of the surface buoy and surface package

F_{cx}, F_{cy} = components of the forces (drag, weight, inertia) acting on half of the upper cable segment in the x- and y-directions, respectively.

I = moment of inertia of the surface buoy and surface package about the center of gravity

g = gravity constant = 32.2 ft/sec^2

I_{sw} = moment of inertia of waterplane area

$= \pi r_w^4/4$ for circular cross section, where r_w is radius of cross section at waterplane

β = slope of surface wave = $\partial y_w / \partial x$ where y_w is the vertical displacement of the surface wave

$\overline{BG} = y_B - y_G$

y_B = longitudinal distance of the center of buoyancy of the surface buoy from the buoy origin

r_x, r_y = normal and longitudinal distances measured from the center of gravity to the cable attachment point

r_{wy} = longitudinal distance measured from the center of gravity to the center of the wind loading force

DESCRIPTION OF NEW SURFACE BUOY TERMS

Surface Package

Equations (1) to (3) show a total of eleven additional terms due to the inertia and drag of the surface package. In addition, the exciting forces FK_x, FK_y, and FK_ψ also reflect the presence of the surface package. The addition of the surface package essentially allows the surface buoy to consist of two bodies, each with different inertia and drag characteristics.

Distribution of Cable Parameters

In Program CABUOY, the forces acting on the entire upper cable segment were distributed to the upper cable node. This was done principally for the sake of simplifying the equations for the buoy. In the present program, half of the forces acting on the upper cable segment are distributed to the surface buoy, giving rise to the terms F_{cx} and F_{cy} in Equations (1) and (2). This results in a more accurate distribution of cable forces.

Calculation of Inertia Coefficients

Reference 1 gives the equations for calculating the inertia coefficients for spar buoys and small spheroidal buoys. The coefficients were calculated for a pre-determined draft H. For the spheroidal buoy cases, H was chosen such that the waterplane cross section corresponded to the maximum cross section. In the present program, the inertia coefficients are calculated for the actual draft. This poses no major problems for the spar buoy cases since the added mass coefficient for each cross section is the value for infinite fluid. For the small spheroidal buoy cases, each draft H would theoretically require a calculation using the free-surface program by Bai.[2] This was beyond the scope of the present work. Instead, the following approach was taken after extensive consideration of the physical aspects of the problem, as well as the data given by Bai for spheroidal and cylindrical buoys.

For the case where the buoy is less than half-submerged, the submerged portion is treated as the lower half of a smaller spheroid with semi-axes given by the draft and waterplane radius. The results using this approach are in good agreement with the three non-semi-submerged cases considered by Bai.

For the case where the buoy is more than half-submerged, the approach taken is somewhat more complex and less accurate. The coefficients for surge and heave, K_S and K_H, are taken to be

$$K_S = K_{So}, \; K_H = V_o K_{Ho}/V$$

where the subscript o denotes values for the half-submerged case. For the pitch and coupled pitch-surge coefficients, $A_{\psi\psi}$ and $A_{\xi\psi}$, the results of Bai suggest that the coefficients for a fully-submerged spheroidal buoy may be roughly equal to those for a cylinder with aspect ratio equal to 0.8 of the fully-submerged spheroid. Linear interpolation between the values for half-submergence and full-submergence are used to obtain the coefficients for in-between submergences. This approach yields coefficients which may be in error by as much as 20 percent. However, the results do follow the proper trend and are likely to be more accurate than those originally obtained by simply fixing the coefficients at the values for half-submergence.

Hydrostatic Buoyancy Force

The hydrostatic buoyancy force is now given by the actual submerged volume of the surface buoy and surface package times the specific gravity of the fluid, $-\rho g(V+V_{sp})$. This is more accurate than the previous calculation of buoyancy change based on the steady-state waterplane area of the buoy. This is particularly true for those cases where the buoy is undergoing large changes in submergence and/or where the variation in waterplane area with submergence is large.

Hydrostatic Pitch Restoring Moment

Equation (3) contains the hydrostatic pitch restoring term, $-\rho \cdot gI_{sw}(\psi-\beta)$, which is due to the shift in the center of buoyancy caused by the relative angle between the pitch of the buoy axis, ψ, and the slope of the ocean surface β. This term is particularly important for discus-like buoys whose submergence is small relative to waterplane radius.

Coefficients for Arbitrary Buoy

The formulation in Program CABUOY restricted the surface buoy to be a spar buoy or a spheroidal buoy whose dimensions are small relative to the significant ocean wavelengths. In the present program, provision is made for the user to input arbitrary coefficients for the inertia $A_{\xi\xi}$, $A_{\xi\psi}$, $A_{\eta\eta}$, and $A_{\psi\psi}$, and the forcing functions FK_x, FK_y, and FK_ψ.

Also, the formulation for the spar buoy is generalized to include cases where the cross section is not circular. In these cases, the user inputs values for the surge added mass coefficient $K_S \neq 1$ and moment of inertia of the waterplane $\neq \pi r_w^4/4$.

EXPANDED OUTPUT FOR SURFACE BUOY

The output for the surface buoy has been expanded to give certain statistical information on the draft and pitch of the buoy. At the end of each print time interval, the program prints out the mean values of the draft H and pitch ψ, and also the percent of time that the draft and the absolute value of pitch exceed prescribed values input by the user.

INPUT INSTRUCTIONS FOR PROGRAM CABMOD

READ STATEMENTS

Input data are entered into the program by means of the following READ statements contained in the MAIN Program and Subroutine BUOY. These statements are given numbers simply for identification purposes.

MAIN Program

```
     READ (5,1) NCASES                                      Card 1
     DO 1000 MC=1, NCASES
     READ(5,301) TITLE                                      Card 2
     READ(5,1) NSM, NSW,NCAB,NCUR,ITER,MTRC,IBUOY,ISPAR     Card 3
     READ(5,2) (FSM (K),K=1,NSM)                            Card 4
     READ(5,2) (AXSM(K),K=1,NSM)                            Card 5
     READ(5,2) (AYSM(K),K=1,NSM)                            Card 6
     READ(5,2) (FIDSM(K),K=1,NSM)                           Card 7
     READ(5,2) (ASW(K),K=1,NSW)                             Card 8
     READ(5,2) (FRSW(K),K=1,NSW)                            Card 9
     READ(5,2) (FIDSW(K),K=1,NSW)                           Card 10
     READ(5,2) RHO, SUBM,TWX,TIY,AMC,AFAC,TMIN              Card 11
     READ(5,2) CDASPX,CDASBX,VSP,SPXK,SPYK,YYSP             Card 12
     READ(5,2) TINVI,DT1,TOTT,DT2,DIR,TBH,TBYMX             Card 13
     READ(5,3) (FLC(K),K=1,NCAB)                            Card 14
     READ(5,2) (DCI(K),K=1, NCAB)                           Card 15
     READ(5,2) (CDN(K),K=1,NCAB)                            Card 16
     READ(5,2) (CDT(K),K=1,NCAB)                            Card 17
     READ(5,2) (WC(K),K=1,NCAB)                             Card 18
     READ(5,4) (CM(K),K=1,NCAB)                             Card 19
     READ(5,3) (TREF(K),K=1,NCAB)                           Card 20
     READ(5,5) (C1(K),K=1,NCAB)                             Card 21
     READ(5,2) (C2(K),K=1,NCAB)                             Card 22
     READ(5,2) (CINT(K),K=1,NCAB)                           Card 23
     READ(5,2) (WBD(K),K=1,NCAB)                            Card 24
     READ(5,2) (CDABX(K),K=1,NCAB)                          Card 25
     READ(5,2) (CDABY(K),K=1,NCAB)                          Card 26
     READ(5,2) (XMBV(K),K=1,NCAB)                           Card 27
     READ(5,2) (YMBV(K),K=1,NCAB)                           Card 28
     READ(5,3) (YY(I),I=1,NCUR)                             Card 29
     READ(5,3) (CCK(I),I=1,NCUR)                            Card 30
     READ(5,2) (PHID(I),I=1,NCAB)                           Card 31
     READ(5,3) (TENI(I),I=1,NCAB)                           Card 32
     READ(5,2) (XPI(I),I=1,NCAB)                            Card 33
     READ(5,2) (YPI(I),I=1,NCAB)                            Card 34
1000 CONTINUE
```

The corresponding FORMAT statements are:

```
  1 FORMAT (24I3)
  2 FORMAT (8F10.4)
  3 FORMAT (8F10.2)
  4 FORMAT (8F10.6)
  5 FORMAT (8F10.0)
301 FORMAT (20A4)
```

Subroutine BUOY

```
     READ (5,1) CDASY,WAST,RWY,RTX,RTY,YCG,BINT                  Card 35
     READ (5,1) XSI,ZETI,SYDI,XPSI,ZTPI,SYPDI,DFTLIM,SYDLIM Card 36
```

For 2900 ≤ FSM(1) < 3000:

```
     READ(5,1) AKZ,AXP,APP,AFKX,AFKZ,AFKP                   Card 37
```

The corresponding FORMAT statement is:

1 FORMAT (8F10.4)

DEFINITION OF INPUT VARIABLES FOR MAIN PROGRAM

NCASES	Number of cases, NCASES $\geq$ 1
TITLE	Title
NSM[3*]	Number of surface motion components, 1 $\leq$ NSM $\leq$ 20
NSW[4]	Number of surface wave components, 1$\leq$ NSW $\leq$20
NCAB	Number of cable segments, 2 $\leq$ NCAB $\leq$ 50
NCUR	Number of current profile points, 2 $\leq$ NCUR $\leq$ 10
ITER[1]	Iteration index
MTRC	MTRC $\leq$ 0 if input data are entered in English units; MTRC $\geq$ 1 if input data are entered in metric units**
IBUOY[2]	Buoy calculation index
ISPAR	Degree of polynomial used to approximate variation of cross-sectional area of spar buoy; ISPAR $\leq$NSM-1
FSM(K)[3] AXSM(K)[3]	$x_{SM} = \sum_{k=1}^{NSM}$ AXSM(K)*cos(-2π* FSM(K)* t + FIDSM(K)*π/180.)
AYSM(K)[3] FIDSM(K)[3]	$y_{SM} = \sum_{k=1}^{NSM}$ - AYSM(K)*sin(-2π* FSM(K)*t + FIDSM(K)*π/180.)
ASW(K)[4]	$x_{SW} = \sum_{k=1}^{NSW}$ ASW(K)*cos(-2π*FRSW(K)*t + FIDSW(K)*π/180.)
FRSW(K)[4] FIDSW(K)[4]	$y_{SW} = \sum_{k=1}^{NSW}$ - ASW(K)*sin(-2π* FRSW(K)*t + FIDSW(K)*π/180.)
RHO	Fluid density in slugs/feet^3 or kilograms/meters^3
SUBM[5]	Submergence of top point of cable below free surface in feet or meters
TWX[5]	Horizontal force acting at top of cable in pounds or Newtons = wind loading on surface buoy
TIY	Vertical component of tension at top of cable in pounds or Newtons

*Superscripts refer to explanatory notes which begin on page 11.
**All data must be input in consistent units.

AMC	Added mass coefficient of cable; AMC = 1.0 for round cable
AFAC	Cross-sectional area of cable = AFAC*$\pi d^2/4$; AFAC=1.0 for round cable
TMIN	Minimum algebraic tension which can be supported by cable in pounds or Newtons; TMIN = 0 for a flexible cable
CDASPX	Drag area of surface package for x-direction in feet^2 or meters^2
CDASBX	Drag area of entire surface buoy, excluding surface package, for x-direction in feet^2 or meters^2
VSP	Volume of surface package in feet^3 or meters^3
SPXK,SPYK	Added mass coefficients for the surface package for surge and heave, respectively
YYSP	Vertical distance of center of buoyancy of surface package measured from origin of local buoy coordinate system in feet or meters; for spheroidal buoys, the origin is at the maximum cross-section.
TINVI	Initial time interval in seconds for dynamic calculations
DT1	Time step in seconds for which print out is desired for $0 \leq t \leq$ TINVI
TOTT	Total time in seconds for which dynamic calculations are desired
DT2	Time step in seconds for which printout is desired for TINVI$< t \leq$TOTT
DIR	DIR<0. if initial conditions are prescribed at the bottom (towing cable case); otherwise DIR$\geq$0
TBH	Applied force in pounds or Newtons on lower weight, body NCAB-1, in x-direction
TBYMX	Maximum absolute value in pounds or Newtons of tension in cable just below buoy; for buoy-cable system, set TBYMX equal to a large number, say, 99999
FLC(K)	Length of Kth cable segment in feet or meters
DCI(K)	Diameter of Kth cable segment in inches or centimeters
CDN(K)	Normal drag coefficient of Kth cable segment
CDT(K)	Tangential drag coefficient of Kth cable segment
WC(K)	Weight in fluid in pounds/foot or Newtons/meter of Kth cable segment at the reference cable tension

CM(K)	Mass of Kth cable segment in slugs/foot or kilograms/meter at the reference cable tension
TREF(K)	Reference tension in pounds or Newtons of Kth cable segment
C1(K)[6],C2(K) CINT(K)	Tension = TREF(K) + $C1(K)*\varepsilon^{C2(K)}$ + CINT(K)* $\dot{\varepsilon}$; for linearly elastic material, C1(K) = AE and C2(K) = 1
WBD(K)	Weight in fluid of Kth body in pounds or Newtons
CDABX(K)[7] CDABY(K)[7]	Drag area of Kth body in feet^2 or meters^2 for flow in (x,y) directions
XMBV(K)[7] YMBV(K)[7]	Virtual mass (mass + added mass) in slugs or kilograms of Kth body in (x,y) directions
YY(I)[8]	Value of y in feet or meters
CCK(I)	Value of current in knots or meters/second at y = YY(I)
PHID(I)[9]	Initial value of ϕ of Ith cable segment in degrees
TENI(I)[9]	Initial value of tension of Ith cable segment in pounds or Newtons
XPI(I)	Initial value of $\dot{x}$ of Ith node in feet/second or meters/second
YPI(I)	Initial value of $\dot{y}$ of Ith node in feet/second of meters/second

DEFINITION OF INPUT VARIABLES FOR SURFACE BUOY

CDASY	Drag area for y-direction in feet^2 or meters^2
WAST	Weight in air in pounds or Newtons of buoy and surface package
RWY	Vertical distance of wind loading center of pressure from buoy center of gravity YCG in feet or meters
RTX,RTY	(x,y) distance of cable attachment point from YCG in feet or meters
YCG	Vertical distance of center of gravity of buoy and surface package measured from the origin of the local buoy coordinate system in feet or meters
BINT	Moment of inertia of buoy and surface package about YCG in slug feet^2 or kilogram meters^2

XSI, ZETI, SYDI[10]	Initial values of (x,ζ,ψ) in feet, feet, and degrees or meters, meters, and degrees, respectively, where ζ is the vertical displacement of the center of gravity from its equilibrium value
XPSI, ZTPI, SYPDI	Initial values of $(\dot{x},\dot{\zeta},\dot{\psi})$ in feet/second, feet/second, and degrees/second or meters/second, meters/second and degrees/second
DFTLIM, SYDLIM	Limiting values of (draft, pitch) in feet and degrees or meters and degrees, respectively, for which the program calculates the percent of time that the draft and absolute value of pitch exceed these values
AKZ	Added mass coefficient for heave for arbitrary buoy
AXP	$A_{\xi\psi}/\rho VL$ for arbitrary buoy, where L is the length of the buoy
APP	$(A_{\psi\psi} - \text{BINT})/\rho VL^2$ for arbitrary buoy
AFKX	$FK_x/\rho V\ddot{x}_w$ for arbitrary buoy, AFKX = 2 for a spar buoy with circular cross-section
AFKZ	$FK_y/\rho V\ddot{y}_w$ for arbitrary buoy, AFKZ = 1 + AKZ for spar buoy
AFKP	$FK_\psi/\rho VL\ddot{x}_w$ for arbitrary buoy

EXPLANATORY NOTES

1. ITER = 0, no iteration (prescribed initial steady-state conditions)
   1, free-floating cable system
   2, moored cable with given length in given depth
   3, iteration scheme to be programmed by user

2. IBUOY ≥ 1 Drag areas and added masses of surface buoy are updated continuously as a function of buoy submergence
   =0 Drag areas and added masses are updated at the end of each print interval
   $-9 \leq$ IBUOY ≤ -1 Drag areas and added masses remain at constant values corresponding to the steady-state draft
   ≤ -10 Drag areas and added masses remain at constant values, in addition, changes in volume are based on the change in draft x steady-state waterplane area

3. For $1000 \leq$ FSM(1) <2000, the program makes the prescribed surface motion components equal to the surface wave components by setting AXSM(K)=AYSM(K)=ASW(K), FSM(K)=FRSW(K), and FIDSM(K)=FIDSW(K) for K=1 to K=NSM; the program automatically sets NSM=NSW.

For 2000 $\leq$FSM(1)< 3000, the program accepts input data for a spar buoy or arbitrary buoy and considers AXSM(K) to be the cross-sectional area of the buoy in feet^2 or meters^2 at vertical distance AYSM(K) feet or meters from the origin of the local buoy coordinate system. AYSM(NSM)-AYSM(1) = total length of buoy, L. In these cases, FIDSM(1) is the added mass coefficient K_S for surge and FIDSM(2) is the ratio $\alpha = I_{sw}/(\pi r_w{}^4/4)$. The rest of the FIDSM(I) may take on any values, such as, say, 0. Since $K_S = \alpha = 1$ for a spar buoy with circular cross-section, FIDSM(1) and FIDSM(2) are internally adjusted to be 1 if they are input with values $\leq$0.

For 2000 $\leq$FSM(1)<2900, the program considers the buoy to be a spar buoy and internally calculates the inertia and forcing coefficients.

For 2900 $\leq$FSM(1)<3000, the program, considers the buoy to be an arbitrary buoy and accepts input data for the inertia and forcing coefficients.

For FSM(1)>3000, the program accepts input data for a spheroidal buoy and considers AXSM(1) and AYSM(1) to be respectively the horizontal and vertical semi-axes in feet or meters. The rest of the input values of AXSM(K) and AYSM(K) as well as all of the FIDSM(K) may take on any values such as, say, 0.

4. For ASW(1)>1000, the program computes the amplitudes of the NSW surface wave components by using the Pierson-Moskowitz sea spectrum. In these cases, the program considers the significant wave height in feet or meters to be (ASW(1) - 1000.) and FRSW(1) and FRSW(2) to respectively be the lower and upper frequencies of the spectrum in cps. The program internally generates the phases of the wave components by considering them to be uniformly separated by 360/NSW degrees. The phase of the lowest frequency component, in degrees, is taken to be the input value of FIDSW(1).

5. For the case of a surface buoy (FSM(1) $\geq$ 2000), the program calculates the drag acting on the surface buoy due to the ocean current by taking the value of the ocean current SUBM feet or meters below the free surface. Thus, 0 < SUBM $\leq$ total draft.

The total horizontal force at the top point of the cable TIX = TWX +(1/2)ρ* CDASX* CCF (SUBM)* ABS (CCF (SUBM)). In cases where there is no surface buoy (i.e., prescribed surface motion), TWX and/or CDASX may be set equal to zero. For cases of a surface buoy, TWX represents the wind loading on the buoy in pounds or Newtons.

6. For free-floating and towing cables where the last (K=NCAB) cable connecting the lower weight to the ocean bottom is fictitious, read in a value for C1(NCAB) less than 0.0001 pounds or 0.0004 Newtons. In these cases, the program sets DCI(NCAB) = CDN(NCAB) = CDT(NCAB) = WC(NCAB) = CM(NCAB) = CINT(NCAB) = 0, FLC(NCAB) = 2 * FLC(NCAB-1), and C2(NCAB) = 1.

7. If CDABX(K) is negative, the program considers the body to be a circular disk with plane perpendicular to the x-axis and calculates drag and added mass forces by using the formulation given in Report NADC-AE-7120. In these cases, CDABX(K) is the negative of the actual drag area and XMBV(K) is the mass (not the virtual mass) of the disk. In these cases, CDABY(K) and YMBV(K) should be positive and retain the definitions given previously. Similar remarks apply if CDABY(K) is read in as a negative number with the exception that the plane of the disk is now perpendicular to the y-axis.

8. When ITER=2, the program takes YY(NCUR) to be the ocean depth.

9. For $|PHID(1)| \geq 360.$, the program takes the initial values of the angle and tension of each cable segment to correspond to their respective steady-state values at the midpoint of each segment. These steady-state values have been previously calculated by the program. This approach will minimize transient dynamic effects. In these cases, input values for the remaining PHID(K) as well as all of the TENI(K) may be arbitrary, such as, say, 0.

10. For $SYDI \geq 360.$, the program sets the initial value for buoy inclination ψ equal to the steady-state value of ψ, which has previously been calculated by the program. This will tend to minimize transient dynamic motions of the surface buoy.

PROGRAM STORAGE AND TIME REQUIREMENTS

On the CDC 6700 currently in use at the Center, program CABMOD requires a memory of approximately 56,700 octal words to load and 42,500 octal words to execute using the OPT=0 computer. Compilation time is approximately 30 seconds. The corresponding values for program CABUOY are 47,200 octal words, 33,700 octal words, and 23 seconds, respectively. A comparison of the execution times for the two programs depends on such factors as the number of cable nodes, buoy configuration, and values for IBUOY and ISPAR. Typically, for NCAB=5, execution times for program CABMOD are 20 to 60 percent greater than those for program CABUOY.

Using the more efficient OPT = 1 compiler, program CABMOD requires a memory of approximately 53,700 octal words to load and 37,500 octal words to execute. Compilation time is increased to approximately 35 seconds but exectuion time is typically reduced by approximately 50 percent. Since execution time will be greater than compilation time for most cases of practical interest, it is recommended that the OPT = 1 compiler be used.

SAMPLE PROBLEMS

To illustrate the significance of the new features for the surface buoy, Program CABMOD was exercised in seven different ways for the spheroidal buoy of aspect ratio 10 considered in Sample Problem 4A of Reference 1. Table 1 shows that the runs differ from each other in the assumption for the type of buoy (spheroidal, spar, or arbitrary), the value for the index IBUOY which determines the frequency and manner of updating the inertia and buoyancy terms, and the manner of distributing the forces acting on the upper half of the upper cable. Table 1 also shows for each case the values of mean draft $\bar{H}$, mean pitch $\bar{\psi}$, $H_{p-p}=H_{max}-H_{min}$, and $\psi_{p-p}=\psi_{max}-\psi_{min}$ for the time interval $30 \leq t \leq 40$ seconds, which represents one complete cycle for the ocean wave.

Cases 1 to 3 show that updating the inertia coefficients after every print interval, IBUOY = 0, may lead to differences of the order of 2 degrees in the values of ψ_{p-p} from the corresponding results for constant inertia, IBUOY$\leq$-1. The values in $\bar{H}$, $\bar{\psi}$, and H_{p-p} remain relatively unchanged.

Cases 2, 4, and 5 show that, for the same buoy, the differences are quite small between the formulations for spheroidal buoy, spar buoy, and arbitrary buoy. The largest difference occurs in ψ_{p-p} where the results for the spheroidal buoy are 0.45 degrees larger than the results for the spar buoy and arbitrary buoy.

Cases 4, 6, and 7 show that the manner of distributing the forces acting on the upper half of the upper cable has significant effects on the numerical results. The spread in the values for $\bar{H}$, $\bar{\psi}$, H_{p-p}, and ψ_{p-p} is 0.23 ft (0.07m), 3.22 degrees, 0.21 ft (0.064m), and 2.88 degrees, respectively. It is of interest to note that, with the excepton of $\bar{H}$, the results obtained by neglecting the cable forces altogether, Case 6, are significantly closer to the approach finally adopted for the present program, Case 4, then the corresponding results obtained by distributing the cable forces to the first cable node, the approach used in Program CABUOY.

CONCLUSIONS

It is recommended that Program CABMOD be used in preference to the previous version, Program CABUOY. The new program contains a number of new options which generalize the formulation for the surface buoy. In addition, revisions such as the allocation of some of the cable forces to the surface buoy result in improved accuracy. Finally, by using a simple formulation for the buoy, such as setting IBUOY = -10, the computer time requirements for the new program are not significantly greater than for Program CABUOY.

REFERENCES

1. Wang, H.T., "A FORTRAN IV Computer Program for the Time Domain Analysis of the Two-Dimensional Dynamic Motions of General Buoy-Cable-Body Systems" DTNSRDC Report 77-0046 (Jun 1977).
2. Bai, K.J., "Zero-Frequency Hydrodynamic Coefficients of Vertical Axisymmetric Bodies at a Free Surface," Journal of Hydronautics, Vol. 11, No. 2, pp. 53-57 (Apr 1977).

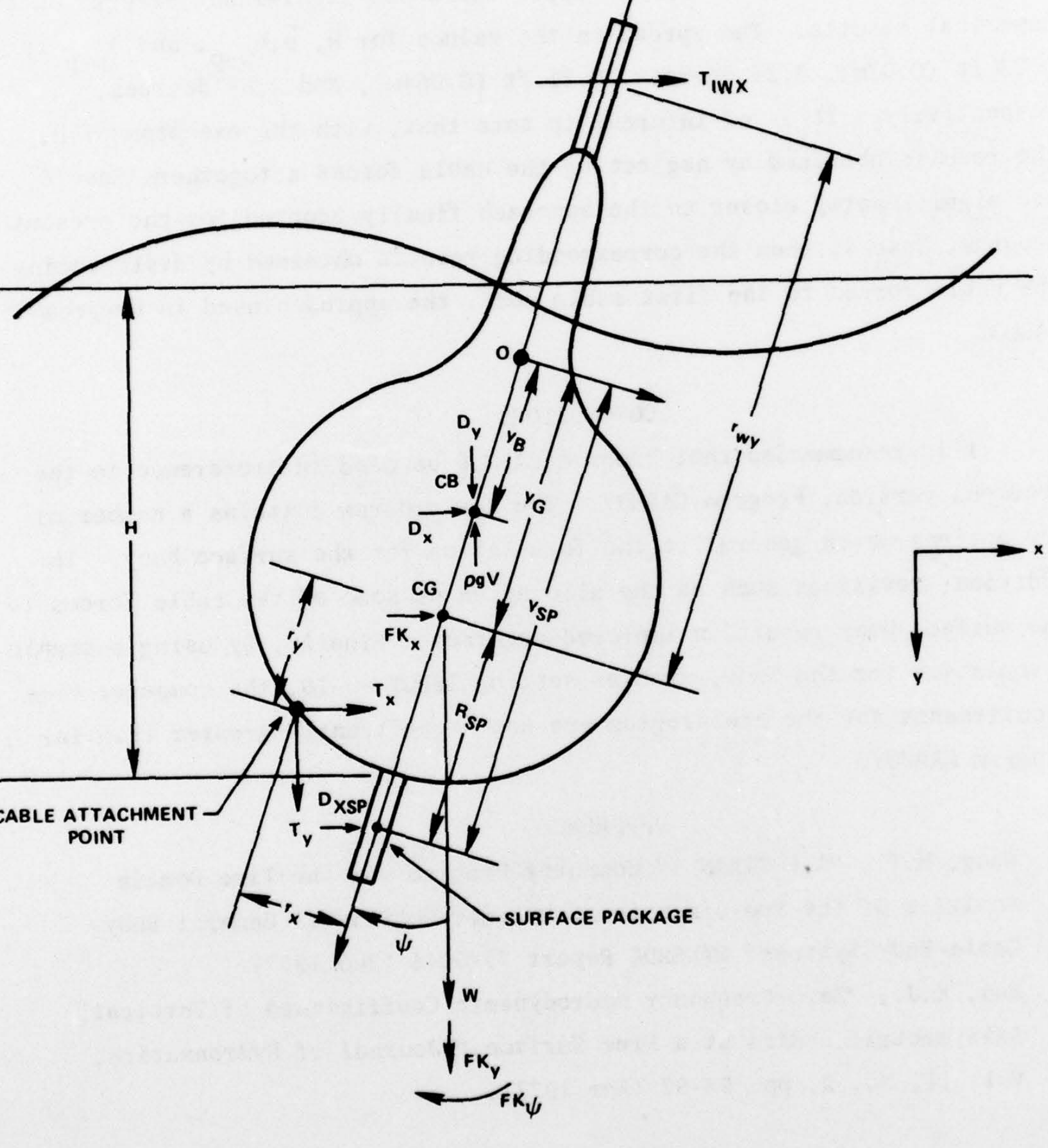

Figure 1 - Definition of Forces Acting on Surface Buoy and Surface Package

TABLE 1

Matrix of Computer Runs for Aspect Ratio 10 Spheroidal Buoy

Case	Buoy	IBUOY	Upper Cable Forces	$\bar{H}$(ft)	$\bar{\psi}$(deg)	H_{p-p}(ft)	ψ_{p-p}(deg)
1	Spheroid	0	To buoy	5.32	24.29	1.52	4.47
2	Spheroid	-1	To buoy	5.28	24.06	1.47	6.63
3	Spheroid	-11	To buoy	5.28	23.99	1.46	6.68
4	Spar	-1	To buoy	5.27	24.36	1.45	6.18
5	Arbitrary	-1	To buoy	5.27	24.42	1.45	6.18
6	Spar	-1	Neglected	5.04	23.61	1.60	5.63
7	Spar	-1	To 1st node	5.21	21.14	1.66	3.30

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