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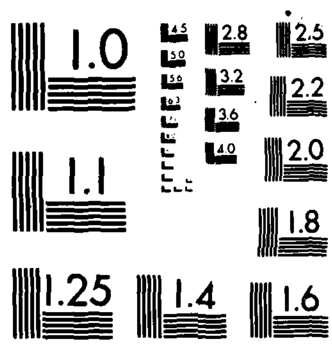

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AFFTC TIM-84-1

AD INEXPLORATA

STORES WEIGHT AND INERTIA SYSTEM UPDATE

AFFTC

- Cable Attachment Redesign
- Flexible Length Parameter Calibration
- Data Sheet Revision

by
Kent Wong
Project Engineer
February 1984

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

This handbook, TIM-84-1, Stores Weight and Inertia System Update, was submitted under Job Order Number SC6320 by the Commander, 6520 Test Group, Edwards Air Force Base, California 93523.

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This memo describes several changes implemented to the SWIS facility since publication of AFFTC-TIM-77-1. This includes a redesign of the cable attachments, a new length calibration method resulting in a figure of 177.1 in, and a proposed data recording sheet. Examples are presented to aid the user in operational and calibration data reduction.

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TABLE OF CONTENTS

	PAGE NO.
INTRODUCTION	1
REDESIGN OF CABLE ATTACHMENTS	2
DESIGN CHANGES	2
STRESS ANALYSIS	2
FLEXIBLE LENGTH PARAMETER CALIBRATION	6
METHODS	6
DATA COLLECTION	8
DATA ANALYSIS	8
EXAMPLE	10
REVISED DATA SHEET	14
EXAMPLE OF DATA REDUCTION	14
REFERENCES	19

A1

LIST OF ILLUSTRATIONS

FIGURE NO.	TITLE	PAGE NO.
1a	Old Cable Attachment	4
1b	New Cable Attachment	4
1c	SWIS Cable Attachment Drawing	5
2	SWIS Length Calibration	7
3	Loading Configuration (2)	11
4	Proposed Data Sheet	15
5	Example Data	17

INTRODUCTION

This memo is presented to inform those engineers and technicians associated with the Stores Weight and Inertia System, SWIS, of changes to the system since publication of AFFTC TIM-77-1. This document discusses the recent redesign of cable attachment points for the store attachment bar, correcting a potentially dangerous situation. It also describes the development of a new length parameter calibration method, the results of which yield an L of 177.1 $\pm$ 1.7 inches. A step-by-step length calibration procedure is outlined and an example is presented. Finally, this memo proposes a new data recording form as well as an example illustrating the correct data analysis methods. It is hoped that this will clarify these procedures for all those involved with the SWIS and bring up to date its documentation.

REDESIGN OF CABLE ATTACHMENTS

DESIGN CHANGES

Inspection of the store attachment bar in late 1983 revealed a bending of the cable attachment angles, causing portions of the attachments to pull away from the I beam. This bending, deemed potentially dangerous, was ostensibly due to the moment inherent in the original design. The new design uses an additional two bolts on each cable attachment, placed to carry the applied load with a much reduced moment. See Figs 1 a, b, c.

The current cable attachments, designed to carry the same 4000 pound load (2000 on each cable) as the previous design, maintains the 30 inch cable separation and approximately the same weight. While incorporating a total of 4 extra bolts, the new design eliminates the aluminum spacer plates previously used. The inertia of the new configuration has been calibrated at 0.25 slug - Ft^2. The data reduction program, SWIS, has been modified to reflect this redesign.

Store Attachment Bar Physical Properties

Weight	9.75 lbs
Inertia	.25 slug - Ft^2
Maximum Load	1000 lbs at 14 in. lug spacing
	4000 lbs at 30 in. lug spacing

STRESS ANALYSIS

The load applied to the system for stress analysis purposes are assumed to be a 2000 lb load at the cable. Equations used are found from references 2 and 3. The margin of safety, ms, is described in reference 1.

Results:

Cable Attachment	Stress (psi)	Margin of Safety
A. Total x-sect area	21,155.6	6.1
B. Breakthrough	16,853.3	7.9
C. X-sect above hole	60,831.0	2.7

A. Total X-sect Area

$$\sigma_m = k\,F/A = \frac{2.38\ (2000\ \text{lbs})}{.225\ \text{in}^2} = 21{,}155.6\ \text{psi}$$

$k = 2.38$
$A = (.9)(.25) = .225\ \text{in}^2$
$F = 2000\ \text{lbs}$

$$ms = \frac{150{,}000}{21{,}155.6} - 1$$

$$\boxed{ms = 6.1}$$

B. Breakthrough

$$\sigma_m = k\,F/A$$

$$= \frac{3.16(2000)}{.375}$$

$$= 16{,}853.3$$

A = 4(.25)(.375) = .375
k = 3.16
F = 2000

$$ms = \frac{150{,}000}{16{,}853.3} - 1 = 7.9$$

$$\boxed{ms = 7.9}$$

C. X-sect above hole only

$$\sigma_m = \frac{2.38(2000)}{.078}$$

$$= 60831 \text{ psi}$$

A = .25(.313)
= .078 in^2

$$ms = \frac{225{,}000}{60{,}831} - 1 = 2.7$$

$$\boxed{ms = 2.7}$$

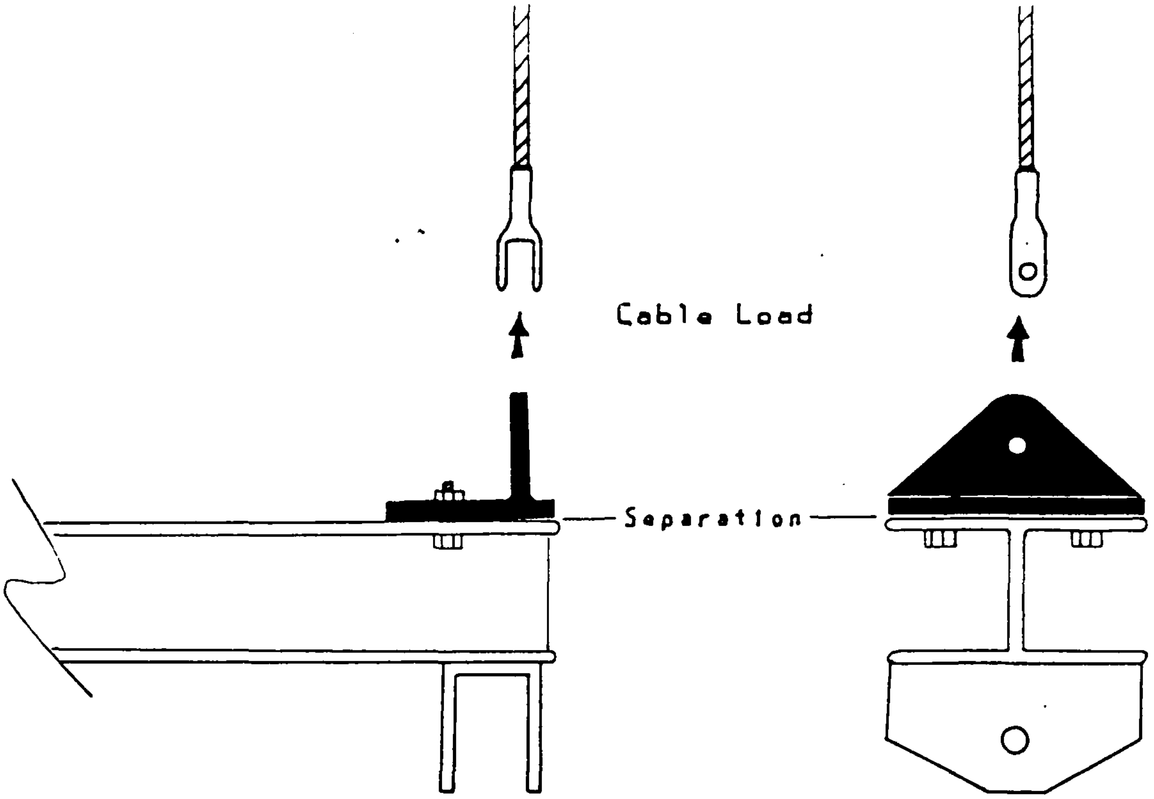

Fig. 1a Old Cable Attachment

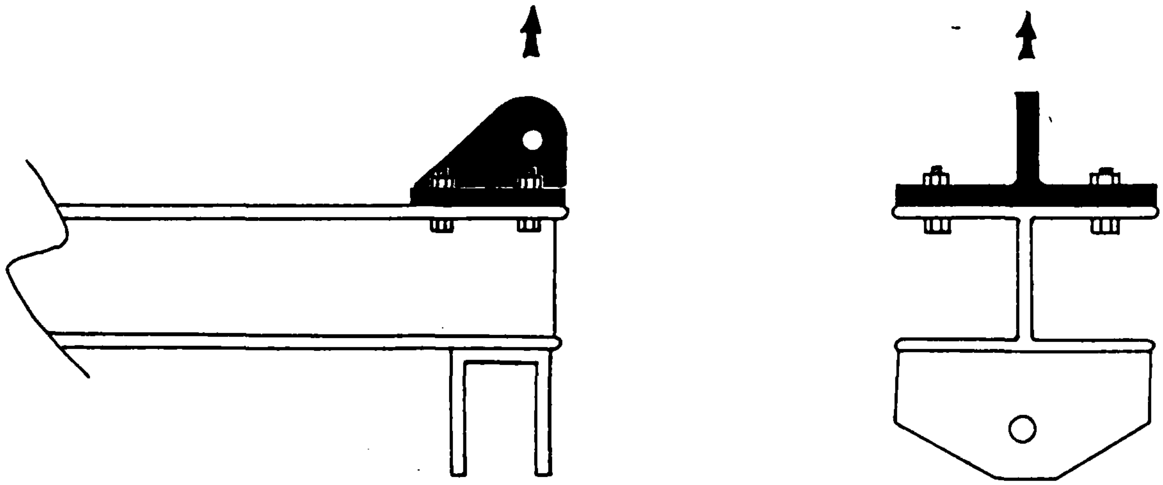

Fig. 1b New Cable Attachment

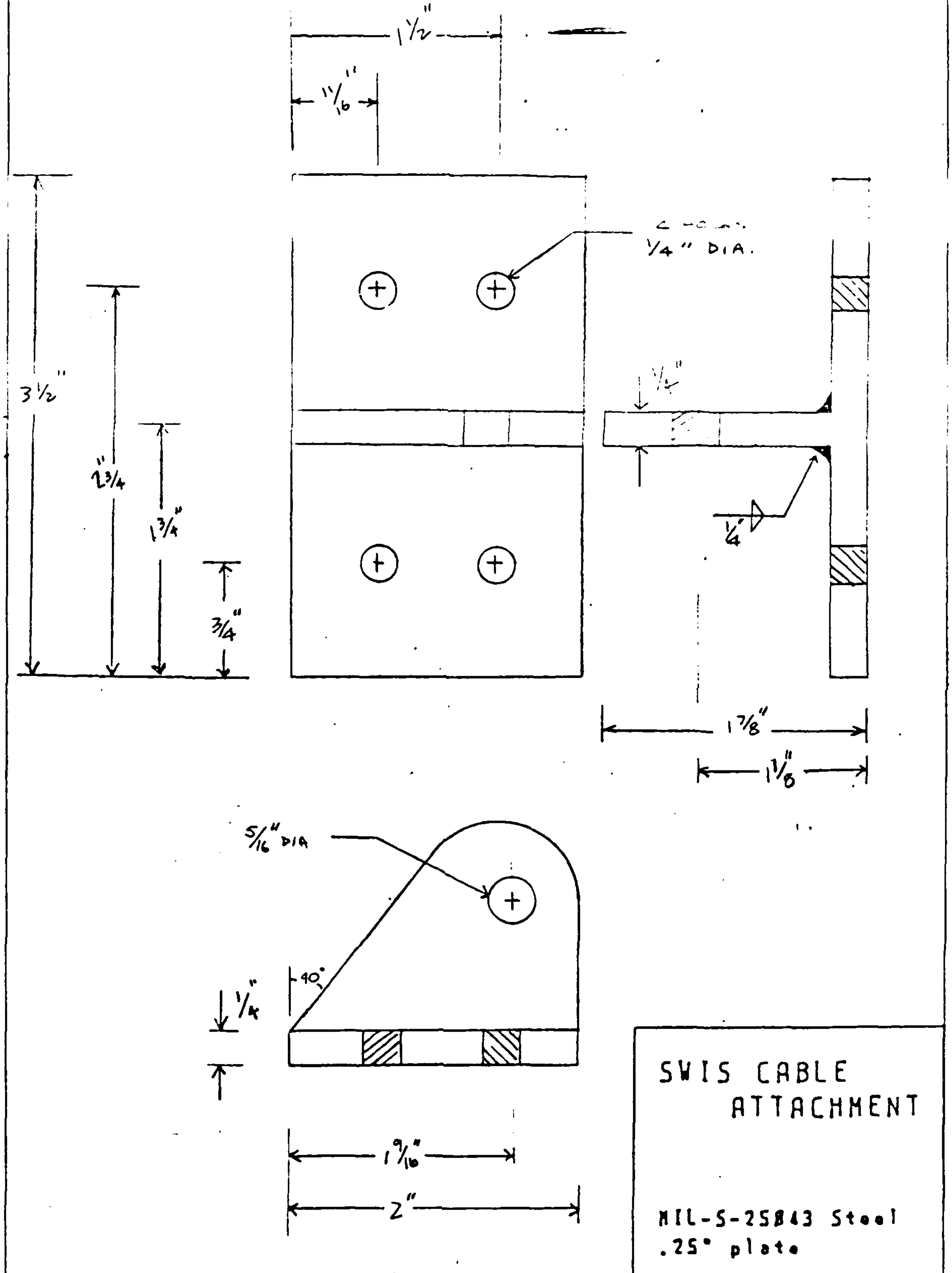
1 1/2"
11/16"
1/4" DIA.
3 1/2"
2 3/4"
1 3/4"
3/4"
1/4"
1/4"
1 7/8"
1 1/8"
5/16" DIA
40°
1/4"
1 9/16"
2"
SWIS CABLE
ATTACHMENT
MIL-S-25843 Steel
.25" plate

Fig. 1c

FLEXIBLE LENGTH PARAMETER CALIBRATION

Questions raised about the previously published flexible length parameter, L, necessitated recalibration of the SWIS facility. Inertia calculations using the questioned value of 193 ± 7 inches were shown to be in error by approximately 11%. A more refined calibration method was developed and implemented on several loading conditions. It was postulated that a particular fixture, for example the store bar, might have a particular length parameter associated with it, while a different fixture configuration, say the variable bar + pitch cage, might have another. The flexible length parameters of the respective fixture configurations were calculated from its set of data. The lengths calculated were generally c e to 176 inches. Subsequent analysis using all the collected data, from ch of the configurations, produced an overall length parameter of 177.1 ± ? inches. This valve showed a very strong correlation, r, of .9998 with t data, see Fig 2. This excellent fit supports the assumption of a va overall system flexible length parameter. The value of 177.1 inches sh ul be used for all iner calculation until future calibration indicates otherwise. The data reduction program, SWIS, has been modified to reflect this latest calibration. The ± 1.73 represents a 95% confidence interval within which the true value of the system lies.

A discussion of the methods used in this calibration, including a step-by-step procedure and an example, is now presented.

METHODS

The previous method of determining the length parameter involved running several runs at different configurations, calculating L and taking the average of these as the system length parameter. The new method takes advantage of the linear relationship between inertia and the quantity WT^2, the weight of the system times the period of oscillation squared as seen in Equation (4), ref 1:

$$I = .47538 \frac{W_t T^2}{L} \quad (1 - \frac{\varepsilon_t^2}{225})$$

Rearranging we have,

$$W_t T^2 = \frac{I}{.47538} \ (1 - \frac{\varepsilon_t^2}{225}) \quad L$$

By swinging configurations of known inertias, calculated from theory, and recording the period of oscillation we can make a plot of $W_t T^2$ vs I theory/.47538 $(1 - \frac{\varepsilon_t^2}{225})$. A best fit line can be fitted through the data by graphical means or by linear regression techniques. The slope of this line can be seen to be the flexible length parameter, L.

The following is a step-by-step procedure for determination of the flexible length:

SWIS LENGTH CALIBRATION

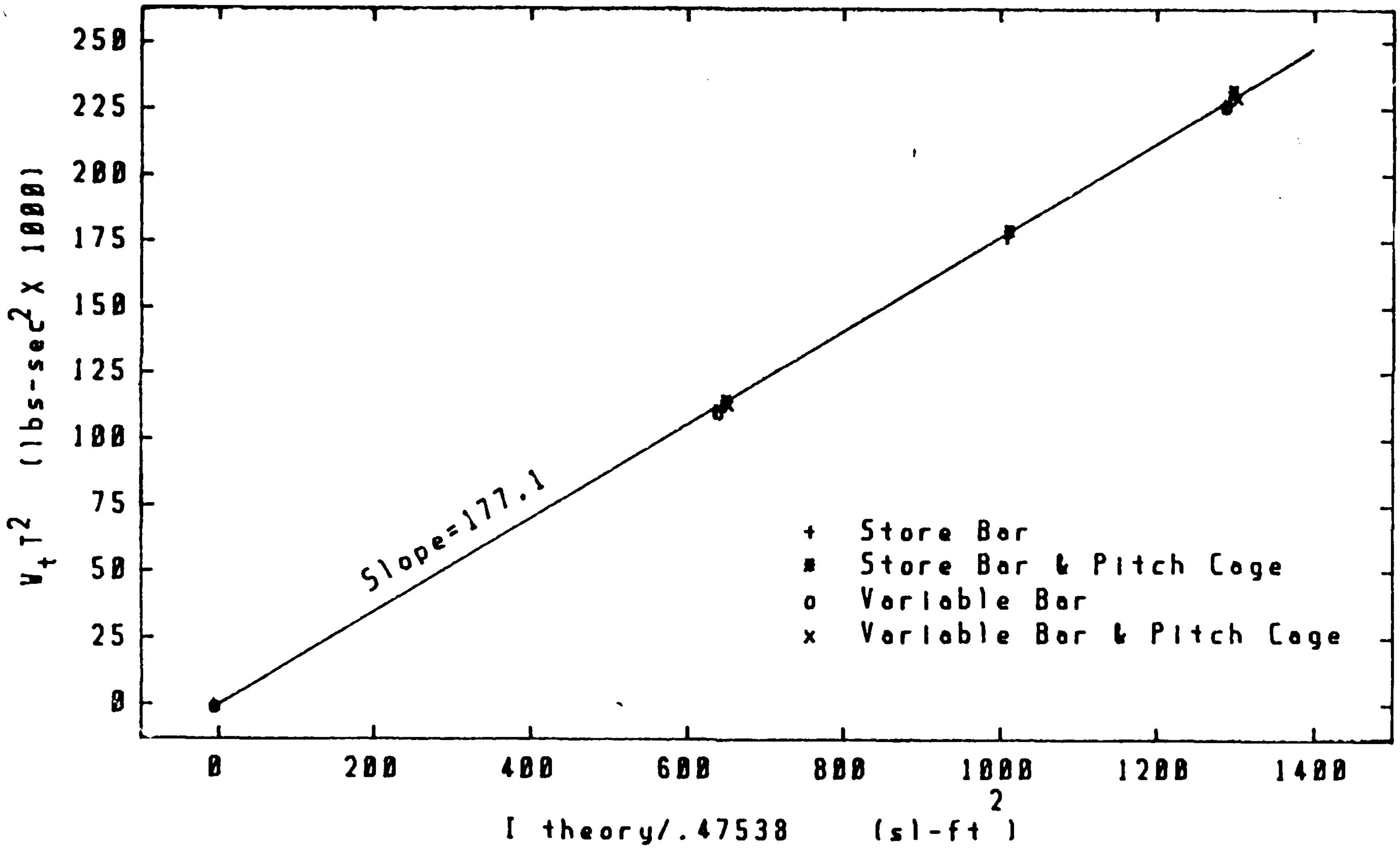

Fig. 2

Data Collection

a. Exercise the system and set-up as if for normal test, placing fixture of interest (i.e. store or variable cg bar with or without pitch cage) on cables.

b. Place calibration beam, the large steel I-beam, on the fixture. If using the pitch cage remove the rollers before loading the beam.

c. Record the weights registered for the fore and aft cables.

d. Swing the configuration and record the period of oscillation. Record data from 3 runs.

e. Place 50 lb weights on the beam and carefully measure the distance of each weight's centroid from the center of gravity of the system. The lugs on the beam provide a convenient reference point for measurement and the distance from each lug to the system's cg can be determined later. Two 50 lb weights placed on each end, for a total of 200 lbs, at approximately 69 inches and 48 inches from the lugs are two configurations which provide well spaced data points for graphing.

f. Record weights registered for cables.

g. Swing configuration and record the period of oscillation. Record data from 3 runs.

h. Repeat e thru g for at least 2 different configurations.

Data Analysis

a. Determine cg for each configuration and the distance D1, the distance from each weight's cg to the configuration c.g.; D2, the distance from the beam's cg to the configuration cg in inches, and $D_{fixture}$, the distance from the fixture's cg to the configuration cg.

b. Calculate $I_{theory} = I_{fixture} + I_{beam} + I_{weights}$

$$+ 2.16 \times 10^{-4} \left[\sum W_{weights} D_1^2 + W_{beam} D_2^2 + W_{fixture} D_{fixture}^2 \right] (\text{sl-ft}^2)$$

Where I fixture = inertia of bar used plus inertia of pitch cage if used, and 2.16×10^{-4} is a conversion from inches to feet and pounds mass to slugs.

c. Calculate the average time per cycle, T

d. Make a plot of $W_t T^2$ (lbs-sec) vs $\frac{I_{\text{~~theory~~}}}{.47538} \left(1 - \frac{\varepsilon_t^2}{225}\right)$ (sl-ft^2)

Where W_t is the total weight of the system. Note that for $\varepsilon_t < 1$ inch the term $\left(1 - \frac{\varepsilon_t^2}{225}\right)$ is largely negligible.

e. Determine the slope of the best fitting line for the data passing through the origin. The method of least squares is recommended (ref 4).

An example of the above method of length parameter calibration is now presented.

CALIBRATION EXAMPLE

Tested configurations

Loading Number	Loading Descriptions
(1)	Store Bar & Calibration Beam
(2)	Store Bar & Cal Beam + 200 lbs FWD: 100 lbs/69.75 inches from FWD lug AFT: 100 lbs/69.5 inches from AFT lug (see Fig 3)
(3)	Store Bar & Cal Beam + 200 lbs FWD: 100 lbs/49 in AFT: 100 lbs/49 in
(4)	Store Bar, Pitch Cage, Cal Beam
(5)	Store Bar, Pitch Cage, Cal Beam + 200 lbs FWD: 100 lbs/69.63 in AFT: 100 lbs/69.25 in
(6)	Store Bar, Pitch Cage, jCal Beam + 200 lbs FWD: 100 lbs/48.1 in AFT: 100 lbs/48 in
(7)	Variable Bar & Cal Beam
(8)	V-Bar & Cal Beam + 200 lbs FWD: 100 lbs/69.8 AFT: 100 lbs/69.3
(9)	V-Bar, Pitch Cage, Cal Beam
(10)	V-Bar, Pitch Cage, Cal Beam + 200 lbs FWD: 100 lbs/69.8 AFT: 100 lbs/69.3

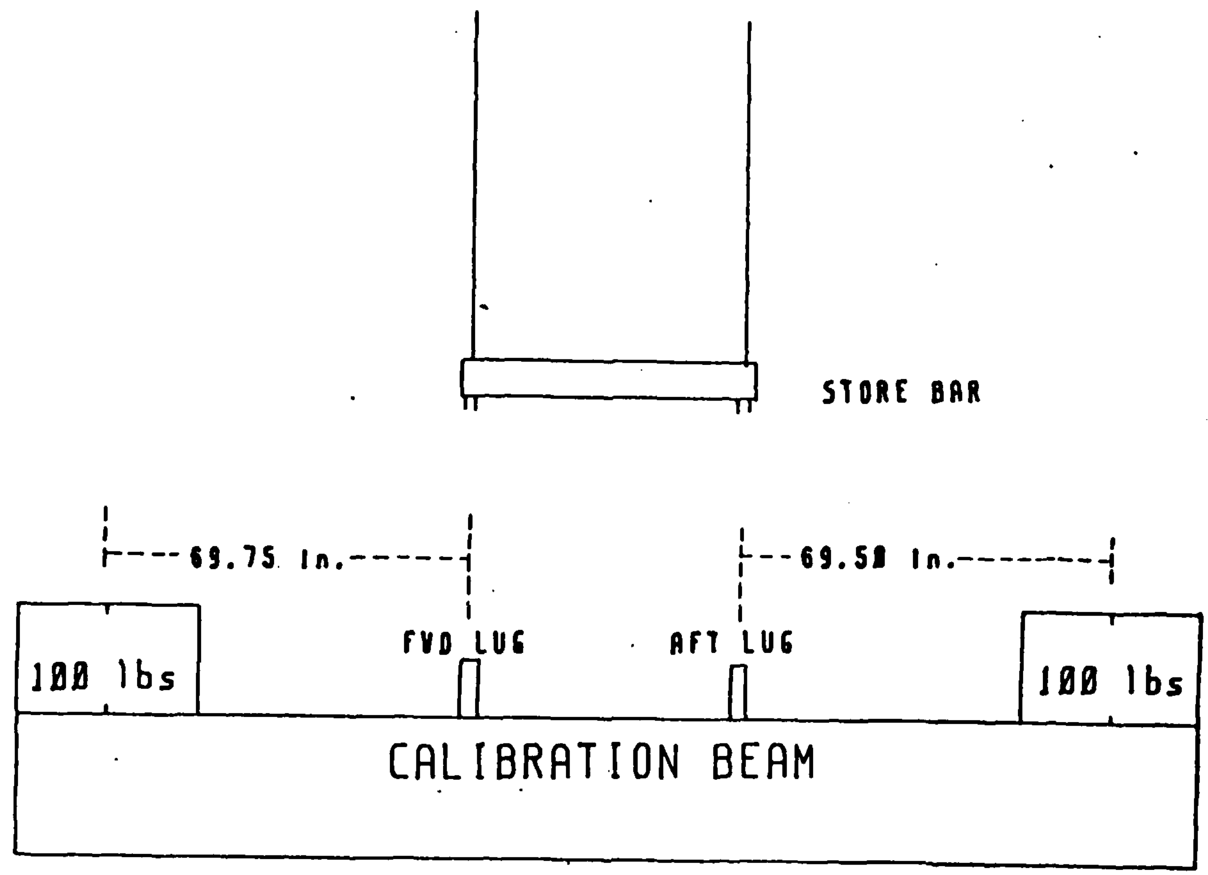

Fig. 3 Loading Configuration (2)

SAMPLE I_{theory} CALCULATION

Loading (2)

Item	Weight (lbs)	cg (in.)	Inertia (sl-ft^2)	Comments
Fixture	10.0	15	0.25	Store bar
Calibration Beam	523.0	14.68	304.3	Large steel I-beam
Added Weight	100.0		0.3	100 lbs on each end of beam

cg_{system} = 14.75 in.

$$I_{theory} = I_{fixture} + I_{beam} + I_{wt} + 2.16x10^{-4}\left[\Sigma W_{wt} D_1^2 + W_{beam} D_2^2 + W_{fixture} D_{fixture}^2\right]$$

$$\sum W_{wt} D_1^2 = 100(69.75 + 14.75)^2 + 100\ (69.5 + 15.25)^2$$

$$= 1.43 \times 10^6$$

$$D_2 = (14.75 - 14.68)$$

$$= 0.07 \text{ in.}$$

$$D_{fixture} = (15 - 14.75)$$

$$= 0.25 \text{ in.}$$

$$I_{theory} = .25 + 304.3 + 2(.3) + 2.16 \times 10^{-4} \left[1.43 \times 10^6 + 523\ (.07)^2 + 10(.25)^2\right]$$

$$I_{theory} = 614.03 \text{ sl-ft}^2$$

RESULTS

LOADING	T (sec)	W_t (lbs)	I THEORY ($SL-FT^2$)	I THEORY/.47538 ($SL-FT^2$)	W_tT^2 ($lbs-sec^2$)
(1)	14.4	533	304.5	641	111×10^3
(2)	17.6	734	614.0	1293	227
(3)	15.6	734	482.1	1014	177
(4)	13.4	635	311.2	655	115
(5)	16.7	834	619.6	1303	232
(6)	14.7	834	483.5	1017	179
(7)	14.0	565	306.4	645	111
(8)	17.2	765	615.3	1294	227
(9)	13.1	666	313.1	659	114
(10)	16.3	867	622.1	1309	230
(11)	--	--	--	0	0

LINEAR REGRESSION

$x = \text{I Theory}/.47538$

$y = W_tT^2$

$\Sigma x = 9.83 \times 10^3$

$\Sigma x^2 = 10.51 \times 10^6$

$\Sigma y = 1.72 \times 10^6$

$\Sigma y^2 = 324 \times 10^9$

$\Sigma xy = 1.85 \times 10^9$

$n = 11$

$\hat{b}$ = best fit slope

$$\hat{b} = \frac{\Sigma xy - \frac{1}{n} \Sigma x (\Sigma y)}{\Sigma x^2 - \frac{1}{n} (\Sigma x)^2}$$

$$L = \hat{b} = \frac{1.85 \times 10^9 - \frac{1}{11} (9.83 \times 10^3)(1.72 \times 10^6)}{10.51 \times 10^6 - \frac{1}{11} (9.83 \times 10^3)^2}$$

L = 177.1 in.

REVISED DATA SHEET

A review of the current data recording form, AFFTC 357, revealed certain inadequacies. Several pieces of information necessary for data reduction, such as the type of bar used and whether or not the pitch fixture was used, are missing from the current format. As a remedy to this problem a new form is being developed, providing areas for this important information.

An example of a proposed format is shown in Fig 4.

Spaces for the bar used, pitch fixture use and cable attachment point (in the case of variable cg bar use) and lug spacing used have been added. In addition, the form is arranged differently to allow a weight build-up approach. By zeroing the gauges with no weight on the cables, the operator can progressively place the fixtures on the cables and record the corresponding weights as he goes. This allows the operator to calculate the exact cg of each piece added. The weight of the fixture must be subtracted from the total weight when determining the center of gravity for the store.

In talking to the operators of this system, the author has discovered a few discrepancies concerning correct reduction of data. The previous documentation is a bit misleading in the data reduction procedure, particularly in regards to the inertia calculation. A blind-faith usage of the equations given without an understanding of their derivation can lead to erroneous results. In an attempt to correct this condition, an example of data reduction from the proposed data sheet is now presented.

<u>Example</u>: MK-84 GP

The data to be used in this analysis, shown in Fig 5, approximates that of a MK-84 GP store. For completeness we shall use the store attachment bar with the pitch fixture, including rollers.

Our first step is to calculate the cg of the system as we add to the cables the various fixtures and finally the store. In order to calculate the system cg we use:

$$cg = \frac{22\, W_a - 8W_f}{W_t} \quad \text{for 14 in. lug spacing}$$

or

$$cg = \frac{30\, W_a}{W_t} \quad \text{for 30 in. lug spacing}$$

MASS PROPERTIES DATA

DATE / TIME	ENGINEERING TECHNICIAN	PHONE

		WEIGHT				TOTAL	TIME (T1)				
		FWD	AFT	C.G.	CYC	WEIGHT	1 ST	2 ND	3 RD	T avg	$Sl \cdot ft^2$
Cable only											
Store Attachment bar											
Variable C.G. bar											
Cable Attach Pt.____											
Pitch Fixture											
Missile bar											
Fixture Total											
Store											
S/N	Type										

Notes:

Project Officer	Organization	Phone

Fig. 4

Where: W_a = AFT weight reading

W_f = FORWARD weight reading

$W_t = W_f + W_a$

It should be emphasized that the weight readings represent the total weight added to each cable. The system cg with the fixtures added is:

$$cg_{fixture} = \frac{30(65)}{(66+65)} = 14.89 \text{ in.}$$

Adding the store, the cg of the total system:

$$cg_{system} = \frac{30(940)}{(1171+940)} = 13.36 \text{ in.}$$

These cg's will be used in the inertia calculation; the STORE's cg is obtained by first subtracting the fixture weights and applying the correct equation from above.

$$cg_{store} = \frac{30\ (940-65)}{(1171-66+940-65)}$$

cg = 13.26 in.

This result, 13.26 in., is compared with specifications for compliance. Our example MK-84 GP meets the spec.

We now calculate the inertia of the system. We use equation (4) in ref (1).

$$I = .47538 \ \frac{W_t T^2}{L} \ \left(1 - \frac{\mathcal{E}_t{}^2}{225}\right)$$

where $I = I_{sys}$, inertia of the system

W_t = total weight of the system, 2111 lbs.

T = average period of 1 oscillation, 8.16 sec.

L = flexible length parameter, 177.1 ins.

$\mathcal{E}_t$ = distance between the system cg and the system midpoint, 15 - 13.36 = 1.64 in.

$$I_{sys} = .47538 \ \frac{(2111)(8.19)^2}{177.1} \ \left(1 - \frac{(1.64)^2}{225}\right)$$

$$= 375.54 \quad \text{sl-ft}^2$$

MASS PROPERTIES DATA

DATE / TIME	ENGINEERING TECHNICIAN	PHONE

	WEIGHT				TOTAL	TIME (T1)				
	FWD	AFT	C.G	CYC	WEIGHT	1 ST	2 ND	3 RD	T avg	Sl-ft^2
Cable only	0	0			0					
Store Attachment bar	5	5			10					
Variable C.G. bar										
Cable Attach Pt.____										
Pitch Fixture	61	60			121					
Missile bar										
Fixture Total	66	65	14.89		132					
Store										
S/N Type										
Mk-84 GP	1171	940	13.36	10	2111	81.5	81.8	81.5	81.6	

$$T = \frac{T_{AVG}}{10\ \text{CYCLES}} = \frac{81.6}{10}$$

$$= 8.16\ \text{SEC}$$

Notes: 30 IN LUG SUPPORTS

Project Officer	Organization	Phone

Fig. 5

Since this is only the system inertia we must subtract the contributions of the fixture's inertia and the inertia due to the offset in the store's cg.

$$I_{store} = I_{sys} - I_{fixture} - 2.16 \times 10^{-4} \left[W_{store} D_1^{\,2} + W_{fixture} D^2_{fixture} \right] \quad sl\text{-}ft^2$$

Where: $I_{fixture}$ = Inertia of fixture, in this case the store bar and pitch cage, found in table; W_{store} is the weight of the store; D_1 is the distance between the cg of the store and the cg of the system and $D_{fixture}$ is the distance between the cg of the fixture and the cg of the system.

$$W_{fixture} = 66 + 65 = 131 \text{ lbs.}$$

$$W_{store} = 1171 - 66 + 940 - 65 \text{ lbs.}$$

$$= 1980 \text{ lbs}$$

$$D_1 = 13.36 - 13.26$$

$$= 0.10 \text{ in.}$$

$$D_{fixture} = 14.89 - 13.36$$

$$= 1.53 \text{ in.}$$

$$I_{store} = 375.54 - 6.93 - 2.16 \times 10^{-4} \; (1980(.10)^2 + 131(1.53)^2)$$

$$\boxed{I_{store} = 368.56 \quad sl\text{-}ft^2}$$

This store is also within specification for the inertia.

To summarize, in data reduction one should always remember the contribution of the fixture to both the cg calculation (subtract the fixture weights) and the inertia calculation (subtract the fixture inertia and the additional inertia from the offset in cg's). The cg and inertia of the store are the quantities we are after and these are what must be compared with the specs.

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