PAP-611

REVIEW OF U.S. FISH AND WILDLIFE NATIONAL FISHERIES RESEARCH CENTER _ MARROWSTONE FIELD STATION

By

K. W. Frizell

D- 3751
PAF-611

D-3752

JUN 10 1992

Memorandum

To: Manager, Service Engineering Center, SEC, U.S. Fish and Wildlife Service, PO Box 25207, Denver CO 80225-0207

ACTING

From: Chief, Research and Laboratory Services Division

Subject: Review of U.S. Fish and Wildlife National Fisheries Research Center, Marrowstone Field Station (Your Letter Dated May 20, 1992) (General Correspondence Research)

Mr. Warren Frizell of our staff has completed a review of the design of the intake structure for the Marrowstone Field Station. It is our conclusion that the intake structure (piping and associated sled) was inadequately weighted to provide stability in the tidal conditions verified at the site. The sleds alone are heavy enough to withstand the currents caused by the outgoing tides; however, the piping will not remain stationary in currents of this magnitude. These statements are made based on estimated weights of the intake sled and the associated piping. In addition, the pipe bundle was simulated as a single cylindrical pipe of larger diameter (1.385 ft). We used current velocities of 5.6 ft/s in the calculations and assumed them to be perpendicular to the pipeline. Mr. Frizell's calculations are enclosed along with a list of reference material used in the analysis.

It is not possible to predict the expected displacements of the sleds from the data available. Additional design considerations, such as lift on the pipeline bundles and effects of surface waves were neglected. Assuming that the bundle behaves as a single cylinder lying on the ocean floor, a lift coefficient of 0.78 has been measured. This produces a corresponding force of 34 lb/ft for the present design. However, the triangular bundle probably has significantly different lift properties than a single cylinder. In addition, lift is a function of angle of attack, shape and local geometry. Previous work on submerged pipelines has shown that as a cylinder is raised above a solid boundary, the lift coefficient actually becomes negative resulting in a net downward force. There is a method to evaluate the effects of surface waves at a depth assuming you have good estimates of wave height and period. The wave-induced horizontal velocities at depth are used to calculate drag and inertial forces. The drag forces are typically negligible due to the small velocities; however, the inertial forces can be substantial at depths similar to this case.

We also looked at the stability of the intake by treating it as a rigid body and doing a summation of moments about the point where the pipe bundle becomes exposed on the ocean floor. We do not have a good estimate for the coefficient of kinetic friction, μ. If we solve the equation for μ, it would have to be greater than 1.0 to provide stability. Since this is a physical impossibility, the intake piping and sled will move as it is currently designed. Once again we made some assumptions regarding the forces which were applied to the structure. The lift and inertia effects were ignored, only the drag forces which are caused by the outgoing tidal currents were considered.

We recommend that the intake/outlet pipelines and sleds be designed for tidal velocities of a magnitude high enough to include an appropriate factor of safety. This factor of safety should also cover some of the uncertainties about lift forces and storm waves. The increase in weight could be realized by adding weight to the sleds or by distributing it over the pipeline length. This second option would require a larger diameter ballast pipe (or additional pipes) than is presently in place.

Our analysis was for the intake piping and sled. Assuming the same current direction, the outlet piping and sled may be more parallel to the current. The drag force would be considerably lower, due to a much lower drag coefficient. Frictional drag would be the predominate force rather than form (pressure) drag.

The question of appropriate grouting practices had previously been discussed with Mr. Pete Aberle of our construction staff. He verified the telephone record prepared by Mr. Bob Hart of your staff and concurred with the information contained within. If you have questions or need more information, please call Warren Frizell at 236-6156.

JAMES R. GRAHAM

Enclosures

bc: D-3700
D-3750
D-3751
D-3752
D-3752 (Frizell)
(w/encl to each)
D-3500 (Aberle)
(w/o encl)

WBR:KWFrizell:flh:6/3/92:236-6156
(c:\wp\d3752\fws.doc)

References

Ippen, A.T., ed. *Estuary and Coastline Hydrodynamics*, Engineering Societies Monographs, New York, McGraw-Hill Book Company, Inc. 1966.

Savage, G.H., "The Design and Analysis of a Submerged, Buoyant, Anchored Pipeline for Transporting Natural Gas Through the Deep Ocean," Department of Petroleum Engineering, School of Earth Sciences, Stanford University, Stanford, CA, August 1970.

Wilson, B.W. and R.O. Reid, Discussion of "Wave Forces for Offshore Pipelines," by H. Beckmann and M.H. Thibodeaux, *Journal of The Waterways and Harbors Division, Proceedings of the ASCE*, vol. 89, February 1963.

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COMPUTATION SHEET

BY	DATE	PROJECT	SHEET
KLFrizell	5/19/92	FWS - MARROWSTONE	SHEET 1 OF
CHKD BY	DATE	FEATURE	
		INLET PIPE STABILITY	
DETAILS			
REVIEW			

CURRENT FORCES

THE MAIN CURRENT FORCES ACTING ON THE INTAKE PIPES AND SLED ARE DUE TO HYDRODYNAMIC DRAG

$$F = \frac{1}{2}\rho C_D A V^2$$

FOR ANALYSIS, WE WILL NEGLECT THE DRAG FORCE ON THE SLED, AND ASSUME THE THREE BUNDLED PIPES BEHAVE AS A SINGLE CYLINDRICAL PIPE OF DIAMETER ~ 1.385 FT.

WE WANT TO FIND THE MAGNITUDE OF THE CURRENT WHICH WILL CAUSE INCIPIENT MOTION OF THE SUBMERGED STRUCTURE.

① APPROXIMATE SUBMERGED WEIGHT OF PIPELINE AND SLED

SLED: CONCRETE - $5' \times 5' \times 1.5'$ @ $140\ lb/ft^3 = 5250\ lb$
HDPE PIPE - ~21' @ $3.76\ lb/ft = 79\ lb$

(VOL OF PIPE DISPLACING CONCRETE: $\frac{\pi(.7188)^2}{4}(16.5) = 6.695\ ft^3$)
WT OF CONCRETE DISPLACED = 937 lb
ONE PIPE FILLED WITH CONCRETE = 242 lb

STEEL - #4 ~ 0.65 lb/ft
~127 ft × 0.65 lb/ft = 83 lb

DRY WT. = 5250 + 79 + 83 + (-937 + 242) = 4717 lb

SUBMERGED WT = DRY WT. - WT. OF WATER DISPLACED

= 4717 - ($37.5 ft^3 \times 64\ lb/ft^3$) = 2317 lb

PIPES: FILLED WITH SEAWATER

INSIDE $0.346\ ft^3/ft \times 64\ lb/ft^3 = 22.14\ lb/ft$
SUB. WT $0.406\ ft^3/ft \times 64\ lb/ft^3 = 25.98\ lb/ft$

TOTAL - 3.76 + 22.14 - 25.98 = -.08 lb/ft

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COMPUTATION SHEET

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CWFrizell	5/19/92	FWS - MARROWSTONE	
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DETAILS			
REVIEW			

PIPES (cont) FILLED WITH CONCRETE

$$\phi.346 \frac{ft^3}{ft} \times 140 \,lb/ft^3 = 48.44 \,lb/ft$$

$$\text{TOTAL} - 3.76 \frac{lb}{ft} + 48.44 \frac{lb}{ft} - 25.98 \frac{lb}{ft} = 26.22 \frac{lb}{ft}$$

WIRE ROPE ~ 1"ϕ 1.8 lb/ft (submerged wt. 1.45 lb/ft)

SO TOTAL PIPE BUNDLE ~ -.08 - .08 + 26.22 + 1.45 = 27.51 lb/ft

AS MENTIONED BEFORE, WE WILL IGNORE DRAG ON THE SLED, HOWEVER, WE WILL DISTRIBUTE ITS WEIGHT OVER THE LENGTH OF THE PIPES.

~ LENGTH IS 355' - SLED AMOUNTS TO 2317/355 = 6.53 lb/ft

② HYDRODYNAMIC DRAG DUE TO CURRENTS

C_D ~ 1.03 FOR THIS CYLINDRICAL SHAPE AGAINST A BOUNDARY

$$F = \frac{1}{2}\left(64 \frac{lbm}{ft^3}\right)\left(\frac{slug}{32.2\,lbm}\right)\left(\frac{lb_f \cdot s^2}{slug \cdot ft}\right)(1.03)(491\,ft^2)(V)^2$$

IF WE SET F EQUAL TO 12208.5 lb (WT OF PIPE AND DISTRIBUTED SLE

AND SOLVE FOR $V^2 = 24.29 \frac{ft^2}{s^2}$ OR $V = 4.9$ ft/s

ON 4/6/92 CURRENT METER READINGS NEAR THE OCEAN FLOOR AT THE SLED LOCATION AND ½ WAY TO SHORE GAVE READINGS IN EXCESS OF 5.5 ft/s — WELL OVER THE VALUE NEEDED FOR INCIPIENT MOTION. THIS HAS ASSUMED A COEFFICIENT OF FRICTION OF 1. THE DRAG FORCE IS RESISTED BY A FRICTIONAL FORCE μN, WHERE μ IS THE FRICTION COEFF. AN N IS THE NORMAL FORCE FROM THE BOUNDARY ON THE PIPE BUNDLE (WEIGHT).

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COMPUTATION SHEET

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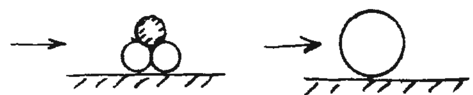
		INLET PIPE STABILITY	

DETAILS
REVIEW - LIFT & OTHER THINGS

③ LIFT DUE TO CURRENTS :

IF WE WERE TO TREAT THE PIPE BUNDLE TRUELY AS A CYLINDER RESTING ON THE OCEAN BOTTOM THERE WOULD ALSO BE A CONSIDERABLE LIFT FORCE. HOWEVER THE ACTUAL BUNDLE SHAPE WOULD HAVE VERY DIFFERENT LIFT CHARACTERISTICS. WE IGNORED LIFT EFFECTS



ADDITIONAL CONSIDERATIONS

IN ADDITION TO THE FORCES DUE TO THE TIDAL CURRENTS, THE SURFACE WAVES CAN INFLUENCE THE LOADING ON THE PIPELINE. HERE THE FORCES ARE DUE TO TWO EFFECTS, DRAG AND INERTIA. EVEN THOUGH THE HORIZONTAL VELOCITIES AT DEPTH ARE SMALL (MAKING DRAG NEGLIGIBLE), THE INERTIAL LOADING DUE TO SURFACE WAVES CAN BE QUITE LARGE. (SEE PG. 4)

IN THE PRECEEDING ANALYSIS, I NEGLECTED THE HYDRODYNAMIC FORCES ON THE SLED. IF WE LOOKED AT THE SLED ALONE,

$$F_D = \frac{1}{2}\rho C_D A V^2$$

$$(2317) = \frac{1}{2}(1.9876)(1.05)(7.5)(V)^2$$

VELOCITY NEEDED TO OVERCOME WEIGHT OF SLED = 17.2 FT/S SO THE SLED ALONE WOULD BE STABLE. HOWEVER THERE IS TREMENDOUS DRAG ON THE PIPE BUNDLE LEADING TO THE SLED.

COMPUTATION SHEET

BY KCWFrizell	DATE 5/20/92	PROJECT	SHEET 4 OF
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DETAILS ESTIMATE OF SURFACE WAVE EFFECTS			

CONSIDER A UNIT LENGTH, 1.383 FT IN DIAMETER, SUBMERGED 40 FT (WEIGHTED AVERAGE).

$$u_{max} = \frac{a e^{ky}}{L^2} \sqrt{2\pi g}$$

$y = -40$ ft
$k = 2\pi / L$
a = ½ wave height
L = wave length

IF STORM WAVES ARE 15 FT AND WE ESTIMATE $L \sim 150$ ft

THEN $$u_{max} = \frac{(7.5)\, e^{(-1.675)}}{150^2} \sqrt{2\pi(32.2)} = 0.0009 \ \tfrac{ft}{s}$$

$$\Delta F_D = C_D \rho D \frac{u^2}{2} = 1.2(1.9876)(1.383)\frac{(.0009)^2}{2} = 1.29 \times 10^{-6} \ \text{lb/ft}$$

$$\dot{u}_{max} = \frac{2\pi}{L} a g e^{ky} = \frac{2\pi}{150} 7.5(32.2)\, e^{(-1.675)} = 1.89 \ \tfrac{ft}{s^2}$$

$$\Delta F_I = C_m \rho \frac{\pi D^2}{4} \dot{u} = 1.5(1.9876)\frac{\pi(1.383)^2}{4} 1.89 = 8.49 \ \tfrac{lbs}{ft}$$

$$\Delta F_T = \Delta F_D + \Delta F_I$$

$$= 1.29 \times 10^{-6} + 8.49 = 8.49 \ \tfrac{lb}{ft}$$ → 3013 lb for 355' of pipeline.

THIS EXTRA WEIGHT WOULD BE REQUIRED TO PROVIDE STABILITY IN A STORM EVENT OF THE MAGNITUDE DISCRIBED ABOVE.

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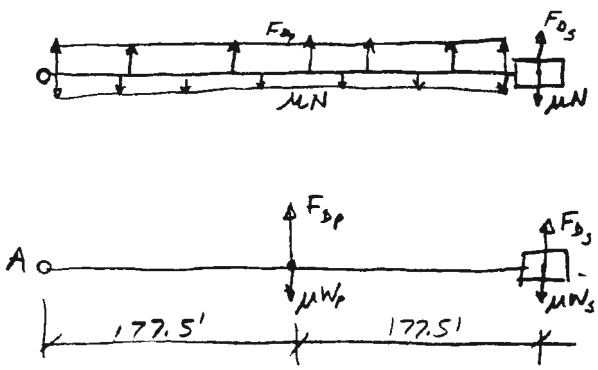
CWFrizell	5/27/92	FWS - Marrowstone	
CHKD BY	DATE	FEATURE	
		INLET PIPE STABILITY	
DETAILS			
RIGID BODY			



@ 5.6 ft/s

$F_{D_s} = 245$ lb

$F_{D_p} = 15761$ lb

$\mu W_p = \mu 9766$

$\mu N_s = \mu 2317$

$\circlearrowleft + \quad \Sigma M_A - \quad 15761(177.5) + 245(355) - \mu 9766(177.5) - \mu 2317(355)$

$= 2884553 - \mu \cdot 2556000$

SO FOR STABILITY $\mu = 1.129$

IF WE ASSUMED A HIGH COEFFICIENT OF KINETIC FRICTION SAY, 0.80.

THEN $\Sigma M_A = +839,753$

TO PROVIDE STABILITY, AN ADDITIONAL 2366 lb WOULD HAVE TO BE ADDED TO THE SLED, OR AN ADDITIONAL 13.3 lb/ft TO THE PIPELINE.

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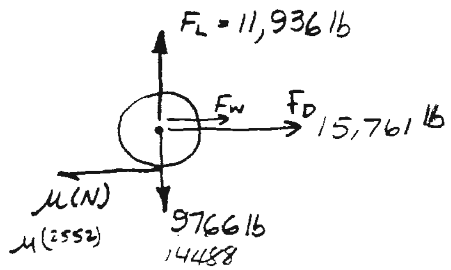
DETAILS			

LIFT + CURRENT (5.6 ft/s) + (WAVES?)



(14488) → μ = .85

$$\Sigma M_A = 15761(177.5) + 245(355) - \mu(2552)177.5 - \mu(2317)(355)$$

$$= 2884553 - \mu\, 1275515$$

$$\mu = 2.26$$