ANALYSIS AND OPTIMIZATION FOR HUMANE TRAP DESIGN

By

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A Thesis

Submitted to the School of Graduate Studies

in Partial Fullfillment of the Requirements

for the Degree

Master of Engineering

McMaster University

April 1974

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MASTER OF ENGINEERING (1974)
(Mechanical Engineering)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Analysis and Optimization for Humane Trap Design

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NUMBER OF PAGES: 298

SCOPE AND CONTENT:

The stirrup type spring that is used in the Conibear series of traps was analyzed and new springs for this type of trap were designed utilizing the non-linear optimization technique.

The Jacob trap concept combined with the concept of a swinging interior mechanism for animal control was developed and optimized and four prototypes were manufactured and evaluated.

Analytical methods for predicting the theoretical energy of closing Conibear and Jacob traps at various jaw openings were developed.

ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to Professor W. R. Newcombe, under whose guidance this project was carried out, for the constant assistance and invaluable advice given throughout the course of this work.

The author would also like to thank Mr. H. Lunn, of the Humane Trap Development Committee for the many expert suggestions required for this project.

The author wishes to acknowledge the financial support which was provided by the Humane Trap Development Committee.

Thanks go to Mr. L. Warren for his assistance in evaluating the traps.

Finally, thanks to Miss Deborah Tudin for her typing of this manuscript.

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GENERAL INTRODUCTION

A) Historical

This is a continuation of a programme that has been carried out, over the past four years, in co-operation with the Humane Trap Development Committee which was formed in 1968 by three groups - the Canadian Federation of Humane Societies, the Canadian Association for Humane Trapping, and the Association for the Protection of Furbearing Animals.

Two predecesors, N. C. Johnston in 1970 and P. H. Tschoepe in 1972 both produced theses in the Master of Engineering Design Programme in this area. In his thesis "Humane Trap Evaluation"[1], N. C. Johnston set up a systematic trap evaluation procedure based on a concept by Zoli Beke and referred to as the Beke-Johnston technique, and tested many of the traps available at that time as part of an effort to establish the standards by which the Humane Traps may be judged.

The definition of a humane death has subsequently been set by the H.T.D.C. and is as follows:

> "That kill in which the animal suffers neither panic nor pain".

In practice this may be achieved by instantaneous death or immediately rendering the animal unconscious with early and irreversible subsidence into death without regain of consciousness,

P. H. Tschoepe[2] continued the evaluation programme. He tested several new and modified traps, discussed various aspeots of optimization in designing new traps and modifying existing traps, and suggested some design changes to the new Conibear series traps. (i.e. the NC series) He also carried out some design and testing on the Jacob trap aimed at optimization of design which appeared to have the most potential for a humane trap. The idea of the original Jacob trap came from A. Jacob in 1969, a trapper from Tilbury, Ontario.

B) Objectives

This is a continuation of the overall Humane Trap Development Programme and the objectives of the present project are:

a) To develop a spring optimization programme for the stirrup type spring that is used in the Conibear series of traps, and to use this programme to redesign new springs for this type of trap.

b) To develop analytical methods for predicting the theoretical energy of a closing trap at various jaw openings.

c) To design, manufacture, test and evaluate Jacob trap prototype including stirrup and different trigger configurations.

The objectives are essentially as outlined in the proposal* submitted by Professor W. R. Newcombe to the H.T.D.C. on March 1, 1973.

* See Appendix "J"

For the design work, throughout the course of the project, a library of non-linear Optimization Subroutines[7], stored as a permanent file on the CDC 6400 computer, was utilized.

PART I - FURTHER ANALYSIS OF THE CONIBEAR TRAP

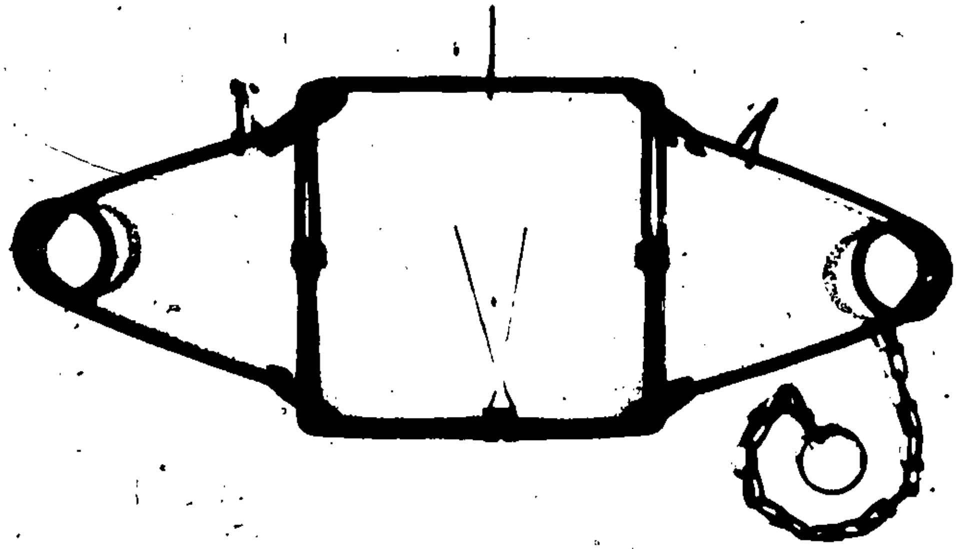
1. INTRODUCTION

As N. Johnston pointed out in his thesis[1] the Conibear trap has many outstanding features, and a considerable effort has been exerted by a number of people including its inventor F. Conibear to test, improve, and modify this trap. The trap is manufactured and is commercially available in three sizes - Model 110/120, 220 and 330. A picture of the 330 is shown in Figure 1-1.

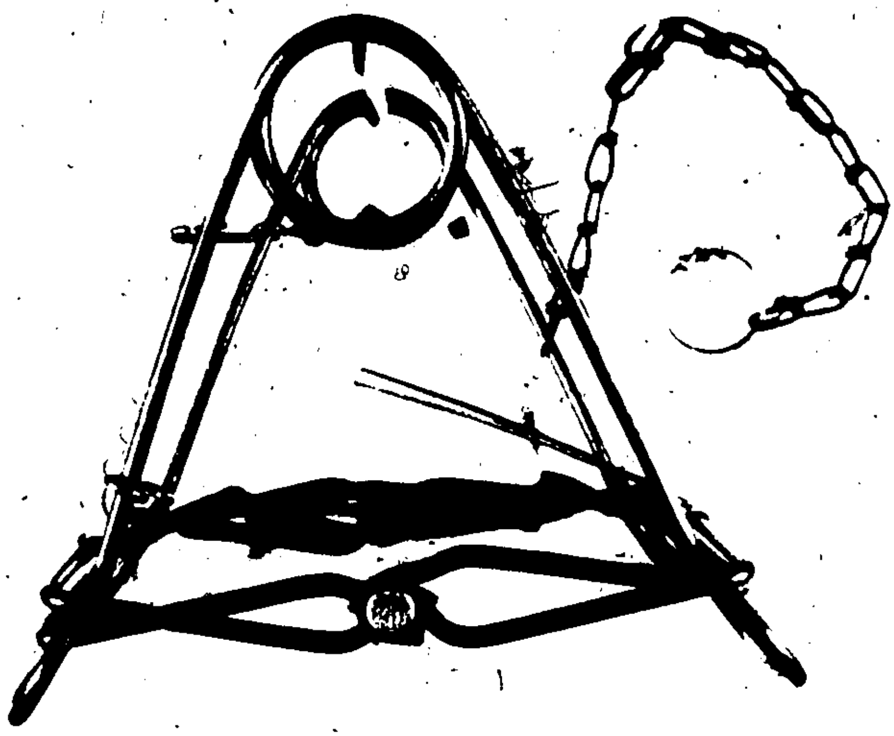
Because the evaluations, so far, on the trap have been performed on an experimental basis, it is required to provide some analytical calculations on the trap to provide a check on the experimental results and a better understanding of them. The approach, adopted here, can be applied to other traps using a method consistent with the geometry of each particular trap. In this sense the Conibear series of traps was further investigated.

One of the most important parts of the trap, the spring, was analysed carefully and approximation equations were formulated. Both the analysis and an auxiliary test programme showed that the original springs were all somewhat overstressed when the traps were set.

A spring optimization computer programme was then set up based on the formulated equations, and new springs were designed using a more favourable lower allowable stress.



(a) Plan view



(b) Side view

FIGURE 1-1: Conibear trap #330

In the next phase of analysis, the theoretical energy levels at various nominal jaw openings were obtained by relating trap angles to spring deflections numerically. The nominal jaw opening is the distance between centerlines of the framewire. Therefore, the effective jaw opening will equal the nominal jaw opening minus the frame wire diameter.

It was noticed that the available kinetic energy levels of the trap frame were very low compared to the theoretical values obtained from the above analysis. The main moving parts of the trap are the trap frame and the springs. The maximum kinetic energy of the free end arms of the springs themselves was almost equal to that of the trap frame in the case of the Conibear trap 330. Whether both energies are exerted on an animal with one blow, which will be more fatal, was difficult to determine from the high speed film analysis and still remains unresolved. Some discussions on this are included in Section 6.

2. SPRING ANALYSIS

2-1 Definition of the parameters

Throughout this part, the following definitions and notations of the parameters will be used:-

d	Wire diameter (in.)
D	Mean coil diameter (in.)
n	Number of coil
ℓ	Free end arm length (in.)
ϕ_1	Initial angular deflection (rad.)
ϕ_2	Total angular deflection (rad.)
E	Modulus of elasticity of the material (lbs/in^2)
L	Inside dimension of the trap frame (in.)
D_L	Mean diameter of the loop at the end of the free end arm (in.)
$\underline{P}$	Tangential force at the end of the free end arm (lbs.)
FF1	$\underline{P}$ at the initial deflection (lbs.)

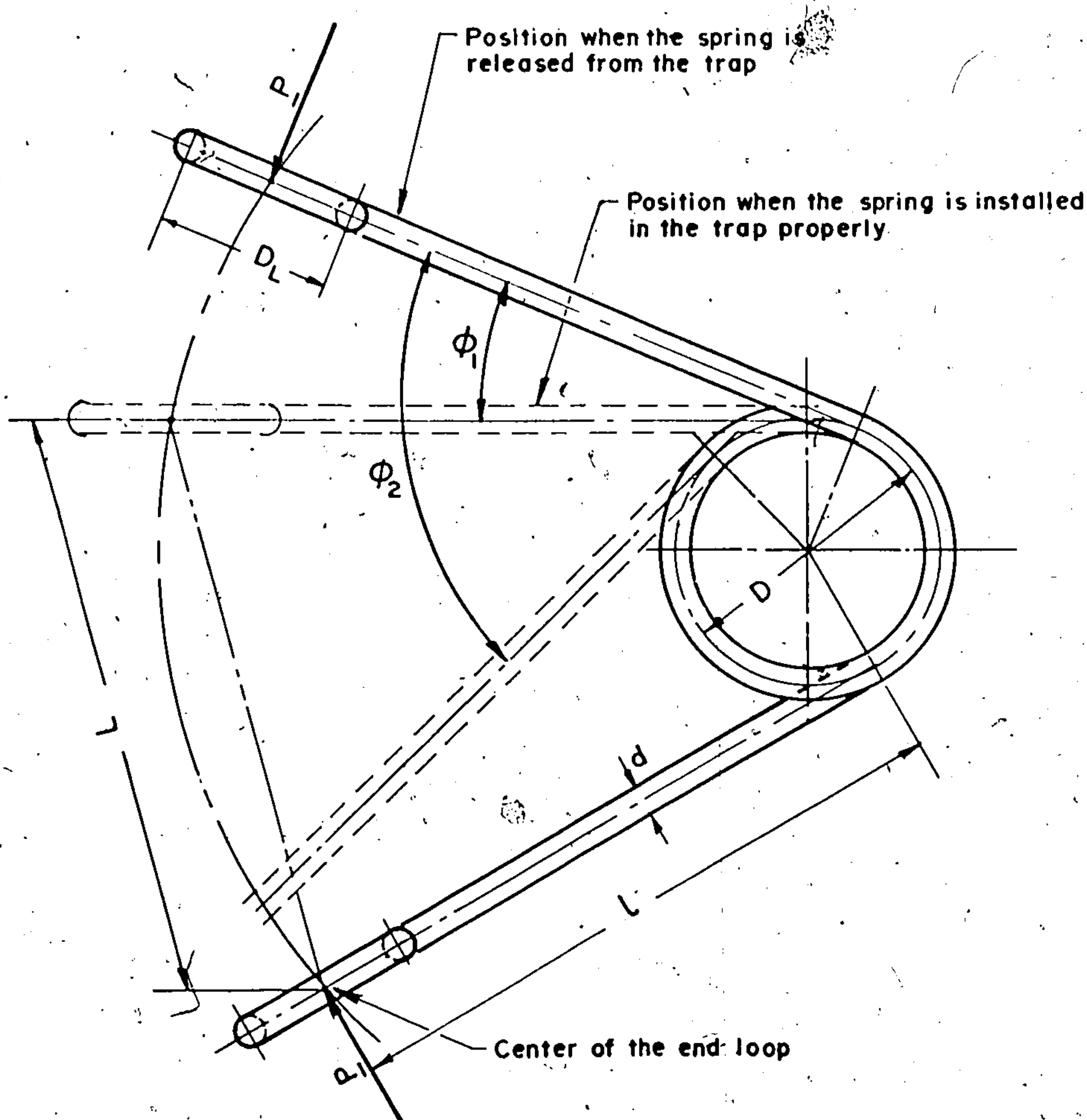


Fig. 2-1 Conibear trap spring

2-2 Strain energy and stress.

The Conibear spring is a typical circular wire helical torsion spring with its free end arms extended.

The entire energy of the trap is from the strain energy which is stored in the springs when they are set.

The spring has two parts, the free end arm acting as a cantilever beam and the coil spring.

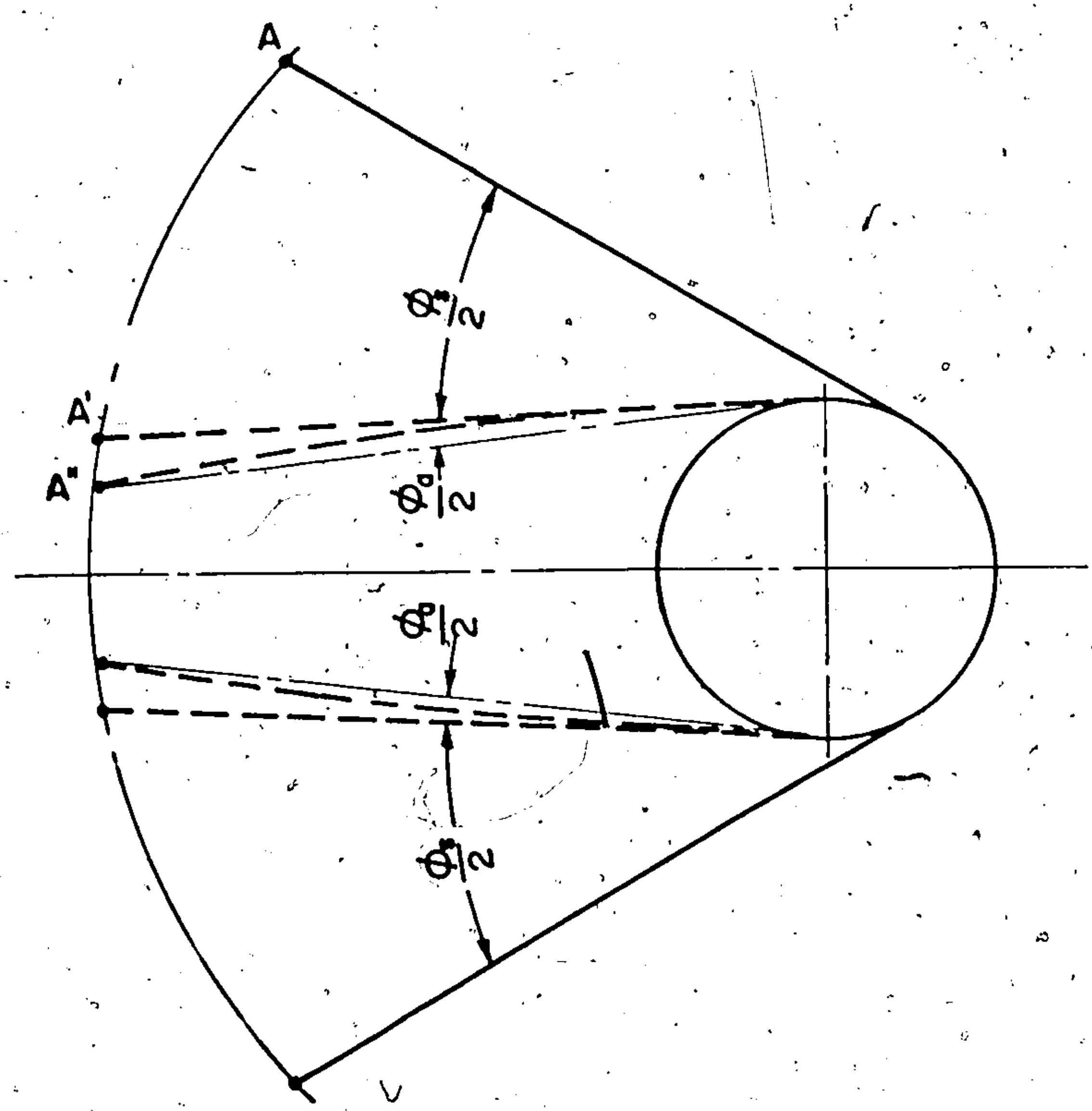


Figure 2-2

Therefore, the deflection of point A, Figure 2-2 to point A" could be divided into two parts, A to A' due to the angular deflection $\phi_s/2$ and the linear deflection A' to A" of the cantilever beam.

From the spring formula[3] the angular deflection of a helical torsion spring in radians for a circular wire is:

$$\phi_s = \frac{64\ \underline{P}\ell\ D\cdot n}{Ed^4} \quad \underline{\text{rad.}} \tag{2-1}$$

And for the cantilever beam, the deflection δ at the end of the free end arm due to the concentrated load $\underline{P}$ for a circular wire cross-section is:

$$\delta = \frac{64}{3}\frac{\underline{P}\ell^3}{E\pi d^4} \tag{2-2}$$

Approximating the linear deflection A'A" as an arc with radius "ℓ", the angle which subtends the arc will be:

$$\phi_a = \frac{128}{3}\frac{\underline{P}\ell^2}{E\pi d^4} \quad \underline{\text{rad.}} \tag{2-3}$$

for the two free end arms.

Therefore, the total deflection angle ϕ will be:

$$\phi = \phi_s + \phi_a$$

$$= \frac{64\ \underline{P}\ell}{Ed^4}\left(D.n + \frac{2\ell}{3\pi}\right) \tag{2-4}$$

Noting that $M = \underline{P}\ell$ is a torsional moment and rearranging the equation (2-4)

$$M = \frac{Ed^4\phi}{64\left(D.n + \frac{2\ell}{3\pi}\right)} \tag{2-5}$$

Hence, the strain energy U can be obtained from the elementary formula,

$$U = \int_{\phi_1}^{\phi_2} M \, d\phi \qquad (2\text{-}6)$$

Substitution and integration reveals:

$$U = \frac{Ed^4}{64(D.n + \frac{2\ell}{3\pi})} \cdot \frac{\phi_2^2 - \phi_1^2}{2} \qquad (2\text{-}7)$$

This is for one spring.

Next, for the spring in which the load applied in such a way that the spring tends to wind up, the maximum bending stress $\sigma_{max.}$ occurs at the inside surface of the coil and it is given[3] as:

$$\sigma_{max.} = K_1 \frac{32M}{\pi d^3} \qquad (2\text{-}8)$$

where $K_1 = \dfrac{4C^2 - C - 1}{4C(C - 1)}$

$C = D/d$

2-3 Calculation results.

The calculations discussed in Section 2-2 could be done by hand, but for the case where there are many sets of data, a computer programme was set up. This is listed in Appendix "B". To test the formulas and the programme, three sample springs from each Conibear series traps, were measured, averaged, and the data was fed into the computer.

The following Tables 2-1, 2-2, and 2-3 show the measurements and the computation results. Figure 2-3 shows the computer results.

The energy values are for two springs in each case.

It should be pointed out, here, that the maximum stress levels are much higher than the reasonable value* suggested by P. H. Tschoepe[2] for a high carbon steel.

* See also page 162

TABLE 2-1: The results of measurements and computations for the spring of the Conibear trap #120

No. of Measurement	Symbol	Measurements 1	2	3	Average
Wire diameter (in.)	d	.1875	.1875	.1875	.1875
Mean coil diameter (in.)	D	2.1250	2.1250	2.1250	2.1250
No. of turns	n	2.298	2.313	2.298	2.303
Free end arm l'th (in.)	ℓ	3.8750	3.9375	3.8750	=3.8750
Mean loop diameter (in.)	D_L	.9375	.9375	.8750	= .9375
Initial deflection angle (deg-min)	ϕ_1	31-45	35-00	43-30	36-45
Total deflection angle (deg-min)	ϕ_2	83-50	90-00	95-45	89-52
Additional deflection angle (deg-min)	$\phi_2 - \phi_1$	52-05	55-00	52-15	53-07
Force at the end of the free end arm at initial deflection (lbs.)	FF1				16.77
Chord of additional deflection angle with the free end arm as a radius (in.)	DEFM	$2 \times 3.875 \times \sin(\frac{53^\circ 17'}{2}) = 3.4581$			
Total strain energy stored (for two springs, in-lbs.)	ENGY		Calculation		206.93
Max. stress (psi)	σ Max.		Calculation		262,546
Weight of one spring (lbs.)					.219

TABLE 2-2: The results of measurements and computations for the spring of the Conibear trap #220D

No. of Measurement	Symbol	Measurements			
		1	2	3	Average
Wire diameter (in.)	d	.2500	.2500	.2500	.2500
Mean coil diameter (in.)	D	.4375	.4375	.4375	.4375
No. of turns	n	2.310	2.302	2.324	2.312
Free end arm l'th (in.)	ℓ	6.4375	6.5000	6.3750	6.4375
Mean loop diameter (in.)	D_L	1.3125	1.3125	1.2500	≈1.3125
Initial deflection angle (deg-min)	ϕ_1	34-30	38-30	32-40	35-13
Total deflection angle (deg-min)	ϕ_2	88-00	91-00	82-15	87-05
Additional deflection angle (deg-min)	$\phi_2 - \phi_1$	53-30	52-30	49-35	51-52
Force at the end of the free end arm at initial deflection (lbs.)	FF1				24.98
Chord of additional deflection angle with the free end arm as a radius (in.)	DEFM	$2 \times 6.4375 \times \sin(\frac{51^\circ 52'}{2}) = 5.6267$			
Total strain energy stored (for two springs, in-lbs.)	ENGY		Calculation		504.98
Max. stress (psi)	$\sigma_{Max.}$		Calculation		280,511
Weight of one spring (lbs.)					.519

TABLE 2-3: The result of measurements and computations for the spring of the Conibear trap #330

No. of Measurement	Symbol	Measurements			
		1	2	3	Average
Wire diameter (in.)	d	.3125	.3125	.3125	.3125
Mean coil diameter (in.)	D	2.8750	2.8750	2.8750	2.8750
No. of turns	n	2.300	2.318	2.315	2.310
Free end arm l'th (in.)	ℓ	8.750	8.750	8.750	8.750
Mean loop diameter (in.)	D_L	2.0625	2.1250	2.1250	=2.125
Initial deflection angle (deg-min)	ϕ_1	34-00	27-30	20-00	20-30
Total deflection angle (deg-min)	ϕ_2	81-00	78-00	80-30	79-30
Additional deflection angle (deg-min)	$\phi_2 - \phi_1$	47-00	50-30	50-30	49-20
Force at the end of the free end arm at initial deflection (lbs.)	FF1				31.98
Chord of additional deflection angle with the free end arm as a radius (in.)	DEFM	$2 \times 8.75 \times \sin(\frac{49^{o}20'}{2})=7.25$			
Total strain energy stored (for two springs, in-lbs.)	ENGY		Calculation		860.5
Max. stress (psi)	q_{max}		Calculation		264,864
Weight of one spring (lbs.)					1.073

*** CONIBEAR TRAP NO. 120 ***

WIRE DIAMETER (IN.)	=	.1875
MEAN COIL DIAMETER (IN.)	=	2.1250
NUMBER OF TURNS OF COIL	=	2.3030
FREE END ARM LENGTH (IN.)	=	3.8750
INITIAL COMP. ANGLE (RAD)	=	.6410
FORCE AT INITIAL DEFLECTION(LBS)	=	.167659E+02
STRESS IN SPRING (LBS/SQ.IN.).	=	.262546E+06
MAXIMUM ENERGY (IN.-LBS)	=	.206926E+03
WEIGHT OF ONE SPRING (LBS)	=	.218706E+00

*** CONIBEAR TRAP NO. 220 ***

WIRE DIAMETER (IN.)	=	.2500
MEAN COIL DIAMETER (IN.)	=	2.4375
NUMBER OF TURNS OF COIL	=	2.3120
FREE END ARM LENGTH (IN.)	=	6.4375
INITIAL COMP. ANGLE (RAD)	=	.6150
FORCE AT INITIAL DEFLECTION(LBS)	=	.249841E+02
STRESS IN SPRING (LBS/SQ.IN.).	=	.280511E+06
MAXIMUM ENERGY (IN.-LBS)	=	.504967E+03
WEIGHT OF ONE SPRING (LBS)	=	.519485E+00

*** CONIBEAR TRAP NO. 330 ***

WIRE DIAMETER (IN.)	=	.3125
MEAN COIL DIAMETER (IN.)	=	2.8750
NUMBER OF TURNS OF COIL	=	2.3100
FREE END ARM LENGTH (IN.)	=	8.7500
INITIAL COMP. ANGLE (RAD)	=	.5320
FORCE AT INITIAL DEFLECTION(LBS)	=	.319834E+02
STRESS IN SPRING (LBS/SQ.IN.).	=	.264864E+06
MAXIMUM ENERGY (IN.-LBS)	=	.862105E+03
WEIGHT OF ONE SPRING (LBS)	=	.107341E+01

FIGURE 2-3: Computer output of the Conibear spring calculation

3. SPRING OPTIMIZATION AND NEW DESIGN

In view of the high stress level in the existing Conibear trap springs as shown in the Tables 2-1, 2-2 and 2-3, new spring designs were required. Therefore, a spring optimization programme was developed based on the formulas as explained in the previous chapter.

3-1 Remarks on the use of the spring equations.

Let us rewrite the energy equation, (2-7)

$$U = \frac{Ed^4}{64(D \cdot n + \frac{2\ell}{3\pi})} \cdot \frac{\phi_2^2 - \phi_1^2}{2} \qquad (3-1)$$

and by substituting the equation (2-5) into the equation (2-8), the maximum stress equation becomes,

$$\sigma_{max.} = K_1 \frac{Ed\phi_2}{2\pi(D \cdot n + \frac{2\ell}{3\pi})} \qquad (3-2)$$

From the energy equation (3-1), it is seen that the strain energy will increase with the wire diameter and the deflection angles, and be reduced with the mean coil diameter, the number of coil and the free end arm length.

Once the size of the trap frame is decided, the additional angular deflection, $\phi_2 - \phi_1$, will almost be fixed with the free end arm chosen. This means that it is better to increase the initial deflection angle ϕ_1, which is also preferable in view of the clamping force. Of course, this will increase the total deflection angle, ϕ_2, increasing the bending stress, but it has a higher power in the energy equation.

The wire diameter of the spring, d, has a drastic effect on the strain energy, but it would also increase the weight and the fabricating cost.

The following derivation is included for the case when one intends to use the equality constraint for the number of turns of the coil spring in the optimization computer programme as explained in the next section.

Let us define additional parameters as shown on Figure 3-1.

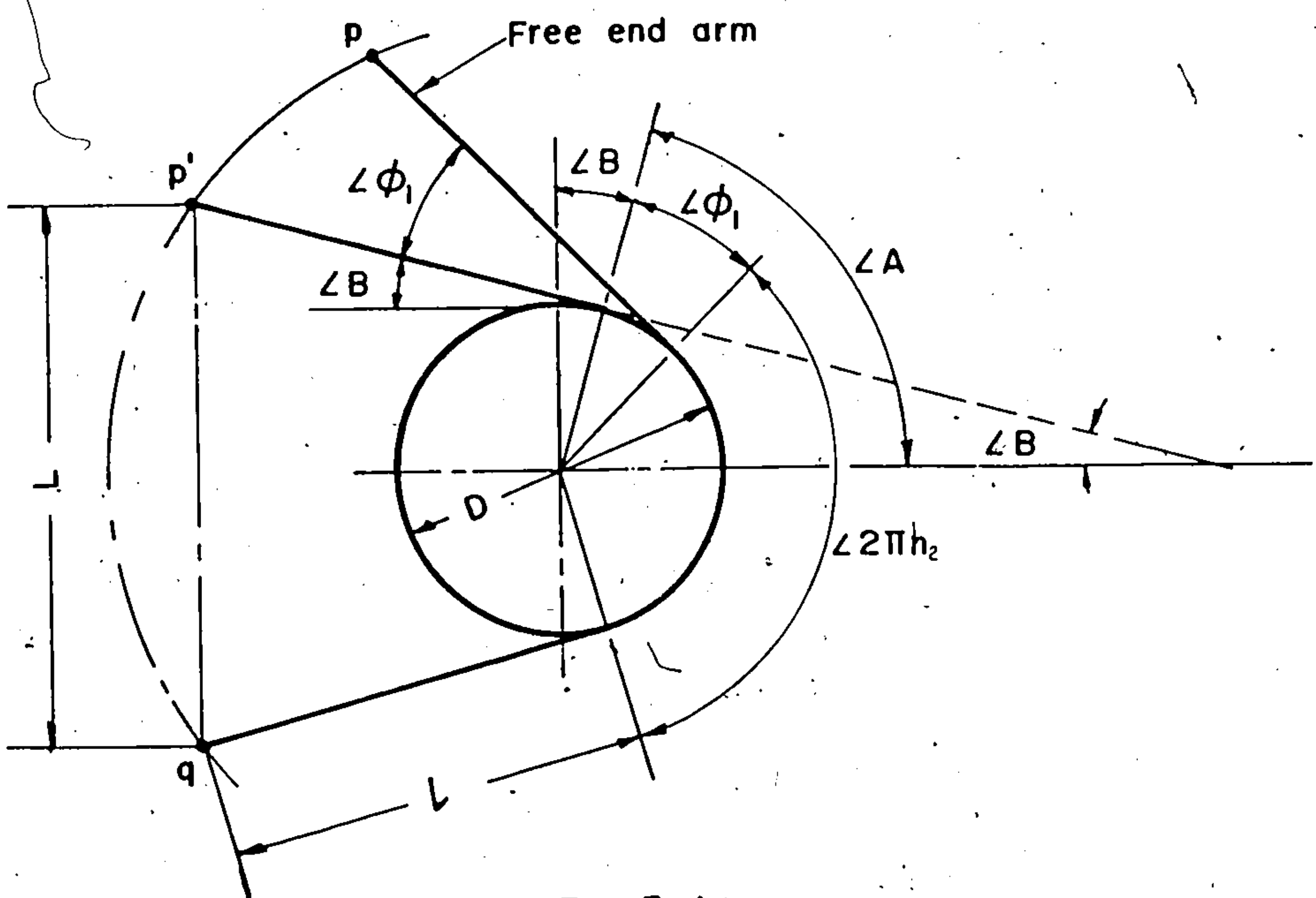


Fig. 3-1

n_1 Integer for the number of coils, n

n_2 Decimal numbers of the n, $(n_1 + n_2 = n)$

After the primary deflection, the end points p',q (Figure 3-1) should fit into the trap frame. Therefore, $p'q = L$ or $\frac{p'q}{2} = \frac{L}{2}$

From the figure:

$$\frac{p'q}{2} = \frac{D}{2}\cos B + \ell \sin B \qquad (3\text{-}3)$$

where $A = \frac{2\pi n_2 + \phi_1}{2}$ rad.

$B = \frac{\pi}{2} - A$ rad.

Therefore, we have,

$$\frac{L}{2} = \left(\frac{D}{2}\cos B + \ell \sin B\right) \qquad (3\text{-}4)$$

3-2 The spring optimization programme.

After the general configuration has been decided, the most preferable spring will be the one which satisfies all the design conditions, and still has the minimum weight in this case. The trap weight and the manufacturing cost will be less if a smaller diameter wire can be used.

The programme was set up according to the OPTISEP manual[7]. The main programme is to define the parameters and read the input data, call the subroutines, and write out the result.

The subroutine UREAL computes the value of the optimization (or objective) function, the spring weight, in the case, for a set of the values of the design variables.

The subroutine CONST computes the values of the inequality constraints for the values of the design variables. Constraints 1 to 5 are for maximum value restrictions. The values of the design variables should not be greater than the allowable maximum values. Constraints 6 to 10 are for the restriction that all the design variables should be positive. The next two constraints, 11 and 12 are for the energy and stress restrictions. The strain energy stored in the spring should be at least its minimum required value, ELOW and the maximum stress in the spring should not exceed the allowable stress, STW. The final constraint is required for clamping force. The tangential force at the free end arm of the spring should be greater than the needed value, FINIT, when the spring is loaded to the initial deflection angle.

The subroutine "ENRGY" carries out all the calculations for the spring utilizing the formulas as outlined in Chapter 2.

The computer result cannot be used in actual design because the wire diameter may not be a commercial size, the values of the design variables are too accurate to be practical, and particularly, the number of turns of the coil spring has to be adjusted to suit. It would make the programme extremely complicated to set it up to accommodate all these aspects, and it would consume more computer time. Instead, they were left to the designer who can adjust the result to suit by giving up some degree of the optimum and noting the effect of each design variable as explained in Section 3-1. Of course, there are two ways to confine a specific design variable or particular relation among them to a specific value. That is, use an equality constraint or sandwich it into two inequality constraints.

From the OPTISEP[7] package, the subroutines SEEK 1 and SIMPLX were used. In the cases where a solution exists the subroutines SEEK 1, with a reasonable starting point, normally gave the best results in terms of computer time. The subroutine SIMPLX gave good results most of the time with less emphasis on the starting point when a solution did exist. However, this subroutine took much more computer time, sometimes 2 to 3 times as much as with SEEK 1. Both subroutines tend to hang up with the equality constraints, therefore, it is better to start from the equality constraint lines.

The programme is listed in the Appendix "A", and the strategies used in the above subroutines are well explained in Chapter 7, Reference [5].

3-3 Evaluation of existing springs and the design of new springs.

The programme was run, first, to check how close to the optimum the existing spring designs of Conibear series traps were, using the same allowable stress as shown in

Tables 2-1, 2-2, and 2-3. These proved to be quite close to the optimum as shown on Tables 3-1, 3-2, and 3-3, Columns 1 and 2, or Figures 3-2, 3-3, and 3-4.

It was mentioned earlier that the present design stress was too high. For the new springs a lower allowable stress of about 190,000 psi*was used.

The computer results, optimum solutions and trimmed values, are listed in Tables 3-1, 3-2, and 3-3, Columns 4 and 5.

Computer outputs are shown in Figures 3-5, 3-6, and 3-7.

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* See page 162

TABLE 3-1: Optimization result of the trap spring (Conibear trap #120)

	Existing	Optimum W/stress at present Level (STW = 262,500 psi)	New Design: Optimum W/altered stress (STW = 190,000 psi)	New Design: Trimmed Result
Wire diameter (in.)	.1875	.1823	.1868	.1875
Mean coil diameter (in.)	2.1250	2.2491	2.8941	3.0000
Number of coils	2.3030	2.2996	3.4645	3.2750
Free end arm length (in.)	3.8750	3.7000	3.0750	2.8750
Initial deflection Angle (deg)	36°45'	40°58'	55°45'	47°00'
Max. stress in the spring (lbs/sq.in)	262,546	262,492	189,982	189,931
Energy of 2-spring (in. lbs.)	206.930	203.210	200.050	209.970
Weight (1 spring, lbs.)	.219	.211	.3300	.3245
Remarks		From SEEK 1	From SEEK 1	

TABLE 3-2: Optimization result of the trap spring (Conibear trap #220D)

	Existing	Optimum W/stress at present Level (STW = 280,500 psi)	New Design	
			Optimum W/altered stress (STW = 190,000 psi)	Trimmed Result
Wire diameter (in.)	.2500	.2443	.2698	.2830
Mean coil diameter (in.)	2.4375	2.7028	3.1544	3.3750
Number of coils	2.3120	2.2437	3.6727	3.2990
Free end arm length (in.)	6.4375	6.3000	5.7000	5.5625
Initial deflection Angle (deg)	35°13'	42°02'	42°08'	32°30'
Max. stress in the spring (lbs/sq.in)	280,511	280,474	189,997	190,618
Energy of 2-spring (in. lbs.)	504.980	500.110	501.070	568.770
Weight (1 spring, lbs.)	.519#	.511#	.884	.942
Remarks		From SEEK 1	From SEEK 1	

TABLE 3-3: Optimization result of the trap spring (Conibear trap #330)

	Existing	Optimum W/stress at present Level (STW = 264,800 psi)	New Design: Optimum W/altered stress (STW = 190,000 psi)	New Design: Trimmed Result
Wire diameter (in.)	.3125	.3029	.2949	.3125
Mean coil diameter (in.)	.2875	2.7078	3.7922	3.7500
Number of coils	2.3100	2.7789	4.4492	4.1860
Free end arm length (in.)	8.7500	8.1192	5.7800	6.8125
Initial deflection Angle (deg)	30°30'	35°53'	54°13'	53°00'
Max. stress in the spring (lbs/sq.in)	264,864	264,797	189,986	189,990
Energy of 2-spring (in. lbs.)	860.570	860.390	861.640	869.740
Weight (1 spring, lbs.)	1.073	1.040	1.464	1.609
Remarks		From SEEK 1	From SEEK 1	

FIGURE 3-2: Optimization computer result of the spring of the Conibear trap #120 (existing) SEEK 1

```
 11/30/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
18.02.13.
18.02.13.HVNTOXE                              HVNTOXE
18.02.13.IP  00000896 WORDS - FILE INPUT  , DC 00
18.02.13.HVNT,T60.
18.02.13.                                 YI Y. J.
18.02.14.ATTACH,OPTISEP.
18.02.14.PFN IS
18.02.14.OPTISEP
18.02.14.PF CYCLE NO. = 001
18.02.14.FTN.
18.02.20.      1.309 CP SECONDS COMPILATION TIME
18.02.20.LDSET,LIB=OPTISEP.
18.02.20.LGO.
18.02.23.        NON-FATAL LOADER ERRORS - SEE MAP
18.02.25.      STOP
18.02.25.       .869 CP SECONDS EXECUTION TIME
18.02.25.OP  00003712 WORDS - FILE OUTPUT , DC 40
18.02.25.CP        004.717 SEC.
18.02.25.PP        007.734 SEC.
18.02.25.IO        002.252 SEC.
18.02.25.IOM       079.286 WS/512
18.02.25.CPM       133.329 WS/512
18.02.25.ENDJOB 11/30/73

***********            HVNTOXE  //// END OF LIST ////
***********            HVNTOXE  //// END OF LIST ////
```

```
$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.1E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.34581E+01,
E       =  0.3E+08,
STW     =  0.2625E+06,
ELOW    =  0.2E+03,
SPWT    =  0.284E+00,
FINIT   =  0.168E+02,
RM      =  0.2E+01,
DLOOP   =  0.9375E+00,
$END
```

```
INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =   1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .   IDATA  =   1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .      N  =   5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =  13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .      F  =     .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM  = 100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.      G  =     .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =   0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .   NSHOT  =   2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .   NTEST  = 100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
  .50000000E+00   .40000000E+01   .50000000E+01   .10000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
 0.              0.              0.              0.              0.
STARTING VALUES OF X(I) . . . . . . . . . . . . .XSTRT(I)  =
  .18800000E+00   .25000000E+01   .25000000E+01   .40000000E+01   .70000000E+00
```

FIGURE 3-2: Continued

FIGURE 3-2: Continued

```
                    OPTIMUM SOLUTION FOUND
                  MINIMUM   U =    .21074603E+00

                         X( 1) =    .18233594E+00
                         X( 2) =    .22490625E+01
                         X( 3) =    .22996094E+01
                         X( 4) =    .37000000E+01
                         X( 5) =    .71500000E+00

INEQUALITY CONSTRAINTS
                       PHI( 1) =    .31766406E+00
                       PHI( 2) =    .17509375E+01
                       PHI( 3) =    .27003906E+01
                       PHI( 4) =    .63000000E+01
                       PHI( 5) =    .12850000E+01
                       PHI( 6) =    .18233594E+00
                       PHI( 7) =    .22490625E+01
                       PHI( 8) =    .22996094E+01
                       PHI( 9) =    .37000000E+01
                       PHI(10) =    .71500000E+00
                       PHI(11) =    .32085792E+01
                       PHI(12) =    .83831006E+01
                       PHI(13) =    .72882236E-02

   FORCE AT INITIAL DEFLECTION(LBS) . . . . . =     .168073E+02
   STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =     .262492E+06
   MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =     .203209E+03

   WIRE DIAMETER (IN.)  . . . . . . . . . . . =      .1823
   MEAN COIL DIAMETER (IN.) . . . . . . . . . =     2.2491
   NUMBER OF TURNS OF COIL  . . . . . . . . . =     2.2996
   FREE END ARM LENGTH (IN.)  . . . . . . . . =     3.7000
   INITIAL COMP. ANGLE (RAD)  . . . . . . . . =      .7150
```

of the Conibear trap #220 (existing) SEEK 1

```
11/30/73 MCMASTER - SCOPE 3.4 AT L348   11/14/73
18.26.16.
18.26.16.HVNTOXW                              HVNTOXW
18.26.16.IP  00000896 WORDS - FILE INPUT  , DC 00
18.26.16.HVNT,T60.
18.26.16.                                  YI Y. J.
18.26.16.ATTACH,OPTISEP.
18.26.16.PFN IS
18.26.16.OPTISEP
18.26.17.PF CYCLE NO. = 001
18.26.17.FTN.
18.26.22.      1.294 CP SECONDS COMPILATION TIME
18.26.22.LDSET,LIB=OPTISEP.
18.26.22.LGO.
18.26.26.      NON-FATAL LOADER ERRORS - SEE MAP
18.26.27.     STOP
18.26.27.      1.022 CP SECONDS EXECUTION TIME
18.26.27.OP  00003776 WORDS - FILE OUTPUT , DC 40
18.26.27.CP        004.850 SEC.
18.26.27.PP        007.581 SEC.
18.26.27.IO        002.252 SEC.
18.26.27.IOM       079.286 WS/512
18.26.27.CPM       135.691 WS/512
18.26.27.ENDJOB 11/30/73

***********          HVNTOXW  //// END OF LIST ////
***********          HVNTOXW  //// END OF LIST ////

$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.1E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.56267E+01,
E       =  0.3E+08,
STW     =  0.2805E+06,
ELOW    =  0.5E+03,
SPWT    =  0.284E+00,
FINIT   =  0.25E+02,
RM      =  0.2E+01,
DLOOP   =  0.13125E+01,
$END
```

```
INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =   1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .   IDATA  =   1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .       N  =   5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =  13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F  =      .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM  = 100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =      .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =   0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .   NSHOT  =   2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .   NTEST  = 100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
  .50000000E+00   .40000000E+01   .50000000E+01   .10000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
 0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . .XSTRT(I)  =
  .25000000E+00   .30000000E+01   .25000000E+01   .70000000E+01   .70000000E+00
```


FIGURE 3-3: Continued

FIGURE 3-3: Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .51057056E+00

X(1) = .24433594E+00
X(2) = .27028125E+01
X(3) = .22437500E+01
X(4) = .63000000E+01
X(5) = .73359375E+00

INEQUALITY CONSTRAINTS

PHI(1) = .25566406E+00
PHI(2) = .12971875E+01
PHI(3) = .27562500E+01
PHI(4) = .37000000E+01
PHI(5) = .12664063E+01
PHI(6) = .24433594E+00
PHI(7) = .27028125E+01
PHI(8) = .22437500E+01
PHI(9) = .63000000E+01
PHI(10) = .73359375E+00
PHI(11) = .10972204E+00
PHI(12) = .26202255E+02
PHI(13) = .12842486E+01

FORCE AT INITIAL DEFLECTION(LBS) . . . . . = .262842E+02
STRESS IN SPRING (LBS/SQ.IN.). . . . . . . = .280474E+06
MAXIMUM ENERGY (IN.-LBS) . . . . = .500110E+03

WIRE DIAMETER (IN.) . . . . = .2443
MEAN COIL DIAMETER (IN.) . . . . = 2.7028
NUMBER OF TURNS OF COIL . . . . = 2.2437
FREE END ARM LENGTH (IN.) . . . . = 6.3000
INITIAL COMP. ANGLE (RAD) . . . . = .7336

FIGURE 3-4: Optimization Computer result of the spring of the Conibear trap #330 (existing) SEEK 1

```
 11/30/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
18.47.26.
18.47.26.HVNTOYE                            HVNTOYE
18.47.26.IP  00000896 WORDS - FILE INPUT  , DC 00
18.47.26.HVNT,T60.
18.47.26.                                 YI Y. J.
18.47.27.ATTACH,OPTISEP.
18.47.27.PFN IS
18.47.27.OPTISEP
18.47.27.PF CYCLE NO. = 001
18.47.27.FTN.
18.47.32.      1.312 CP SECONDS COMPILATION TIME
18.47.33.LDSET,LIB=OPTISEP.
18.47.33.LGO.
18.47.36.      NON-FATAL LOADER ERRORS - SEE MAP
18.47.38.     STOP
18.47.38.      1.472 CP SECONDS EXECUTION TIME
18.47.38.OP  00003840 WORDS - FILE OUTPUT , DC 40
18.47.38.CP        005.300 SEC.
18.47.38.PP        007.639 SEC.
18.47.38.IO        002.254 SEC.
18.47.38.IOM       079.323 WS/512
18.47.38.CPM       144.371 WS/512
18.47.38.ENDJOB 11/30/73

***********          HVNTOYE  //// END OF LIST ////
***********          HVNTOYE  //// END OF LIST ////

$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.12E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.725E+01,
E       =  0.3E+08,
STW     =  0.2648E+06,
ELOW    =  0.86E+03,
SPWT    =  0.284E+00,
FINIT   =  0.32E+02,
RM      =  0.2E+01,
DLOOP   =  0.2125E+01,
$END
```

```
INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =     1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .   IDATA  =     1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .       N  =     5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =    13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F  =      .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED. . . . . . . .     MAXM  =   100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =      .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =     0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .   NSHOT  =     2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .   NTEST  =   100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
  .50000000E+00   .40000000E+01   .50000000E+01   .12000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
 0.              0.              0.              0.              0.
STARTING VALUES OF X(I) . . . . . . . . . . . . .XSTRT(I)  =
  .31300000E+00   .30000000E+01   .25000000E+01   .90000000E+01   .75000000E+00
```

FIGURE 3-4: Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .10396452E+01

X(1)	=	.30290014E+00
X(2)	=	.27078103E+01
X(3)	=	.27788816E+01
X(4)	=	.81191545E+01
X(5)	=	.62638799E+00

INEQUALITY CONSTRAINTS

PHI(1)	=	.19709986E+00
PHI(2)	=	.12921897E+01
PHI(3)	=	.22211184E+01
PHI(4)	=	.38808455E+01
PHI(5)	=	.13736120E+01
PHI(6)	=	.30290014E+00
PHI(7)	=	.27078103E+01
PHI(8)	=	.27788816E+01
PHI(9)	=	.81191545E+01
PHI(10)	=	.62638799E+00
PHI(11)	=	.38892571E+00
PHI(12)	=	.32419379E+01
PHI(13)	=	.91862816E+00

FORCE AT INITIAL DEFLECTION(LBS) . . . . . =	.329186E+02
STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =	.264797E+06
MAXIMUM ENERGY (IN.-LBS) . . . . =	.860389E+03
WIRE DIAMETER (IN.) . . . . =	.3029
MEAN COIL DIAMETER (IN.) . . . . =	2.7078
NUMBER OF TURNS OF COIL . . . . =	2.7789
FREE END ARM LENGTH (IN.) . . . . =	8.1192
INITIAL COMP. ANGLE (RAD) . . . . =	.6264

```
12/05/73 MCMASTER - SCOPE 3.4 AT L348      12/14/73
12.43.23.
12.43.23.HVNTOAH                                HVNTOAH
12.43.23.IP  00000896 WORDS - FILE INPUT  , DC 00
12.43.23.HVNT,T60.
12.43.23.                                YI Y. J.
12.43.24.ATTACH,OPTISEP.
12.43.24.PFN IS
12.43.24.OPTISEP
12.43.24.PF CYCLE NO. = 001
12.43.24.FTN.
12.43.30.     1.306 CP SECONDS COMPILATION TIME
12.43.30.LDSET,LIB=OPTISEP.
12.43.30.LGO.
12.43.33.     NON-FATAL LOADER ERRORS - SEE MAP
12.43.35.     STOP
12.43.35.     1.074 CP SECONDS EXECUTION TIME
12.43.35.OP  00003776 WORDS - FILE OUTPUT , DC 40
12.43.35.CP        004.915 SEC.
12.43.35.PP        008.803 SEC.
12.43.35.IO        002.253 SEC.
12.43.35.IOM       079.323 WS/512
12.43.35.CPM       137.046 WS/512
12.43.35.ENDJOB 12/05/73

***********          HVNTOAH  //// END OF LIST ////
***********          HVNTOAH  //// END OF LIST ////
```

```
$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.1E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.34581E+01,
E       =  0.3E+08,
STW     =  0.19E+06,
ELOW    =  0.2E+03,
SPWT    =  0.284E+00,
FINIT   =  0.168E+02,
RM      =  0.2E+01,
DLOOP   =  0.9375E+00,
$END
```

FIGURE 3-5(a): Continued

```
INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .   IPRINT  =      1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .   IDATA   =      1
NUMBER OF INDEPENDENT VARIABLES. . . . . . . . .        N   =      5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS   =     13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F   =         .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM   =    100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G   =         .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS   =      0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .   NSHOT   =      2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .   NTEST   =    100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . .  RMAX(I)  =
  .50000000E+00   .40000000E+01   .50000000E+01   .10000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . .  RMIN(I)  =
 0.              0.              0.              0.              0.
STARTING VALUES OF X(I) . . . . . . . . . . . . .  XSTRT(I) =
  .20000000E+00   .30000000E+01   .35000000E+01   .30000000E+01   .10000000E+01
```

```
                    OPTIMUM SOLUTION FOUND
                  MINIMUM   U =     .32997755E+00

                     X( 1) =      .18675781E+00
                     X( 2) =      .28940625E+01
                     X( 3) =      .34644531E+01
                     X( 4) =      .30750000E+01
                     X( 5) =      .97125000E+00

INEQUALITY CONSTRAINTS
                   PHI( 1) =      .31324219E+00
                   PHI( 2) =      .11059375E+01
                   PHI( 3) =      .15355469E+01
                   PHI( 4) =      .69250000E+01
                   PHI( 5) =      .10287500E+01
                   PHI( 6) =      .18675781E+00
                   PHI( 7) =      .28940625E+01
                   PHI( 8) =      .34644531E+01
                   PHI( 9) =      .30750000E+01
                   PHI(10) =      .97125000E+00
                   PHI(11) =      .49144840E-01
                   PHI(12) =      .18008409E+02
                   PHI(13) =      .66176263E-01

   FORCE AT INITIAL DEFLECTION(LBS) . . . . . =      .168662E+02
   STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =      .189982E+06
   MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =      .200049E+03

   WIRE DIAMETER (IN.)  . . . . . . . . . . . =      .1868
   MEAN COIL DIAMETER (IN.) . . . . . . . . . =     2.8941
   NUMBER OF TURNS OF COIL  . . . . . . . . . =     3.4645
   FREE END ARM LENGTH (IN.)  . . . . . . . . =     3.0750
   INITIAL COMP. ANGLE (RAD)  . . . . . . . . =      .9712
```

of the Conlbear trap #120 (new design) SIMPLX

```
 12/03/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
14.52.21.
14.52.21.HVNTOGZ                                  HVNTOGZ
14.52.21.IP  00000896 WORDS - FILE INPUT  , DC 00
14.52.22.HVNT,T60.
14.52.22.                                     YI Y. J.
14.52.23.ATTACH,OPTISEP.
14.52.23.PFN IS
14.52.23.OPTISEP
14.52.23.PF CYCLE NO. = 001
14.52.24.FTN.
14.52.34.     1.362 CP SECONDS COMPILATION TIME
14.52.36.LDSET,LIB=OPTISEP.
14.52.36.LGO.
14.52.43.     NON-FATAL LOADER ERRORS - SEE MAP
14.53.07.    STOP
14.53.07.     7.201 CP SECONDS EXECUTION TIME
14.53.07.OP  00007616 WORDS - FILE OUTPUT , DC 40
14.53.07.CP         010.970 SEC.
14.53.07.PP         013.157 SEC.
14.53.07.IO         002.304 SEC.
14.53.07.IOM        080.281 WS/512
14.53.07.CPM        251.359 WS/512
14.53.07.ENDJOB 12/03/73

***********         HVNTOGZ  //// END OF LIST ////
***********         HVNTOGZ  //// END OF LIST ////

$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.1E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.34581E+01,
E       =  0.3E+08,
STW     =  0.19E+06,
ELOW    =  0.2E+03,
SPWR    =  0.284E+00,
FINIT   =  0.168E+02,
RM      =  0.2E+01,
DLOOP   =  0.9375E+00,
$END
```

```
OPTIMIZATION BY SIMPLX METHOD,

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =     1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA   =     1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .       N  =     5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =    13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F  =      .10000000E+01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM  =   500
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =      .20000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =     0
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
  .50000000E+00   .40000000E+01   .50000000E+01   .10000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
  0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . . XSTRT(I) =
  .28000000E+00   .30000000E+01   .30000000E+01   .50000000E+01   .10000000E+01
```

FIGURE 3-5(b): Continued

FIGURE 3-5(b): Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .34508431E+00

```
X( 1) = .18113503E+01
X( 2) = .31607182E+01
X( 3) = .36902307E+01
X( 4) = .28693044E+01
X( 5) = .12412674E+01
```

INEQUALITY CONSTRAINTS

```
PHI( 1) = .31886497E+00
PHI( 2) = .83928175E+00
PHI( 3) = .13097593E+01
PHI( 4) = .71306956E+01
PHI( 5) = .75873260E+00
PHI( 6) = .18113503E+00
PHI( 7) = .31607182E+01
PHI( 8) = .36902307E+01
PHI( 9) = .28693044E+01
PHI(10) = .12412674E+01
PHI(11) = .82694367E+00
PHI(12) = .33847764E+04
PHI(13) = .98692515E+00
```

FORCE AT INITIAL DEFLECTION(LBS)	. . . . . =	.177869E+02
STRESS IN SPRING (LBS/SQ.IN.)	. . . . =	.186615E+06
MAXIMUM ENERGY (IN.-LBS)	. . . . =	.200827E+03
WIRE DIAMETER (IN.)	. . . . =	.1811
MEAN COIL DIAMETER (IN.)	. . . . =	3.1607
NUMBER OF TURNS OF COIL	. . . . =	3.6902
FREE END ARM LENGTH (IN.)	. . . . =	2.8693
INITIAL COMP. ANGLE (RAD)	. . . . =	1.2413

FIGURE 3-6(a): Optimization computer result of the spring of the Conibear trap #220 (new design) SEEK 1

```
 12/05/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
10.59.27.
10.59.27.HVNT039                               HVNT039
10.59.27.IP  00000896 WORDS - FILE INPUT  , DC 00
10.59.27.HVNT,T60.
10.59.27.                                    YI Y. J.
10.59.27.ATTACH,OPTISEP.
10.59.27.PFN IS
10.59.27.OPTISEP
10.59.27.PF CYCLE NO. = 001
10.59.28.FIN.
10.59.33.      1.286 CP SECONDS COMPILATION TIME
10.59.33.LDSET,LIB=OPTISEP.
10.59.34.LGO.
10.59.37.      NON-FATAL LOADER ERRORS - SEE MAP
10.59.38.     STOP
10.59.38.      1.850 CP SECONDS EXECUTION TIME
10.59.38.CP   00003976 WORDS - FILE OUTPUT , DC 40
10.59.39.CP         004.882 SEC.
10.59.39.PP         007.694 SEC.
10.59.39.IO         002.253 SEC.
10.59.39.IOM        079.323 WS/512
10.59.39.CPM        136.408 WS/512
10.59.39.ENDJOB 12/05/73


***********            HVNT039  //// END OF LIST ////
***********            HVNT039  //// END OF LIST ////


$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.1E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.56267E+01,
E       =  0.3E+08,
STW     =  0.19E+06,
ELOW    =  0.5E+03,
SPWT    =  0.284E+00,
FINIT   =  0.25E+02,
RM      =  0.2E+01,
DLOOP   =  0.13125E+01,
$END
```

```
INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .    IPRINT   =        1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .     IDATA   =        1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . . .       N   =        5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . . .   NCONS   =       13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . . .       F   =            .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . . .    MAXM   =      100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.         G   =            .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . . .   NEQUS   =        0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . . .   NSHOT   =        2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . . .   NTEST   =      100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . . RMAX(I)   =
  .50000000E+00   .40000000E+01   .50000000E+01   .10000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . . RMIN(I)   =
  0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . . .XSTRT(I)   =
  .30000000E+00   .35000000E+01   .40000000E+01   .60000000E+01   .80000000E+00
```

FIGURE 3-6(a): Continued

```
                    OPTIMUM SOLUTION FOUND
                  MINIMUM  U =     .88400675E+00

                     X( 1) =      .26976562E+00
                     X( 2) =      .31543750E+01
                     X( 3) =      .36726563E+01
                     X( 4) =      .57000000E+01
                     X( 5) =      .73453125E+00

INEQUALITY CONSTRAINTS
                   PHI( 1) =      .23023438E+00
                   PHI( 2) =      .84562500E+00
                   PHI( 3) =      .13273437E+01
                   PHI( 4) =      .43000000E+01
                   PHI( 5) =      .12654687E+01
                   PHI( 6) =      .26976562E+00
                   PHI( 7) =      .31543750E+01
                   PHI( 8) =      .36726563E+01
                   PHI( 9) =      .57000000E+01
                   PHI(10) =      .73453125E+00
                   PHI(11) =      .10650511E+01
                   PHI(12) =      .28548152E+01
                   PHI(13) =      .34184898E-02

    FORCE AT INITIAL DEFLECTION(LBS) . . . . . =     .250034E+02
    STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =     .189997E+06
    MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =     .501065E+03

    WIRE DIAMETER (IN.)  . . . . . . . . . . . =     .2698
    MEAN COIL DIAMETER (IN.) . . . . . . . . . =     3.1544
    NUMBER OF TURNS OF COIL  . . . . . . . . . =     3.6727
    FREE END ARM LENGTH (IN.)  . . . . . . . . =     5.7000
    INITIAL COMP. ANGLE (RAD)  . . . . . . . . =     .7345
```

FIGURE 3-6(b): Optimization computer result of the [illegible] of the Conibear trap #220 (new design) SIMPLX

```
 12/03/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
15.39.08.
15.39.08.HVNTOKM                          HVNTOKM
15.39.08.IP  00000896 WORDS - FILE INPUT  , DC 00
15.39.08.HVNT,T60.
15.39.08.                                YI Y. J.
15.39.09.ATTACH,OPTISEP.
15.39.09.PFN IS
15.39.09.OPTISEP
15.39.09.PF CYCLE NO. = 001
15.39.09.FTN.
15.39.18.     1.362 CP SECONDS COMPILATION TIME
15.39.19.LDSET,LIB=OPTISEP.
15.39.20.LGO.
15.39.29.      NON-FATAL LOADER ERRORS - SEE MAP
15.40.09.     STOP
15.40.09.     10.784 CP SECONDS EXECUTION TIME
15.40.09.OP   00009728 WORDS - FILE OUTPUT , DC 40
15.40.09.CP        014.532 SEC.
15.40.09.PP        010.273 SEC.
15.40.09.IO        002.337 SEC.
15.40.09.IOM       080.929 WS/512
15.40.09.CPM       319.475 WS/512
15.40.09.ENDJOB 12/03/73.


***********            HVNTOKM  //// END OF LIST ////
***********            HVNTOKM  //// END OF LIST ////


$INPUT
X1MAX    =   0.5E+00,
X2MAX    =   0.4E+01,
X3MAX    =   0.5E+01,
X4MAX    =   0.1E+02,
X5MAX    =   0.2E+01,
DEFM     =   0.56267E+01,
E        =   0.3E+08,
STW      =   0.19E+06,
ELOW     =   0.5E+03,
SPWT     =   0.284E+00,
FINIT    =   0.25E+02,
RM       =   0.2E+01,
DLOOP    =   0.13125E+01,
$END
```

```
OPTIMIZATION BY SIMPLX METHOD,

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =      1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA   =      1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .       N  =      5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =     13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F  =        .10000000E+01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM  =    500
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =        .20000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =      0
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
  .50000000E+00   .40000000E+01   .50000000E+01   .10000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
  0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . .XSTRT(I)  =
  .35000000E+00   .35000000E+01   .30000000E+01   .80000000E+01   .10000000E+01
```

FIGURE 3-6(b): Continued

```
                    OPTIMUM SOLUTION FOUND
                 MINIMUM   U =    .90549376E+00

                      X( 1) =     .27148695E+00
                      X( 2) =     .33474693E+01
                      X( 3) =     .35844366E+01
                      X( 4) =     .53600691E+01
                      X( 5) =     .69318719E+00

INEQUALITY CONSTRAINTS
                    PHI( 1) =     .22851305E+00
                    PHI( 2) =     .65253072E+00
                    PHI( 3) =     .14155634E+01
                    PHI( 4) =     .46399309E+01
                    PHI( 5) =     .13068129E+01
                    PHI( 6) =     .27148695E+00
                    PHI( 7) =     .33474693E+01
                    PHI( 8) =     .35844366E+01
                    PHI( 9) =     .53600691E+01
                    PHI(10) =     .69318719E+00
                    PHI(11) =     .33753741E+02
                    PHI(12) =     .11170273E+04
                    PHI(13) =     .69542275E-01


   FORCE AT INITIAL DEFLECTION(LBS) . . . . . =     .250695E+02
   STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =     .188883E+06
   MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =     .533754E+03

   WIRE DIAMETER (IN.)  . . . . . . . . . . . =      .2715
   MEAN COIL DIAMETER (IN.) . . . . . . . . . =     3.3475
   NUMBER OF TURNS OF COIL  . . . . . . . . . =     3.5844
   FREE END ARM LENGTH (IN.)  . . . . . . . . =     5.3601
   INITIAL COMP. ANGLE (RAD)  . . . . . . . . =      .6932
```

of the Coalbear trap #330 (new design) SEES 1

```
12/05/73 MCMASTER - SCOPE 3.4 AT L348     11/14/73
12.42.31.
12.42.31.HVNTOAG                               HVNTOAG
12.42.31.IP  00000896 WORDS - FILE INPUT  , DC 00
12.42.31.HVNT,T60.
12.42.31.                                YI Y. J.
12.42.31.ATTACH,OPTISEP.
12.42.31.PFN IS
12.42.31.OPTISEP
12.42.32.PF CYCLE NO. = 001
12.42.32.FIN.
12.42.38.     1.368 CP SECONDS COMPILATION TIME
12.42.38.LDSET,LIB=OPTISEP.
12.42.38.LGO.
12.42.41.      NON-FATAL LOADER ERRORS - SEE MAP
12.42.43.     STOP
12.42.43.      1.177 CP SECONDS EXECUTION TIME
12.42.43.OP   00003840 WORDS - FILE OUTPUT , DC 40
12.42.43.CP        005.015 SEC.
12.42.43.PP        007.675 SEC.
12.42.43.IO        002.255 SEC.
12.42.43.IOM       079.370 WS/512
12.42.43.CPM       138.988 WS/512
12.42.43.ENDJOB 12/05/73

***********            HVNTOAG  //// END OF LIST ////
***********            HVNTOAG  //// END OF LIST ////
```

```
$INPUT
XIMAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.12E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.725E+01,
E       =  0.3E+08,
STW     =  0.19E+06,
ELOW    =  0.86E+03,
SPWT    =  0.284E+00,
FINIT   =  0.32E+02,
RM      =  0.2E+01,
DLOOP   =  0.2125E+01,
$END
```

```
INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .   IPRINT  =    1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .   IDATA   =    1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .        N  =    5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS   =   13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .        F  =      .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .     MAXM  =  100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.        G  =      .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS   =    0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .   NSHOT   =    2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .   NTEST   =  100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)   =
  .50000000E+00   .40000000E+01   .50000000E+01   .12000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)   =
 0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . . XSTRT(I)  =
  .30000000E+00   .40000000E+01   .45000000E+01   .59000000E+01   .10000000E+01
```

FIGURE 3-7(a): Continued

FIGURE 3-7(a): Continued

```
                    OPTIMUM SOLUTION FOUND
                    MINIMUM  U =    .14643362E+01

                         X( 1) =    .29468281E+00
                         X( 2) =    .37921875E+01
                         X( 3) =    .44492187E+01
                         X( 4) =    .57800000E+01
                         X( 5) =    .94468750E+00

INEQUALITY CONSTRAINTS
                       PHI( 1) =    .20511719E+00
                       PHI( 2) =    .20781250E+00
                       PHI( 3) =    .55078125E+00
                       PHI( 4) =    .62200000E+01
                       PHI( 5) =    .10553125E+01
                       PHI( 6) =    .29468281E+00
                       PHI( 7) =    .37921875E+01
                       PHI( 8) =    .44492187E+01
                       PHI( 9) =    .57800000E+01
                       PHI(10) =    .94468750E+00
                       PHI(11) =    .16423019E+01
                       PHI(12) =    .13560731E+02
                       PHI(13) =    .73007667E-02

  FORCE AT INITIAL DEFLECTION(LBS) . . . . . =     .320073E+02
  STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =     .189986E+06
  MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =     .661642E+03

  WIRE DIAMETER (IN.)  . . . . . . . . . . . =      .2949
  MEAN COIL DIAMETER (IN.) . . . . . . . . . =     3.7922
  NUMBER OF TURNS OF COIL  . . . . . . . . . =     4.4492
  FREE END ARM LENGTH (IN.)  . . . . . . . . =     5.7800
  INITIAL COMP. ANGLE (RAD)  . . . . . . . . =      .9447
```

FIGURE 3-7(b): Optimization computer result of the spring of the Conibear trap #330 (new design) SIMPLX

```
12/05/73 MCMASTER - SCOPE 3.4 AT L348   11/14/73
11.42.24.
11.42.24.HVNT065                         HVNT065
11.42.24.IP  00000896 WORDS - FILE INPUT , DC 00
11.42.24.HVNT,T60.
11.42.24.                                YI Y. J.
11.42.24.ATTACH,OPTISEP.
11.42.24.PFN IS
11.42.24.OPTISEP
11.42.25.PF CYCLE NO. = 001
11.42.25.FTN.
11.42.33.    1.376 CP SECONDS COMPILATION TIME
11.42.34.LDSET,LIB=OPTISEP.
11.42.34.LGO.
11.42.39.    NON-FATAL LOADER ERRORS - SEE MAP
11.42.59.    STOP
11.42.59.    9.904 CP SECONDS EXECUTION TIME
11.42.59.CP  00009216 WORDS - FILE OUTPUT , DC 40
11.42.59.CP        013.635 SEC.
11.42.59.PP        008.674 SEC.
11.42.59.IO        002.328 SEC.
11.42.59.IOM       080.753 WS/512
11.42.59.CPM       301.370 WS/512
11.42.59.ENDJOB 12/05/73

***********          HVNT065  //// END OF LIST ////
***********          HVNT065  //// END OF LIST ////
```

```
$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.4E+01,
X3MAX   =  0.5E+01,
X4MAX   =  0.12E+02,
X5MAX   =  0.2E+01,
DEFM    =  0.725E+01,
E       =  0.3E+08,
STW     =  0.19E+06,
ELOW    =  0.86E+03,
SPWT    =  0.284E+00,
FINIT   =  0.32E+02,
RM      =  0.2E+01,
DLOCP   =  0.2125E+01
$END
```

```
OPTIMIZATION BY SIMPLX METHOD,

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =     1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA   =     1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .       N  =     5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =    13
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F  =         .10000000F+00
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM  =   500
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =         .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =     0
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
  .50000000E+00   .40000000E+01   .50000000E+01   .12000000E+02   .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
 0.               0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . .XSTRT(I)  =
  .30000000E+00   .40000000E+01   .40000000E+01   .70000000E+01   .10000000E+01
```

FIGURE 3-7(b): Continued

FIGURE 3-7(b): Continued

```
                 OPTIMUM SOLUTION FOUND
                 MINIMUM  U =    .14702662E+01

                      X( 1) =    .29435956E+00
                      X( 2) =    .39240421E+01
                      X( 3) =    .43459239E+01
                      X( 4) =    .57826610E+01
                      X( 5) =    .97537363E+00

INEQUALITY CONSTRAINTS
                    PHI( 1) =    .20564044E+00
                    PHI( 2) =    .75957923E-01
                    PHI( 3) =    .65407611E+00
                    PHI( 4) =    .62173390E+01
                    PHI( 5) =    .10246264E+01
                    PHI( 6) =    .29435956E+00
                    PHI( 7) =    .39240421E+01
                    PHI( 8) =    .43459239E+01
                    PHI( 9) =    .57826610E+01
                    PHI(10) =    .97537363E+00
                    PHI(11) =    .23847030E+01
                    PHI(12) =    .20490310E+03
                    PHI(13) =    .47163644E+00

   FORCE AT INITIAL DEFLECTION(LBS) . . . . =      .324716E+02
   STRESS IN SPRING (LBS/SQ.IN.). . . . . . =      .189795E+06
   MAXIMUM ENERGY (IN.-LBS) . . . . . . . . =      .862385E+03

   WIRE DIAMETER (IN.) . . . . . . . . . . =       .2944
   MEAN COIL DIAMETER (IN.) . . . . . . . . =      3.9240
   NUMBER OF TURNS OF COIL . . . . . . . . =      4.3459
   FREE END ARM LENGTH (IN.) . . . . . . . =      5.7827
   INITIAL COMP. ANGLE (RAD) . . . . . . . =       .9754
```

4. ENERGY PREDICTION

Strictly speaking, "prediction" may not be the proper word to use here, but we can anticipate the theoretical energy level at the various jaw openings of the trap, by relating the jaw opening to the spring deflection angle.

4-1 Definition of the parameters.

Let us define additional parameters as shown in Figure 4-1.

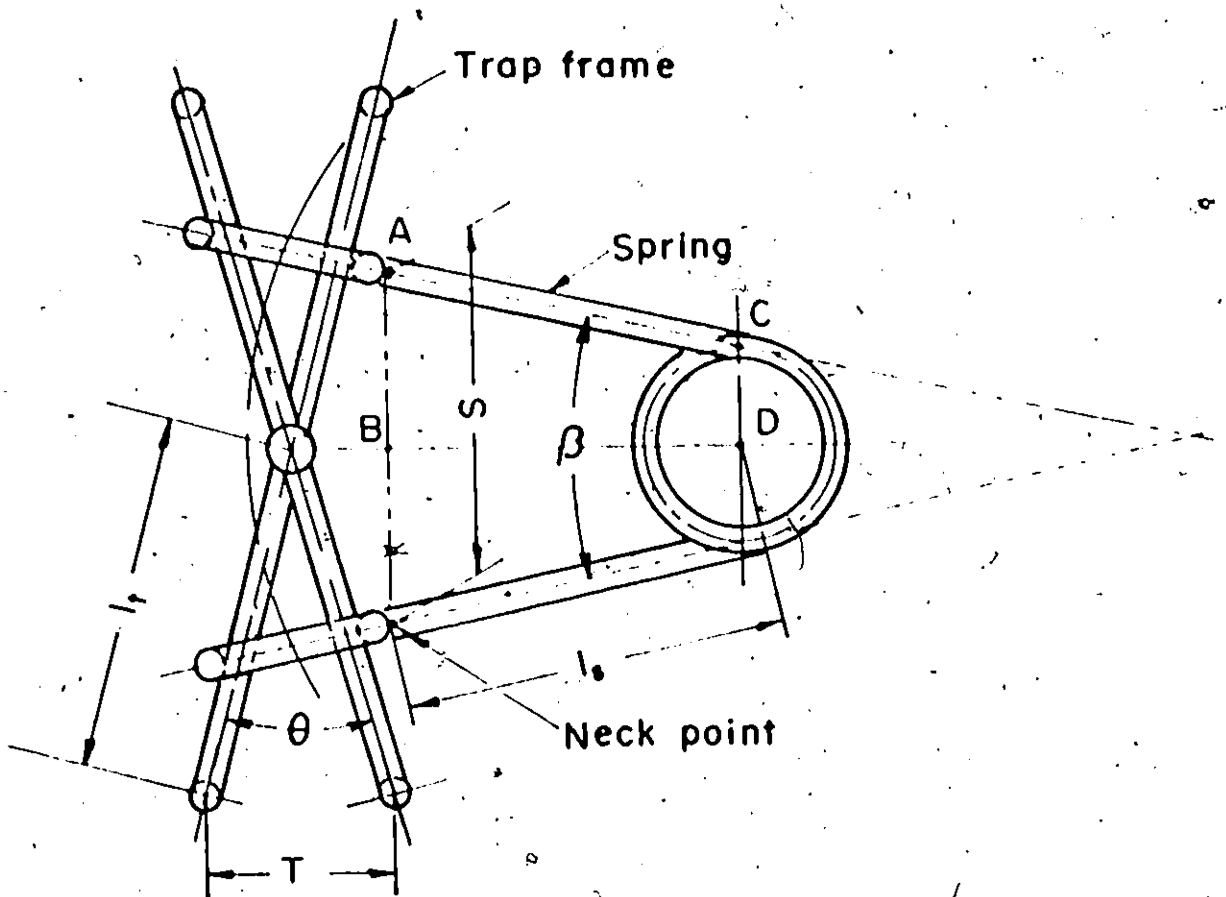

Fig. 4-1 Side view of the Conibear trap

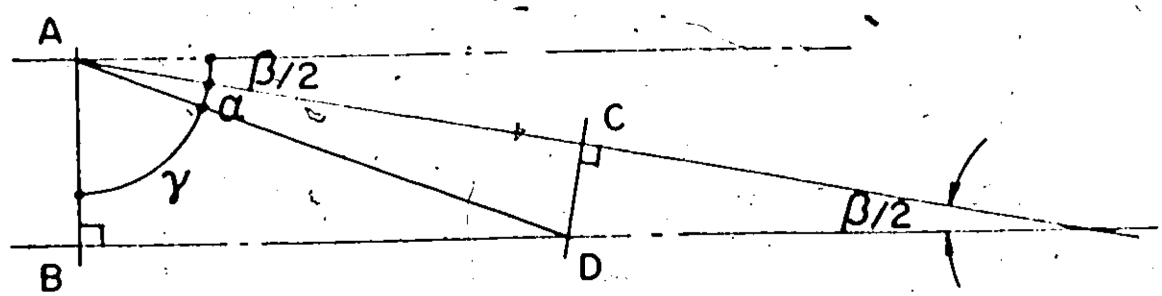

Fig. 4-2 The quadrangle ABCD in Fig. 4-1

ℓ_t Distance from the fulcrum to the outer frame of the trap

ℓ_s Spring arm length to the neck

T Nominal jaw opening

S Distance between the necks of the spring

θ Trap angle

β Spring angle

4-2 Theoretical energy calculations.

The theoretical energy level at a certain trap jaw opening will be equal to the strain energy released from the spring to that point from the full deflection.

Therefore, the jaw opening should be related to the spring deflection angle. Let us first relate the nominal jaw opening or the trap angle to the spring angle. It is assumed that the free end arm and the spring coil do not change the shape during the deflection.

The nominal jaw opening T, and the distance, S, between the neck point of the free end arms were measured altering the opening by a certain increment.

Then the trap angle, θ will be

$$\theta = 2 \text{ X } \sin^{-1}\left(\frac{T}{2\ell_t}\right) \qquad (4\text{-}1)$$

Redrawing the quadrangle ABCD in Figure 4-2 the spring angle, β will be

$$\beta = 2[\pi/2 - (\alpha + \gamma)] \qquad (4-2)$$

where

$$\alpha = \tan^{-1}\left(\frac{D}{2\ell_s}\right)$$

$$\gamma = \cos^{-1}\left(\frac{S}{2\sqrt{\ell_s^2 + (D/2)^2}}\right)$$

The numerical relationship between the trap angle and the spring angle is smoothed by using the polynomial approximation to get a continuous curve as shown in Figure 4-4. The numerical data is shown in Figure 4-5.

The spring deflection angle ϕ is, from the Figure 4-3,

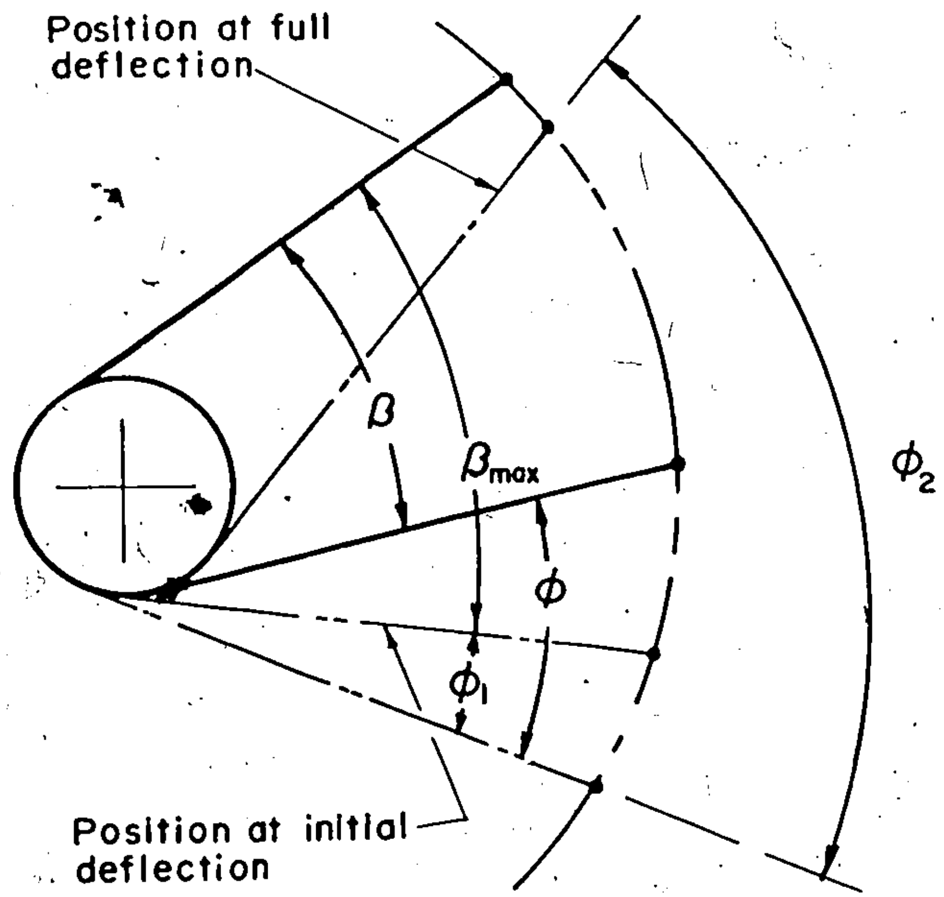

Figure 4-3

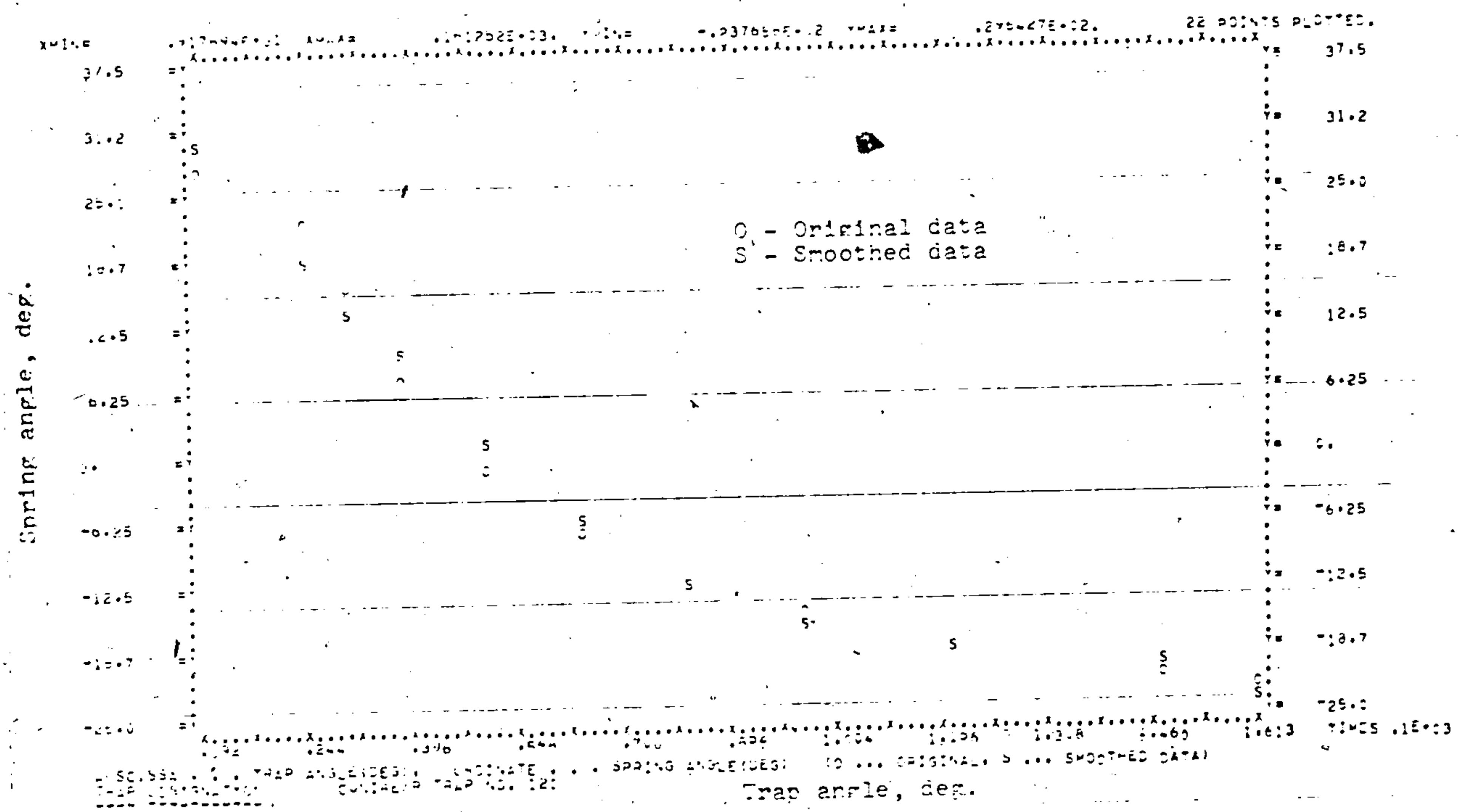

FIGURE 4-4(a): Relation between the trap angle and the spring angle - (Conibear trap #120)

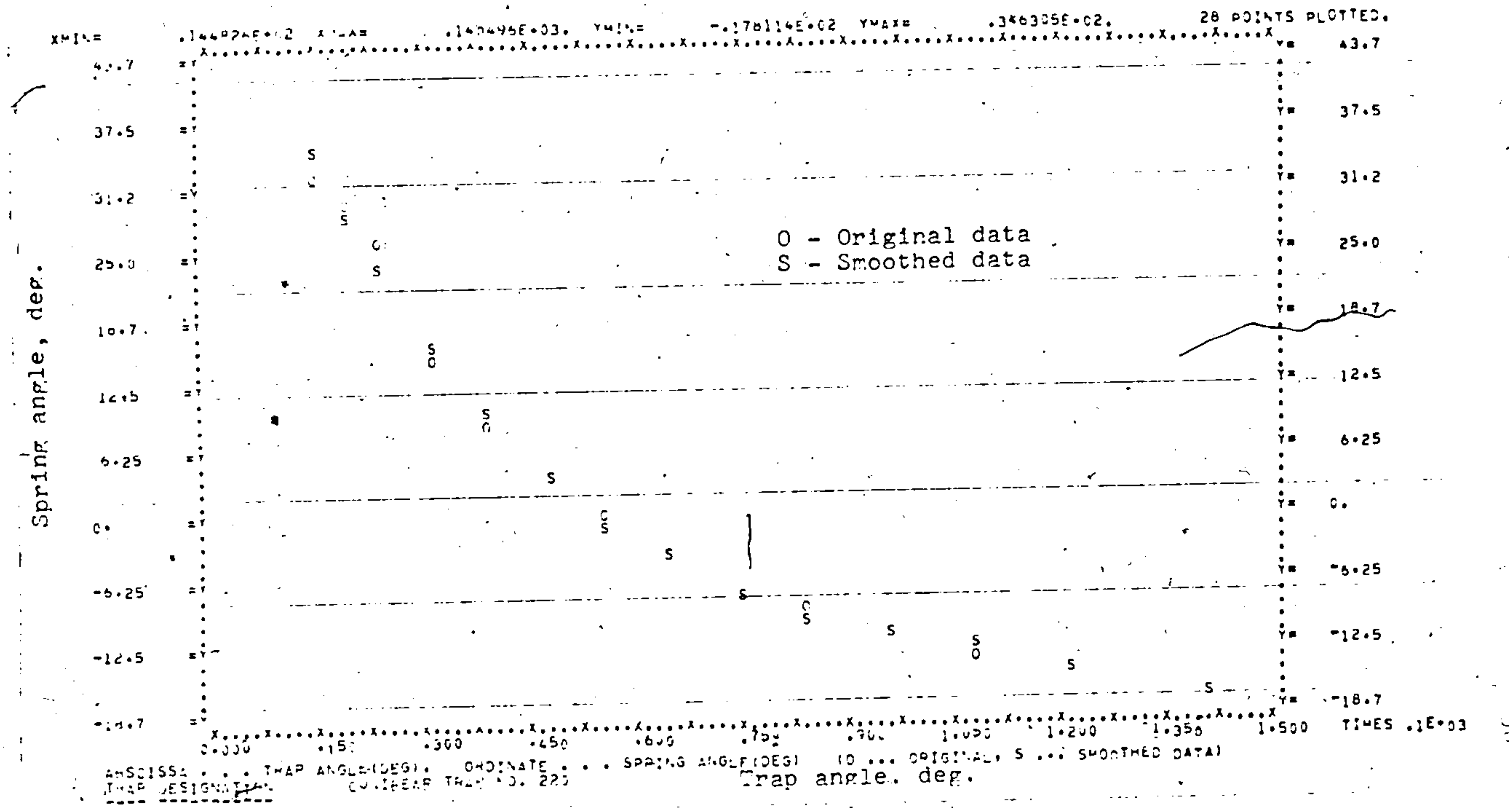

FIGURE 4-4(b): Relation between the trap angle and the spring angle - Conibear trap #220D

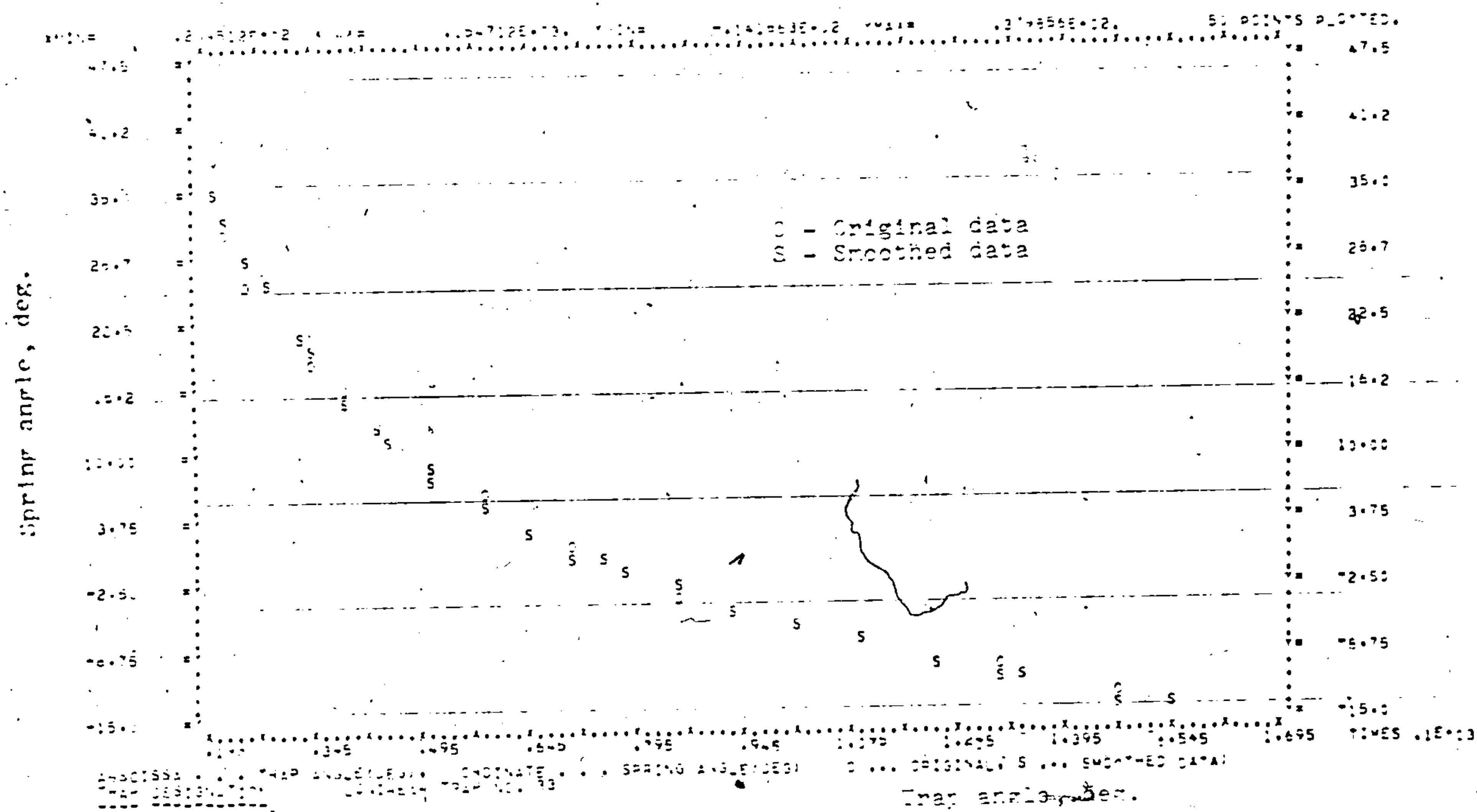

FIGURE 4-4(C): Relation between the trap angle and the spring angle - Conibear trap #330

$$\phi = \beta_{max.} - \beta + \phi_1 \qquad (4-3)$$

Hence from the equation (2-7), the theoretical energy at the nominal jaw opening will be:

$$U = \frac{Ed^4}{64(D \cdot n + \frac{2\ell}{3\pi})} \cdot \frac{\phi_2{}^2 - \phi^2}{2} \qquad (4-4)$$

per spring

Figure 4-5 and 4-6 show the computer calculation results and the graphs.

The computer programme is listed in the Appendix "C" with explanations for the user.

FIGURE 4-5(a): Energy prediction - Conibear trap #120

TRAP DESIGNATION CONIBEAR TRAP NO. 120

EF. OF POLYNOMIAL = .354540E+02 -.582575E+00 -.660345E-02 .108208E-03 -.365749E-06

NO.	NOM. OPENING (IN.)	DIST. BTW. SPRING NECK(IN)	TRAP ANGLE (DEG.)	SPRING ANGLE (DEG.)	DEFLECTION ANGLE(DEG.)	ANGLE DIFF.(DEG.)	THEORET ENERGY(
1	4.62500	.75000	161.25161	-23.76577	89.86700	0.00000	0.0
2	4.50000	.81250	147.47121	-20.00612	86.39878	3.46822	18.8
3	4.00000	1.03130	117.14819	-18.32662	84.71927	5.14773	27.7
4	3.50000	1.21880	96.60216	-16.74092	83.13358	6.73342	35.9
5	3.00000	1.40530	79.58160	-12.85205	79.24471	10.62229	55.4
6	2.50000	1.65630	64.46636	-6.85950	73.25215	16.61485	83.6
7	2.00000	2.03130	50.51125	.75367	65.63898	24.22802	116.3
8	1.50000	2.53130	37.32502	9.43659	56.95607	32.91093	149.1
9	1.25000	3.03130	30.93134	13.99377	52.39889	37.46811	164.5
10	1.00000	3.40630	24.63500	18.58779	47.80487	42.06213	178.7
11	.37500	3.68750	9.17694	29.64266	36.75000	53.11700	207.6

ENERGY(IN-LBS) AT 2.00 OPENING OF JAW . . . . = 116.3216

ENERGY(IN-LBS) AT 4.00 OPENING OF JAW . . . . = 27.7473

MAXIMUM ENERGY(IN-LBS), JAW OPENING AT .3750 IN. = 207.6448

FIGURE 4-5(6): ENERGY PREDICTION - CONIBEAR TRAP [illegible]

TRAP DESIGNATION CONIBEAR TRAP NO. 220

E. OF POLYNOMIAL = .572269E+02 -.180065E+01 .176878E-01 -.766631E-04 .106281E-06

NO.	NOM. OPENING (IN.)	DIST. BTW. SPRING NECK (IN)	TRAP ANGLE (DEG.)	SPRING ANGLE (DEG.)	DEFLECTION ANGLE (DEG.)	ANGLE DIFF. (DEG.)	THEORETI ENERGY (I
1	7.00000	.71880	140.49586	-17.81142	87.17500	0.00000	0.00
2	6.50000	.96880	121.83903	-14.82844	84.67576	2.49924	34.21
3	6.00000	1.15630	107.55180	-12.98929	82.83660	4.33840	58.79
4	5.50000	1.37500	95.37527	-11.33092	81.17824	5.99676	80.42
5	5.00000	1.53130	84.48345	-9.46536	79.31267	7.86233	104.27
6	4.50000	1.75000	74.46256	-7.16528	77.01260	10.16240	132.92
7	4.00000	2.06250	65.06907	-4.26518	74.11250	13.06250	167.83
8	3.50000	2.40030	56.14415	-.62550	70.47281	16.70219	209.79
9	3.00000	2.75000	47.57628	3.88393	65.96338	21.21162	258.77
10	2.50000	3.21880	39.28253	9.39321	60.45410	26.72090	314.29
11	2.00000	3.87500	31.19811	16.03877	53.80854	33.36646	374.74
12	1.50000	4.87500	23.27020	23.96859	45.87872	41.29628	437.72
13	1.25000	5.16750	19.35066	28.46575	41.38156	45.79344	468.98
14	.93750	5.43750	14.48264	34.63051	35.21680	51.95820	506.60

ENERGY(IN-LBS) AT 2.00 OPENING OF JAW . . . . = 374.7473

ENERGY(IN-LBS) AT 4.00 OPENING OF JAW . . . . = 167.8368

ENERGY(IN-LBS) AT 6.00 OPENING OF JAW . . . . = 58.7561

MAXIMUM ENERGY(IN-LBS), JAW OPENING AT .9375 IN. = 506.6014

FIGURE 4-5(c): Energy prediction - Conibear trap #330

TRAP DESIGNATION   CONIBEAR TRAP NO. 330

C. OF POLYNOMIAL = .731645E+02   -.240364E+01   .305864E-01   -.187619E-03   .432396E-06

NO.	NOM. OPENING (IN.)	DIST. BTW. SPRING NECK (IN)	TRAP ANGLE (DEG.)	SPRING ANGLE (DEG.)	DEFLECTION ANGLE (DEG.)	ANGLE DIFF. (DEG.)	THEORETI ENERGY (I
					79.50000	0.00000	0.00
1	10.06250	1.06250	154.71156	-13.64328	78.34472	1.15528	29.22
2	9.37500	1.25000	146.49806	-13.25039	76.85138	2.64862	66.35
3	9.50000	1.37500	134.20524	-11.75705	76.31201	3.18799	79.59
4	9.37500	1.53130	130.75762	-11.21768	74.73764	4.76236	117.73
5	9.00000	1.64060	121.55227	-9.64331	72.82973	6.67027	162.81
6	8.50000	1.85490	111.02190	-7.73540	71.12645	8.37355	202.10
7	8.00000	2.06250	101.74617	-6.03212	69.54846	9.95154	237.68
8	7.50000	2.28130	93.31531	-4.45413	68.00036	11.49964	271.83
9	7.00000	2.37500	85.49697	-2.90603	66.38439	13.11561	306.63
10	6.50000	2.68750	78.14406	-1.29006	65.52054	13.97946	324.86
11	6.25000	2.87500	74.60956	-.42621	64.60332	14.89668	343.95
12	6.00000	2.96880	71.15626	.49101	62.56040	16.93960	385.61
13	5.50000	3.25000	64.46120	2.53393	60.15840	19.34160	432.84
14	5.00000	3.59380	58.00448	4.93593	57.29841	22.20159	486.67
15	4.50000	3.85420	51.74365	7.79592	56.90367	22.59633	493.90
16	4.43750	4.00000	50.97306	8.19066	53.87846	25.62154	547.60
17	4.00000	4.25000	45.64468	11.21587	52.92363	26.57637	563.94
18	3.87500	4.43750	44.14184	12.17070	49.79219	29.70781	615.4
19	3.50000	4.84360	39.67951	15.30214	44.92737	34.57263	689.3
20	3.00000	5.20830	33.82444	20.16696			

21	2.87500	5.50000	32.37543	21.51866	43.57567	35.92433	708.4
22	2.50000	6.03130	28.05905	25.93002	39.16431	40.33569	766.9
23	2.31250	6.06250	25.91641	28.34871	36.74562	42.75438	796.4
24	2.00000	6.71880	22.36533	32.72018	32.37415	47.12585	844.8
25	1.87500	7.43750	20.95116	34.59433	30.50000	49.00000	863.7

ENERGY(IN-LBS) AT 2.00 OPENING OF JAW . . . . = 844.8223
ENERGY(IN-LBS) AT 4.00 OPENING OF JAW . . . . = 547.6050
ENERGY(IN-LBS) AT 6.00 OPENING OF JAW . . . . = 343.9853
MAXIMUM ENERGY(IN-LBS), JAW OPENING AT 1.8750 IN. = 863.7045

FIGURE 4-5(c): Continued

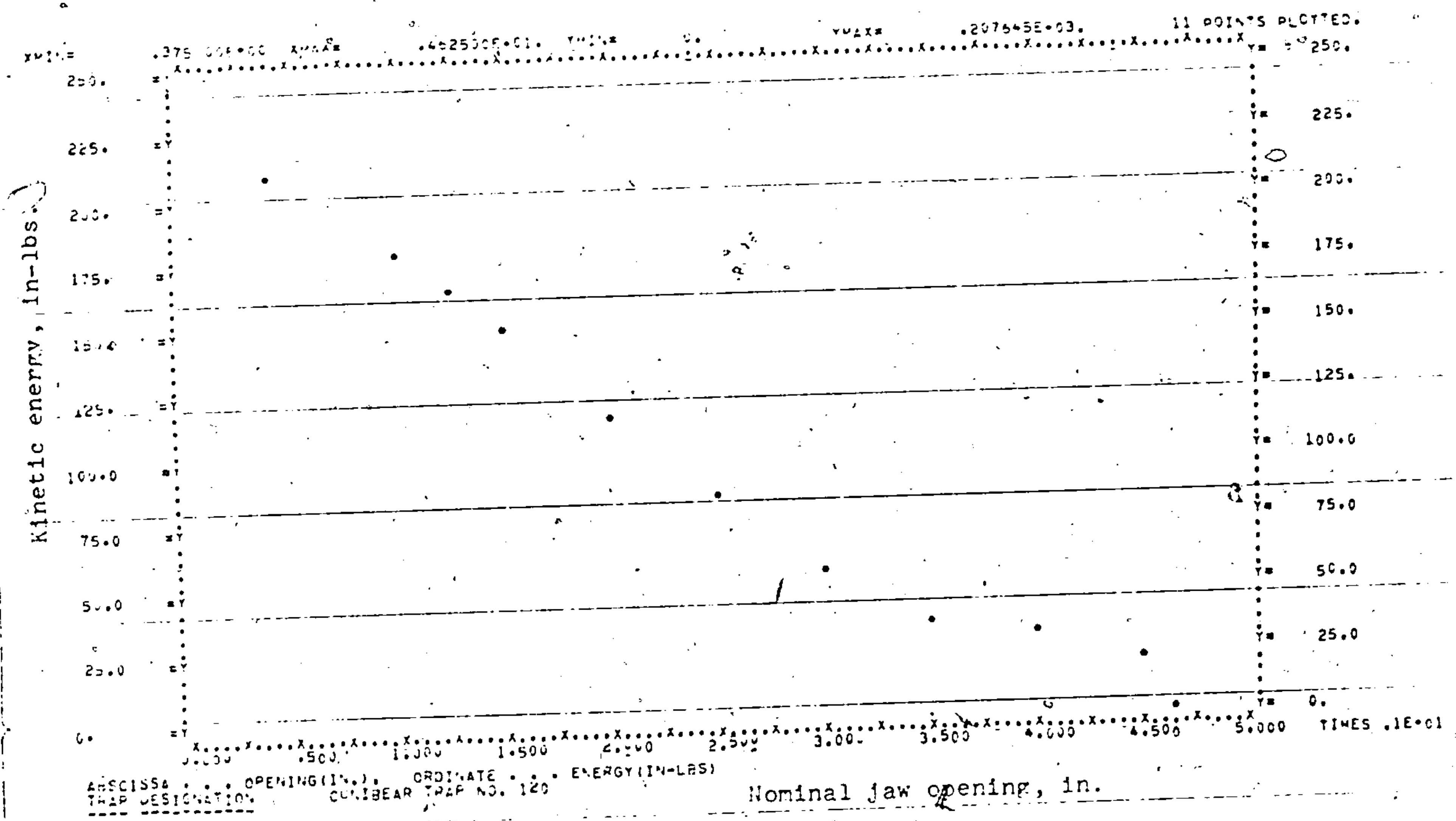

FIGURE 4-6(a): Theoretical energy level - Conibear trap #120

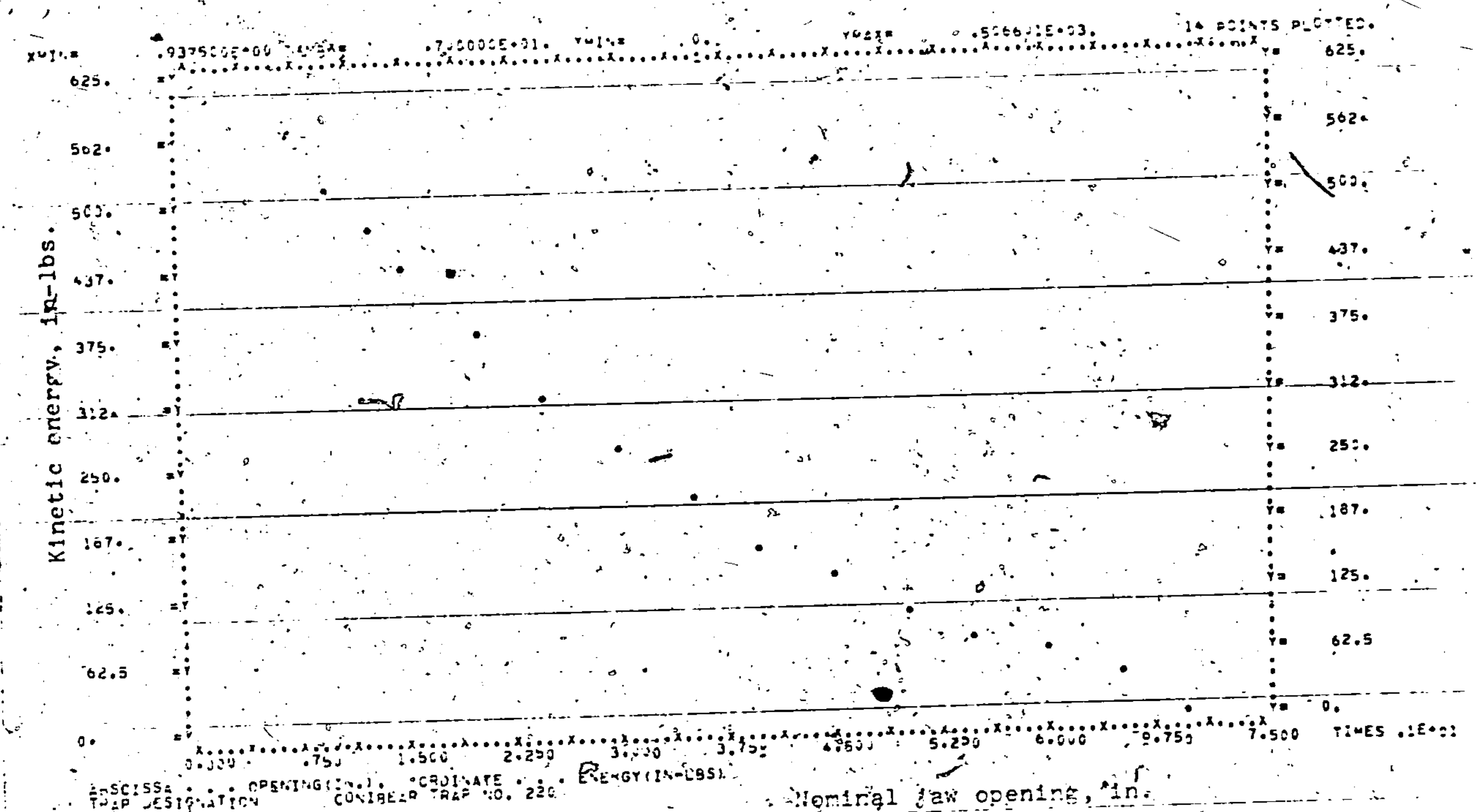

FIGURE 4-6(b): Theoretical energy level - Conibear trap #220D

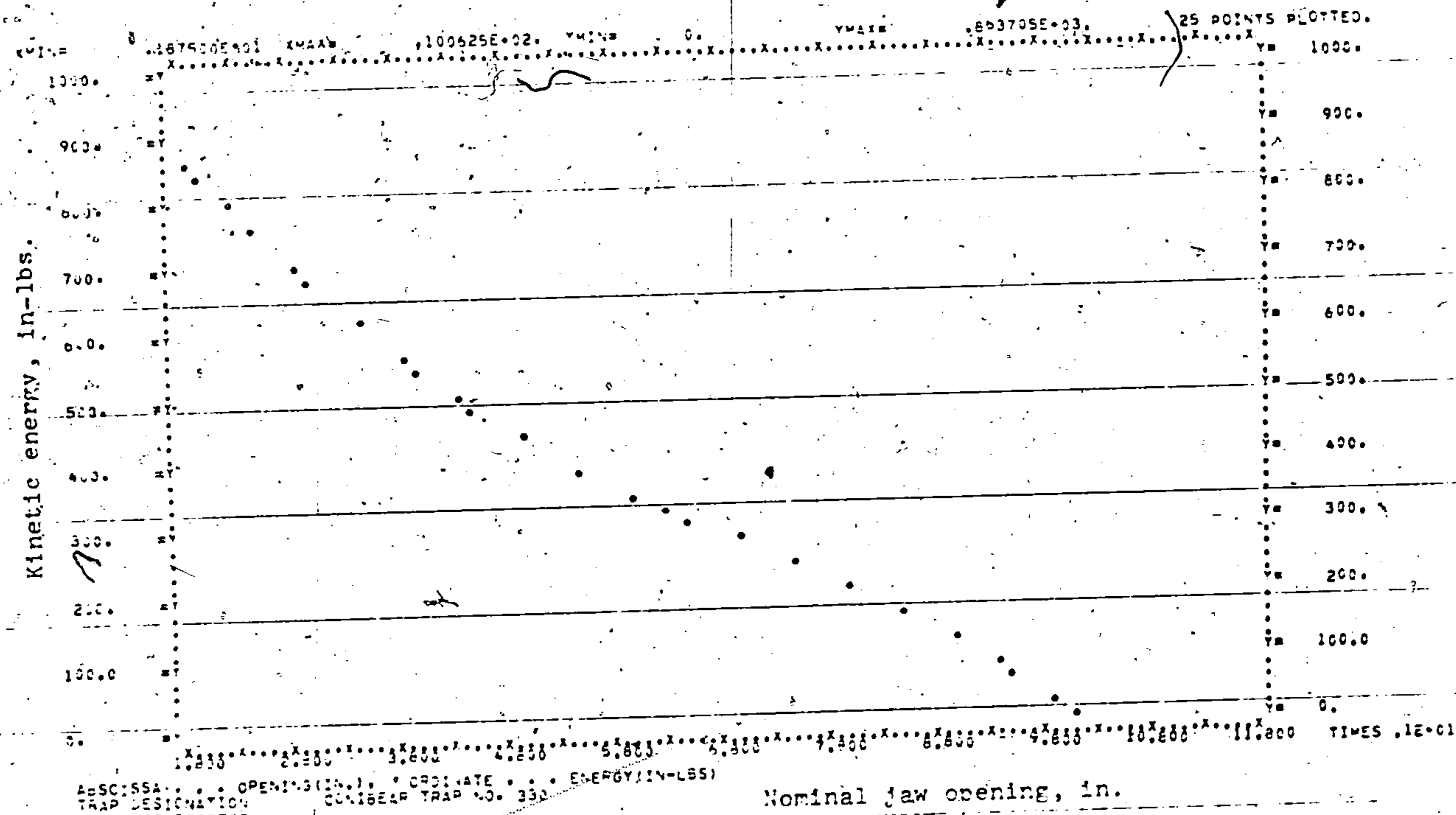

FIGURE 4-6(c): Theoretical energy level - Conibear trap #330

Although the theoretical energy levels can be computed at various jaw openings, as explained in Chapters 2 and 4, the actual available energy can only be determined by an experimental technique because of the complexity of the motion of each trap part and the various friction points.

The source of the energy loss can be summarized as follows:

a) Friction between the trap mechanisms

b) Friction of the moving trap parts with the environment. (air, water or ice)

c) Energy consumed by the undesirable motion of the trap parts (ex: the velocity of the whole spring itself in a direction perpendicular to the free end arm.)

d) Other minor losses

5-1 Review of the previous work

It is known that there are four prime factors in evaluating the traps from the mechanical point of view. These are, the impact energy, the clamping and prying forces, and the closing time for various jaw openings of the trap. The clamping and prying forces are straight-forward and easy to measure, but for the impact energy which is a major factor in judging the humane trap, it was established from the beginning, at McMaster University, to use the kinetic energy method which proved to be relatively independent from the testing method. The kinetic energy levels of the trap at various jaw openings are obtained by analysing the high speed film and it is well documented in Appendix A of the N.C. Johnston's thesis. The Modified Conibear Scales[1] are based on these test results. Also for the experiments being carried out at Guelph University, a test device has been supplied in which the kinetic energy levels can be varied. Thus, kinetic energy is being used as a prime measure of trap effectiveness.

5-2 Revision of the testing method.

Because the kinetic energy of the Conibear trap comprises mainly of two parts, the kinetic energies of the trap frame and the free end arms of the trap spring(s), it is required to have the motions of both the trap frame and the free end arms of the spring on high speed film. Therefore, instead of fixing one of the trap frames to the stand, a piece of pipe was placed through the spring coils and one end of the pipe was clamped to a stand as shown in Figure 5-1.

Pictures were taken in a direction parallel to the center line of the pipe.

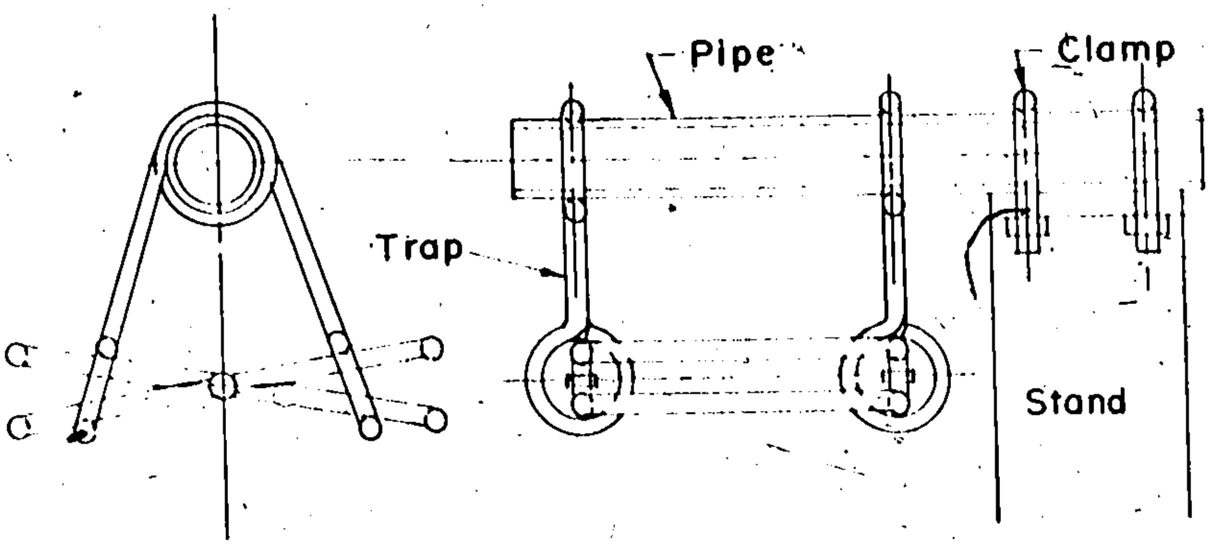

Figure 5-1

In this case, the high speed films were analyzed in a different way.

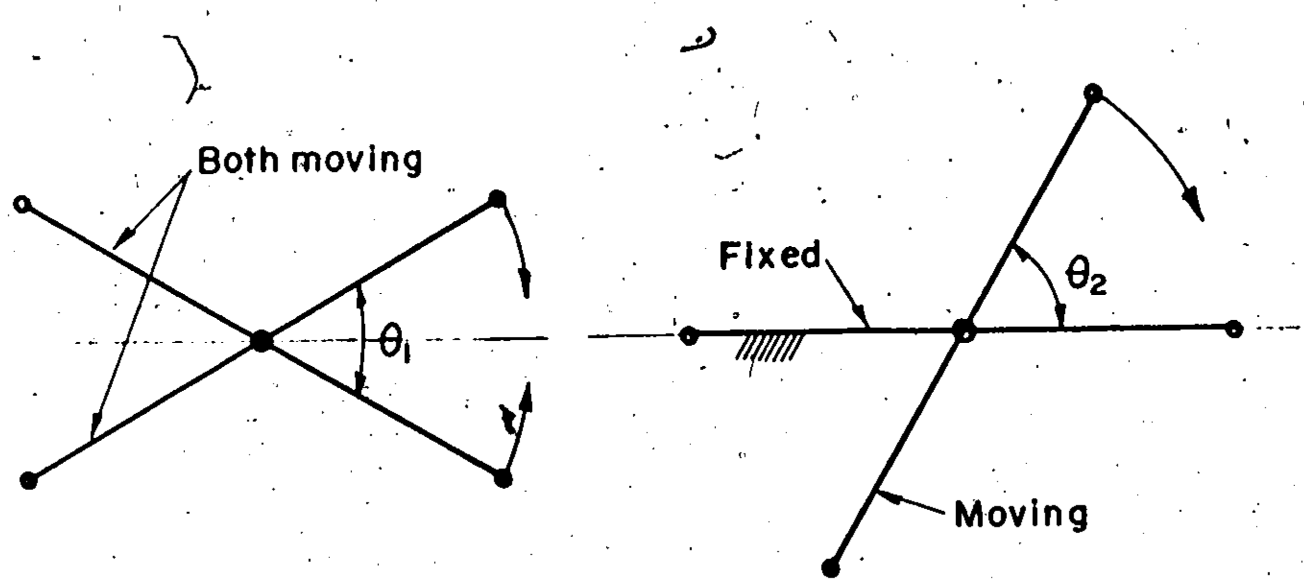

Fig. 5-2 Side view of the trap frame

In Figure 5-2(a), let us assume the trap angle θ_1, is decreased by $\Delta\theta_1$ during the time interval Δt_1, then the angular speed, ω_1, of one frame will be:

$$\omega_1 = \frac{\Delta\theta_1}{2} X \frac{}{\Delta t_1}$$

therefore, the average kinetic energy during the time interval will be:

$$E_1 = 2 X(\frac{1}{2} X I\omega_1{}^2)$$

where I = mass moment of inertia of the one frame about the axis of rotation.

The same formula can be applied to the free end arms of the spring.

Whereas, in the case of Figure 5-2(b), they will be:

$$\omega_2 = \frac{\Delta\theta_2}{\Delta t_2}$$

$$E_2 = \frac{1}{2} X I\omega_2{}^2$$

5-3 Programme modification and test results.

The computer programme [1] which analyzes the high speed film readings was modified to accommodate new information. Firstly, the plotted points of the kinetic energy, computed from the data of the high speed film readings, ususally had a considerable scatter as shown in Figures 5-3 (a) and (b). In view of the fact that the kinetic energy equation is continuous

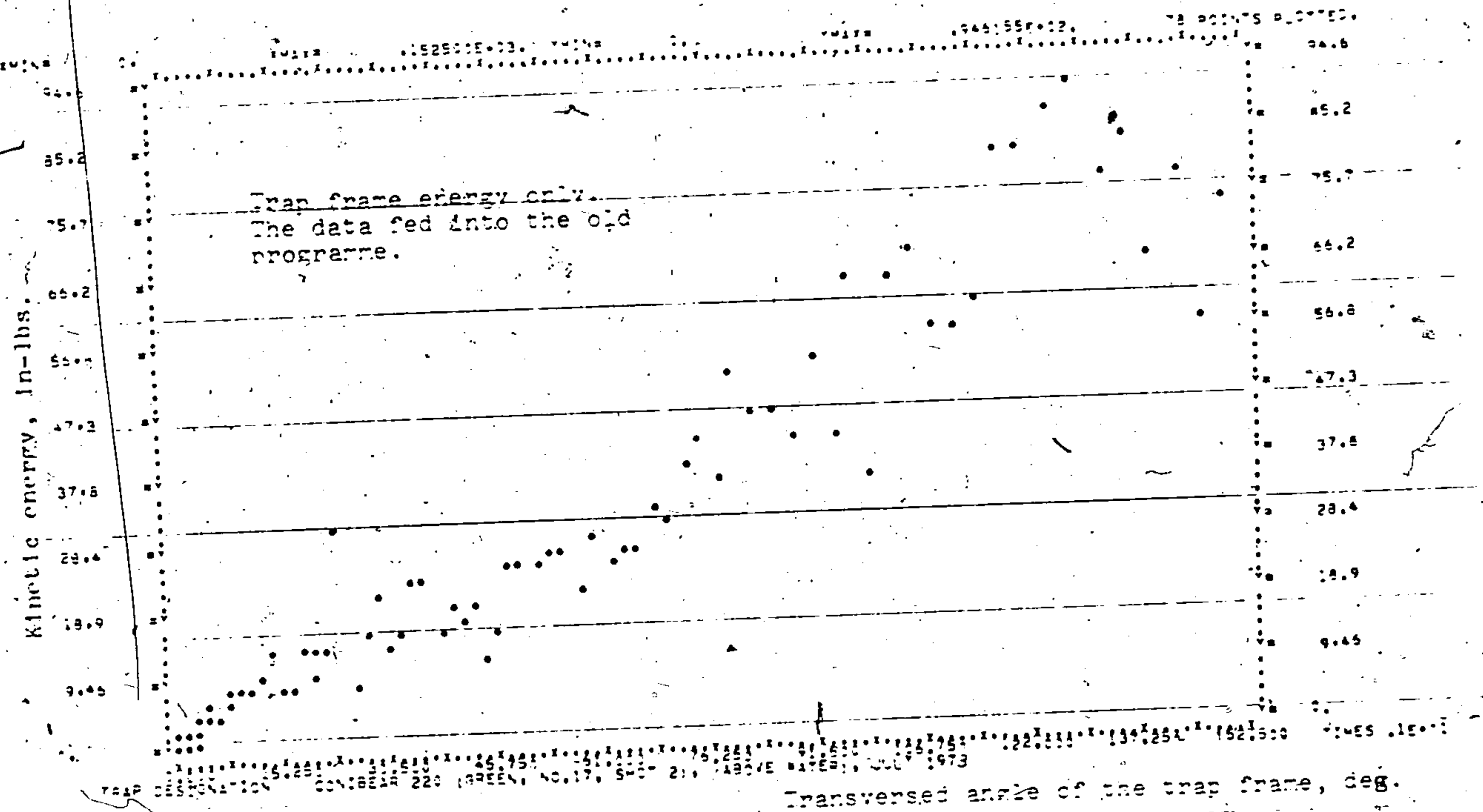

FIGURE 5-3(a): Kinetic energy of the Conibear trap #220

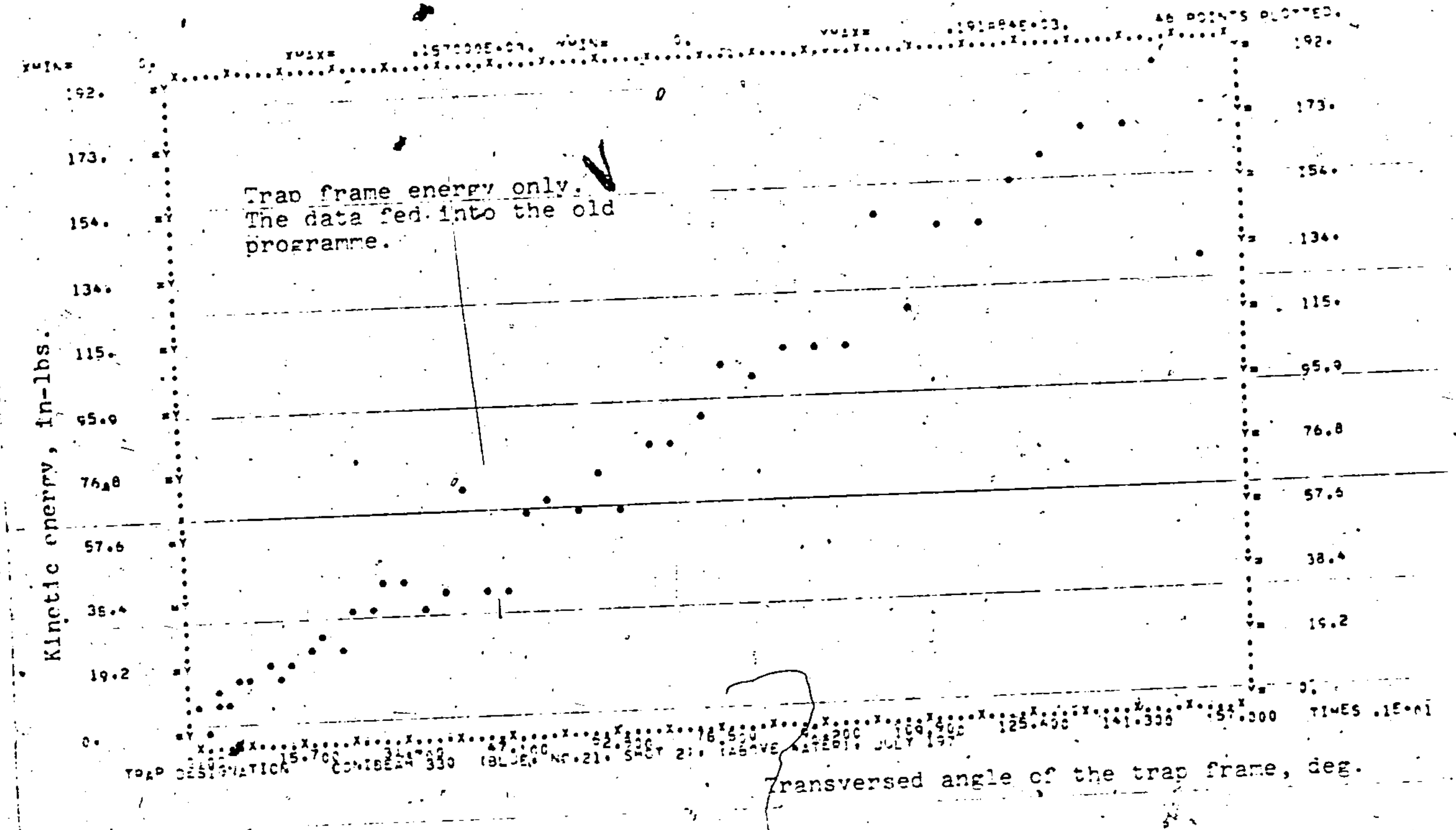

FIGURE 5-3(b): Kinetic energy of the Conibear trap #330 in the finite interval, the phenomena was considered to come from the error in the high speed film readings. Therefore, the film speed was doubled to 2,000 frames per second with the same 25 feet of the film per shot, and a polynomial approximation method to the discrete data was added to the programme to smooth the curve.

Secondly, the programme was modified to read and process the high speed film readings for the free end arms of the spring as explained in the previous section. Other miscellaneous changes have been made accordingly.

The programme is listed in Appendix "D" with the user's manual, and the testing results are shown in Tables 5-1, 5-2, and Figures 5-4 and 5-5.

As mentioned earlier, the kinetic energy level used in the past for the Conibear traps included only the trap frame energy. Therefore, the revised method will provide a much more meaningful result. However, the available energy levels measured are still only approximately 50% of the theoretical energy stored in the spring. Although the test results were supported by an auxiliary test programme result which was carried out on samples of four traps of each size, further testing should be done on a statistical basis to establish more reliable results.

Specification of the Trap

Trap name	Conibear
Trap model	Model #330 (Green coloured)
Trap type	Production
Number of springs	2
Spring modulus (Calculated)	9.180 in.lbs./deg.
Trigger type	Double acting prong trigger
Trap frame size	10.3125"X 10.3125"
Moment of inertia to its center of rotation	
Trap frame	15.91 lb.-in.^{2}
Free end of the spring	14.31 lb.-in^2
Distance from fulcrum to the outer frame	5.16"
Length of the free end arm	8.75"

TABLE 5-[illegible]: KINETIC ENERGIES OF CONIBEAR TRAP #330 ([illegible], [illegible], ABOVE WATER.

FRAME NUMBER	CUMULATIVE TIME X 10^2 (sec.)	TRANSVERSED ANGLE (DEG.)	KINETIC ENERGY (in-lbs.)			NOMINAL JAW OPENINGS
			Trap Frame	Spring(s)	Total	
1	.0000	.00	.00	.00	.00	9.95
3	.1175	1.11	5.75	.06	5.80	9.92
5	.2341	3.49	15.82	.55	16.37	9.86
7	.3501	6.69	26.64	1.10	27.74	9.77
9	.4653	10.49	36.66	1.47	38.13	9.66
11	.5793	14.75	45.51	1.69	47.20	9.52
13	.6935	19.36	53.44	1.85	55.29	9.35
15	.8065	24.26	60.96	2.06	63.02	9.16
17	.9189	29.44	68.64	2.44	71.08	8.93
19	1.0300	34.90	77.06	3.12	80.19	8.68
21	1.1410	40.65	86.71	4.29	91.00	8.39
23	1.2520	46.72	97.96	6.21	104.17	8.06
25	1.3610	53.14	111.06	9.20	120.27	7.69
27	1.4700	59.95	126.08	13.70	139.78	7.26
29	1.5790	67.16	142.81	20.19	162.99	6.79
31	1.6870	74.76	160.78	29.16	189.94	6.26
22	1.7940	82.76	179.13	41.11	220.24	5.67
25	1.9000	91.11	196.6[illegible]	56.40	253.04	5.03
27	2.0060	99.75	211.66	75.24	286.89	4.34
29	2.1120	108.57	222.21	97.60	319.80	3.[illegible]
41	2.2170	117.47	226.11	123.13	349.24	2.[illegible]
43	2.3210	126.27	221.1[illegible]	151.15	372.33	2.0[illegible]
45	2.4250	134.76	205.6[illegible]	[illegible]	[illegible]	1.32
47	2.5280	142.71	178.5[illegible]	[illegible]	[illegible].35	.61

TABLE 5-2: KINETIC ENERGIES OF CONIBEAR TRAP #330 [illegible], SHOT 2, FROM WATER.

FRAME NUMBER	CUMULATIVE TIME X 10^2 (sec.)	TRANSVERSED ANGLE (DEG.)	KINETIC ENERGY (in lbs.) Trap Frame	Spring(s)	Total	NOMINAL JAW OPENINGS
1	.0000	.00	.00	.00	.00	9.95
3	.1429	--	--	--	--	--
5	.2857	.86	4.08	.39	4.47	9.92
7	.4286	3.66	15.40	1.20	16.60	9.86
9	.5714	7.77	29.78	1.73	31.51	9.74
11	.7143	12.94	44.94	1.94	46.88	9.58
13	.8571	18.93	59.85	2.06	61.92	9.37
15	1.0000	25.76	74.27	2.34	76.61	9.09
17	1.1430	33.19	88.53	3.02	91.38	8.76
19	1.2860	41.22	102.43	4.48	106.91	8.36
21	1.4280	49.75	116.89	7.25	124.05	7.89
23	1.5690	58.74	131.67	12.08	143.75	7.34
25	1.7080	68.18	147.13	19.89	167.02	6.72
27	1.8470	78.06	163.04	31.62	194.66	6.02
29	1.9840	88.33	178.99	47.39	226.93	5.25
31	2.1210	98.97	194.23	69.29	263.53	4.40
33	2.2560	109.90	207.74	95.07	302.81	3.49
35	2.3900	121.02	218.12	123.89	342.01	2.54
37	2.5230	132.20	223.23	153.26	377.01	1.55
39	2.6540	143.29	223.18	179.78	402.96	0.56

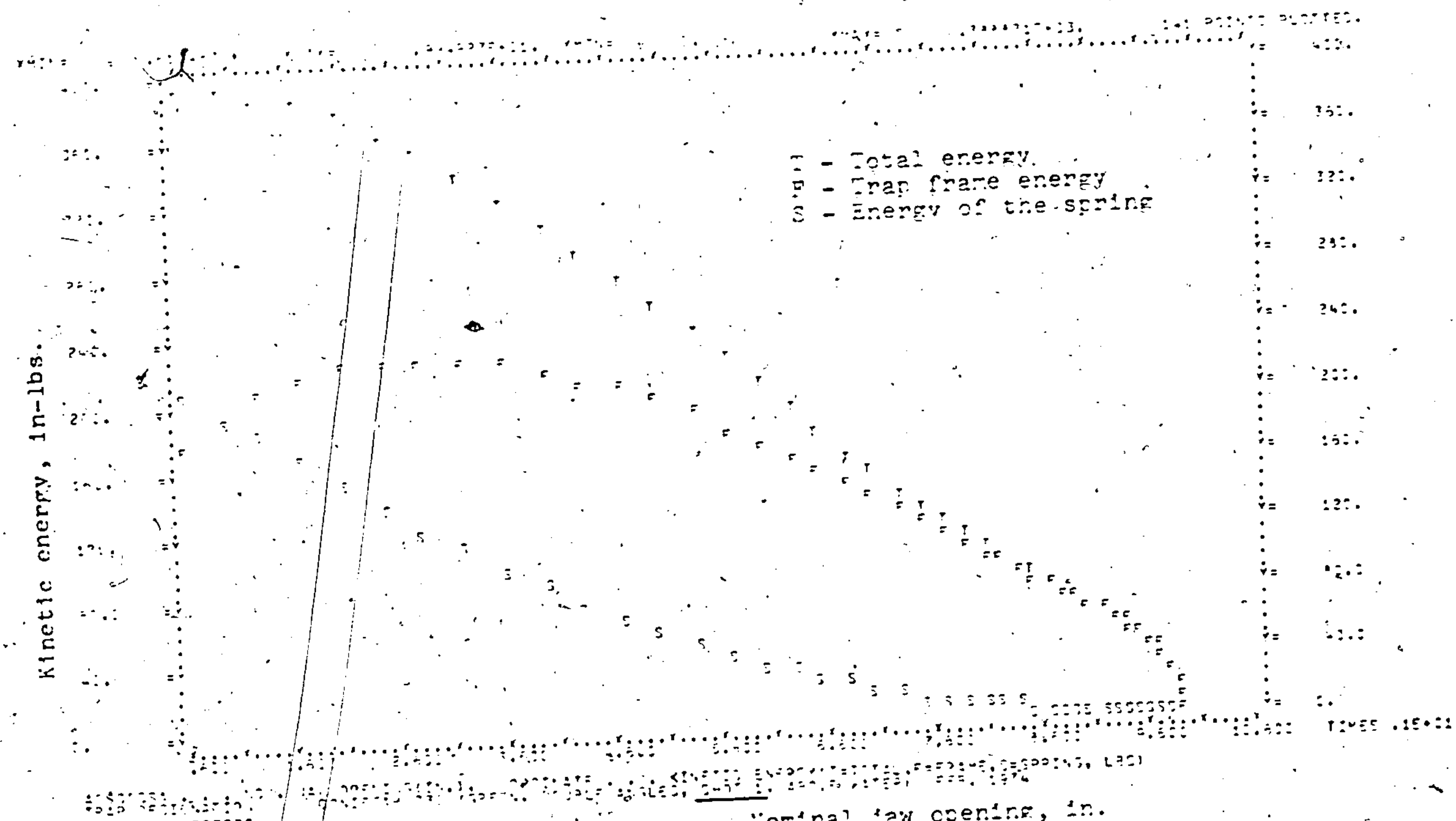

FIGURE 5-4: Kinetic energy of the Conibear trap #330 (Trap frame and spring)

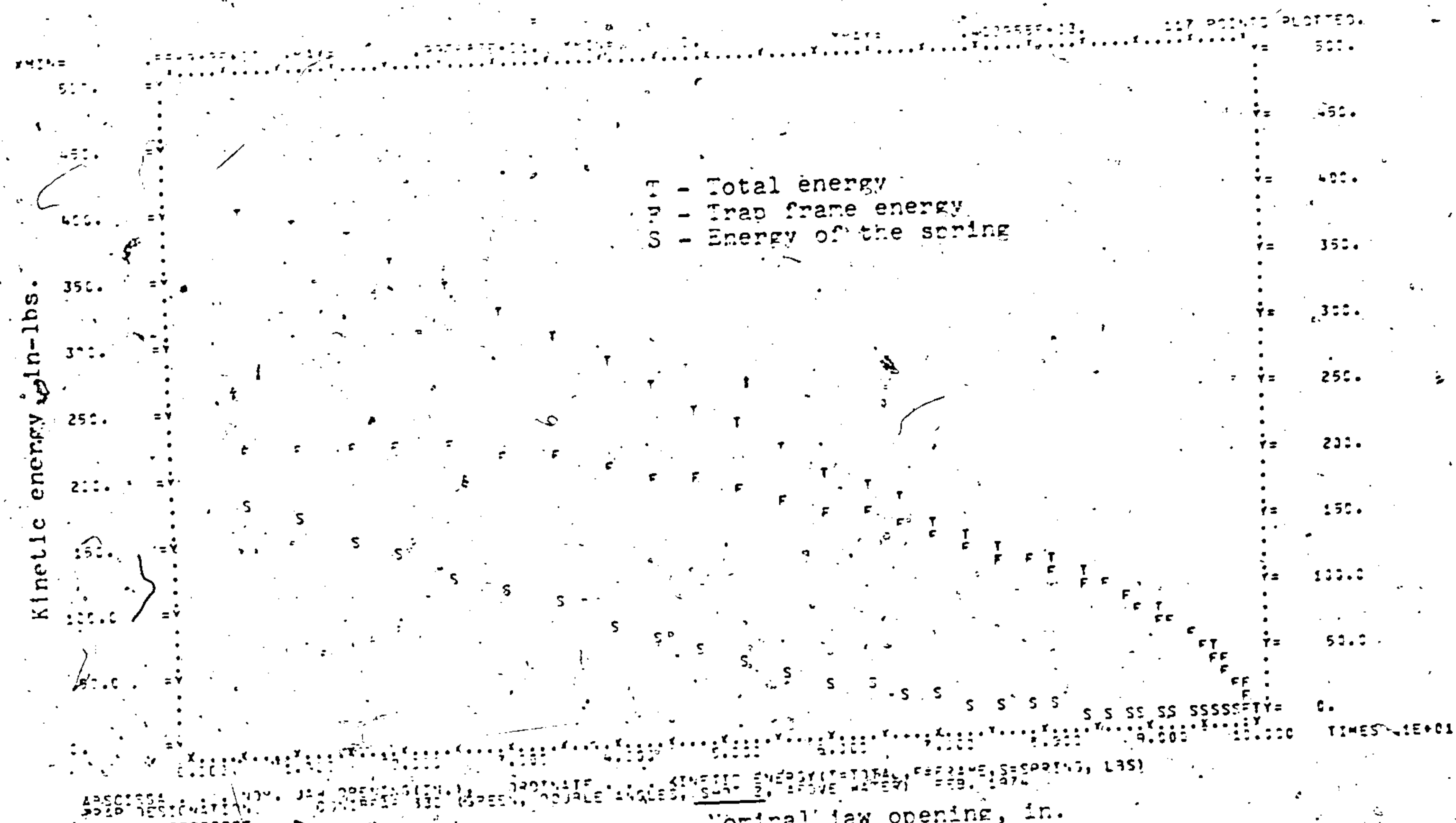

FIGURE 5-5: Kinetic energy of the Conibear trap #330 (Trap frame and spring)

6. DISCUSSION

In this Part I, the spring analysis formulas were developed for the Conibear traps and spring optimization and design programmes were formulated based on these, which will provide a means of determining proper spring dimensions to provide specified energy levels in the various trap sizes. These energy levels will be more properly set when experimental data is available from the programme being carried on at Guelph University.

The analysis presented here will allow the energy distribution over the separate springs and jaws of the trap to be determined and predicted for any jaw opening. Whereas, in the previous work only the kinetic energy in the jaws was determined by high speed photography, this was only part of the available energy. However, the available energy obtained from the revised method was still approximately half of the theoretical energy stored in the spring. The main objective here was to develop and test the feasibility of this method of energy measurement, and limited test work has been done. Therefore, there is no statistical base for the results. It is recommended that further testing be done in this area on a larger sample.

On some high speed film analysis it was shown that the trap jaw led the motion of the free end arm of the spring, especially in the later part of the collapsing motion. It is difficult to determine whether they exert one total blow or two separate lower level impacts and if it is the latter case, what the time interval is and at what opening the jaws begin to lead the springs. Furthermore, both springs do not necessarily provide identical action.

An impact transducer* and charge amplifier** could be used with an oscilloscope to determine the nature of this separate action with reasonable accuracy. Although the values of the separate impacts would likely be quite variable with each test, the proportion of the two impacts and time intervals between them would be very useful information. If these tests reveal that there are two separate impacts on trap closure, either more mass can be added to the trap jaws until their motion is slowed down to match the spring opening velocity, or the trap frame shape could be modified so that it is not accelerated so early during the closing motion.

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* For example Model #218A by PCB Piezotronics Co.

** For example Model #5001 by Kistler Co.

PART II

JACOB TRAP

7. INTRODUCTION

The main objectives of this part were to design, manufacture and test prototypes of the Jacob concept. Among many aspects as we deal with the humane trap, the most vital criteria from the mechanical point of view are:

a) Animal control - the capability of delivering the blow to the most vulnerable point of the animal, ie. to the back of the neck just below the base of the skull.

b) Sufficient energy to humanely dispatch the largest animal that may be encountered in the species for which the trap is used.

c) Sufficient clamping force.

d) Good safety features.

The first two items are these features that must be designed into any trap that is to meet the definition of a humane trap, and these features are inter-related. If the blow can always be delivered to the most vital spot the required impact can be minimized. It has become evident that animal control is the most important and most difficult feature to be designed into a humane trap.

Experience gained in the previous evaluation programmes has suggested that the trap concept invented by A. Jacob has good potential to satisfy the above criteria.

P. H. Tschoepe[2] carried out some preliminary work on this trap and it has become evident that several features need to be improved. The required improvements are as follows:

a) Underwater performances.

b) Remodelling the interior mechanism to avoid the scissor action and replacing the anvil plate with some other device.

c) Redesign of the spring to give the higher impact energy required.

d) To devise better triggering devices.

Along with these, the idea of using a stirrup was suggested by H. C. Lunn. This is a loop (Figure 9-12) which is hung at shoulder height within the surrounding spring. This loop can swing with the trap jaws when the animal puts his head through it. The swinging action triggers the trap, and because the closing trap jaws swing with the loop they follow the animal through the trap and the blow will be delivered to the back of the neck. This is a most promising idea for animal control, and it requires further investigation.

In view of these proposed major design changes and higher required energy levels indicated by the Guelph programme, it was believed that the most effective approach would be to redesign from the beginning.

8. REVIEW OF PREVIOUS WORK

The preliminary work carried out by P. H. Tschoepe on the Jacob trap, as presented in his thesis[2] in Chapter 3, was carefully reviewed and a brief summary is presented here.

8-1 Mechanism Design

The original form of Jacob trap, as conceived by its inventor A. Jacob, is shown in Figure 8-1.

It operates as a planar mechanism and is, therefore, inferior in respect to animal control. The first attempt to overcome this disadvantage was by:

a). Using a wide flat bar spring frame and installing two pairs of jaws located some axial distance apart.

b) Connecting two individual traps in parallel.

Neither of these proposals was adopted because of the complexity of the mechanism that would be involved. Next, to obtain the optimum configuration and mathematical model of the trap, it was idealized into a 5-bar kinematic chain. By constructing kinematic models and using trial and error methods, the following formula was obtained for the basic trap geometry

$$\frac{\text{length of moment arm}}{\text{base}} = \frac{2.25}{1}$$

This was based on the following design criteria:

a) To aim to center an animal in the trap's transverse direction

b) To maximize the mechanical advantage of the jaws

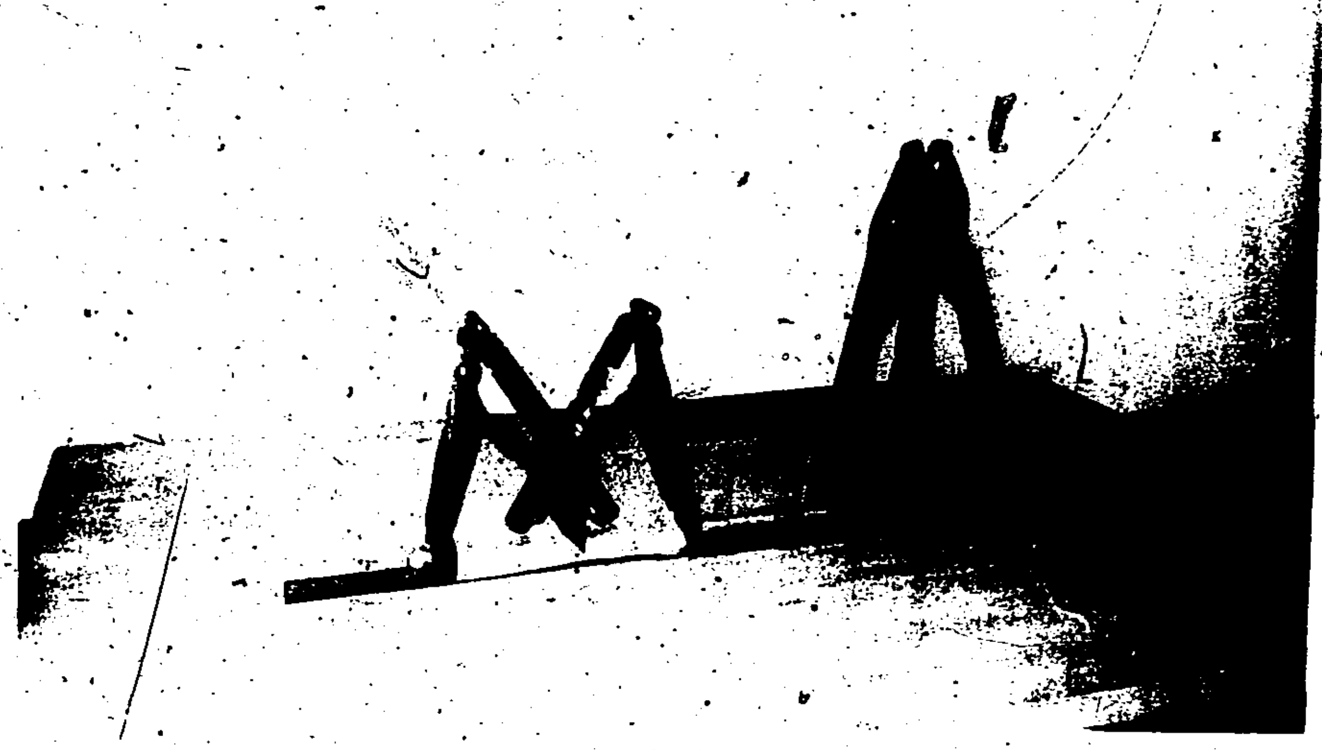


FIGURE 8-1: Original Jacob Concept
by A. Jacob (1969)

c) To maximize the space swing of the jaws.

d) To minimize the overall geometric size of the trap.

It was also suggested that an anvil plate be used at the bottom of the trap to close the gap between the lower points of the jaws and the spring base when the trap is in the closed position and to act as a strike plate.

To determine a range of sizes for the trap to accommodate the different animal groups, the Conibear series was used as a reference base, and the heights of the Jacob traps I, II, & III were chosen to be 6, 8, and 11 inches. This is 1 inch higher than the Conibear traps 120, 220 and 330, in view of the low energy level in the first stage of the jaw motion.

8-2 Spring Frame Design - Tschoepe

Although the frame design started with the idealized 5 bar mechanism, it was found necessary to introduce a reasonable radius at the corner where the free end arm joins with the base. This was mainly to reduce the internal stress when the spring is loaded.

After the overall configuration was decided, the thickness of the spring material was calculated from the curved spring equation* restricting the internal stress below the allowable stress. Then the width of the spring bar was determined according to the force requirement at the end of the free end arm.

For the sake of comparison and reference, the dimensions of Tschoepe's final spring designs are shown in Table 8-1. Using these dimensions and the spring formulae developed for this project in Chapter 10, new values for deflection, stress, strain energy stored in the spring, etc. are calculated and are also listed in Table 8-1.

8-3 Test Results - Tschoepe

Because of the nature of the mechanism, the clamping and prying forces are identical in the Jacob trap and it was idealized as a slider crank mechanism to compute the kinetic energy from the high speed film readings. The results are shown here for convenience and for reference, in Table 8-2.

---

* Appendix E of ref. (2)

TABLE 8-1: P.H. Tschoepe's Design Results of the Jacob Trap

Description	Jacob Trap		
	I	II	III
Thickness of the spring material (in.)	.0678	.1000	.1250
Width of the spring material (in.)	1.50	1.75	2.00
Free end arm length (in.)	5.80	7.75	10.30
Base length (in.*)	.20	.45	.50
Radius of Curvature of the curved spring (in.)	1.00	1.20	1.75
Angle of curvature of the curved spring (rad.)	1.780	1.780	1.780
Calculated values by the author using formulae developed for this project and above dimensions.			
Initial compression angle (rad.)	0	0	0
Total horizontal deflection at the end of the free end arm (in.)	3.500	4.175	6.500
Horizontal force at full deflection at the end of the free end arm (lbs.)	28.00	53.00	76.00
Spring constant (lbs/in.)	8.00	12.69	11.69
Stress in the spring (lbs/in²)	165,954	162,937	176,138
Strain energy stored in the spring (in-lbs.)	98.00	221.28	494.00
Weight of the spring	.45#	1.03#	1.98#

* This value is the half of the original value according to new definition in this project.

TABLE 8-2: P. Tschoepe's test results of Jacob trap

Description	Jaw Opening	Jacob I		Jacob II		Jacob III	
		Above Water	Under Water	Above Water	Under Water	Above Water	Under Water
Kinetic Energy (in-lbs.)	Max.	83.27	23.09	197.24	40.16	535.09	87.14
	9"	---	---	---	---	13.00	5.2
	7"	---	---	7.00	2.00	194.00	49.8
	5"	---	---	143.00	25.00	535.00	84.1
	4"	36.00	2.60	---	---	---	---
	3"	47.00	11.80	---	---	---	---
	2"	---	2.40	---	---	---	---
Closing Time (milli-sec)		14.4	26.1	19.6	30.4	21.2	40.0
Clamping Prying force (lbs.)	3.5"	---		101.5		134.7	
	3"	96.2		87.0		120.0	
	2"	66.9		57.0		83.1	
	1"	37.0		30.8		39.0	
	0.5"	20.0		18.5		---	
Moment of inertia (lbs.sq.in)		3.036		12.026		45.930	
Spring modulus (lbs./in.)		6.000		9.375		7.920	
Trap weight (lbs.)		.8		1.5		2.75	

9. SPRING CONFIGURATION AND INTERIOR MECHANISM

Assuming that the conventional spring-powered strike trap is a solution to the humane trapping problem, there is one most important constraint that must be satisfied. This constraint requires that the animal must be controlled by the trap itself during the firing action so that the blow is always delivered to the most vital spot.

As mentioned in the introduction, the idea of using a stirrup which carries the trap jaws in its plane, and is swung by the animal upon entry thus triggering the trap, appears to have great potential.

The main aim of the design work in this project was to develop this idea which until now was only in the conceptual stage. However, the workability of this concept has been proven insofar as its compatibility with the animal. Two rough models were tested at Guelph with live animals to determine if the animal would approach the stirrup, and continue to push on it after contact to effect sufficient swing to trigger the trap. The results of these tests warranted further development of this idea, and the next stage which was undertaken in this project was to make it workable from a mechanical viewpoint satisfying the constraints of energy, clamping force, underwater performance, etc. The spring frame, strike bars, stirrups and trigger are the four principal parts to be considered in designing the Jacob trap. The latter three parts are called the interior mechanism. The strike bars and the stirrup are inter-related, and they are discussed together in a separate section.

9-1 Spring Configuration

The spring, which is also the frame of the Jacob trap, stores strain energy and supports the interior mechanism. The original spring, which was made out of a uniform width of flat bar had to be modified to reduce the drastic energy loss in the underwater performance. Since the energy loss is mainly due to the upper part of the free end arm which travels with a high speed, the main concern is to try to reduce the frontal area of the free end arm that is presented to the fluid during closing travel. An additional constraint which had to be satisfied in this continuation of the spring design programme was the need to obtain higher energy output. This need was determined from preliminary results of the associated Guelph zoologically oriented programme.

A. Flat Bar Spring

Several alternative designs were produced and are shown in Figure 9-1. The configuration (a) consists of three flat bars with the bottom of each free end arm welded to the base spring. Although it is simple in shape and easy to fabricate, the welding of the spring material is undesirable. (b) shows that both of the free end arms are twisted 90 degrees to the base spring to reduce the area perpendicular to the direction of its travel. However, as the required energy becomes higher, the width of the flat spring gets wider and the

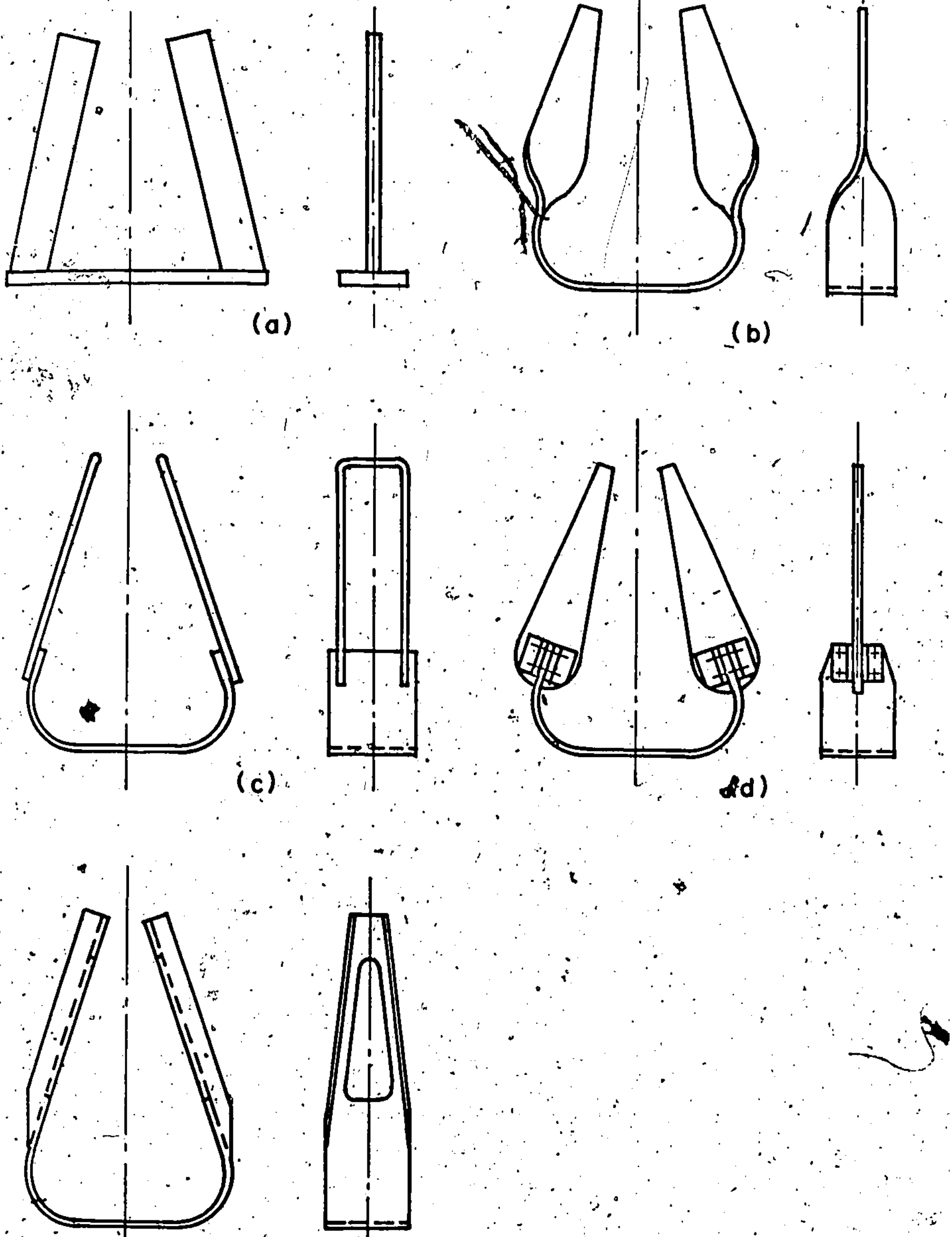


Fig. 9-1 Flat springs for the Jacop trap

twisting length longer, which would cancel the aim. (c) shows the flat spring for the base and the formed wire for the free end arm. This was not adopted because it is inadvisable to weld the wire to the base spring and a simple connection between the free end arm and the interior mechanism was difficult to attain. (d) is an alternative to the configurations (b) & (c). The free end arms were made out of a mild steel bar and connection brackets were welded to these. The brackets were joined to the base spring with machine screws. Two spring frames of this type were fabricated and tested and the results are included in Chapter 12. Configuration (e) is the most sophisticated one. It is attempted to achieve the aim without welding, riveting or twisting. Therefore, the spring material was cut out from the inside of the free end arm and the edges were bent away from the undesirable direction. The bending of the edges forms a channel section which reinforces the free end arms. If the proper tools are made, the manufacturing cost could be held to a practical level.

B. Circular Wire Spring

Two helical torsion springs are joined at the base and the other ends of the coils extended to become the free end arms. Figures 9-2 (a) and (b) shows initial configurations. The base bar of (a) is as high as the diameter of the spring coil and is in the way of the animal's travel. Idea (b) was discarded because the spring coils interfere with the interior mechanism, and also it tends to unwind the spring coils as the

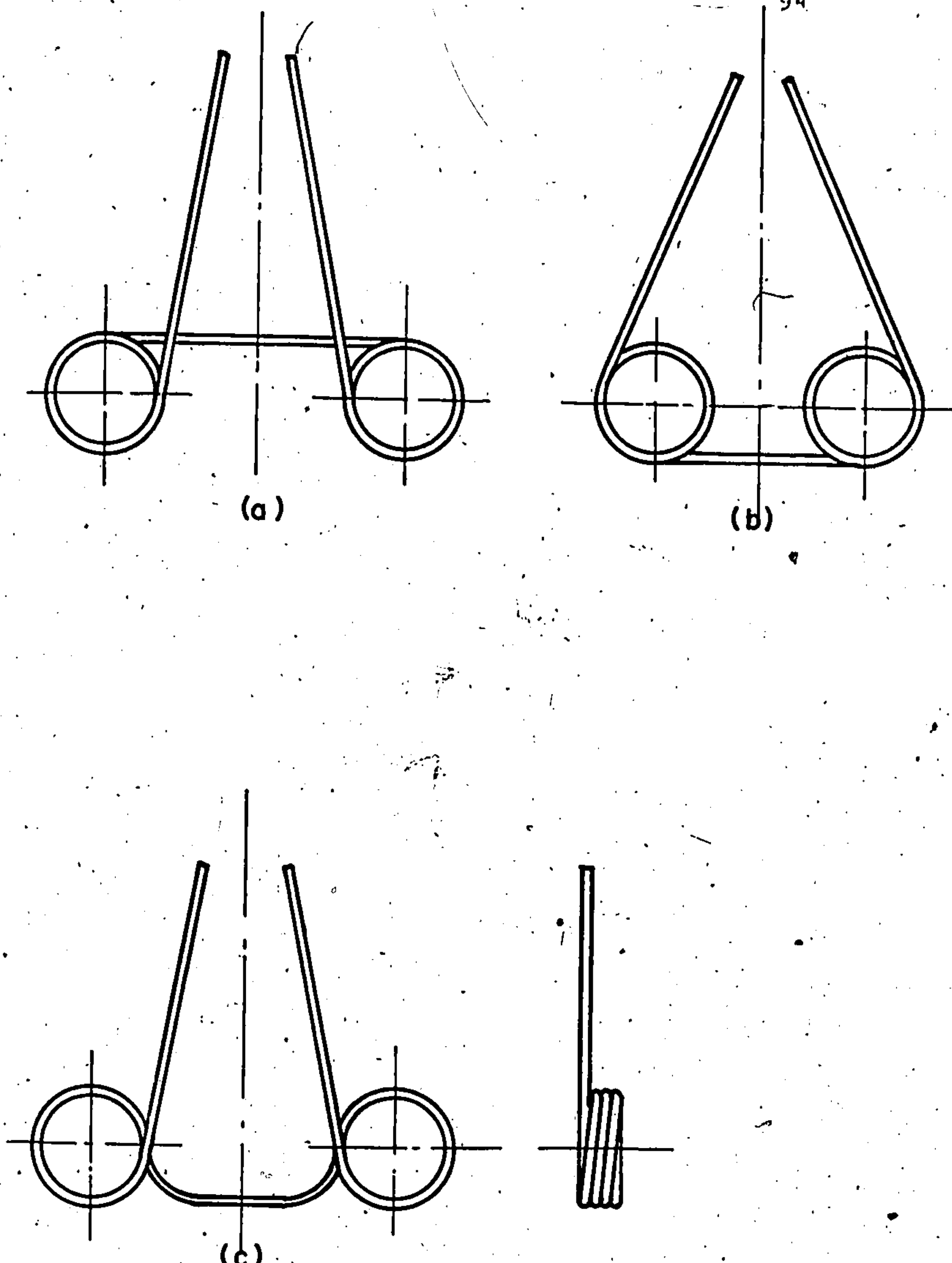


Fig. 9-2 Circular wire springs for the Jacob trap

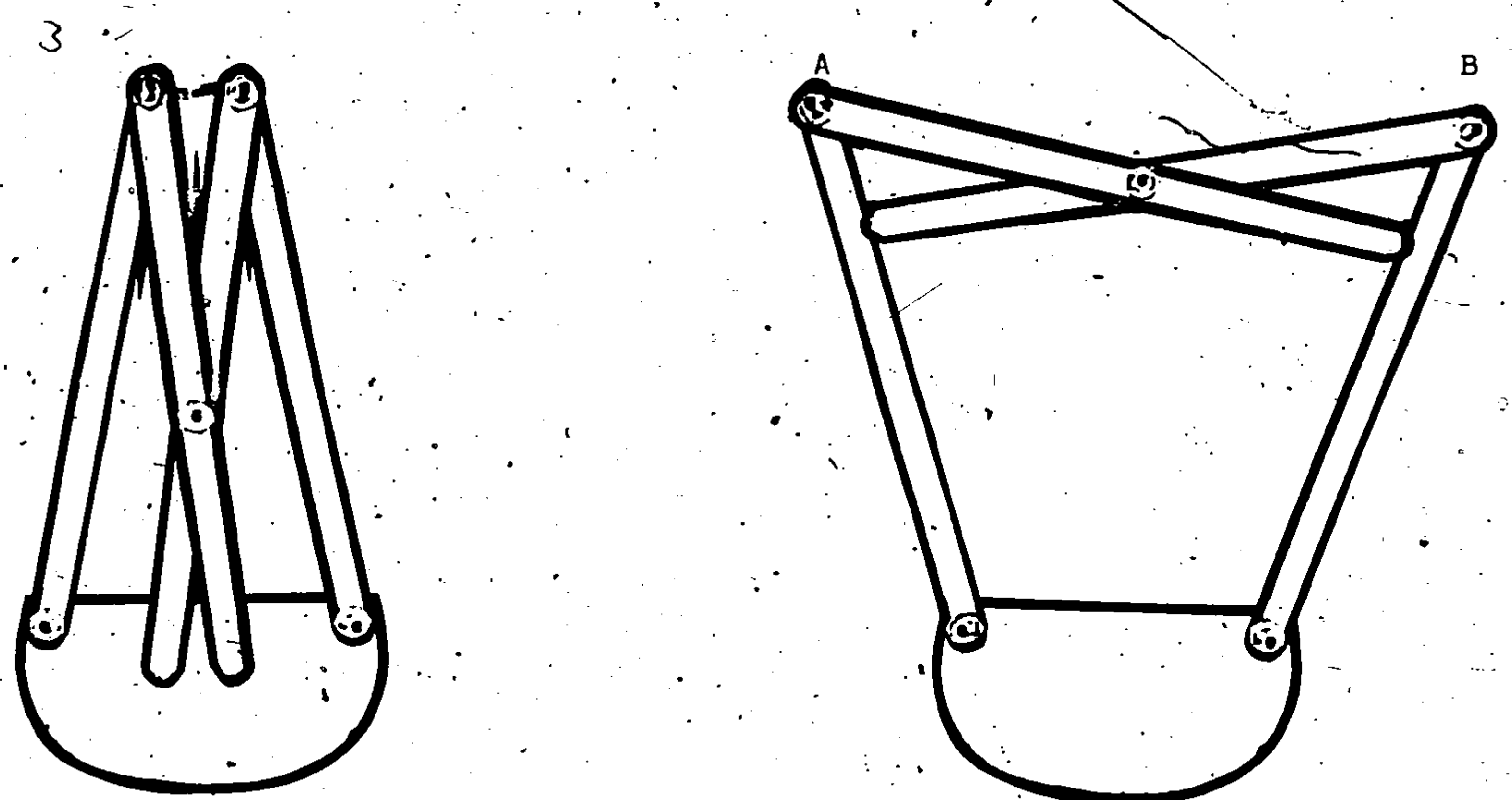
trap is loaded. Therefore, the base bar of the configuration (a) is bent downward as shown in Figure 9-2 (c). One of this type of spring was manufactured for the Jacob trap III as shown in Figure 12-4. However, it was difficult, as discovered later, to make the spring exactly symmetrical about both sides and the difference caused the free end arms to move in different planes. The interior mechanism was twisted when the trap was closed as a result. Also, there were manufacturing difficulties in making the spring with one piece of wire. The prototype was made out of two separate springs, one for each side, and these were brazed together at the base.

Although some of the above ideas did not materialize, one can still modify and further investigate the possibilities of utilizing some of these in the Jacob trap. It should be noted that the free end arms, except in the case of Figure 9-1 (c) and Figure 9-2, can be considered as rigid bars for analytical purposes.

9-2 Strike Bars and Stirrup

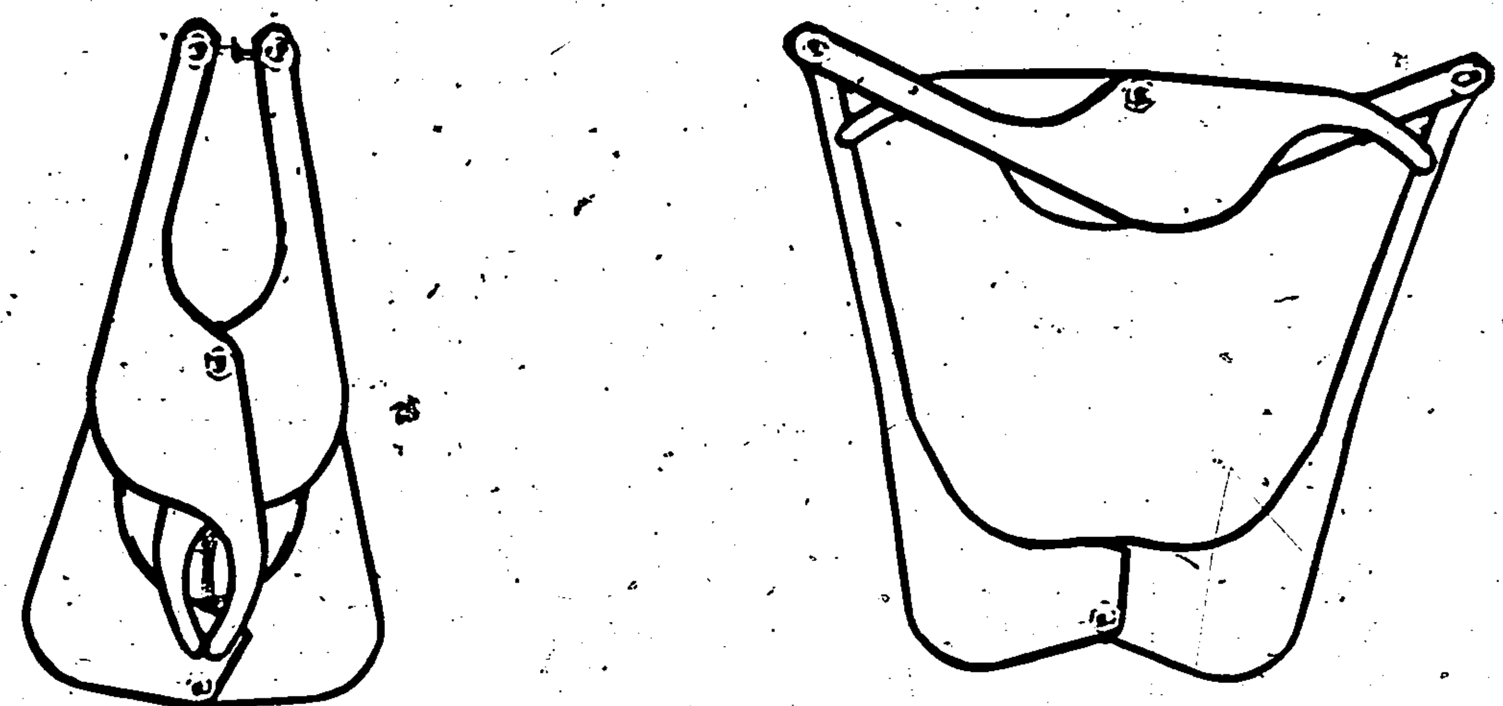
The strike bars and the stirrup make up the interior mechanism. The original design had an anvil plate at the bottom of the trap. When the concept of the stirrup was introduced, two straight bars were added to join the corners of the anvil to the hinges A and B in Figure 9-3. Then, one

FIGURE 9-3: Model of the Jacob trap interior mechanism



(a) Closed (b) Open

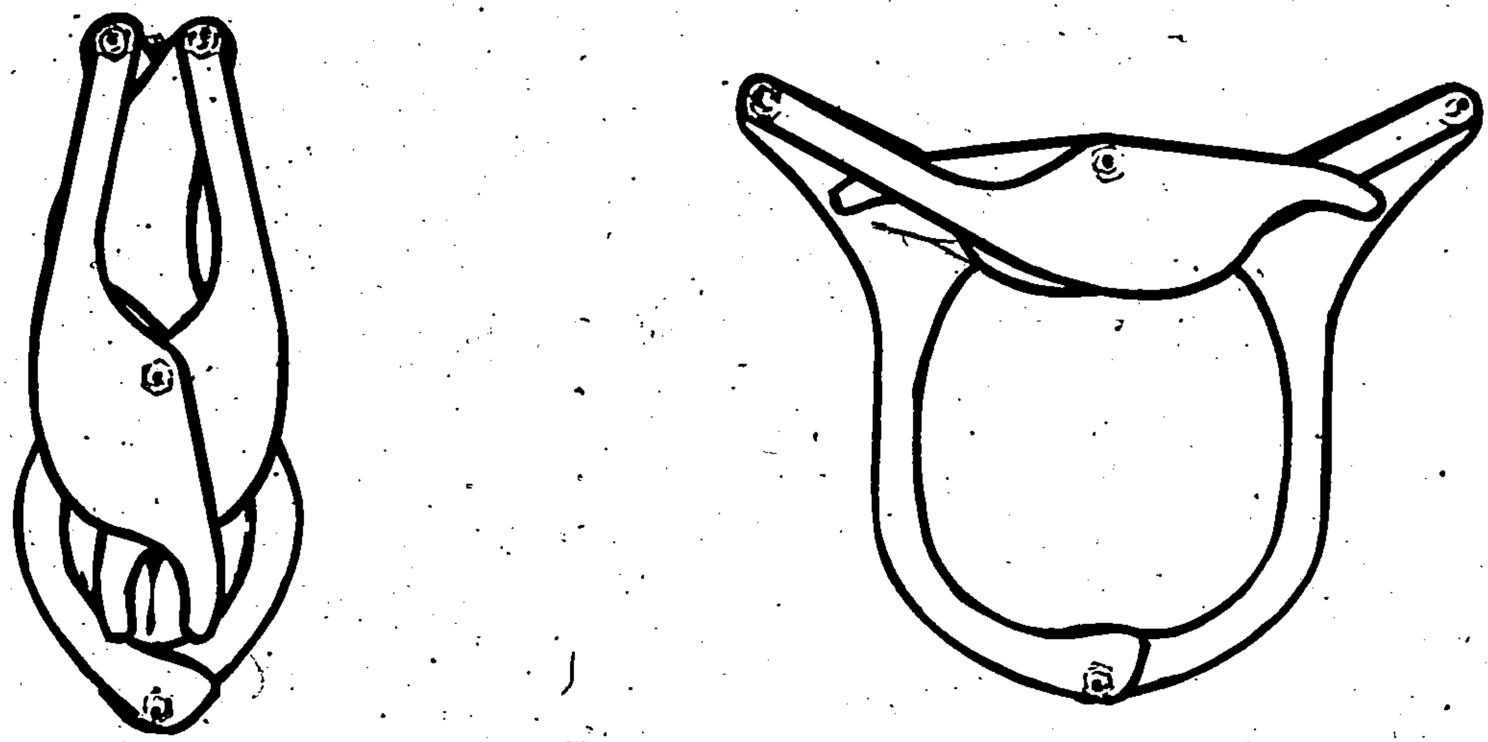
FIGURE 9-4: Model of the Jacob trap interior mechanism



(a) Closed

(b) Open

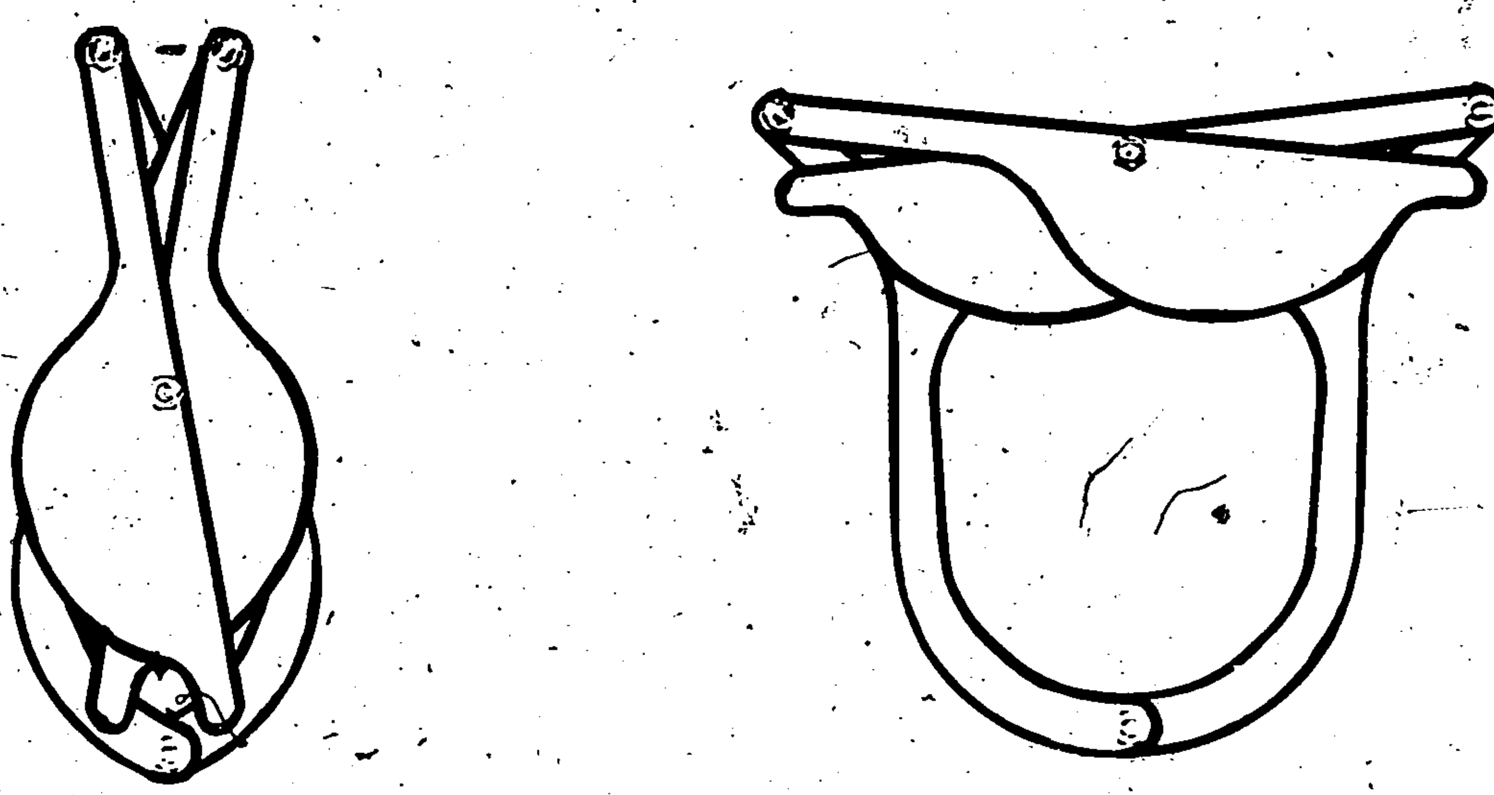
FIGURE 9-5: Model of the Jacob trap interior mechanism



(a) Closed

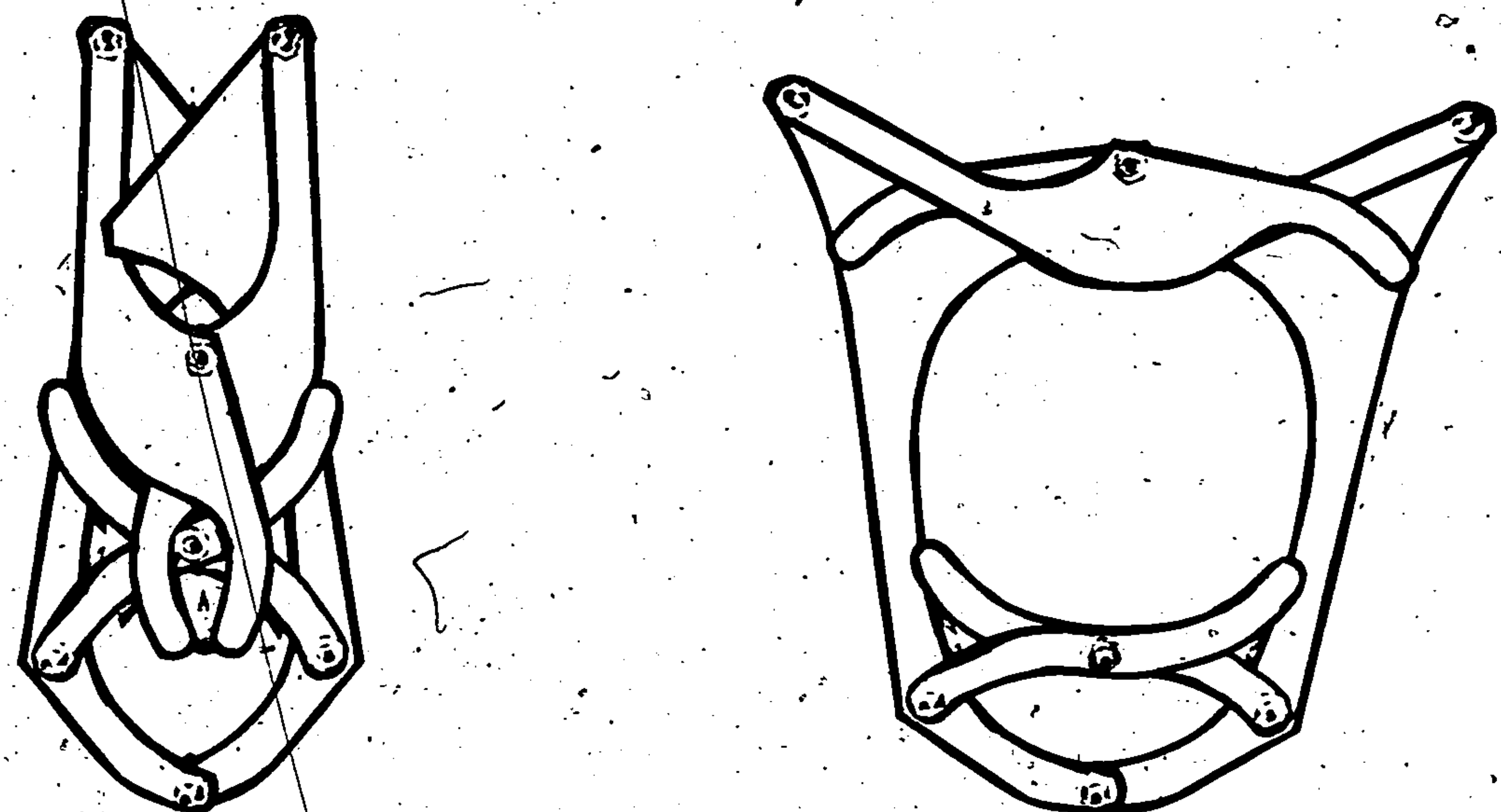
(b) Open

FIGURE 9-6: Model of the Jacob trap interior mechanism



(a) Closed (b) Open

FIGURE 9-7: Model of the Jacob trap interior mechanism



(a) Closed (b) Open

joint in the anvil plate was eliminated to make the model simple, and to avoid the extra degree of freedom of motion in the anvil plate assembly as shown in Figure 9-4. Thus, the linkage called the stirrup was introduced. Also the strike bars were reshaped to avoid the scissor cutting action. They are modified in such a way that the common tangent line to the lower curves of the strike bars remains horizontal for the most part of the striking action. They were designed in such a way that the horizontal portion will exert the impact energy on the animal without damaging the pelt, and the end portion of the strike bars will squeeze the neck of the animal from the sides. Then the idea evolved that the inner shape of the jaw should be made close to a circular shape to minimize the peripheral spaces which could distract the animal's attention to them. Therefore, the stirrup was modified again as shown in Figure 9-5. Although the shape of the opening presented to the animal was reasonable when the jaw was in the open position, there was a sizable amount of gap between the bottom ends of the strike bars and the stirrup when the jaw was in the closed position as shown in Figure 9-5(a). Three ways were considered to reduce this gap without increasing, too much, the overall size of the interior mechanism for the required jaw opening. The first way was to lower the bottom ends of the strike bars by increasing the upper length of the strike bars. This would reduce the preset jaw opening and increase the gap between the interior mechanism and the spring frame due to the increased horizontal deflection at the end of the free end arm. The second way was to lift up the stirrup by shortening the length of the stirrup, but this would also reduce the preset jaw opening. The third way was to thicken up the bottom part of the strike bars as shown in Figure 9-6, and this is the last configuration of the model. Figure 9-7 shows an alternative model. Instead of modifying the strike bars, two bars, called cradle, which are given a flattenend shape to eliminate any scissor action, were added to the stirrup as shown in Figure 9-7. When the strike bars move downward the cradle moves upward closing the jaw completely without leaving any gap at all or could be modelled to provide a small aperture. Another suggestion was to install the strike bars and the stirrup apart about 1/2 in. In this case, when the strike bars hit the animal's neck they will tend to break the neck as illustrated in Figure 9-8.

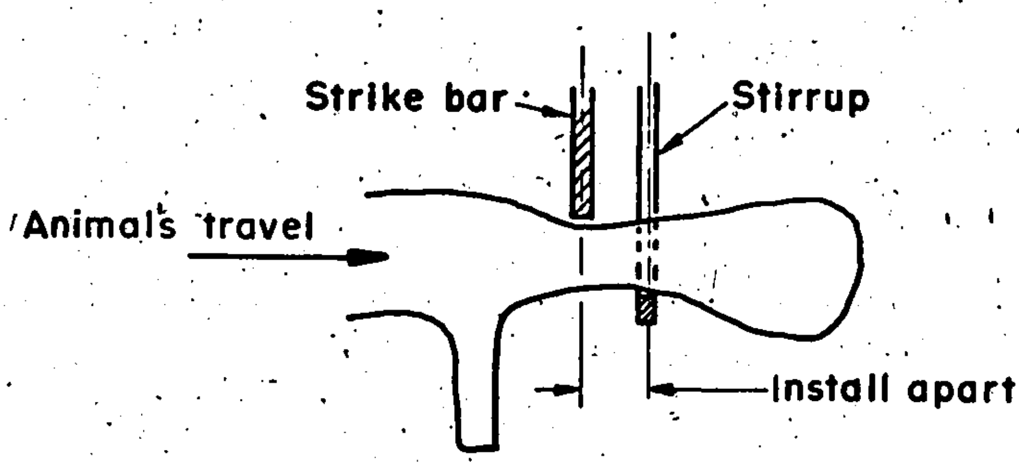


Fig. 9-8

This can be done by putting spacers between the strike bars and stirrup at the hinges. The model in Figure 9-7 requires shorter spacers because the cradle can be placed on one side of the stirrup and the strike bars on the other side of the stirrup.

9-3 Trigger Design

Two common types of triggers are now in commercial use, the pan type and the prong type. When the stirrup was introduced in the Jacob trap design several other trigger designs, which are tripped by the swinging stirrup, were considered. One of the advantages of this type of trigger is that it does not interfere with the passage through the jaw opening and as mentioned before, the real aim is to have positive animal control. When the animal puts his head through the trap opening his shoulders will contact the stirrup causing it to swing, thus firing the trap. The energy-delivering jaws swing with the stirrup, and should always hit the animal at the base of the skull. The model in Figure 9-9 uses a trigger bar with a stop welded on both ends. The trigger bar holds the spring-frame open. When the stirrup is swung from either side, it will rotate the hinge bracket and its extended V-notch to push the trigger bar off the swing and release it. The trigger bar can be chained to the spring. This needs further consideration when the free end arm inclines too much from the vertical or the free end arm is rotated 90 degrees to reduce the under-

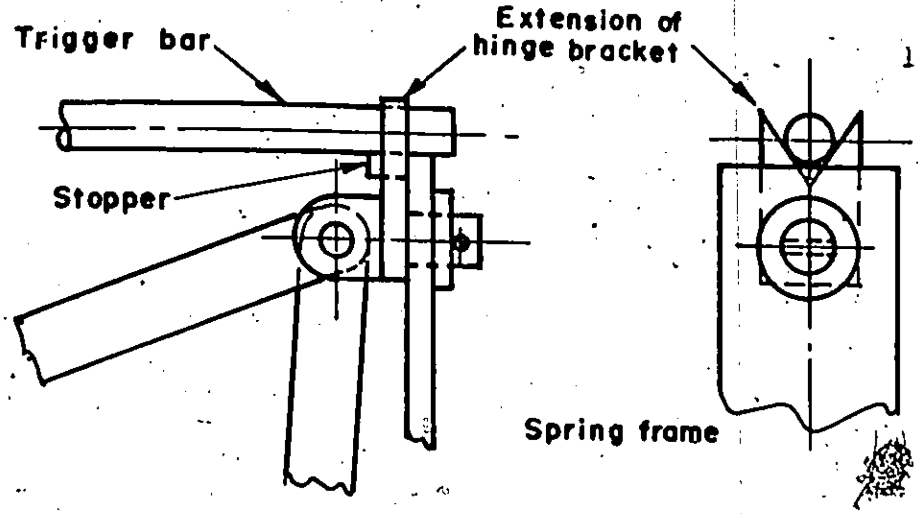


Fig. 9-9

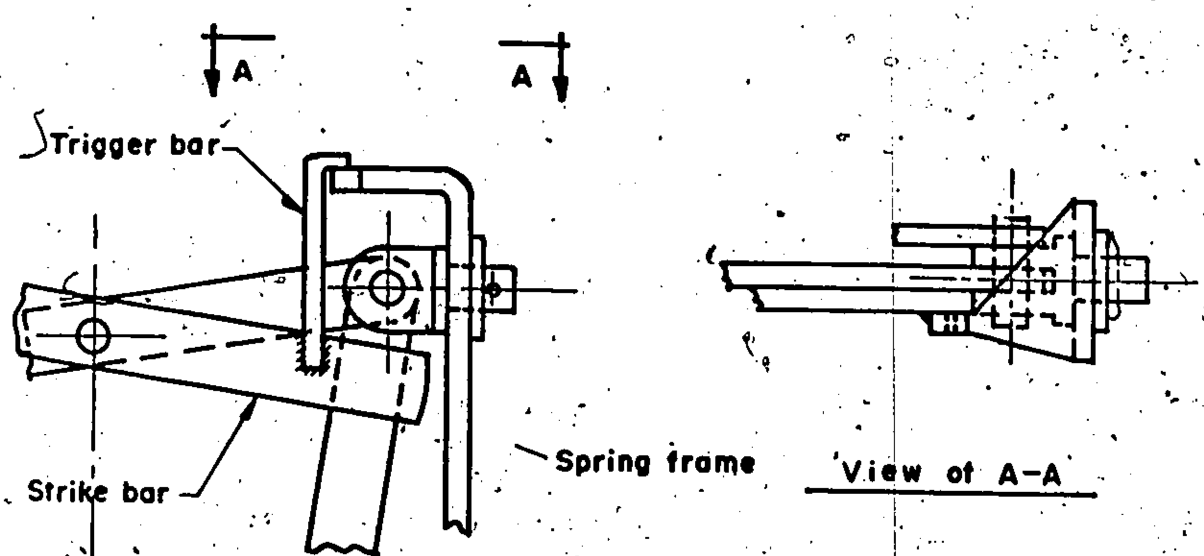


Fig. 9-10

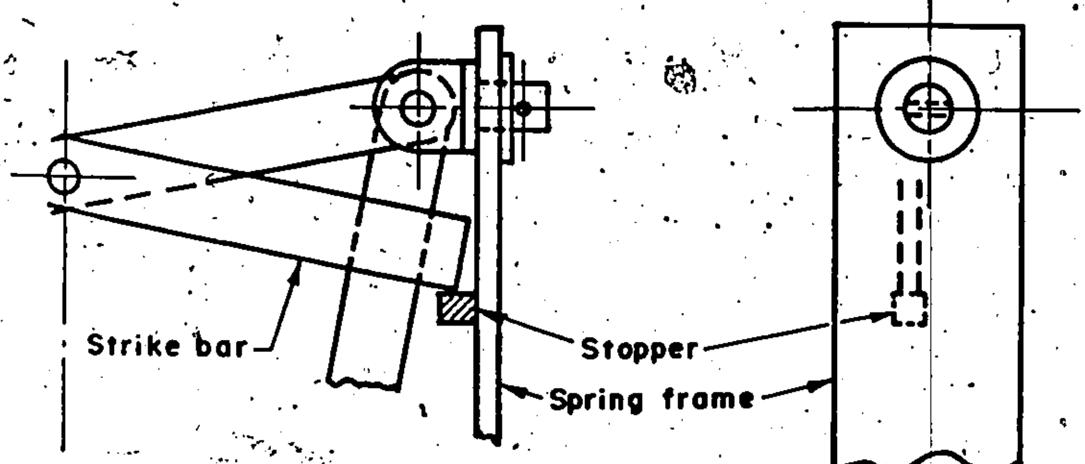


Fig. 9-11

water energy loss. In Figure 9-10, the idea was to attach a trigger to the bottom end of one of the strike bars. The extension of the spring frame becomes the counter-part of the trigger bar. However, to avoid the complicated design, both of them are replaced with a stop as shown in Figure 9-11, which can be a part of the spring frame. The bottom end of a strike bar is shaped to sit on the stop when the trap is set. By altering the width of the stop, the swing angle of the stirrup, required to trip the trap, can be adjusted. The design is simple, no additional large parts are required, and the contact force between the stop and the strike bar can be reduced by raising the stop to its possible highest point. However, when this was tried it turned out that the stirrup (which is the trigger) was not sensitive enough due to the friction in the hinge brackets which are under the direct spring forces.

The trigger bar, in Figure 9-12, which is connected by a pin to the formed free end arm on one end and the half circle groove of the other end sets the trap like the ordinary prong type triggers. The hinge bracket when it is rotated by the stirrup, pushes up the counterpart, which is a piece of steel sheet welded to the trigger bar. The swing angle of the stirrup required to trip the trap can be adjusted by altering the width of the steel bar. As the direct spring forces are supported by the trigger bar, the stirrup is free to rotate, which makes the trigger sensitive. This configuration was

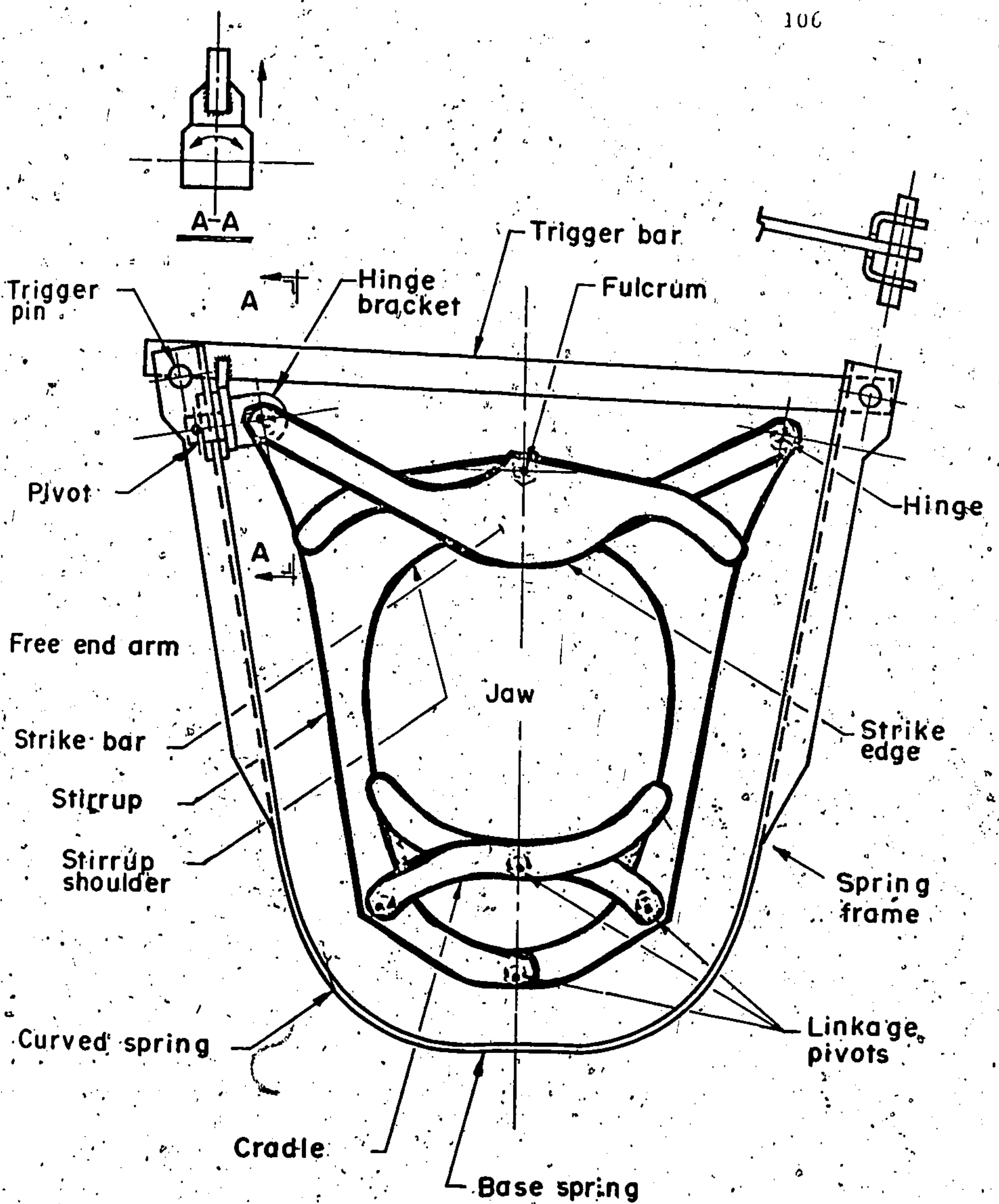


Fig. 9-12 Parts name designation for the Jacob trap

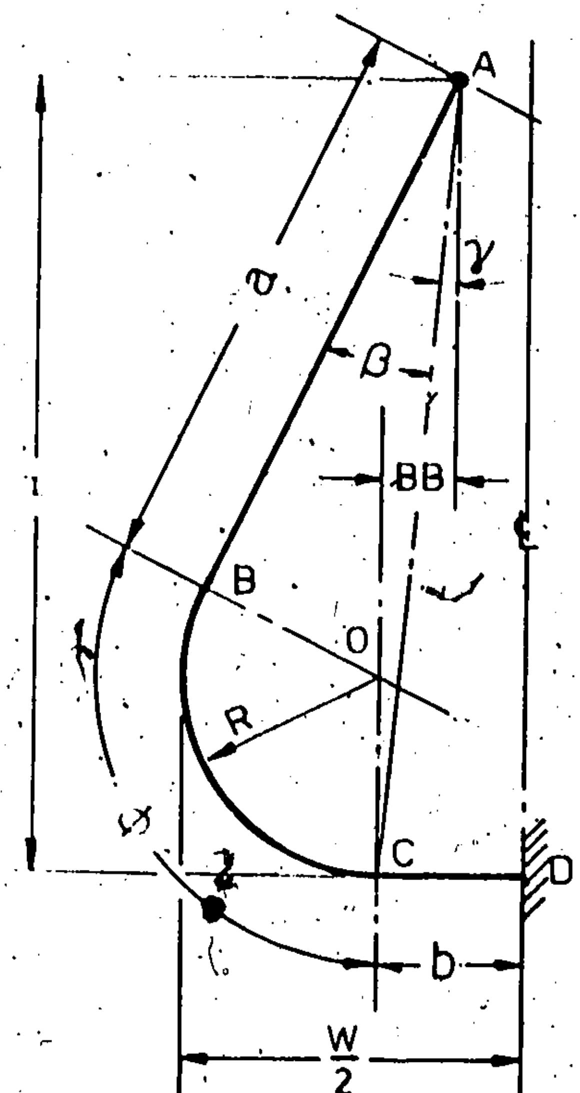
manufactured and tested and it appeared to be the most satisfactory of the alternatives considered.

To facilitate the remainder of the work the parts of the Jacob trap as conceived in this project are named and shown in Figure 9-12.

10. FLAT SPRING DESIGN

The flat spring was considered as the most suitable one for the Jacob trap and in Section 9-1, we have already discussed the general configuration of the spring. The approximate overall size of the spring will be determined by the interior mechanism, which is also designed for a size range of the animals, according to the procedure as explained in Section 9-2. Then the optimum spring, which is close to the configuration and can deliver the required impact energy, should be designed. Although the formulae concerning the various curved springs are well explained in the references (3), (4) and (8), it was convenient to derive, here, the combined equations for the purpose of formulating a computer programme for optimization of the spring design. Firstly, the equations for the new spring with the free end arm, which is regarded as a rigid body, will be derived. Secondly, the equations for the spring from the previous project[2] will be explained for reference.

10-1 Definition of the Parameters



$\beta = \phi - \pi/2$

$BB = a \sin\beta - R \cos\beta$

$H = a \cos\beta + R \sin\beta + R$

$\gamma = \tan^{-1}(\frac{BB}{H})$

$I = \frac{wt^3}{12}$

Fig. 10-1.

ℓ	Free end arm length (in.)
b	Base spring length (in.)
H	Height of the spring
R	Radius of curvature of the curved spring (in.)
ϕ	Angle of curvature of the curved spring (rad.)
W	Width of the spring (in.)
t	Thickness of the spring material (in.)
w	Width of the spring material (in.)
E	Modulus of elasticity of the material (lbs/sq.in.)
I	Area moment of inertia of the spring cross-section ($in.^4$)
Z	Section modulus of the cross-section ($in.^3$)
A	Cross-sectional area of the spring ($in.^2$)
$\sigma_{max.}$	Maximum internal stress (lbs/in^2)
θ	Angle from the radial line OB, counter clockwise (rad.)

10-2 Design Formulae (1) - Curved Spring With Rigid Free End Arm

Upon setting the trap one applies a horizontal force at A which varies from F_1 up to its maximum value F_2. However, to comply with the references [3],[4],[8] and for convenience a force applied in the opposite direction for the opening force is used as shown in Figure 10-2. The energy accummulated in the spring in the form of strain energy during the set-up, will deliver the impact energy when it is released.

Let us assume that the force F is a function of the horizontal displacement, y, of the point A.

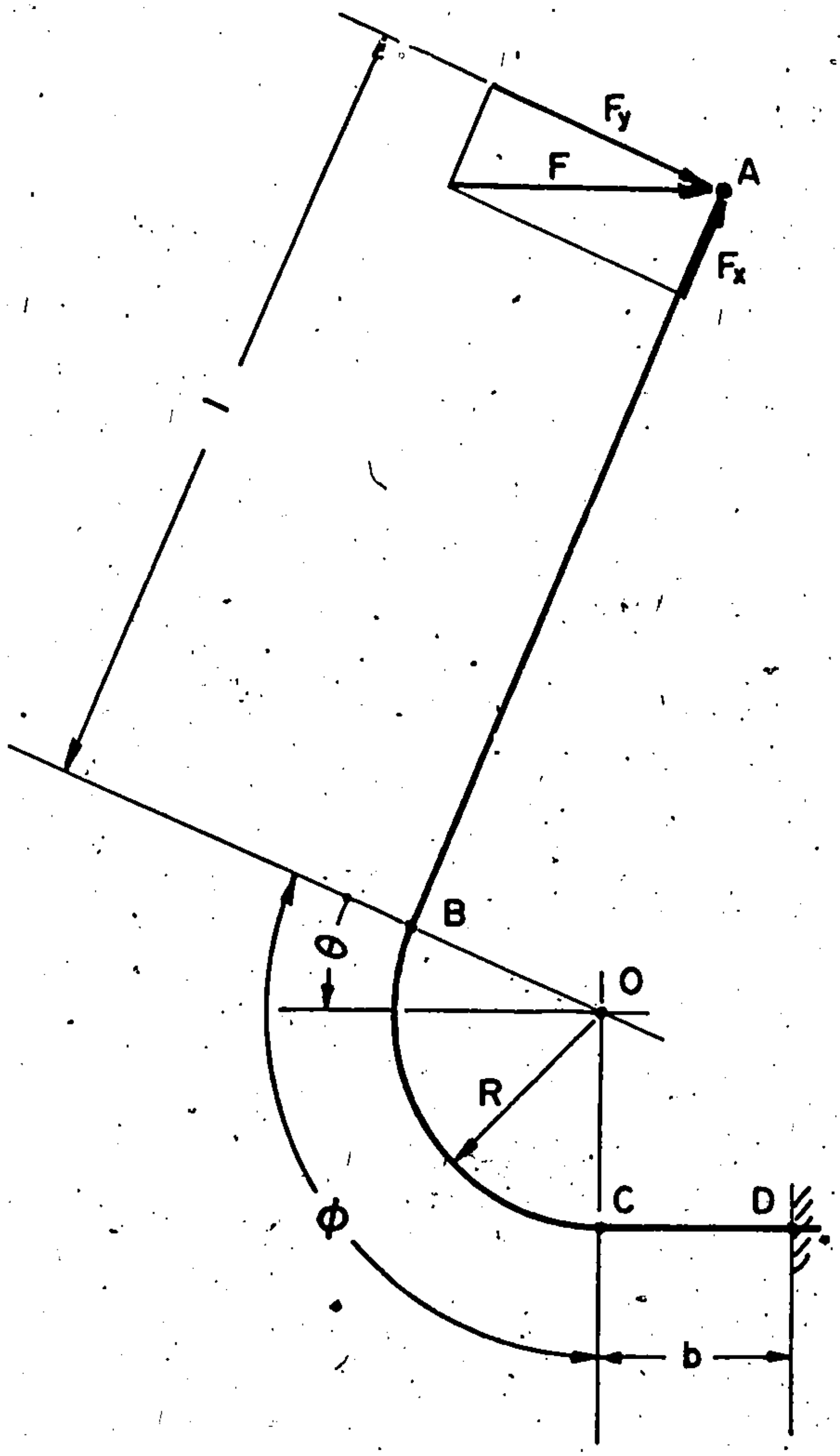


Fig. 10-2

$F = f(y)$ (10-1)

And the strain energy stored in the spring during the horizontal displacement y_1 to y_2 will be:

$$ENGY = \int_{y_1}^{y_2} F\,dy \qquad (10\text{-}2)$$

If F is a linear function of y, which will be shown later, and putting $F_1 = f(y_1)$, $F_2 = f(y_2)$ and $y_2 - y_1 = DEFM$, Eq. (10-2) becomes

$$ENGY = \frac{DEFM}{2}(F_2 + F_1) \qquad (10\text{-}3)$$

F_1 is not zero in the case where the spring is initially loaded before setting up the trap. Let us consider the left half of the spring, since the both sides are symmetrical. The spring consists of the curved spring, BC and the base spring CD (or the cantilever beam). The displacement of A will be the resultant deflection from both of the springs. The equations for the base spring are discussed in Section 10-4. The horizontal force is divided into two components, parallel with and perpendicular to the free end arm:

$$F_y = F\cos\beta$$
$$F_x = F\sin\beta \qquad (10\text{-}4)$$

where $\beta = \phi - \pi/2$

The curved spring and the free end arm are shown again in Figure 10-3 rotated clockwise by $(90-\beta)$ degrees.

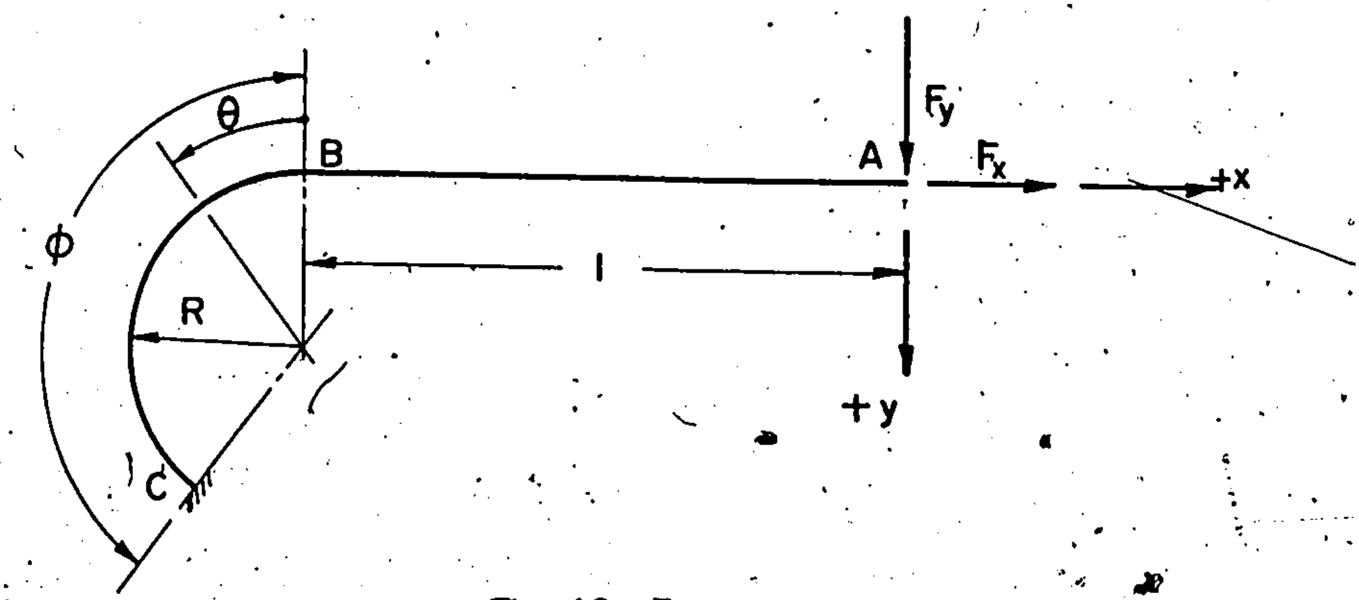


Fig. 10-3

Because the free end arm is regarded as a rigid body, let us consider the deflections at the point B, due to the loads of F_y and F_x at the point A. The forces F_y and F_x can be moved to the point B by adding the end moment $M_o = F_y \cdot \ell$ to the point B without changing the condition. The bending moment at any point defined by the angle, θ, along the curved spring will be,

$$M = -F_y R \sin\theta - F_x R(1-\cos\theta) - M_o \qquad (10\text{-}5)$$

The negative signs indicate simply that the moments cause tension on the outer fiber of the spring.

By Castigliano's theorem, the vertical and horizontal deflections at the point B will be:

$$Y_1 = \frac{1}{EI}\int_0^{\phi} M \frac{\partial M}{\partial F_y} R d\theta \qquad (10\text{-}6)$$

$$X_1 = \frac{1}{EI}\int_0^{\phi} M \frac{\partial M}{\partial F_x} R d\theta \qquad (10\text{-}7)$$

for small amounts of deflection.

From the equation (10-5)

$$\frac{\partial M}{\partial F_y} = -R \sin\theta \qquad (10\text{-}8)$$

Substituting Eqs. (10-4) and (10-8) into Eq. (10-6)

$$Y_1 = \frac{1}{EI}\int_0^{\phi} [-F_y R \sin\theta - F_x R(1-\cos\theta) - M_o](-R \sin\theta) R d\theta$$

Introducing $M_o = F_y \cdot \ell$, $k = \frac{\ell}{R}$ and rearranging the terms,

$$Y_1 = \frac{R^3}{EI}\int_0^{\phi} [F_y(k+\sin^2\theta) + F_x \sin\theta(1-\cos\theta)] d\theta$$

Integrating and substituting the relevant limits,

$$Y_1 = \frac{R^3}{EI} [F_y(0.5\phi - .25 \sin 2\phi + k - k \cos\phi) + F_x(.75 - \cos\phi + .25 \cos 2\phi)] \qquad (10\text{-}9)$$

The horizontal displacement at the point B, X_1, is obtained through the same procedure,

$$X_1 = \frac{R^3}{EI}[F_y(k\phi - k\sin\phi - \cos\phi + .25\cos 2\phi + .75) + F_x(1.5\phi - 2\sin\phi + .25\sin 2\phi)] \tag{10-10}$$

To get the deflection at the point A, the slope at the point B after the displacement should be known.

From Eq. (10-5), $\frac{\partial M}{\partial M_o} = -1$

and the slope δ becomes

$$\delta = \frac{1}{EI}\int_0^\phi M\frac{\partial M}{\partial M_o} R\,d\theta$$

$$= \frac{R^2}{EI}\int_0^\phi [F_y(k+\sin\theta) + F_x(1-\cos\theta)]d\theta$$

Therefore

$$\delta = \frac{R^2}{EI}[F_x(\phi - \sin\phi) + F_y(k\phi - \cos\phi + 1)] \tag{10-11}$$

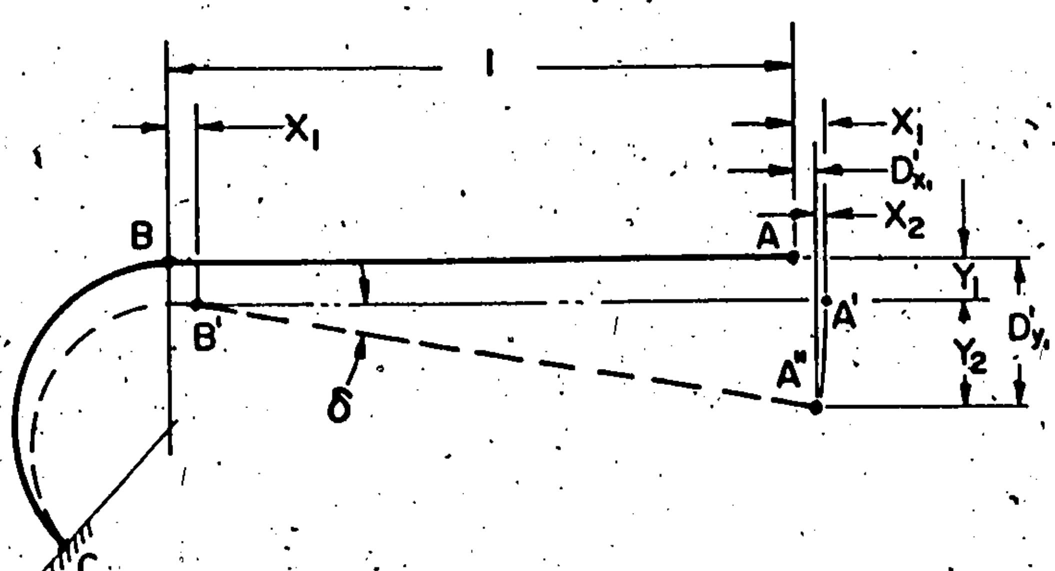


Fig. 10-4

In Figure 10-4, the displacement AA' has come from the deflection BB' and the additional displacement A'A" is due to the slope at the point B', the angle of which is δ. The vertical and horizontal projections of the displacement A'A", Y_2, X_2 can be obtained from trignometry.

$$Y_2 = \ell \sin\delta \qquad (10\text{-}12)$$

$$X_2 = \ell(1-\cos\delta) \qquad (10\text{-}13)$$

Therefore, the total vertical and horizontal displacements $D'y_1$, $D'x_1$ will be

$$D'y_1 = Y_1 + Y_2 \qquad (10\text{-}14)$$

$$D'x_1 = X_1 - X_2 \qquad (10\text{-}15)$$

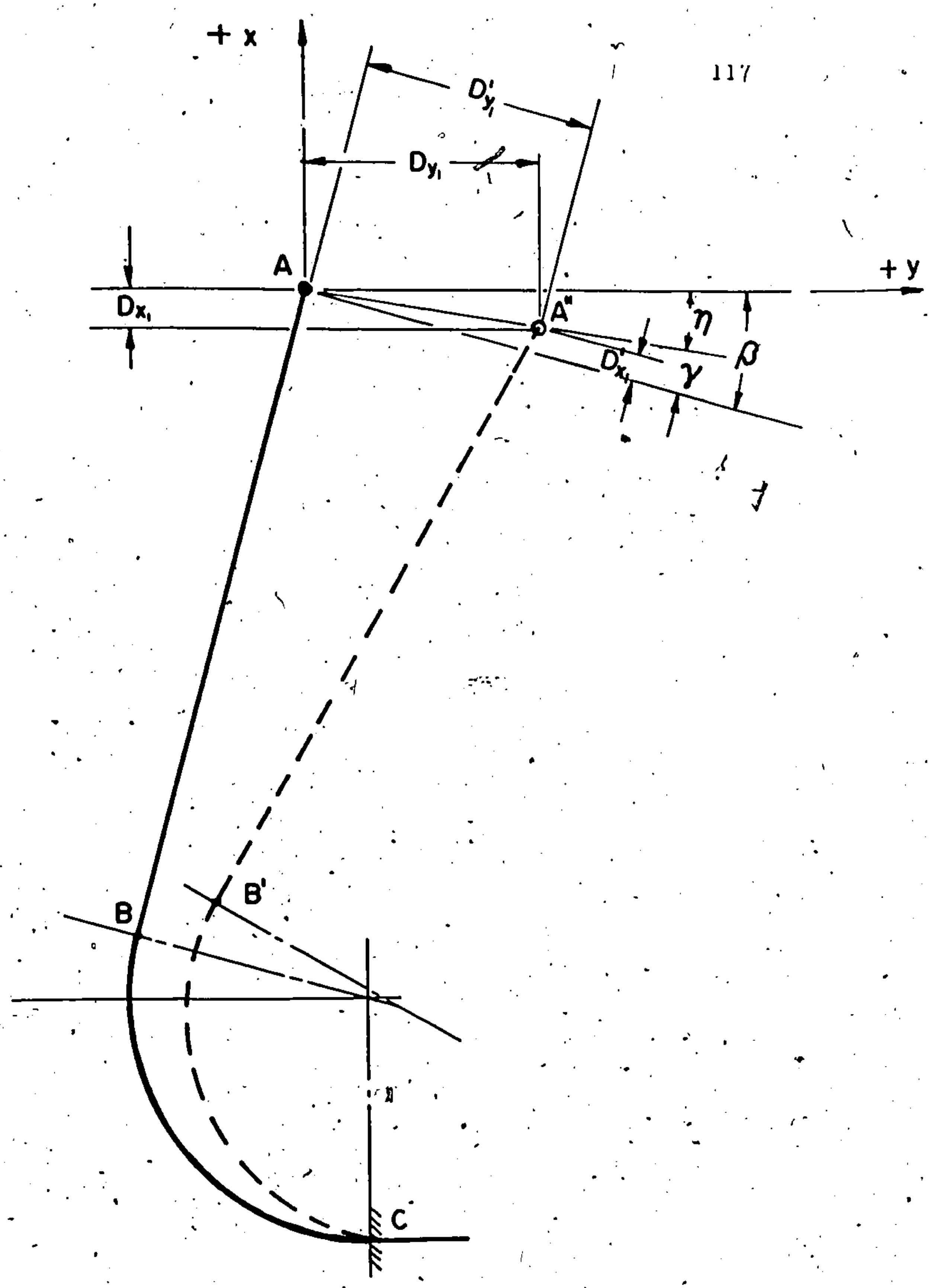


Fig. 10-5

Now let us go back to Figure 10-2 and redraw the figure with the displacements, $D'y_1$ and $D'x_1$ which are parallel with and perpendicular to the free end arm as shown in Figure 10-5. The required horizontal and vertical displacements (which are parallel and perpendicular to the base) Dy_1, Dx_1 can be obtained from the figure

$$\gamma = \tan^{-1} \frac{D'x_1}{D'y_1}$$

$$\eta = \beta - \gamma \qquad \text{where } \beta = \phi - \frac{\pi}{2}$$

Therefore

$$Dy_1 = \sqrt{D'y_1^2 + D'x_1^2} \cdot \cos \eta \qquad (10\text{-}16)$$

$$Dx_1 = \sqrt{D'y_1^2 + D'x_1^2} \cdot \sin \eta \qquad (10\text{-}17)$$

10-3 Design formulas (2) - Curved spring with a flexible free end arm

Before we come to the base spring, let us consider a curved spring with a flexible free end arm.

In Figure 10-6, the displacement of the point A to A" will be the same as shown in Figure 10-4. But the additional displacement A"A'" occurs due to the deflection of the free end arm AB itself. There are two ways to calculate the total displacement $D'y_1$.

One way is to compute the individual deflections and add them up.

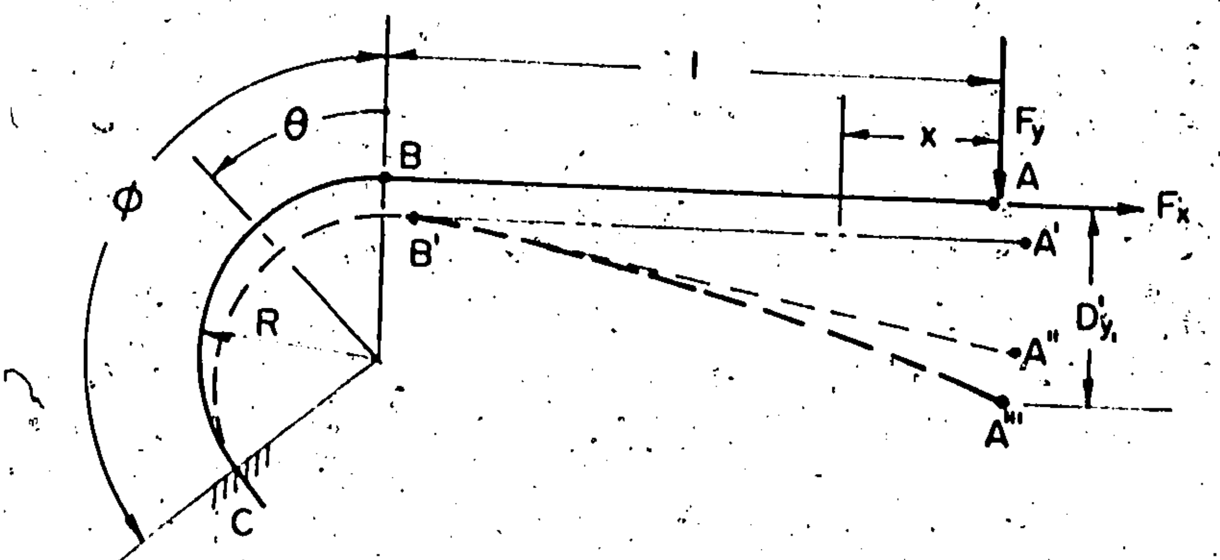


Fig. 10-6

The other method calculates the total displacement directly as follows.

The bending moment at any point defined by the distance, x, along the free end arm AB.

$$M_1 = -F_y x \tag{10-18}$$

and the bending moment at any point defined by the angle θ along the curved spring BC

$$M_2 = -F_y R(k+\sin\theta) - F_x R(1-\cos\theta) \tag{10-19}$$

where $k = \ell/R$.

Applying Castigliano's theorem again,

$$D'y_1 = \frac{1}{EI}\int_0^{\ell} M_1 \frac{\partial M_1}{\partial F_y}\, dx + \frac{1}{EI}\int_0^{\phi} M_2 \frac{\partial M_2}{\partial F_y}\, R d\theta \qquad (10\text{-}20)$$

From the equations (10-18) and (10-19)

$$\frac{\partial M_1}{\partial F_y} = -x \qquad (10\text{-}21)$$

$$\frac{\partial M_2}{\partial F_y} = -R(k + \sin\theta) \qquad (10\text{-}22)$$

Substituting Eqs. (10-21) and (10-22) into Eq. (10-20) and rearranging the terms,

$$D'y_1 = \frac{F_y}{EI}\int_0^{\ell} x^2 dx + \frac{R^3}{EI}\int_0^{\phi} [F_y(k^2+2k\sin\theta+\sin^2\theta)$$

$$+ F_x(k-k\cos\theta+\sin\theta-\sin\theta\cos\theta)]d\theta$$

Integrating and substituting the relevant limits

$$D'y_1 = \frac{R^3}{EI}[F_y(.33k^3+k^2\phi+2k-2k\cos\phi+.5\phi-.25\sin 2\phi)$$

$$+F_x(k\phi-k\sin\phi-\cos\phi+.25\cos 2\phi+.750] \qquad (10\text{-}23)$$

The equation (10-23) is equivalent to the equation (10-14) in section 10-2. The horizontal deflection will be the same as the equation (10-15) if the infinitesimal horizontal projection A"A"' is neglected.

Therefore

$$D'x_1 = X_1 - X_2 \qquad (10\text{-}24)$$

where X_1 and X_2 are defined in the equations (10-10) and (10-13). Also the equations (10-16) and (10-17) can be used as is, substituting the relevant values.

10-4 Design Formulae (3) - The Base Spring

So far, the point C in Figure 10-7 was considered as a built-in end, but this is the end point of the cantilever beam or the base sping $\overline{CD}$. Therefore, we should consider the effect of the base spring on the displacement of the point A. Let us assume an imaginary rigid bar $\overline{AC}$ in Figure 10-7. For the base spring the horizontal force F acting at the point A results in the end moment M_o=FH and the direct tension F in $\overline{CD}$. To make it simple, it is assumed that the point C moves to C' on the same vertical line during the deflection due to the end moment and the elongation in $\overline{CD}$ due to direct force F is negligible. The displacement of the point A to A" can be considered as it moved first to A' due to the end slope θ and then moved to A" by the vertical deflection, CC'. The end slope at C due to the end moment:

$$\theta = \frac{M_o b}{EI} = \frac{F \cdot H \cdot b}{EI} \qquad (10\text{-}25)$$

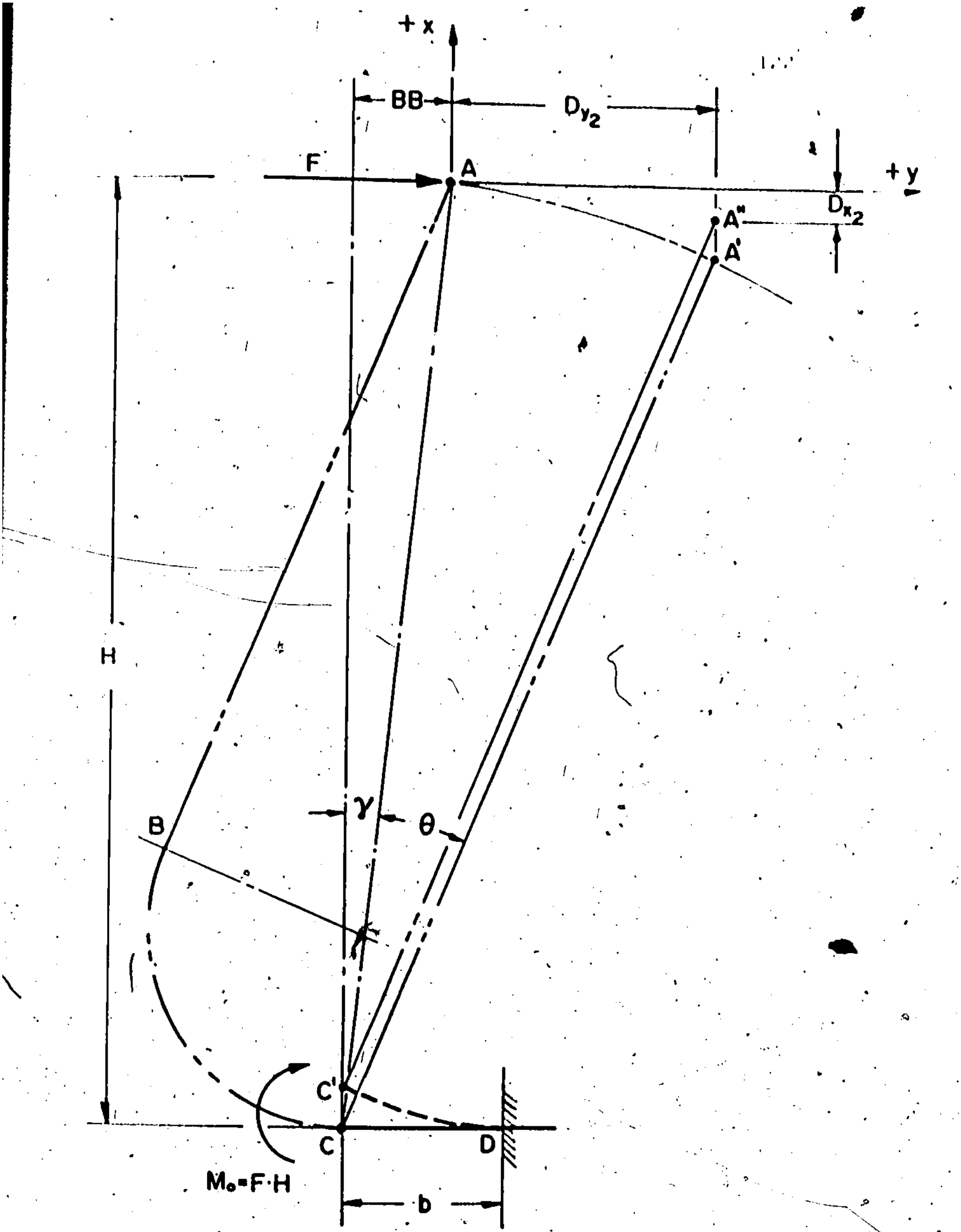


Fig. 10-7

Therefore, the horizontal movement of the point A

$$Dy_2 = \frac{H}{Cos\gamma}[sin(\theta+\gamma) - sin\gamma] \qquad (10\text{-}26)$$

and from the figure

$$\gamma = tan^{-1}(\frac{BB}{H}) \qquad (10\text{-}27)$$

Substituting Eq. (10-27) to Eq. (10-26) and rearranging the terms:

$$Dy_2 = H\ sin\theta + BB(cos\theta - 1) \qquad (10\text{-}28)$$

The difference in vertical projection of AC before and after the deflection due to the end slope, and the vertical displacement of point C constitute the vertical movement of A.

From the vertical projection difference

$$\frac{H}{cos\gamma}[cos(\theta+\gamma) - cos\gamma] \qquad (10\text{-}29)$$

and the vertical deflection of the point C, CC'

$$\frac{F \cdot H \cdot b^2}{2EI} \qquad (10\text{-}30)$$

Adding Eqs. (10-29) and (10-30), and substituting Eq. (10-27) for γ

$$Dx_2 = H(cos\theta - 1) - BB\ sin\theta + \frac{FHb^2}{2EI} \qquad (10\text{-}31)$$

10-5 Total Deflections, stress and energy

In the previous three sections, the deflection formulae are derived for each case. The total horizontal deflection DEFY (Y-direction as defined in Fig. 10-5) will be the addition of Eqs. (10-16) and (10-28),

$$DEFY = Dy_1 + Dy_2 \qquad (10\text{-}32)$$

And the total vertical deflection DEFX (X-direction as defined in Figure 10-6) will be the addition of Eqs. (10-17) and (10-31)

$$DEFX = Dx_1 + Dx_2 \qquad (10-33)$$

Now that we have established the functional relationship of Eq. (10-1), the strain energy can be computed from Eqs. (10-2) and (10-3). Finally the maximum stress in the spring will be:

$$\sigma_{max.} = \frac{M}{Z} + \frac{F}{A} \qquad (10-34)$$

where $M = F(\ell+R)$

taking the maximum possible moment arm to be on the safe side.

10-6 Approximation to the spring configuration

In establishing the functional relation between the horizontal force F and the deflections of the point A, horizontal and vertical, in Figure 10-2, it is assumed that the deflections are comparatively small and they are functions of only the applied force. But in our case, the configuration of the spring changes continuously during the application of the force. The problem is even worse with the spring which has a flexible free end arm.

Instead of getting into a complicated analytical solution, a numerical approximation method was applied. In Figure 10-8, let us assume the original configuration has

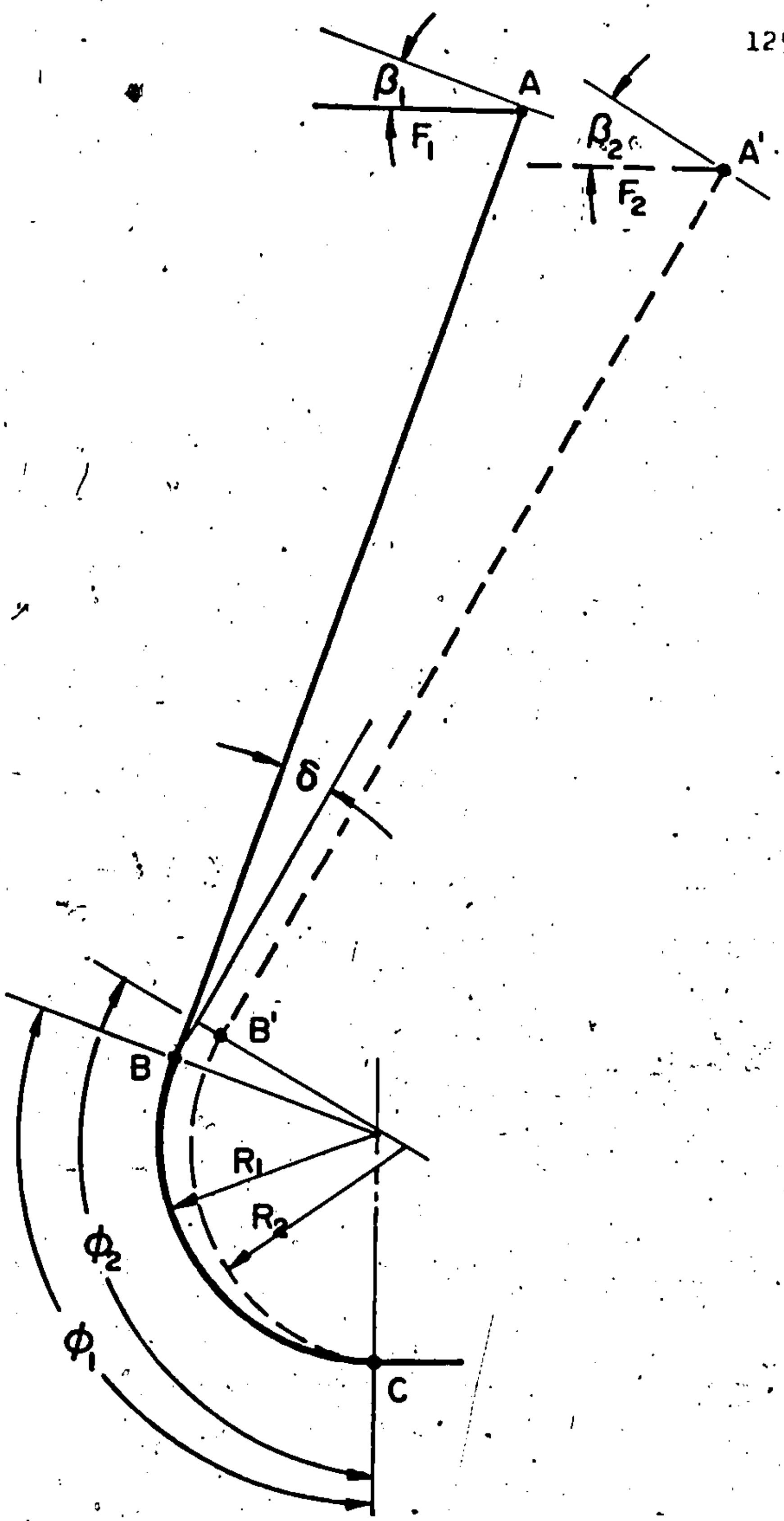


Fig. 10-8

the parameters ϕ_1, R_1 and ℓ. They will be changed into ϕ_2, R_2 and ℓ, for example after a small amount of the force (say 1, 2 or 3 lbs. etc) is applied, for the case of the spring with the rigid free end arm. Although the moment along the curved spring varies with the angle θ resulting in different deflections, it is assumed that the curvature of the curved spring remains uniform and equal to ϕ_1 plus the deflection angle δ at the point B, that is:

$$\phi_2 = \phi_1 + \delta \tag{10-35}$$

This is an arbitrary assumption, but the results were satisfactory for our purpose. Therefore, from the equation $\phi_1 R_1 = \phi_2 R_2$, the new radius of curvature can be determined by

$$R_2 = R_1 \cdot \frac{\phi_1}{\phi_2} \tag{10-36}$$

With the new configuration of the spring another force F_2 ($=F_1$) is applied and the procedures is repeated until the total horizontal deflection reaches the predetermined value. The algebric addition of the horizontal forces will give the total force applied and similarly for the total deflection.

10-7 Optimization computer programme

The design configuration and rough size of the flat spring will be first determined as explained in Chapter 9 along with the allowable maximum and minimum values of the design variables. The computer programme finds the optimum spring for the configuration. That is, the spring with least weight for the required energy. Of course the interior mechanism may have to be adjusted in the course of the optimization.

The main programme reads in the data, sets the input parameters according to the OPTISEP[7] manual, calls the relevant subroutines, and writes out the result.

The subroutine, UREAL, computes the weight of the spring, the objective function of the optimization, for a set of the values of the design varialbes.

The subroutine, CONST, computes the values of the inequality constraints for the design values. The constraints 1 to 12, 18 and 19 are, for the maximum and minimum restrictions of the design variables or their combinations. Constraints 15 to 17 are for the required energy, the allowable stress and the minimum required initial deflection force. The constraints 13, 14 and 20 came from the consistency of the spring configuration.

The subroutine CONST has a bypass to save some computer time. If a set of the design values does not satisfy the first 12 constraints, penalty values are given to the rest of the values of the inequality constraint equations.

The subroutine ENRGY carries out all the calculations for the spring according to the equations and the method as explained in the previous sections of the chapter except Section 10-3. The same notations or the names of the notations are used in most cases if it is possible.

If the material of the optimum solution is not a readily available commercial size, the programme can be run again putting the design variable into two inequality constraints, that is

$$X_{i\,min.} \leq X_i \leq X_{i\,max.}$$

where $X_{i\,min.} = X_{i\,max.}$

The trim programme is also set up for the cases when the designer wants to adjust the optimum result or check the performance of a manufactured spring. Both programmes are listed in the appendices E and F.

The optimization strategies are well explained in the reference (5).

10-8 The design results

Flat springs were designed for the Jacob traps I and III, and Jacob trap I was split into four detailed design as shown in Table 10-1.

TABLE 10-1: Four models of Jacob trap I

Trap ...ration	Spring Design	Spring Configuration	Interior Mechansiam	Max. target energy(in-lbs
1	A	Fig. 9-1(e)	Fig. 9-7	350
2	A	Fig. 9-1(d)	Fig. 9-7	350
1	B	Fig. 9-1(e)	Fig. 9-6	300
2	B	Fig. 9-1(d)	Fig. 9-6	300

The maximum energy levels aimed at were 350 in-lbs. for the Jacob trap I and 800 in-lbs. for the Jacob trap III. But it was found later that the practical attainable maximum energy for the Jacob trap I (design B) was 300 in-lbs. The optimum and trimmed design resuls are shown in Table 10-2 and the computer results in Fig. 10-9 to 10-11.

d

TABLE 10-2: The Design Results for the Jacob traps

	Jacob I (A)		Jacob I (B)		Jacob III	
	Optimum	Trim	Optimum	Trim	Optimum	Trim
ckness of the erial (in.)	.1090	.1090	.1000	.1000	.1720	.1720
h of the material)	2.1815	2.2500	1.9700	2.0000	2.2180	2.3000
end arm length)	5.2183	5.2500	4.6498	4.6250	12.4750	12.5000
length (in.)	.4094	.4375	.4130	.3438	1.2091	1.1875
us of curvature	1.9000	1.8750	1.9000	1.9375	2.3376	2.3750
le of curvature .)	1.9200	1.9200	1.9800	1.9809	1.8238	1.8326
ial horizontal lection (in.)	.5282	.5345	.6314	.6609	.5879	.6912
ignal horizontal lection (in.)	2.50	2.50	2.50	2.50	5.00	5.00
ontal force at al deflection (lbs.)	25.00	22.00	25.00	22.00	20.00	18.00
ontal force at deflection (lbs.)	115.00	119.00	95.00	97.00	140.00	145.00
ng constant .(in)	37.98	39.22	30.34	30.69	25.05	25.48
um stress in the g (lbs/in²)	189,991	190,789	189,984	191,454	189,993	190,558
um energy stored he spring (in-lbs.)	350.00	352.50	300.00	297.50	800.00	815.00
ximate weight of spring (lbs.)	.98	1.001	.79	.80	2.84	2.95

(TIGHT BINDING

FIGURE 10-9: Optimization computer result of the flat spring of the Jacob trap I (design A) SEEK 1

```
 01/29/74 MCMASTER - SCOPE 3.4 AT L348   R.D 00.30
18.14.02.
18.14.02.HVNTOV1
18.14.02.IP  C0001280 WORDS - FILE INPUT , DC 00   HVNTOV1
18.14.03.HVNT,T60.
18.14.03.
18.14.03.ATTACH,OPTISEP.                    YI Y. J.
18.14.03.PFN IS
18.14.03.OPTISEP
18.14.03.PF CYCLE NO. = 003
18.14.03.FTN.
18.14.11.      2.459 CP SECONDS COMPILATION TIME
18.14.11.LDSET,LIB=OPTISEP.
18.14.11.LGO.
18.14.16.      NON-FATAL LOADER ERRORS - SEE MAP
18.14.43.     STOP
18.14.43.     25.147 CP SECONDS EXECUTION TIME
18.14.43.OP  00004992 WORDS - FILE OUTPUT , DC 40
18.14.43.CP       031.738 SEC.
18.14.43.PP       009.329 SEC.
18.14.43.IO       012.427 SEC.
18.14.43.IOM      097.443 WS/512
18.14.43.CPM      892.487 WS/512
18.14.43.ENDJOB 01/29/74


***********               HVNTOV1  //// END OF LIST ////
***********               HVNTOV1  //// END OF LIST ////

$INPUT

X1MAX   =  0.109E+00,
X2MAX   =  0.25E+01,
X3MAX   =  0.6E+01,
X4MAX   =  0.15E+01,
X5MAX   =  0.2E+01,
X6MAX   =  0.2E+01,
DEFM    =  0.25E+01,
E       =  0.3E+08,
HMAX    =  0.725E+01,
WMAX    =  0.5E+01,
STW     =  0.19E+06,
ELOW    =  0.35E+03,
SPWT    =  0.284E+00,
FINIT   =  0.1E+02,
HE      =  0.1875E+01,
$END
```

```
DIRECT SEARCH OPTIMIZATION USING SEEK1

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =    1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .   IDATA  =    1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . . .     N  =    6
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =   20
FRACTION OF RANGE USED AS STEP SIZE . . . . . . . .     F  =        .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . . .  MAXM  =  100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =        .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . . . NEQUS  =    0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . . . NSHOT  =    2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . . . NTEST  =  100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . . RMAX(I) =
  .10900000E+00   .25000000E+01   .60000000E+01   .15000000E+01   .20000000E+01
  .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . . RMIN(I) =
 0.              0.              0.              0.              0.
 0.

STARTING VALUES OF X(I) . . . . . . . . . . . . . . XSTRT(I) =
  .10900000E+00   .23000000E+01   .55000000E+01   .50000000E+00   .20000000E+01
  .19000000E+01
```

FIGURE 10-9: Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .38113771E+00

```
X( 1) = .10900000E+00
X( 2) = .21814453E+01
X( 3) = .52182812E+01
X( 4) = .40941465E+00
X( 5) = .19000000E+01
X( 6) = .19200000E+01
```

INEQUALITY CONSTRAINTS

```
PHI( 1) = .13322676E-14
PHI( 2) = .31955469E+00
PHI( 3) = .78171975E+00
PHI( 4) = .10005859E+01
PHI( 5) = .10000000E+00
PHI( 6) = .80000000E-01
PHI( 7) = -.13322676E-14
PHI( 8) = .21814453E+01
PHI( 9) = .52182812E+01
PHI(10) = .40941465E+00
PHI(11) = .19000000E+01
PHI(12) = .19200000E+01
PHI(13) = .19578923E-03
PHI(14) = .40930735E+00
PHI(15) = 0.
PHI(16) = .96333080E+01
PHI(17) = .15000000E+02
PHI(18) = .20341869E+00
PHI(19) = .38117187E+00
PHI(20) = .13563853E+01
```

```
THICKNESS OF THE SPRING (IN.) . . . . . . =           .109000E+00
WIDTH OF THE SPRING (IN.) . . . . . . . . =           .218145E+01
FREE END ARM LENGTH (IN.) . . . . . . . . =           .521828E+01
BASE LENGTH (IN.) . . . . . . . . . . . . =           .409414E+00
RADIUS OF CURVATURE (IN.) . . . . . . . . =           .190000E+01
ANGLE OF CURVATURE (RAD.) . . . . . . . . =           .192000E+01
INITIAL HORIZONTAL DEFLECTION (IN.) . . . =           .523193E+00
HORIZ. FORCE AT INITIAL DEFLECTION (LBS) =           -.250000E+02
HORIZ. FORCE AT FULL DEFLECTION (LBS) . . =           -.115000E+03
SPRING CONSTANT (LBS/IN.) . . . . . . . . =           .379764E+02
STRESS IN SPRING (LBS/SQ.IN) . . . . . . =           .189991E+06
MAXIMUM ENERGY (IN.-LBS) . . . . . . . . =           .350000E+03
```

FIGURE 10-10: Optimization computer result of the flat spring of the Jacob trap I (design B) SEEK 1

```
 01/29/74 MCMASTER - SCOPE 3.4 AT L349    R.D 00.00
18.11.35.
18.11.35.HVNTOVY
18.11.35.IP  00001280 WORDS - FILE INPUT   HVNTOVY
18.11.35.HVNT,T60.                         , DC 00
18.11.35.
18.11.35.ATTACH,OPTISEP.                  YI Y. J.
18.11.35.PFN IS
18.11.35.OPTISEP
18.11.35.PF CYCLE NO. = 003
18.11.36.FTN.
18.11.43.      2.463 CP SECONDS COMPILATION TIME
18.11.43.LDSET,LIB=OPTISEP.
18.11.43.LGO.
18.11.47.      NON-FATAL LOADER ERRORS - SEE MAP
18.12.13.     STOP
18.12.13.     25.019 CP SECONDS EXECUTION TIME
18.12.13.OP  00005056 WORDS - FILE OUTPUT , DC 40
18.12.13.CP        030.590 SEC.
18.12.13.PP        003.170 SEC.
18.12.13.IO        002.425 SEC.
18.12.13.IOM       087.505 WS/512
18.12.13.CPM       861.808 WS/512
18.12.13.ENDJOB  01/29/74

***********            HVNTOVY  //// END OF LIST ////
***********            HVNTOVY  //// END OF LIST ////

 $INPUT
 X1MAX   =  0.1E+00,
 X2MAX   =  0.25E+01,
 X3MAX   =  0.6E+01,
 X4MAX   =  0.15E+01,
 X5MAX   =  0.2E+01,
 X6MAX   =  0.2E+01,
 DEFM    =  0.25E+01,
 E       =  0.3E+08,
 HMAX    =  0.675E+01,
 WMAX    =  0.5E+01,
 STW     =  0.19E+06,
 ELOW    =  0.3E+03,
 SPWT    =  0.284E+00,
 FINIT   =  0.1E+02,
 HE      =  0.1875E+01,
 $END
```

```
DIRECT SEARCH OPTIMIZATION-USING SEEK1

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =    1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .   IDATA  =    1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . . .     N  =    6
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =   20
FRACTION OF RANGE USED AS STEP SIZE . . . . . . . .     F  =       .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . . .  MAXM  =  100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =       .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . . . NEQUS  =    0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . . . NSHOT  =    2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . . . NTEST  =  100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =

 .10000000E+00  .25000000E+01  .60000000E+01  .15000000E+01  .20000000E+01
 .20000000E+01

ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =

 0.             0.             0.             0.             0.
 0.

STARTING VALUES OF X(I) . . . . . . . . . . . . .XSTRT(I)  =

 .10000000E+00  .22500000E+01  .50000000E+01  .50000000E+00  .20000000E+01
 .19000000E+01
```

FIGURE 10-10: Continued

FIGURE 10-10: Continued

```
                    OPTIMUM SOLUTION FOUND
                  MINIMUM   U =     .79339155E+00

                      X( 1) =       .10000000E+00
                      X( 2) =       .19701172E+01
                      X( 3) =       .46498439E+01
                      X( 4) =       .41304688E+00
                      X( 5) =       .19000000E+01
                      X( 6) =       .19800000E+01

INEQUALITY CONSTRAINTS
                    PHI( 1) =       .84376950E-14
                    PHI( 2) =       .52988281E+00
                    PHI( 3) =       .13501562E+01
                    PHI( 4) =       .10869531E+01
                    PHI( 5) =       .10000000E+00
                    PHI( 6) =       .20000000E-01
                    PHI( 7) =      -.84376950E-14
                    PHI( 8) =       .19701172E+01
                    PHI( 9) =       .46498439E+01
                    PHI(10) =       .41304688E+00
                    PHI(11) =       .19000000E+01
                    PHI(12) =       .19800000E+01
                    PHI(13) =       .10594249E+00
                    PHI(14) =       .30610440E+00
                    PHI(15) =     0.
                    PHI(16) =       .15822346E+02
                    PHI(17) =       .15000000E+02
                    PHI(18) =       .17191300E+00
                    PHI(19) =       .37390525E+00
                    PHI(20) =       .12627912E+01

THICKNESS OF THE SPRING (IN.) . . . . . . =               .100000E+00
WIDTH OF THE SPRING (IN.) . . . . . . . . =               .197012E+01
FREE END ARM LENGTH (IN.) . . . . . . . . =               .464984E+01
BASE LENGTH (IN.) . . . . . . . . . . . . =               .413047E+00
RADIUS OF CURVATURE (IN.) . . . . . . . . =               .190000E+01
ANGLE OF CURVATURE (RAD.) . . . . . . . . =               .198000E+01
INITIAL HORIZONTAL DEFLECTION (IN.) . . . =               .631396E+00
HORIZ. FORCE AT INITIAL DEFLECTION (LBS)  =              -.250000E+02
HORIZ. FORCE AT FULL DEFLECTION (LBS) . . =              -.950000E+02
SPRING CONSTANT (LBS/IN.) . . . . . . . . =               .303379E+02
STRESS IN SPRING (LBS/SQ.IN) . . . . . .  =               .189934E+06
MAXIMUM ENERGY (IN.-LBS) . . . . . . . .  =               .300000E+03
```

FIGURE 10-11: Optimization computer result of the flat spring of the Jacob tran III (SEEK 1)

```
  02/04/74 MCMASTER - SCOPE 3.4 AT L34A    11/14/73
19.51.36.
19.51.35.HVNT038
19.51.35.IP  00001280 WORDS - FILE INPUT  HVNT038
                                          , DC 00
19.51.35.HVNT,T60.
19.51.35.
19.51.36.ATTACH,OPTISEP.                 YI Y. J.
19.51.36.PFN IS
19.51.36.OPTISEP
19.51.36.PF CYCLE NO. = 003
19.51.37.FTN.
19.51.48.     2.483 CP SECONDS COMPILATION TIME
19.51.48.LDSET,LIB=OPTISEP.
19.51.48.LGO.
19.51.54.     NON-FATAL LOADER ERRORS - SEE MAP
19.53.30.    STOP
19.53.30.    36.552 CP SECONDS EXECUTION TIME
19.53.30.OP  00005056 WORDS - FILE OUTPUT , DC 40
19.53.30.CP       042.192 SEC.
19.53.30.PP       011.342 SEC.
19.53.30.IO       002.426 SEC.
19.53.30.IOM      087.519 WS/512
19.53.30.CPM     1172.404 WS/512
19.53.30.ENDJOB 02/04/74

***********          HVNT038  //// END OF LIST ////
***********          HVNT038  //// END OF LIST ////
 $INPUT
 X1MAX    =  0.172E+00,
 X2MAX    =  0.25E+01,
 X3MAX    =  0.14E+02,
 X4MAX    =  0.2E+01,
 X5MAX    =  0.3E+01,
 X6MAX    =  0.2E+01,
 DEFM     =  0.5E+01,
 E        =  0.3E+08,
 HMAX     =  0.15E+02,
 WMAX     =  0.8E+01,
 STW      =  0.19E+06,
 ELOW     =  0.8E+03,
 SPWT     =  0.284E+00,
 FINIT    =  0.2E+02,
 HE       =  0.1875E+01,
 $END
```

```
DIRECT SEARCH OPTIMIZATION USING SEEK1

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =   1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA   =   1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .  N       =   6
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .  NCONS   =   20
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .  F       =      .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .  MAXM    =   100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.  G       =      .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .  NEQUS   =   0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .  NSHOT   =   2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .  NTEST   =   100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . .  RMAX(I) =
  .17200000E+00   .25000000E+01   .14000000E+02   .20000000E+01   .30000000E+01
  .20000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . .  RMIN(I) =
  0.              0.              0.              0.              0.
  0.

STARTING VALUES OF X(I) . . . . . . . . . . . . .  XSTRT(I) =
  .17200000E+00   .22500000E+01   .12440000E+02   .12958000E+01   .23713000E+01
  .18338000E+01
```

FIGURE 10-11: Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .28420481E+01

```
X( 1) = .17200000E+00
X( 2) = .22179687E+01
X( 3) = .12475000E+02
X( 4) = .12090813E+01
X( 5) = .23375500E+01
X( 6) = .18238000E+01
```

INEQUALITY CONSTRAINTS

```
PHI( 1) = -.71054274E-14
PHI( 2) = .28203125E+00
PHI( 3) = .15250000E+01
PHI( 4) = .79091875E+00
PHI( 5) = .66245000E+00
PHI( 6) = .17620000E+00
PHI( 7) = -.71054274E-14
PHI( 8) = .22179687E+01
PHI( 9) = .12475000E+02
PHI(10) = .12090813E+01
PHI(11) = .23375500E+01
PHI(12) = .18238000E+01
PHI(13) = .85952243E+00
PHI(14) = .34955882E+00
PHI(15) = 0.
PHI(16) = .74924118E+01
PHI(17) = 0.
PHI(18) = .52698818E-03
PHI(19) = .90673750E+00
PHI(20) = .11758824E+01
```

```
THICKNESS OF THE SPRING (IN.) . . . . . =            .172000E+00
WIDTH OF THE SPRING (IN.) . . . . . . . . =          .221797E+01
FREE END ARM LENGTH (IN.) . . . . . . . . =          .124750E+02
BASE LENGTH (IN.) . . . . . . . . . . . . =          .120908E+01
RADIUS OF CURVATURE (IN.) . . . . . . . . =          .233755E+01
ANGLE OF CURVATURE (RAD.) . . . . . . . . =          .182380E+01
INITIAL HORIZONTAL DEFLECTION (IN.) . . . =          .587941E+00
HORIZ. FORCE AT INITIAL DEFLECTION (LBS) =          -.200000E+02
HORIZ. FORCE AT FULL DEFLECTION (LBS) . =          -.140000E+03
SPRING CONSTANT (LBS/IN.) . . . . . . . . =          .250540E+02
STRESS IN SPRING (LBS/SQ.IN) . . . . . . . =          .189993E+06
MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =          .800000E+03
```

11. ROUND WIRE COIL SPRING DESIGN

The round wire coil spring provides an alternative to the flat spring in an attempt to increase the underwater performance of the Jacob trap. The helical torsion spring frame was designed and manufactured for the Jacob trap III.

11-1 Definition of the parameters

Throughout this chapter, the following definitions and notations of the parameters will be used (see Figure 11-1)

d	Wire diameter (in.)
D	Mean coil diameter (in.)
n	Number of coil
ℓ	Free end arm length (in.)
ϕ_1, ϕ_2	Initial and final deflection (torsion) angle (rad.)
E	Modulus of elasticity of the material (lbs/sq.in.)
DEFM	Chord of the additional deflection angle with the free end arm length as a radius (in.)
H	Height of the spring (in.)
B	Base length of the spring (in.)
P	Tangential force at the end of the free end arm (lbs.)
FW1	P at the initial deflection (lbs.)

11-2 Strain energy and stress

In setting up the equations, it is assumed that the base of the spring frame is a rigid bar. It is intended to

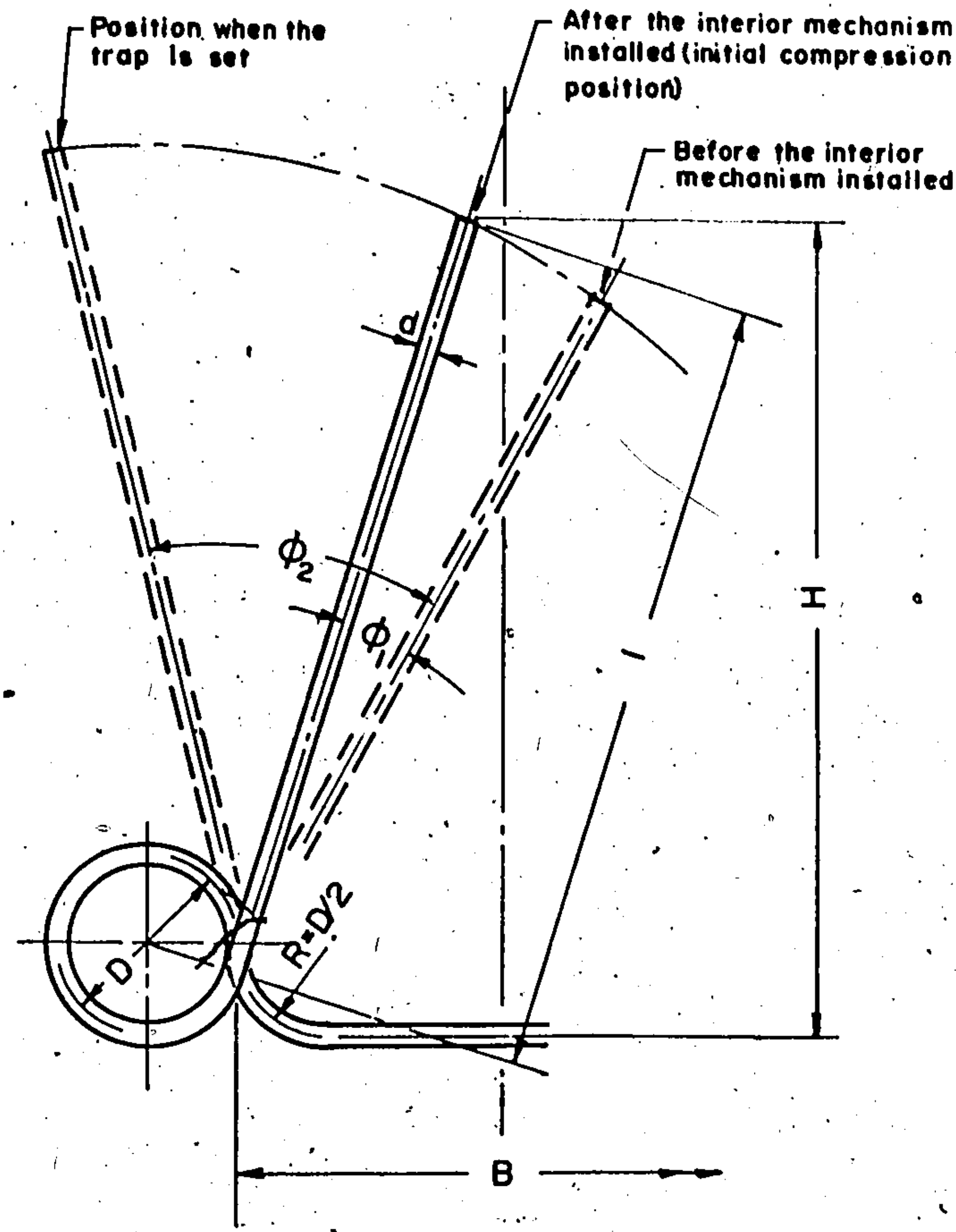

Position when the trap is set
After the interior mechanism installed (initial compression position)
Before the interior mechanism installed
d
ϕ_2
ϕ_1
H
l
D
R=D/2
B

Fig. II - 1

clamp a mounting plate to the base. This makes the left (or right) of the frame identical to the Conibear trap spring except for one free end arm instead of two. Therefore, the same formulae as discussed in Section 2-2 can be used with suitable modification.

Equation (2-3) becomes

$$\phi_a = \frac{64}{3}\frac{P\ell^2}{E\pi d^4} \tag{11-1}$$

considering only one free end arm. Combining equations (2-1) and (11-1), the total deflection angle ϕ_2 will be:

$$\phi_2 = \phi_s + \phi_a \tag{11-2}$$

$$= \frac{64P\ell}{Ed^4}\left(D\cdot n + \frac{\ell}{3\pi}\right)$$

Noting that $M=P\ell$ is a torsional moment and rearranging the equation (11-2)

$$M = \frac{Ed^4\phi_2}{64\left(D\cdot n + \frac{\ell}{3\pi}\right)} \tag{11-3}$$

And the energy equation becomes:

$$U = \frac{Ed^4}{64\left(D.n + \frac{\ell}{3\pi}\right)}\,\frac{\phi_2^{\,2} - \phi_1^{\,2}}{2} \times 2 \tag{11-4}$$

for both sides of the spring. The maximum bending stress $\sigma_{max.}$ occurs at the inside surface of the coil and is the same as equation (2-8) that is:

$$\sigma_{max.} = K_1\frac{32M}{\pi d^3} \tag{11-5}$$

where $K_1 = \frac{4c^2-c-1}{4c(c-1)}$

$c = D/d$

11-3 Optimization computer programme and design results

The computer programme is set up in almost the same way as for the Conibear trap spring as explained in Section 3-2. The equations in the subroutines UREAL and ENRGY are altered for the Jacob trap, some of them as explained in the previous section. Also, the trim programme is provided to adjust the optimum result if it is required. Subroutines SEEK 1 and SIMPLX from the OPTISEP[7] package are utilized. The programmes are listed in the appendices G and H. As in the case of the flat spring, the input parameters are decided from a preliminary investigation of the interior mechanism. The springs for the Jacob traps III and I only were designed and listed in Table 11-1 The optimum result of the Jacob trap I is trimmed in two ways, one for a commercial size of wire larger than the optimum and the other for a smaller commercial size. The computer results are shown on Figure 11-2 to 11-3.

TABLE 11-1: Design results of the Jacob trap with the circular wire spring.

	Jacob III			Jacob I			
	SEEK 1	SIMPLX	TRIM	SEEK 1	SIMPLX	TRIM(A)	TRIM(B)
re dia. (in.)	.4375	.4364	.4375	.3286	.3204	.3120	.3430
an coil dia (n.)	2.7674	2.8018	2.7500	1.9803	2.2093	2.1250	2.0000
. of turns f coil	2.8498	2.7202	2.9194	2.9769	3.0383	2.9083	2.9431
ree end arm ength (in.)*	11.600	12.2238	12.5000	5.6495	5.5255	6.0000	6.0000
itial def. gle (rad.)	.3000	.3068	.3316	.2431	.3427	.4363	.2182
rce at initial ef. (lbs.)	48.43	47.84	48.70	36.31	41.98	47.38	36.17
tress in ring (psi)	189,998	189,947	186,007	189,999	187,763	210,037	183,615
ax. energy tored in the rings (in-lbs)	839.6	805.4	788.0	350.1	352.7	353.5	357.4
eight (lbs.)	3.50	3.46	3.61	1.23	1.33	1.21	1.41

FIGURE 11- 2(a): Optimization computer result of the circular wire spring of the Jacob trap III - SEEK 1

```
12/29/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
12.08.09.
12.08.09.HVNT02H                               HVNT02H
12.08.09.IP  00000896 WORDS - FILE INPUT   , DC 00
12.08.09.HVNT,T60.
12.08.09.                                  YI Y. J.
12.08.09.ATTACH,OPTISEP.
12.08.09.PEN IS
12.08.09.OPTISEP
12.08.09.PF CYCLE NO. = 002
12.08.09.FTN.
12.08.16.      1.314 CP SECONDS COMPILATION TIME
12.08.16.LDSET,LIB=OPTISEP.
12.08.16.LGO.
12.08.21.      STOP
12.08.21.       1.521 CP SECONDS EXECUTION TIME
12.08.21.OP  00004096 WORDS - FILE OUTPUT , DC 40
12.08.21.CP        005.104 SEC.
12.08.21.PP        008.601 SEC.
12.08.21.IO        002.612 SEC.
12.08.21.IOM       093.714 WS/512
12.08.21.CPM       139.067 WS/512
12.08.21.ENDJOB 12/29/73

************          HVNT02H  //// END OF LIST ////
************          HVNT02H  //// END OF LIST ////

$INPUT
X1MAX    =  0.5E+00,
X2MAX    =  0.31E+01,
X3MAX    =  0.31E+01,
X4MAX    =  0.135E+02,
X5MAX    =  0.5E+00,
DEFM     =  0.5E+01,
E        =  0.3E+08,
STW      =  0.19E+06,
EUOW     =  0.8E+03,
SPWT     =  0.284E+00,
FINIT    =  0.2E+02,
BASE     =  0.75E+01,
HMIN     =  0.13E+02,
$END
```

```
DIRECT SEARCH OPTIMIZATION USING SEEK1

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . . IPRINT =     1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA =     1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .      N =     5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .  NCONS =    14
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .      F =       .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .   MAXM =   100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.      G =       .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .  NEQUS =     1
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .  NSHOT =     2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .  NTEST =   100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I) =
 .50000000E+00   .31000000E+01   .31000000E+01   .13500000E+02   .50000000E+00
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I) =
 0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . . XSTRT(I) =
 .43750000E+00   .27500000E+01   .28500000E+01   .11660000E+02   .30000000E+00
```

FIGURE 11-12(a): Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .34988449E+01

```
X( 1) = .43750000E+00
X( 2) = .27674375E+01
X( 3) = .28497578E+01
X( 4) = .11660000E+02
X( 5) = .30000000E+00
```

INEQUALITY CONSTRAINTS

```
PHI( 1) = .62500000E-01
PHI( 2) = .33256250E+00
PHI( 3) = .25024219E+00
PHI( 4) = .18400000E+01
PHI( 5) = .20000000E+00
PHI( 6) = .43750000E+00
PHI( 7) = .27674375E+01
PHI( 8) = .28497578E+01
PHI( 9) = .11660000E+02
PHI(10) = .30000000E+00
PHI(11) = .39636767E+02
PHI(12) = .22427896E+01
PHI(13) = .28429016E+02
PHI(14) = .43718750E-01
```

EQUALITY CONSTRAINTS

```
PSI( 1) = .18474111E-12
```

```
FORCE AT INITIAL DEFLECTION(LBS) . . . . . =        .484290E+02
STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =        .189998E+06
MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =        .839637E+03

WIRE DIAMETER (IN.) . . . . . . . . . . . =         .4375
MEAN COIL DIAMETER (IN.) . . . . . . . . . =        2.7674
NUMBER OF TURNS OF COIL . . . . . . . . . =         2.8498
FREE END ARM LENGTH (IN.) . . . . . . . . =         11.6600
INITIAL DEFLECTION ANLGE (RAD.) . . . . . =         .3000
```

FIGURE 11- 2(b): Optimization computer result of the circular wire spring of the Jacob trap III - SIMPLX

```
12/29/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
12.56.54.
12.56.54.HVNT028
12.56.54.IP  00000960 WORDS - FILE INPUT     HVNT028
                                           , DC 00
12.56.54.HVNT,T60.
12.56.54.                                YI Y. J.
12.56.54.ATTACH,OPTISEP.
12.56.54.PFN IS
12.56.54.OPTISEP
12.56.54.PF CYCLE NO. = 002
12.56.54.FTN.
12.57.01.       1.378 CP SECONDS COMPILATION TIME
12.57.01.RDSET,LIB=OPTISEP.
12.57.01.LGO.
12.57.09.      STOP
12.57.09.       4.908 CP SECONDS EXECUTION TIME
12.57.10.OP  00006080 WORDS - FILE OUTPUT , DC 40
12.57.10.CP       008.460 SEC.
12.57.10.PP       009.800 SEC.
12.57.10.IO       002.635 SEC.
12.57.10.IOM      094.170 WS/512
12.57.10.CPM      202.518 WS/512
12.57.10.ENDJOB 12/29/73

***********          HVNT028  //// END OF LIST ////
***********          HVNT028  //// END OF LIST ////

$INPUT
X1MAX    =  0.5E+00,
X2MAX    =  0.31E+01,
X3MAX    =  0.31E+01,
X4MAX    =  0.135E+02,
X5MAX    =  0.5E+00,
DEFM     =  0.5E+01,
E        =  0.3E+08,
STW      =  0.19E+06,
ELOW     =  0.8E+03,
SPWT     =  0.284E+00,
FINIT    =  0.2E+02,
BASE     =  0.75E+01,
HMIN     =  0.13E+02,
$END
```

```
              OPTIMIZATION BY SIMPLX METHOD,

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =    1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA   =    1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .       N  =    5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =   14
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F  =      .10000000E+00
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM  =  500
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =      .20000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =    1
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
 .50000000E+00   .31000000E+01   .31000000E+01   .13500000E+02   .50000000E+00
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
 0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . . XSTRT(I) =
 .43750000E+00   .30000000E+01   .30000000E+01   .12000000E+02   .25000000E+00
```

FIGURE 11-12(b): Continued

```
OPTIMUM SOLUTION FOUND
MINIMUM  U =   .34593616E+01

           X( 1) =   .43640869E+00
           X( 2) =   .28017993E+01
           X( 3) =   .27201613E+01
           X( 4) =   .12223757E+02
           X( 5) =   .30675179E+00

INEQUALITY CONSTRAINTS
         PHI( 1) =   .63591314E-01
         PHI( 2) =   .29820068E+00
         PHI( 3) =   .37983875E+00
         PHI( 4) =   .12762426E+01
         PHI( 5) =   .19324821E+00
         PHI( 6) =   .43640869E+00
         PHI( 7) =   .28017993E+01
         PHI( 8) =   .27201613E+01
         PHI( 9) =   .12223757E+02
         PHI(10) =   .30675179E+00
         PHI(11) =   .53529704E+01
         PHI(12) =   .52806678E+02
         PHI(13) =   .27842495E+02
         PHI(14) =   .62465710E+00

EQUALITY CONSTRAINTS
         PSI( 1) =   .10913140E-02

FORCE AT INITIAL DEFLECTION(LBS) . . . . . =   .473425E+02
STRESS IN SPRING (LBS/SQ.IN.). . . . . . . =   .189947E+06
MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =   .805353E+03

WIRE DIAMETER (IN.) . . . . . . . . . . . =     .4364
MEAN COIL DIAMETER (IN.) . . . . . . . . . =    2.8018
NUMBER OF TURNS OF COIL . . . . . . . . . =    2.7202
FREE END ARM LENGTH (IN.) . . . . . . . . =   12.2238
INITIAL DEFLECTION ANLGE (RAD.) . . . . . =     .3068
```

FIGURE 11-3(a): Optimization computer result of the circular wire spring of the Jacob trap I - SEEK 1

```
  12/29/73 MCMASTER - SCOPE 3.4 AT L348     11/14/73
12.27.05.
12.27.05.HVNT02V                           HVNT02V
12.27.05.IP  00000896 WORDS - FILE INPUT , DC 00
12.27.05.HVNT,T60.
12.27.05.                              YI Y. J.
12.27.05.ATTACH,OPTISEP.
12.27.05.PFN IS
12.27.05.OPTISEP
12.27.06.PF CYCLE NO. = 002
12.27.06.FTN.
12.27.11.    1.264 CP SECONDS COMPILATION TIME
12.27.12.LDSET,LIB=OPTISEP.
12.27.12.LGO.
12.27.15.     NON-FATAL LOADER ERRORS - SEE MAP
12.27.16.    STOP
12.27.16.      .983 CP SECONDS EXECUTION TIME
12.27.16.OP  00003712 WORDS - FILE OUTPUT , DC 40
12.27.16.CP        004.582 SEC.
12.27.16.PP        007.647 SEC.
12.27.16.IO        002.277 SEC.
12.27.16.IOM       080.104 WS/512
12.27.16.CPM       128.739 WS/512
12.27.16.ENDJOB 12/29/73

***********          HVNT02V  //// END OF LIST ////
***********          HVNT02V  //// END OF LIST ////

$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.3E+01,
X3MAX   =  0.4E+01,
X4MAX   =  0.7E+01,
X5MAX   =  0.1E+01,
DEFM    =  0.25E+01,
E       =  0.3E+08,
STW     =  0.19E+06,
ELOW    =  0.35E+03,
SPWT    =  0.284E+00,
FINIT   =  0.15E+02,
BASE    =  0.35E+01,
HMIN    =  0.65E+01,
$END
```

```
DIRECT SEARCH OPTIMIZATION USING SEEK1

INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . . IPRINT  =   1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA  =   1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .      N  =   5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .  NCONS  =  14
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .      F  =    .10000000E-01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .   MAXM  = 100
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.      G  =    .10000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .  NEQUS  =   0
NUMBER OF SHOTGUN SEARCHES PERMITTED. . . . . . .  NSHOT  =   2
NUMBER OF TEST POINTS IN SHOTGUN SEARCH . . . . .  NTEST  = 100
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I) =
  .50000000E+00   .30000000E+01   .40000000E+01   .70000000E+01   .10000000E+01
ESTIMATED LOWER-BOUND ON RANGE OF X(I). . . . . . RMIN(I) =
 0.              0.              0.              0.              0.

STARTING VALUES OF X(I) . . . . . . . . . . . . . XSTRT(I) =
  .35000000E+00   .20000000E+01   .30000000E+01   .60000000E+01   .25000000E+00
```

FIGURE 11-3(a): Continued

FIGURE 11-3(a): Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .12757130E+01

X(1) = .32859375E+00
X(2) = .19803125E+01
X(3) = .29768750E+01
X(4) = .56494531E+01
X(5) = .24312500E+00

INEQUALITY CONSTRAINTS

PHI(1) = .17140625E+00
PHI(2) = .10196875E+01
PHI(3) = .10231250E+01
PHI(4) = .13505469E+01
PHI(5) = .75687500E+00
PHI(6) = .32859375E+00
PHI(7) = .19803125E+01
PHI(8) = .29768750E+01
PHI(9) = .56494531E+01
PHI(10) = .24312500E+00
PHI(11) = .10836927E+00
PHI(12) = .13538866E+01
PHI(13) = .21211907E+02
PHI(14) = .13960937E+00

FORCE AT INITIAL DEFLECTION(LBS) . . . . . = .362119E+02
STRESS IN SPRING (LBS/SQ.IN.). . . . . . . = .189999E+06
MAXIMUM ENERGY (IN.-LBS) . . . . = .350108E+03

WIRE DIAMETER (IN.) . . . . = .3286
MEAN COIL DIAMETER (IN.) . . . . = 1.9803
NUMBER OF TURNS OF COIL . . . . = 2.9769
FREE END ARM LENGTH (IN.) . . . . = 5.6495
INITIAL DEFLECTION ANLGE (RAD.) . . . . . = .2431

FIGURE 11-3(b): Optimization computer results of the circular wire spring of the Jacob trap I - SIMPLX

```
 12/29/73 MCMASTER - SCOPE 3.4 AT L348    11/14/73
12.26.05.
12.26.05.HVNT02T                                  HVNT02T
12.26.05.IP  00000896 WORDS - FILE INPUT  , DC 00
12.26.05.HVNT02T60.
12.26.05.                                   YI Y. J.
12.26.05.ATTACH,OPTISEP.
12.26.05.PFN IS
12.26.05.OPTISEP
12.26.05.PF CYCLE NO. = 002
12.26.05.FTN.
12.26.13.      1.324 CP SECONDS COMPILATION TIME
12.26.13.LDSET,LIB=OPTISEP.
12.26.14.LGO.
12.26.18.      NON-FATAL LOADER ERRORS - SEE MAP
12.26.35.     STOP
12.26.35.     10.343 CP SECONDS EXECUTION TIME
12.26.35.OP  00008960 WORDS - FILE OUTPUT , DC 40
12.26.35.CP        014.077 SEC.
12.26.35.PP        008.599 SEC.
12.26.35.IO        002.351 SEC.
12.26.36.IOM       081.496 WS/512
12.26.36.CPM       307.864 WS/512
12.26.36.ENDJOB 12/29/73

************          HVNT02T  //// END OF LIST ////
************          HVNT02T  //// END OF LIST ////

$INPUT
X1MAX   =  0.5E+00,
X2MAX   =  0.3E+01,
X3MAX   =  0.4E+01,
X4MAX   =  0.7E+01,
X5MAX   =  0.1E+01,
DEFM    =  0.25E+01,
E       =  0.3E+08,
STW     =  0.19E+06,
FLOW    =  0.35E+03,
SPWT    =  0.284E+00,
FINIT   =  0.15E+02,
BASE    =  0.35E+01,
HMIN    =  0.65E+01,
$END
```

OPTIMIZATION BY SIMPLX METHOD,

```
INTERMEDIATE OUTPUT EVERY IPRINT(TH) CYCLE. . . .  IPRINT  =   1
INPUT DATA IS PRINTED OUT FOR IDATA=1 ONLY. . . .  IDATA   =   1
NUMBER OF INDEPENDENT VARIABLES . . . . . . . . .       N  =   5
NUMBER OF INEQUALITY (.GE.) CONSTRAINTS . . . . .   NCONS  =   14
FRACTION OF RANGE USED AS STEP SIZE . . . . . . .       F  =      .10000000E+01
MAXIMUM NUMBER OF MOVES PERMITTED . . . . . . . .    MAXM  =   500
STEP SIZE FRACTION USED AS CONVERGENCE CRITERION.       G  =      .20000000E-01
NUMBER OF EQUALITY CONSTRAINTS. . . . . . . . . .   NEQUS  =   0
ESTIMATED UPPER BOUND ON RANGE OF X(I). . . . . . RMAX(I)  =
  .50000000E+00   .30000000E+01   .40000000E+01   .70000000E+01   .10000000E+01
ESTIMATED LOWER BOUND ON RANGE OF X(I). . . . . . RMIN(I)  =
 0.               0.              0.              0.              0.
STARTING VALUES OF X(I) . . . . . . . . . . . . . XSTRT(I) =
  .25000000E+00   .15000000E+01   .20000000E+01   .35000000E+01   .50000000E+00
```

FIGURE 11-3(b): Continued

OPTIMUM SOLUTION FOUND

MINIMUM U = .13278263E+01

```
X( 1) =   .32040393E+00
X( 2) =   .22093285E+01
X( 3) =   .30382532E+01
X( 4) =   .55254709E+01
X( 5) =   .34267641E+00
```

INEQUALITY CONSTRAINTS

```
PHI( 1) =   .17959607E+00
PHI( 2) =   .79067146E+00
PHI( 3) =   .96174684E+00
PHI( 4) =   .14745291E+01
PHI( 5) =   .65732359E+00
PHI( 6) =   .32040393E+00
PHI( 7) =   .22093285E+01
PHI( 8) =   .30382532E+01
PHI( 9) =   .55254709E+01
PHI(10) =   .34267641E+00
PHI(11) =   .26972474E+01
PHI(12) =   .22370117E+04
PHI(13) =   .26975692E+02
PHI(14) =   .13013519E+00
```

```
FORCE AT INITIAL DEFLECTION(LBS) . . . . =      .419757E+02
STRESS IN SPRING (LBS/SQ.IN.). . . . . . =      .187763E+06
MAXIMUM ENERGY (IN.-LBS) . . . . . . . . =      .352697E+03

WIRE DIAMETER (IN.)  . . . . . . . . . . =      .3204
MEAN COIL DIAMETER (IN.) . . . . . . . . =     2.2093
NUMBER OF TURNS OF COIL  . . . . . . . . =     3.0383
FREE END ARM LENGTH (IN.)  . . . . . . . =     5.5255
INITIAL DEFLECTION ANLGE (RAD.)  . . . . =      .3427
```

12. JACOB TRAP EVALUATION

It has been mentioned earlier in Chapter 5, that the actual available Kinetic energy can only be determined by test.

The energy losses in the case of the Jacob trap are mainly due to:

(a) The friction between the parts of the mechanism.

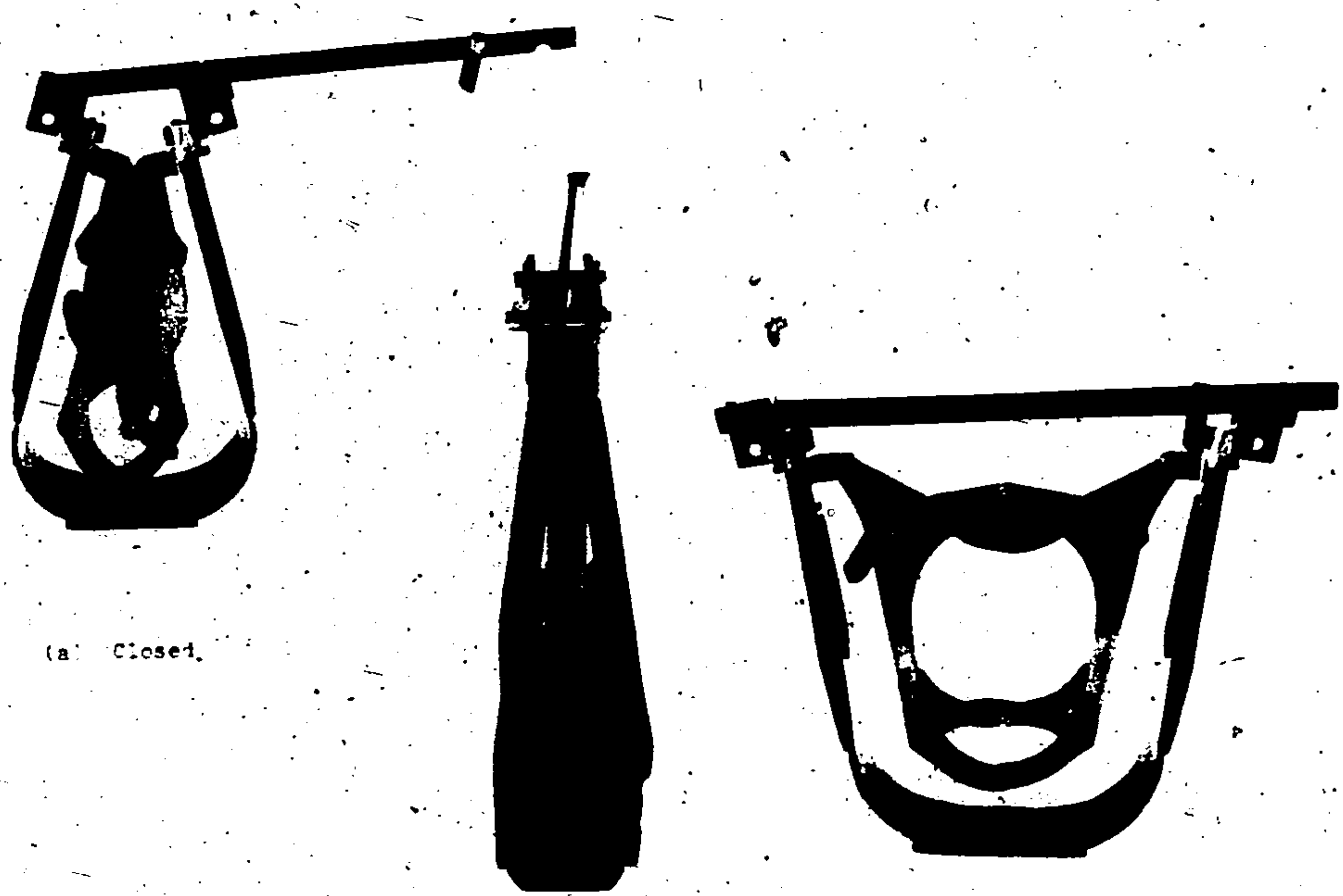
(b) The friction of the moving parts with the environment. (air, water or ice).

(c) The Kinetic energy consumed by the stirrup, the cradle and the trigger bar.

In this chapter, the horizontal forces at the end of the free end arms, clamping forces and both the theoretical and actual Kinetic energy were obtained and compared at various jaw openings. A new method is developed and programmed for the analysis of the high speed film readings to obtain the kinetic energy output of the Jacob trap.

12-1 Jacob trap prototypes

Four prototypes* were actually fabricated, the three different models of Jacob trap I and one Jacob trap III as shown in Figures 12-1 to 12-4. The actual configuration of the springs for the Jacob trap I models as fabricated, turned out to be slightly different from the designs as in Table 10-2. The manufactured spring and trap specifications are listed in Tables 12-1. The method of obtaining the dimensions, shown



(a) Closed.

(b) Side view

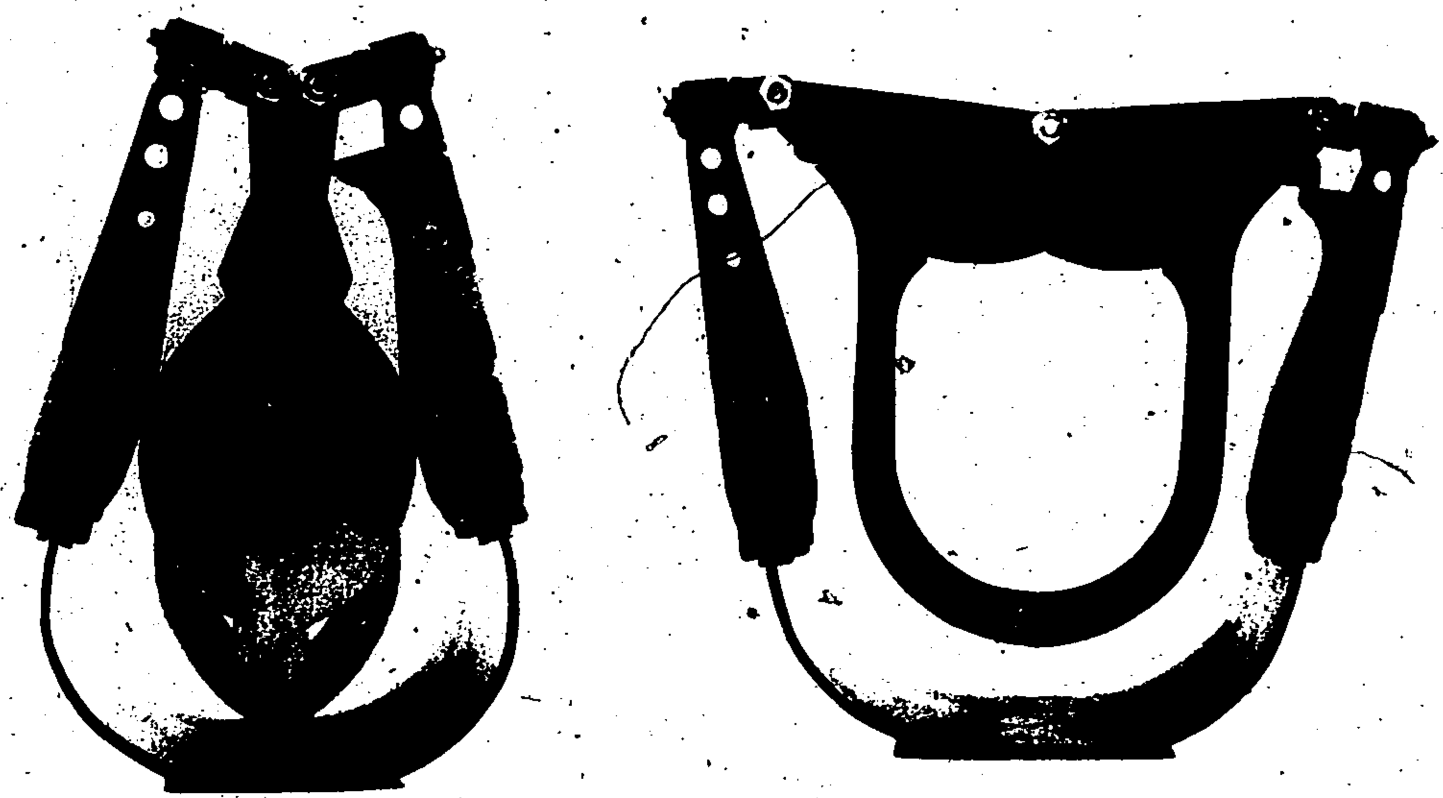
(c) Open

Figure 12-1 Jacob Trap I - Prototype A1

(a) Closed

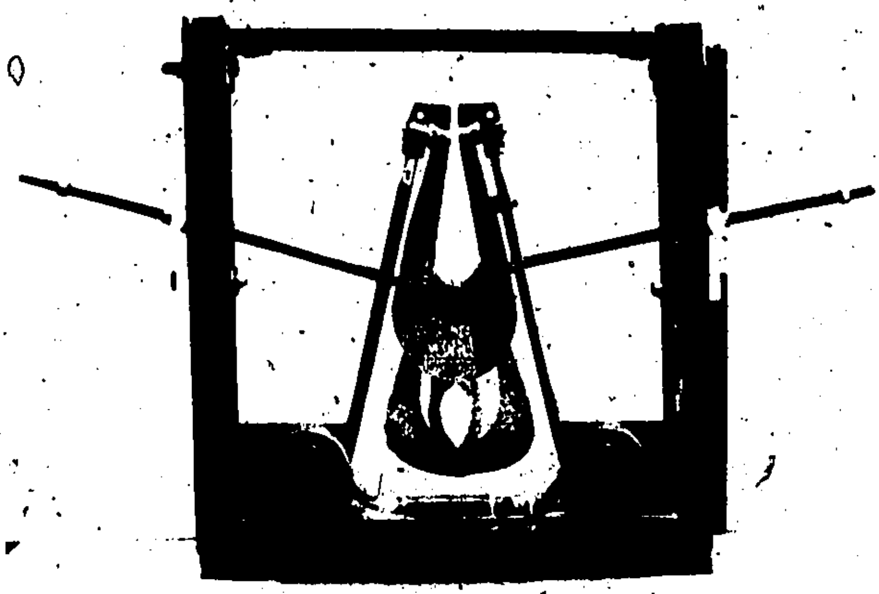
(b) Open

Figure 12-2 Jacob Trap I - Prototype A2

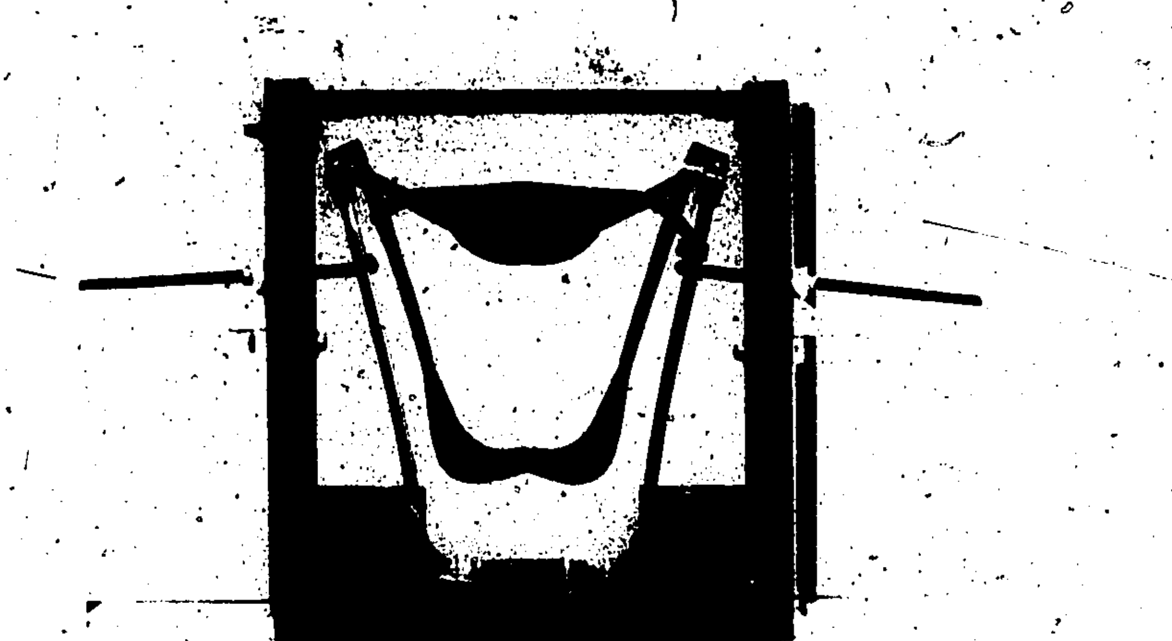


(a) Closed (b) Open

Figure 12-3 Jacob Trap I - Prototype P2



(a) Closed



(b) Open

Figure 12-4 Jacob Trap III.- Prototype

in the table of the imaginary slider crank mechanism is explained later in this chapter. Also the specifications for the springs which were manufactured for the previous project[2], are shown in Table 12-2 for the reference. No further testing was carried out on the Jacob trap III prototype, the spring of which was made out of circular wire, because the motion of the two free end arms were not on the same plane and unstable, resulting in twisting of the interior mechanism when the trap was closed.

---

* The spring material is SAE and AISI #1075. In this size range, the material has been heat treated to produce a tensile strength of 238,000 to 290,000 psi and a hardness between Rc 44 and Rc 48.

For thicker Springs, it is necessary to use a more expensive material such as Chromium-Vandium alloy steel, SAE #6150 or Manganese-Silicon alloy steel, SAE #9254.

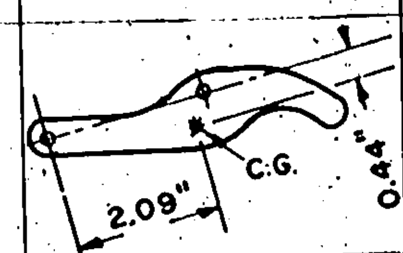
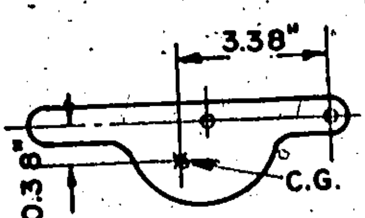
The above data were obtained from the Barnes-Wallace Co. Ltd., Hamilton, Ontario.

Using the lower value of 238,000 psi tensile strength, the allowable stress 190,000 psi will give a factor of safety [9] of 1.25.

TABLE 12-13. Specifications for the Jacob trap I prototypes

Specification \ Model	A1	A2	B2
Thickness of the spring material (in.)	.1090	.1000	.1000
Width of the spring material (in.)	2.125	2.300	2.300
Length of the free end arm (in.)	5.4375	5.6250	4.9375
Length of the base spring (in.)	.5313	.7500	.4219
Radius of curvature of the curved spring (in.)	1.7500	1.6250	1.7500
Angle of the curvature of the curved spring (in.)	1.9199	1.9286	1.8937
Initial horizontal deflection (in.)	.6217	.6354	.4228
Additional horizontal deflection (in.)	2.500	2.500	2.500
Horizontal force at initial deflection (lbs.)	24.00	20.00	17.00
Horizontal force at full deflection (lbs.)	117.00	96.00	111.00
Spring constant (lbs. per in. of horizontal def.)	37.48	30.62	37.98
Max. stress (lbs./in^2)	200,355	181,983	194,129
Max. strain energy stored (in-lbs)	352.50	290.00	320.00
Weight of the spring (lbs.)	.9538	.9547	.8809

TABLE 12-1: Specifications of the Jacob trap I prototypes (cont'd)

		Model / Specifications	A1	A2	B2
...x. overall di-...ions (HxWxD, In.)			9.5 x 4.8 x 2.25	8.6 x 5.4 x 2.3	7.5 x 5.2 x 2.3
...hts ...)	free end arm		.563	.800	.750
	strike bar		.188	.188	.250
	total		2.50	2.75	2.50
...ension ...the ...ehar- ...sm, ...s, ...mbs ...)	crank length		6.75	6.63	6.25
	rocker length		3.00	3.00	3.00
	offset		1.91	2.10	1.72
...ent ...Iner- ...(lb.in²)	The free end arms w.r.t. its center of rotation		16.53	9.84	9.77
	Strike bar w.r.t. its center of gravity		.416	.416	.487
...ation of C.G. of ...strike bar (In.)				The same as A1	
...ure			Fig. 12-1	Fig. 12-2	Fig. 12-3
...ge Configuration			Fig. 9-1(c)	Fig. 9-1(d)	Fig. 9-1(d)
...ke bar and Stirrup			Fig. 9-7	Fig. 9-7	Fig. 9-6
...ger			Fig. 9-12	Fig. 9-11	Fig. 9-11

TIGHT BINDING

TABLE 1?-?: Specifications of the Jacob trap prototypes (manufactured for the previous project[2])

Model / Specifications	Jacob trap I		Jacob trap II		Jacob trap III	
	Design	Mfg'd	Design	Mfg'd	Design	Mfg'd
...ickness of the ...ring material (in)	.0678	.0680	.1000	.1000	.1250	.1265
...th of the spring ...terial (in.)	1.5000	1.5000	1.7500	1.7500	2.0000	2.0234
...gth of the free ... arm (in.)	5.8000	5.4375	7.7500	7.1875	10.3000	10.0625
...gth of the base ...ring (in.)	.2000	.1563	.4500	.4063	.5000	.3281
...dius of curvature ... the curved spring ...(in.)	1.0000	1.1250	1.2000	1.3125	1.7500	2.0000
...le of the curva-...re of the curved ...ring (in.)	1.7800	1.7104	1.7800	1.7435	1.7800	1.7628
...itial deflection (in.)	0	0	0	0	0	0
...itiona deflec-...on (in.)	3.5000	3.5000	4.1750	4.1750	6.5000	6.5000
...rce at initial ...flection (lbs.)	0	0	0	0	0	0
...rce at full ...flection (lbs.)	28.00	31.00	53.00	61.00	76.00	79.00
...ring constant (lbs./in.)	8.000	8.857	12.69	14.61	11.69	12.15
...x. stress (lbs/in²)	165,954	176,288	162,937	178,120	176,138	176,890
...x. energy (in-lbs)	98.00	108.50	221.28	254.68	494.00	513.50
...ight of spring (lbs.)	.4494	.4356	1.0274	.9823	1.9760	2.0233

TIGHT BINDING

12-2 Spring test

The flat springs manufactured for the project and from the previous project were tested to compare the results with the calculated data. It is also a way to confirm the design equations and methods as explained in Chapter 10. They were reasonably close as shown in the following Tables 12-3 to 12-8 and Figures 12-5 to 12-10. The fairly large deviation between the initial and the following test in the case of the prototype A1 (Table 12-3 and Fig. 12-5) was because the spring was overstressed accidentally during the initial test.

For the springs from the previous project where the free end arm is deflectable, the test values deviate from the calculated data, and the deviation increases with the amount of the horizontal deflection. This is because the equations used are linear approximations to the non-linear relation between the applied force and the horizontal deflection at the end of the free end arm.

The theoretical values are from the result of the computer programme in Appendix F.

TABLE 12-3: Test data of the spring for the Jacob trap I-prototype A1

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
.50	20.2	12.5	10.6	10.3	11.13	22.5
1.0	36.0	28.5	27.2	25.6	27.10	38.9
1.5	53.8	45.8	44.6	43.8	44.73	57.0
2.0	71.8	64.2	62.6	62.0	62.93	75.8
2.5	90.0	83.0	81.7	80.7	81.80	93.8
3.0	106.5	101.6	100.8	99.8	100.73	112.9

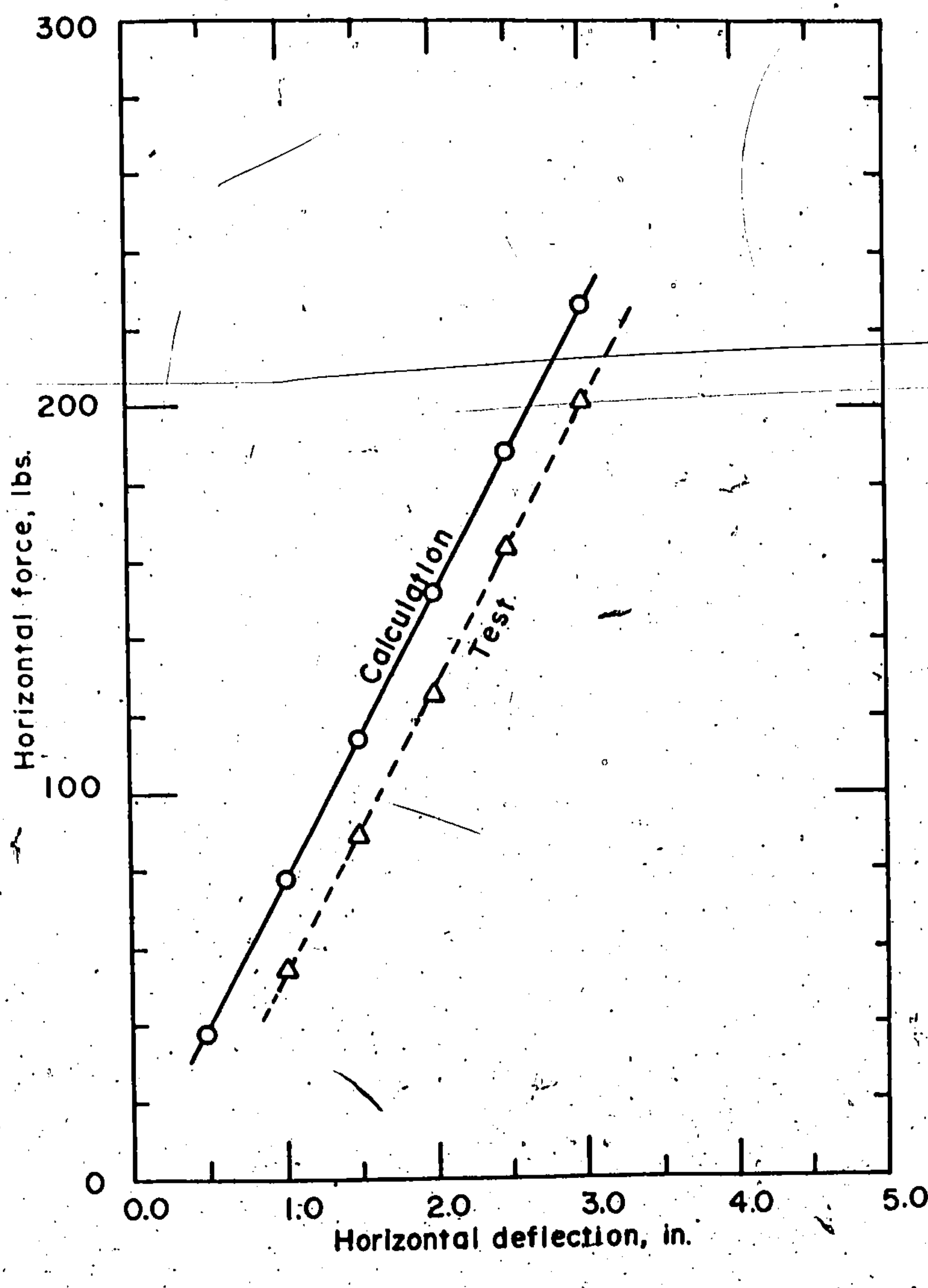


FIGURE 12-5: Horizontal force - deflection diagram of the flat spring for the Jacob tram I - Prototype A1

TABLE 12-4: Test data of the spring for the Jacob trap I - prototype A2

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
0.6"	24	19	18.6	18.0	18.5	19.2
1.1	39	33.2	33	32.4	32.9	34.2
1.6	52	47	47	47.2	47.1	49.0
2.1	65	61	60.6	60.0	60.5	64.0
2.6	80.8	78	75.6	75.2	76.3	79.0
3.1	93	92.5	92.0	92.0	92.2	94.0

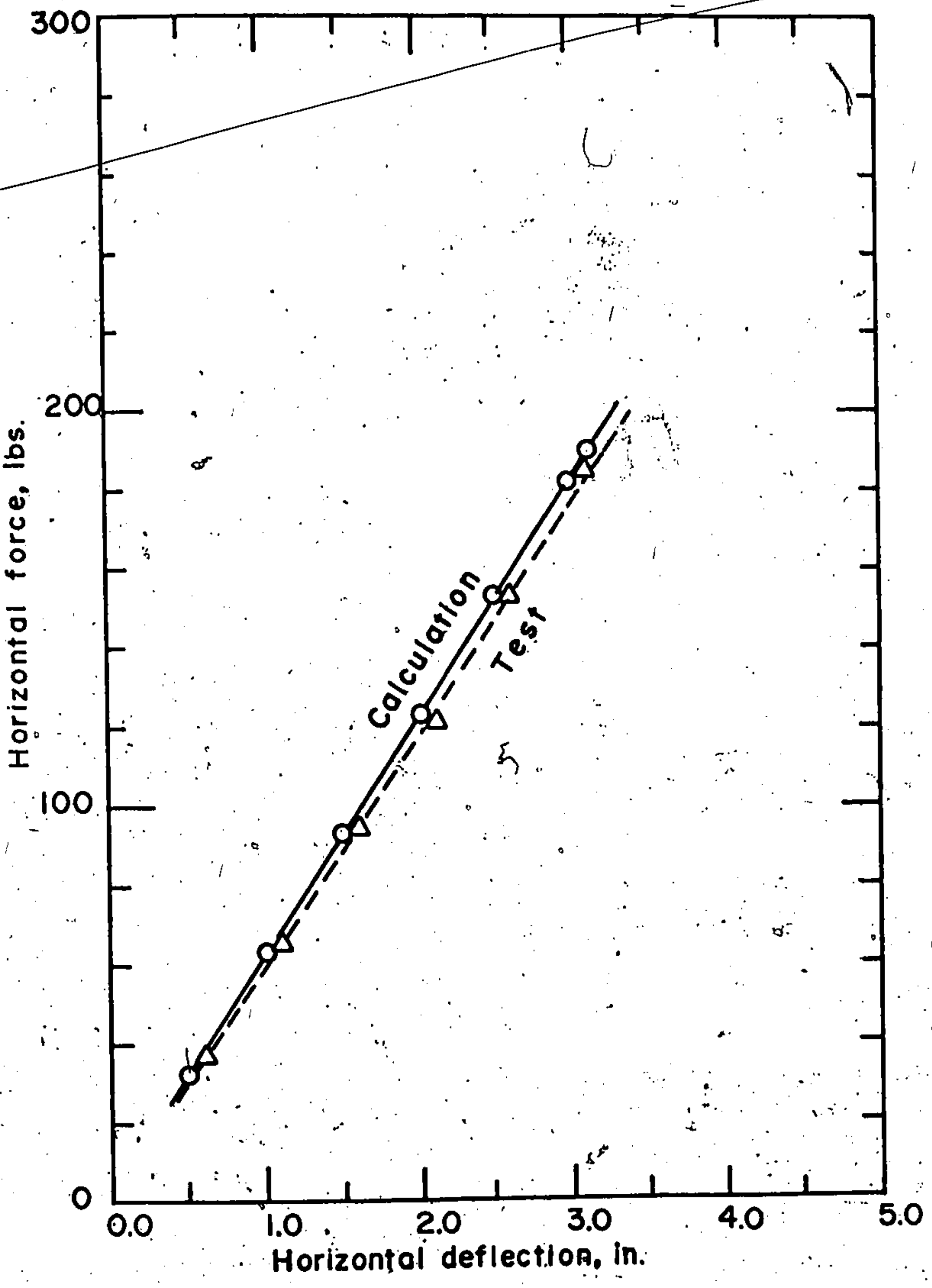


FIGURE 12-6: Horizontal force - deflection diagram of the flat spring for the Jacob trap 1 - Prototype A2

TABLE 12-5: Test data for the spring for the Jacob trap I - prototype B2

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
0.4	26.4	16.6	16.6	16.8	16.7	16.7
0.9	44.4	36.4	35.9	34.4	35.6	35.2
1.4	61.4	53.4	53.9	53.9	53.7	53.6
1.9	79.4	72.4	72.0	72.9	72.4	72.4
2.4	98.4	94.0	94.0	94.4	94.1	91.2
2.9	113.6	113.0	113.6	113.9	113.5	110.3

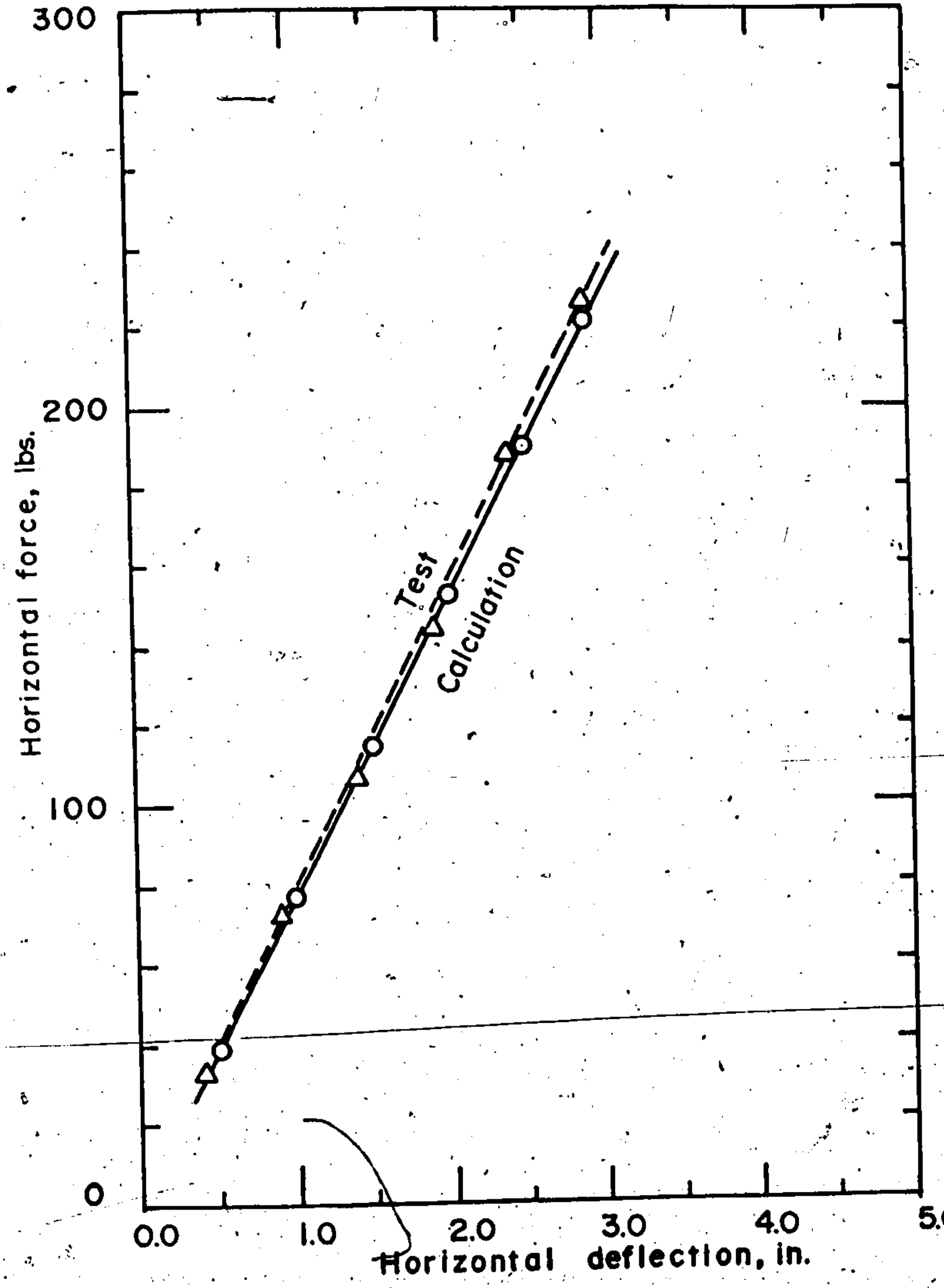


FIGURE 12-7: Horizontal force - deflection diagram of the flat spring for the Jacob trap I - Prototype B2

TABLE 12-6: Test data of the spring for the Jacob trap I - Manufactured for the previous project [2].

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
0						
0.5	—	3.7	3.6	—	3.65	4.4
1.0		8.5	8.4		8.45	8.5
1.5		13.8	13.4		13.60	13.6
2.0		19.0	18.6		18.80	17.8
2.5		24.8	24.4		24.60	22.2

TABLE 12-6: Cont'd

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
3.0		31.3	31.1		31.20	26.6
3.5		38.9	38.7		38.80	31.0

TABLE 12-7: Test data of the spring for the Jacob trap II - Manufactured for the previous project [2].

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
0						
0.5		6.0	5.5		5.75	7.2
1.0		13.0	13.0		13.00	14.5
1.5		20.5	20.5		20.50	21.7
2.0		27.8	27.6		27.70	29.0
2.5		35.5	35.4		35.45	36.2

TABLE 12-7: Cont'd

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
3.0		43.6	43.4		43.50	43.5
3.5		52.0	51.8		51.90	50.7
4.0		61.0	61.0		61.00	58.0
4.25		64.5	64.4		64.45	60.5

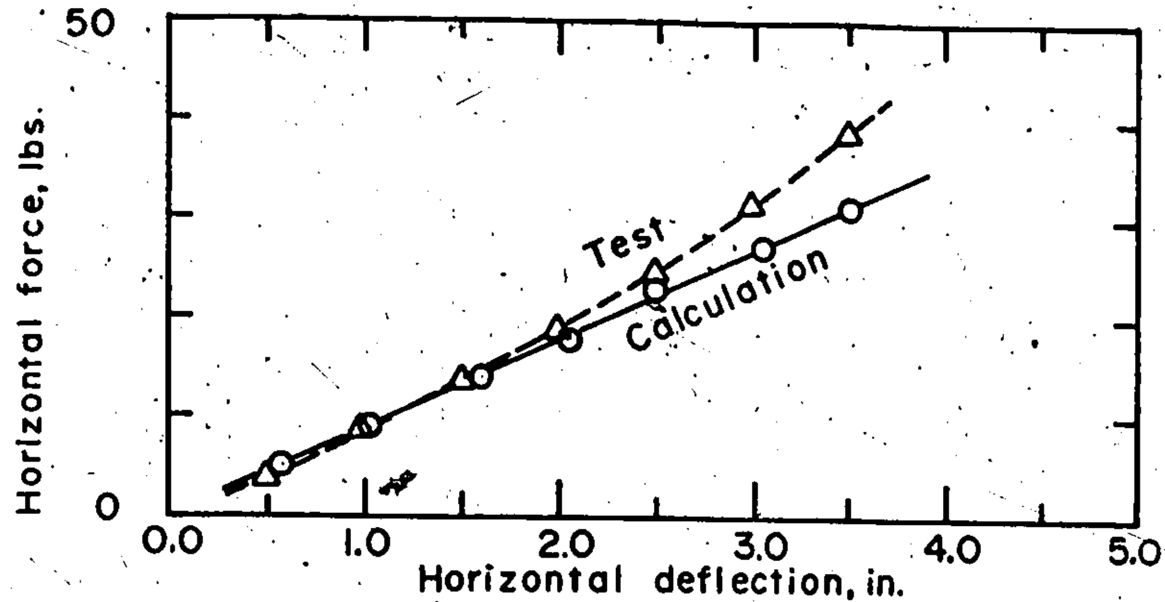


FIGURE 12-8: Horizontal force-deflection diagram of the Jacob trap - From the previous project.

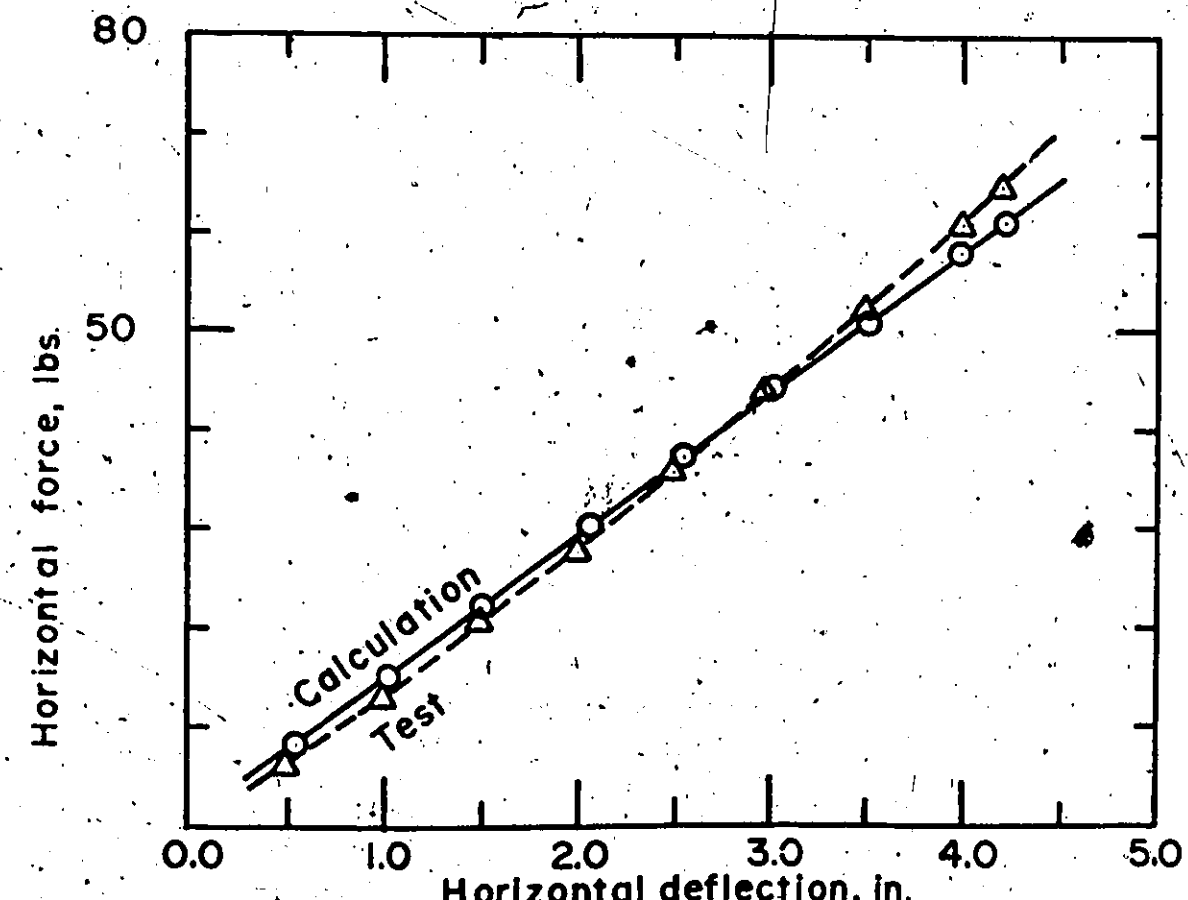


FIGURE 12-9: Horizontal force-deflection diagram of the Jacob trap II - From the previous project.

TABLE 12-8: Test data of the flat spring for the Jacob trap III Manufactured for the previous project [2]

Horizontal Deflection (in)	Horizontal forces at the end of the free end arm (lbs)					
	Initial Test	Test data				Theoretical Values
		1	2	3	Average	
0.5		5.8	5.8	5.8	5.8	6.2
1.5		16.9	17.0	16.4	16.8	18.2
2.5		29.4	28.4	28.6	28.8	30.3
3.5		42.4	40.9	41.6	41.6	42.4
4.5		56.0	56.8	53.8	55.5	54.3
5.5		72.6	70.9	70.4	71.3	66.7
6.5		89.6	90.4	89.9	90.0	78.8

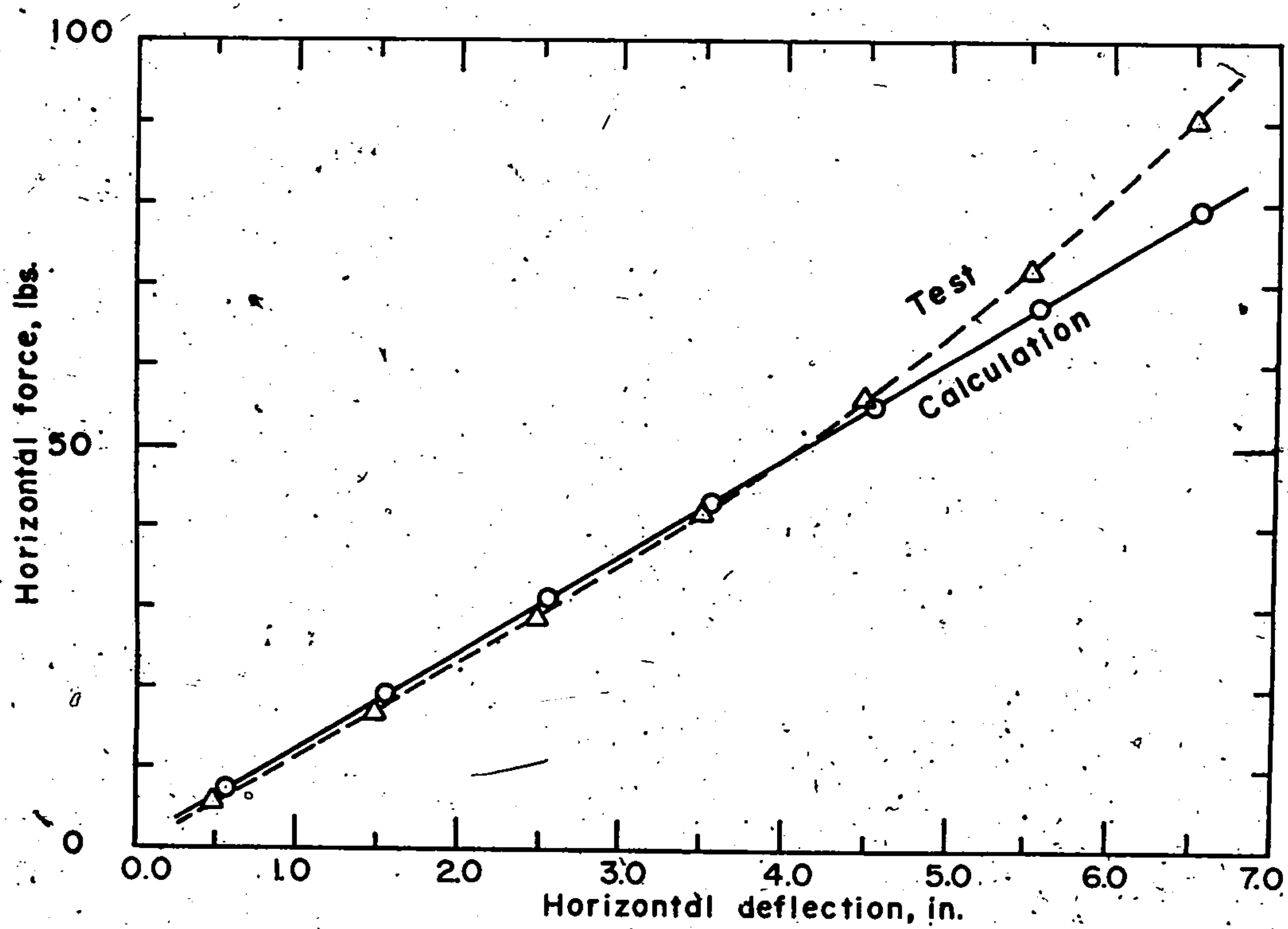


FIGURE II-16: Horizontal force - deflection diagram of the Jacob trap III
* From the previous project

12-3. Clamping and prying forces

The clamping force is defined here as the vertical static force at the fulcrum of the strike bars which is exerted at various jaw openings. The prying force is the force resisting opening of the trap by lifting the jaw. These forces are the same for the Jacob trap because the spring forces are directly transmitted through the hinges to the strike bars rather than indirectly as in the case of the Conibear trap. Once the horizontal spring forces are known, the theoretical clamping (or prying) forces can be calculated by measuring the sides of the triangle, the vertices of which are the two hinges and the fulcrum. The theoretical and tested values are listed in Tables 12-9 to 12-11 and Figs. 12-11 to 12-13 show the plotted curves. The test results compare fairly well with the calculated values until the jaws are nearly closed, and then a large deviation occurs.

This is because in the test method used the bottom of the spring was clamped to the base of the testing device. At the time it was unforeseen that the bottom of the stirrup should have been clamped instead. By clamping the spring it was caused to elongate in a vertical direction when the load became high, and thus its output was modified. The effective free end arm length i.e.

moment arm was increased and thus the horizontal output force was decreased. The extrapolated curves are shown in the figures, which would be expected when the bottom of the stirrups were clamped.

TABLE 12-9: Clamping and prying forces of the Jacob trap I - Prototype A1

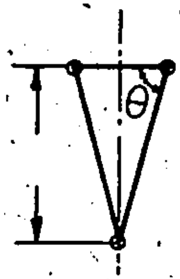
Jaw Opening (in.)	The sides of the triangle (in.)	Horizontal force (FF, lbs.)		tan θ	Theoretical Values (lbs.) 2.FF.tanθ	Test Values 1	Test Values 2	Test Values Average
3.42	5.96 x 3 x 3	110.96	.346	.116	25.74	16.10	18.54	17.32
2.80	5.75 "	106.93	.857	.298	63.73	59.00	62.89	60.95
2.58	5.62 "	104.67	1.051	.374	78.29	73.62	77.03	75.33
2.10	5.25 "	97.78	1.452	.553	108.14	106.27	104.81	105.54
1.68	4.75 "	88.63	1.833	.772	136.84	135.52	132.52	134.06
1.50	4.50 "	84.06	1.984	.882	148.28	145.27	140.88	143.08
1.34	4.25 "	79.48	2.118	.996	158.32	156.48	150.63	153.56
1.02	3.76 "	70.33	2.338	1.244	174.98	164.27	161.35	162.81
.73	3.26 "	61.18	2.519	1.545	189.05	175.00	165.25	170.13
.50	2.77 "	52.03	2.661	1.921	199.90	169.64	160.37	165.01
.20	2.02 "	38.31	2.825	2.797	214.31	148.96	146.73	147.85

TABLE 12-10: Clamping and Prying forces of the Jacob trap I - Prototype A2

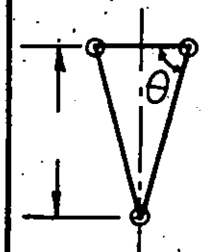
Jaw Opening (in.)	The sides of the triangle (in.)	Horizontal force (FF,lbs.)		tan θ	Theoretical Values (lbs.) 2.FF.tanθ	Test Values 1	Test Values 2	Test Values Average
3.44	5.94 x 3 x 3	94.00	.423	.142	26.70	17.08	17.57	17.33
2.94	5.79 "	92.15	.787	.272	50.13	49.28	47.30	48.29
2.69	5.66 "	90.34	.996	.352	63.60	59.00	61.43	60.22
2.07	5.16 "	83.02	1.531	.593	98.46	95.55	97.50	96.53
1.80	4.91 "	79.36	1.724	.702	111.42	107.49	111.15	109.32
1.42	4.41 "	72.04	2.034	.923	132.99	129.67	132.11	130.89
1.29	4.16 "	68.38	2.162	1.039	142.09	136.98	140.88	138.93
1.00	3.66 "	61.06	2.377	1.299	158.63	149.16	153.55	151.36
.72	3.16 "	53.74	2.550	1.614	173.47	162.32	161.35	161.84
.48	2.66 "	46.42	2.689	2.022	187.72	158.91	159.40	159.11
.23	2.16 "	39.10	2.800	2.592	202.69	151.11	147.70	149.41

TABLE 12-11: Clamping and prying forces of the Jacob trap - Prototype B2

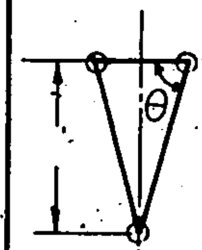
Jaw Opening (in.)	The sides of the triangle (in.)	Horizontal force (FF, lbs.)		tan θ	Theoretical Values (lbs.) 2.FF.tanθ	Test Values 1	Test Values 2	Test Values Average
3.63	5.98 x 3 x 3	116.11	.245	.082	19.04	19.03	18.54	18.79
2.94	5.77 "	113.40	.823	.252	57.15	54.12	55.10	54.61
2.41	5.39 "	106.42	1.318	.489	104.08	95.79	98.96	93.38
1.94	4.90 "	96.73	1.731	.707	136.78	128.69	133.57	131.13
1.50	4.14 "	82.00	2.171	1.049	172.04	162.32	162.32	162.32
1.25	3.63 "	72.31	2.389	1.316	190.32	168.66	169.64	169.15
1.06	3.15 "	62.62	2.553	1.621	203.01	167.20	169.14	168.17
.75	2.14 "	43.24	2.803	2.619	226.49	151.60	162.32	156.96
.63	1.67 "	33.55	2.881	3.451	231.56	120.90	129.18	125.04

FIGURE 12-11: Clamping force - Jaw opening diagram of the Jacob trap - Prototype A1

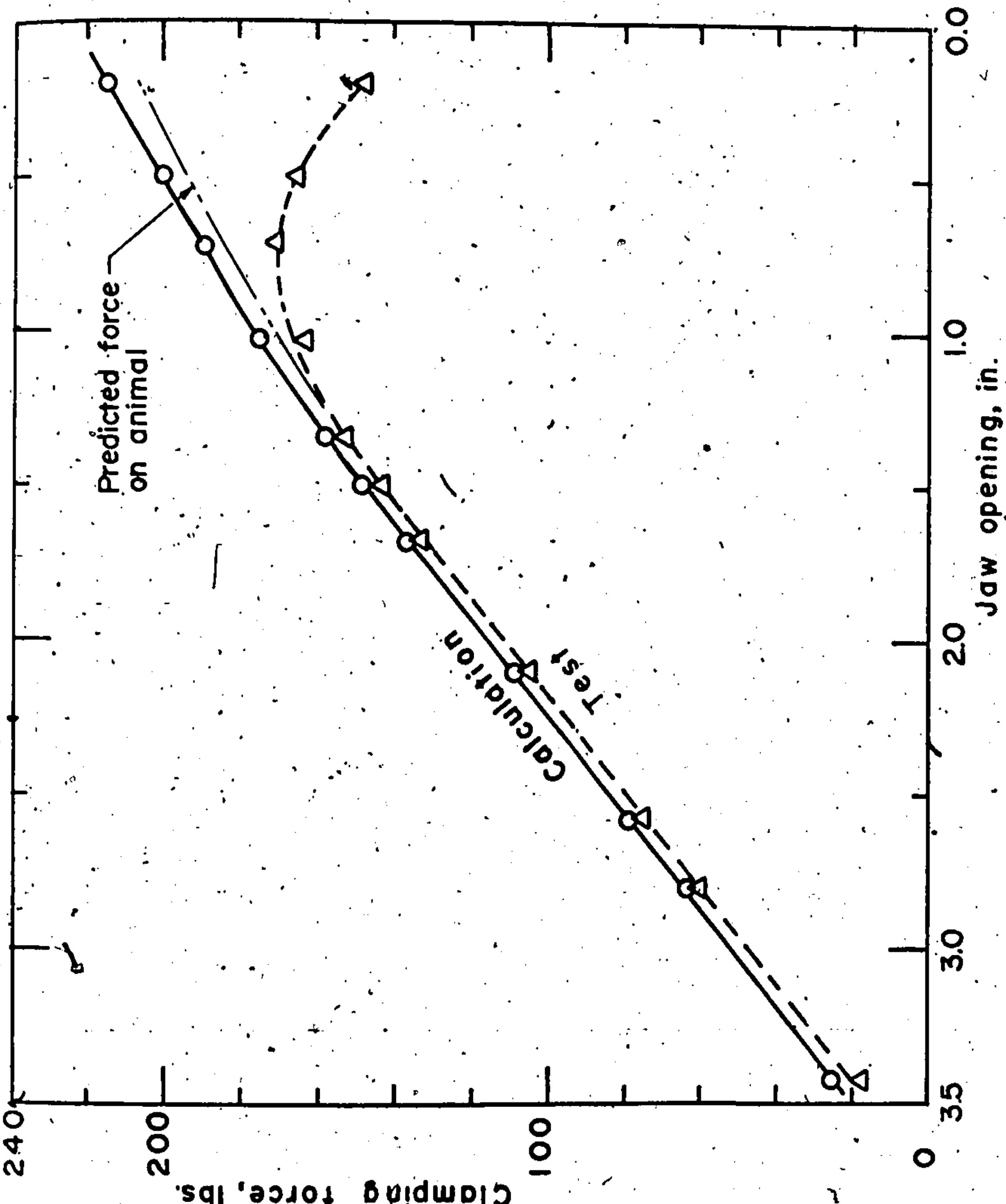


FIGURE 12-12: Clamping force - jaw opening diagram of the Jacob trap I. - Prototype A2

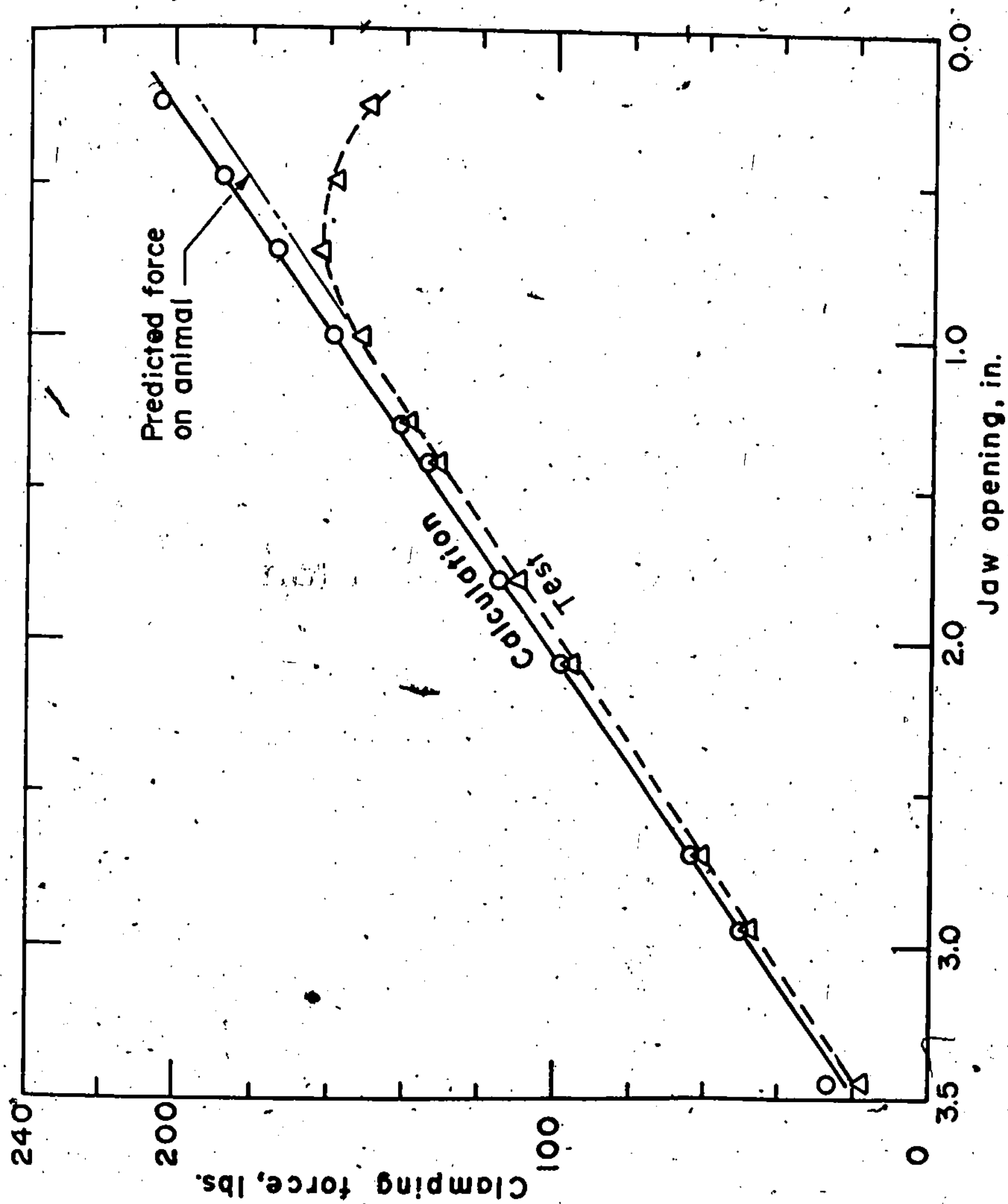
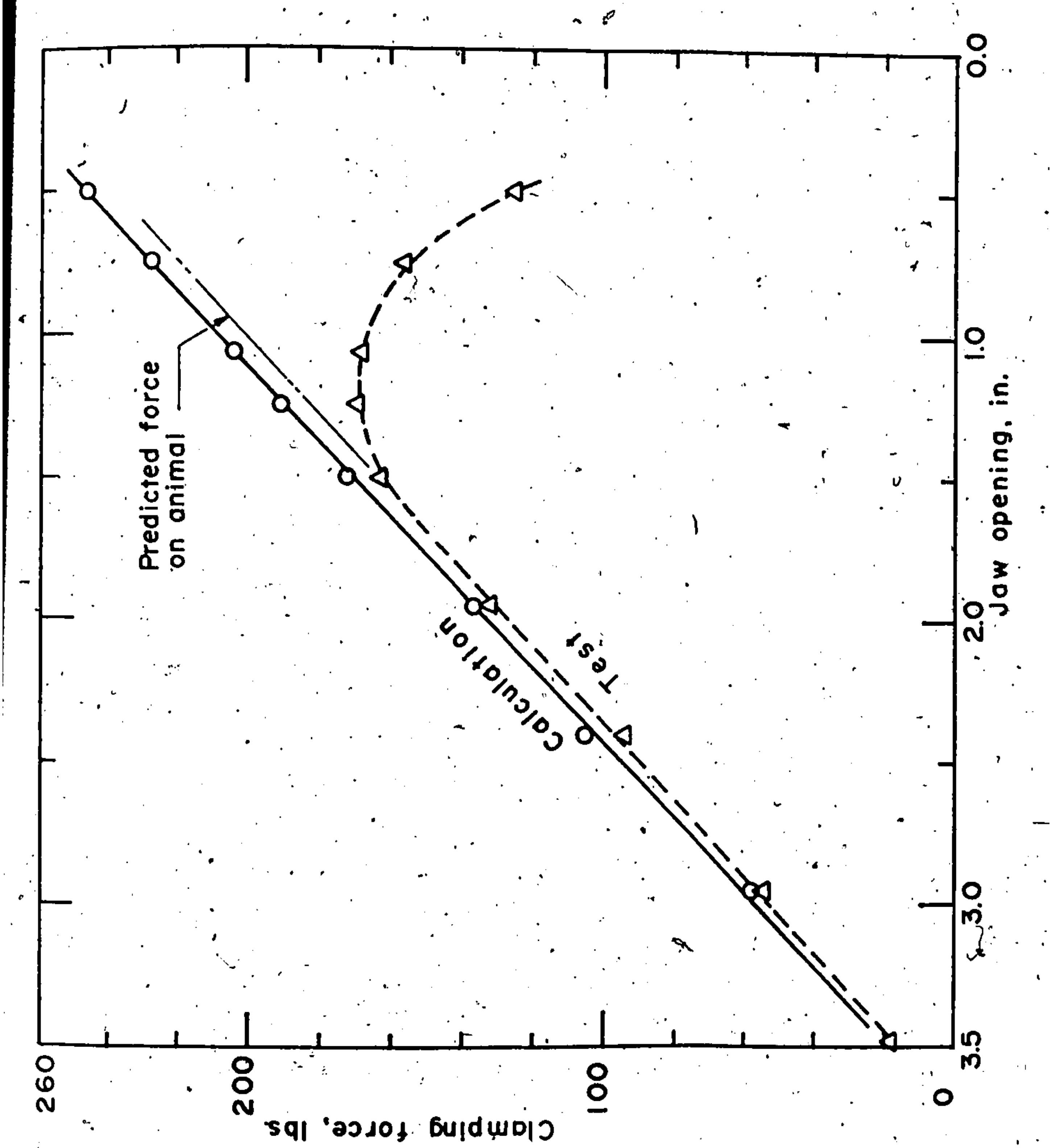


FIGURE 12-13: Clamping force - Jaw opening diagram of the Jacob trap I - B2



12-4 Theoretical energy level

The strain energy stored during the trap setting will be released when the trap is triggered. The released energy for a particular jaw opening is called the theoretical energy level at that jaw opening, and it can be calculated from the graph of the horizontal forces vs. the horizontal deflection at the end of the free end arm. It is the area under the curve, which is linear in this case, between the maximum deflection and the deflection at which the energy is to be computed. The discrete data for the actual horizontal forces, the horizontal deflections and the jaw openings are obtained from tests and measurements, therefore, they are numerically related. The results are tabulated in Tables 12-12 to 12-14.

TABLE 12-12: Theoretical energy - Jacob trap I - Prototype A1

No. of Measurement	Horizontal Deflection (in.)	*	Horizontal force (lbs.)	Theoretical energy (in-lbs.)	Jaw Opening (in.)
1	3.29	.00	110.96	.00	3.42
2	3.18	.11	106.93	23.97	2.80
3	3.12	.17	104.67	36.66	2.58
4	3.06	.24	102.36	51.20	2.40
5	2.93	.36	97.78	75.15	2.10
6	2.81	.49	93.21	100.04	1.90
7	2.68	.61	88.63	121.75	1.68
8	2.56	.74	84.06	144.31	1.50
9	2.43	.86	79.48	163.78	1.34
10	2.31	.99	74.91	184.01	1.15
11	2.18	1.11	70.33	201.23	1.02
12	2.06	1.24	65.76	219.13	.87
13	1.93	1.36	61.18	234.11	.73
14	1.81	1.49	56.61	249.68	.60
15	1.68	1.61	52.03	262.41	.50
16	1.56	1.74	47.46	275.65	.38
17	1.43	1.86	42.88	286.14	.28
18	1.31	1.99	38.31	297.05	.20
19	1.18	2.11	33.73	305.30	.13
20	1.06	2.24	29.16	313.87	.00
21	.93	2.36	24.58	319.87	.00
22	.81	2.49	20.01	326.12	.00
23	.68	2.61	15.43	329.88	.00
24	.62	2.67	13.17	331.43	.00

* Diference between maximum horizontal deflection and the horizontal deflection at which the energy is required.

TABLE 12-13: Theoretical energy - Jacob trap I - Prototype A2

No. of measurement	Horizontal Deflection (in.)	*	Horizontal force (lbs.)	Theoretical energy (in-lbs.)	Jaw Opening (in.)
1	3.20	.00	94.00	.00	3.44
2	3.14	.06	92.15	11.17	2.94
3	3.07	.13	90.34	23.96	2.69
4	2.95	.25	86.68	45.17	2.33
5	2.82	.38	83.02	67.27	2.07
6	2.70	.50	79.36	86.68	1.80
7	2.57	.63	75.70	106.91	1.61
8	2.45	.75	72.04	124.53	1.42
9	2.32	.88	68.38	142.89	1.29
10	2.20	1.00	64.72	158.72	1.13
11	2.07	1.13	61.06	175.21	1.00
12	1.95	1.25	57.40	189.25	.86
13	1.82	1.38	53.74	203.88	.72
14	1.70	1.50	50.08	216.12	.61
15	1.57	1.63	46.42	228.88	.48
16	1.45	1.75	42.76	239.33	.35
17	1.32	1.88	39.10	250.23	.23
18	1.20	2.00	35.44	258.88	.13
19	1.07	2.13	31.78	267.91	.10
20	.95	2.25	28.12	274.77	.00
21	.82	2.38	24.46	281.93	.00
22	.70	2.50	20.80	287.00	.00
23	.64	2.56	18.96	289.18	.00

* Diference between maximum horizontal deflection and the horizontal deflection at which the energy is required.

TABLE 12-14: Theoretical energy - Jacob trap I - Prototype B2

No. of Measurement	Horizontal Deflection (in.)	*	Horizontal force (lbs.)	Theoretical energy (in-lbs.)	Jaw Opening (in.)
1	2.99	.00	116.11	.00	3.63
2	2.92	.06	113.40	13.77	2.94
3	2.86	.13	111.07	29.53	2.69
4	2.74	.25	106.42	55.63	2.41
5	2.61	.38	101.38	82.64	2.19
6	2.49	.50	96.73	106.42	1.94
7	2.36	.63	91.69	130.91	1.81
8	2.24	.75	87.04	152.36	1.63
9	2.11	.88	82.00	174.34	1.50
10	1.99	1.00	77.35	193.46	1.38
11	1.86	1.13	72.31	212.91	1.25
12	1.74	1.25	67.66	229.71	1.16
13	1.61	1.38	62.62	246.65	1.06
14	1.49	1.50	57.97	261.12	.97
15	1.36	1.63	52.93	275.54	.91
16	1.24	1.75	48.28	287.68	.81
17	1.11	1.88	43.24	299.58	.75
18	.99	2.00	38.59	309.40	.69
19	.86	2.13	33.55	318.78	.63
20	.74	2.25	28.90	326.27	.56
21	.61	2.38	23.86	333.13	.53
22	.49	2.50	19.21	338.20	.50
23	.42	2.56	16.50	339.48	.48

* Diference between maximum horizontal deflection and the horizontal deflection at which the energy is required.

12-5 Kinetic energy testing method

The Jacob trap is synthesized as a slider crank mechanism graphically by tracing the actual configuration changes during the motion. Let us define the parameters of the mechanism as follows (see Figure 12-14(a)).

a_1	Crank length
a_2	Coupler link length
a_3	Distance of the offset (negative in this case)
ϕ	Crank angle measured ccw
θ	Angle between the coupler link and the path of the slider
V_c	Tangential velocity of the crank pin
V_{cv} & V_{ch}	Components of V_c as shown
V_s	Velocity of the slider
V_{sv} & V_{sh}	Components of V_s as shown
s	Slider position

From the high speed film analysis, the slider velocities, V_s, will be calculated first. The angular velocities, ω_1, of the crank are obtained by calculating the crank angles at the slider positions from the equation[6].

$$2a_1 s \cos\phi + 2a_1 a_3 \sin\phi - (a_1^2 - a_2^2 + a_3^2) = s^2 \quad (12\text{-}1)$$

Substituting $\cos\phi = \sqrt{1-\sin^2\phi}$, squaring both sides and rearranging the terms, Eq. (12-1) becomes:

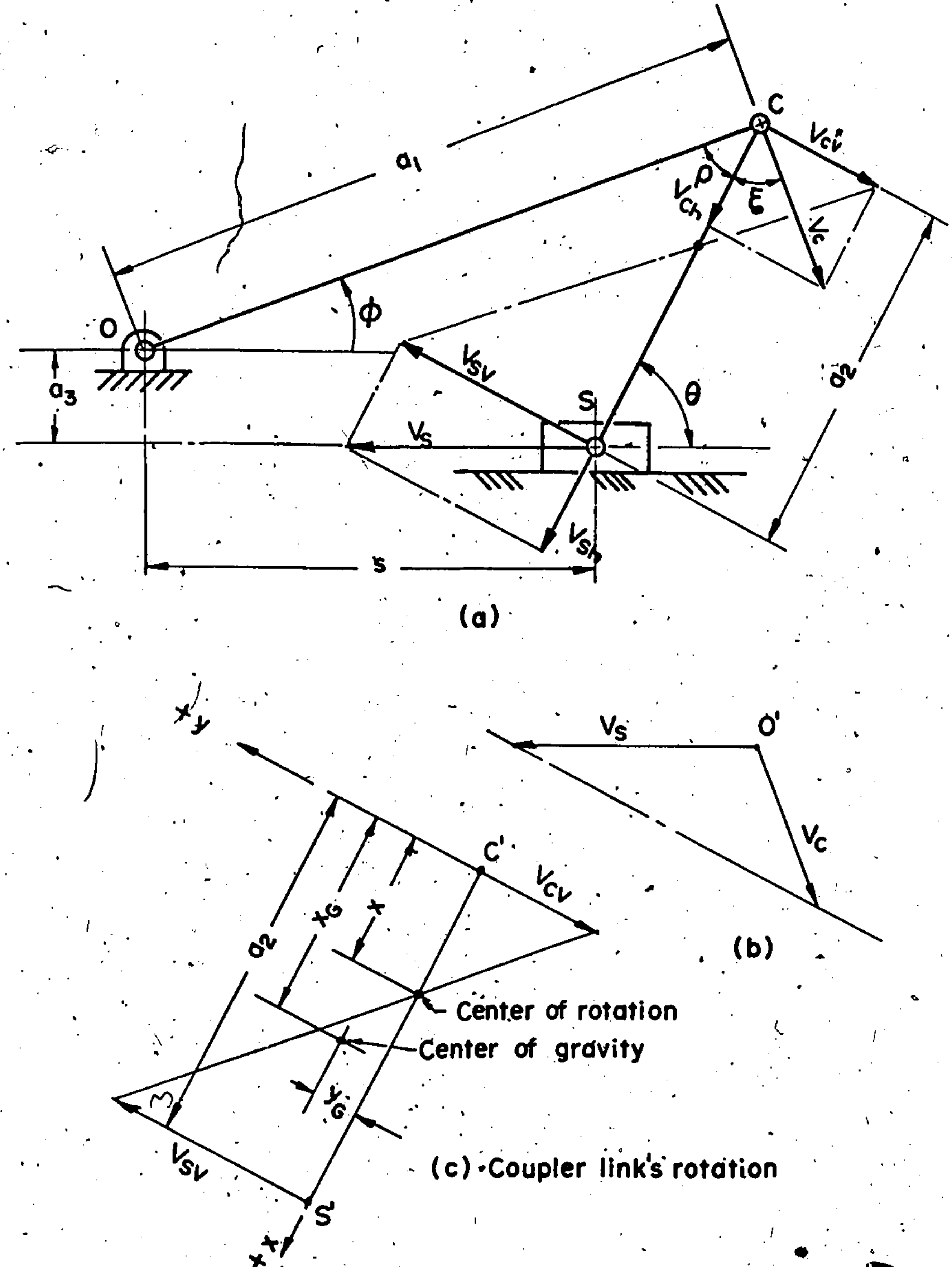


Fig. 12-14 Imaginary slider crank mechanism for the Jacob trap

$$A \sin^2\phi + B \sin\phi + C = 0 \tag{12-2}$$

where
$$A = 4a^2(a_3{}^2 + s_1{}^2)$$
$$B = -4a_1a_3(a_1{}^2 - a_2{}^2 + a_3{}^2 + s_1{}^2)$$
$$C = (a_1{}^2 - a_2{}^2 + a_3{}^2 + s^2)^2 - 4a_1{}^2 s_1{}^2$$

Taking the positive sign of the roots of the quadratic equation

$$\phi = \sin^{-1}\left(\frac{-B + \sqrt{B^2-4AC}}{2A}\right) \tag{12-3}$$

The motion of the coupler link can be divided into two components, the linear and the angular motions.

The velocities, V_{sv} and V_{sh}, perpendicular and parallel to the coupler link at the point, S, are:

$$V_{sv} = V_s \sin\theta \tag{12-4}$$

$$V_{sh} = V_s \cos\theta \tag{12-5}$$

where $\theta = \sin^{-1}\left(\frac{a_1 \sin\phi - a_3}{a_2}\right)$

And for the crank pin, C, they are:

$$V_{cv} = -V_c \sin(\pi/2+\phi-\theta) \tag{12-6}$$

$$V_{ch} = V_c \cos(\pi/2+\phi-\theta) \tag{12-7}$$

where $V_c = \omega_1 a_1$

The negative sign in Eq. (12-6) shows that the direction of V_{cv} is opposite to V_{sv}. Of course, $V_{sh} = V_{ch}$ as the coupler link is a rigid bar.

In Figure 12-14(c) the distance x from the crank pin C' to the center of rotation of the coupler link is:

$$x = \frac{a_2 V_{cv}}{V_{cv} - V_{sv}}$$

Therefore, the angular velocity of the coupler link will be:

$$\omega_2 = \frac{V_{sv}}{(a_2 - x)} \qquad (12\text{-}8)$$

If the co-ordinates of the center of gravity of the coupler link are (x_G, y_G) as shown in Figure 12-14(c), then the moment of inertia of the coupler link to the center of rotation will be:

$$I = I_o + m \cdot (x_G^2 + y_G^2) \qquad (12\text{-}9)$$

where I_o - moment of inertia to the C.G.

m - mass of the coupler link

12-6 Computer programme and the results

Based on the equations explained in Section 12-5, a kinetic energy calculation programme is formulated to process the data from the high speed film readings.

Because the calculation is based on the linear velocities of the fulcrum in the strike bars of the Jacob trap, the data from the high speed film readings should first be converted to the the actual distances by the method of proportion , and then to the slider position of the imaginary slider crank mechanism (Section 12-5). Then the corresponding crank angles are obtained from the slider position. The angular and linear velocities of the crank and coupler link are calculated from the change rates of the discrete data as usual. Separate tables are read in to numerically relate the jaw opening to the slider position and also to the kinetic energy. In the main programme, the input data are read in and processed to obtain the velocities calling the relevant subroutines. Also the output statements are included in the main programme. The subroutine ADJUST converts the input data of S1 and S2 into full scale slider positions. The subroutine ANGLE calculates the crank angles to the corresponding slider positions. The calculations explained in Section 12-5 to obtain the kinetic energies are carried out in the subroutine ENGRY. The programme is listed in Appendix I along with the explanation to use. The results are tabulated in Tables 12-15 to 12-26 and Figures 12-15 to 12-17.

TABLE 12-15: Kinetic energies of Jacob trap I - Prototype A1, Above water, shot 1

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	0.00	.00	3.42
20	.48	22.47	.31	3.37
30	.74	32.57	.65	3.34
39	1.30	52.01	1.68	3.28
40	2.23	77.98	3.84	3.20
50	3.65	107.87	7.55	3.09
68	5.72	139.29	13.12	2.94
78	8.60	170.09	20.83	2.76
88	12.41	198.38	31.01	2.58
97	17.25	222.47	44.11	2.31
107	23.10	240.92	60.75	2.05
116	29.86	252.44	81.51	1.76
126	37.23	255.86	106.32	1.44
135	44.62	250.14	133.49	1.08
145	51.07	234.41	158.25	.74
154	55.07	208.00	171.22	.40
164	54.32	170.44	158.55	.16
173	45.67	147.38	108.52	.00

TABLE 12-16: Kinetic energy of Jacob trap I - Prototype A1
Above water, shot 2

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.42
21	.63	28.25	.49	3.35
31	.93	38.57	.92	3.31
41	1.56	58.22	2.12	3.24
52	2.62	84.52	4.56	3.15
62	4.26	114.93	8.72	3.02
72	6.65	147.04	15.02	2.86
82	10.02	178.58	23.91	2.67
92	14.52	207.40	35.99	2.43
103	20.25	231.49	52.06	2.15
113	27.19	248.92	73.08	1.89
123	35.12	257.93	99.63	1.53
133	43.47	256.82	130.74	1.15
143	51.22	243.96	161.76	.82
153	56.47	217.74	181.18	.44
163	56.06	176.63	168.97	.16
168	52.28	150.03	144.13	.00

TABLE 12-17: Kinetic energy of Jacob trap I - Prototype Al
Under water, shot 1

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.42
20	.18	8.84	.05	3.40
31	.39	18.59	.21	3.37
41	.94	41.55	1.06	3.32
51	1.89	72.85	3.31	3.24
61	3.38	108.21	7.49	3.11
71	5.59	143.92	13.82	2.94
82	8.69	176.91	22.31	2.74
92	12.75	204.68	32.93	2.51
102	17.72	225.33	45.66	2.22
112	23.40	237.56	60.43	1.95
122	29.43	240.67	76.69	1.61
133	35.25	234.56	92.98	1.32
143	40.16	219.71	106.53	.99
153	43.35	197.21	113.45	.63
163	44.05	168.75	109.93	.36
173	41.71	136.62	94.34	.17
184	36.33	103.68	69.52	.00

TABLE 12-18: Kinetic energy of Jacob trap I, Prototype A1, Under water, shot 2.

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.42
21	.58	27.21	.45	3.36
31	.70	30.32	.57	3.32
41	1.13	45.18	1.27	3.27
52	1.94	68.27	2.94	3.19
62	3.21	96.42	6.01	3.07
72	5.10	126.75	10.81	2.92
82	7.75	156.74	17.55	2.74
93	11.29	184.18	26.46	2.54
103	15.78	207.19	37.80	2.26
113	21.18	224.23	51.94	2.00
124	27.33	234.06	69.07	1.69
134	33.88	235.79	88.79	1.39
144	40.24	228.85	109.37	1.04
155	45.58	213.00	126.87	.68
165	48.68	188.31	134.68	.36
175	47.96	155.20	124.35	.15
186	41.47	114.41	89.99	.00

TABLE 12-19: Kinetic energy of Jacob trap I - Prototype A2 Above water, Shot 1.

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.44
11	.99	39.50	.95	3.40
22	1.45	52.02	1.66	3.34
33	2.23	70.29	3.08	3.26
44	3.53	95.08	5.74	3.14
56	5.63	126.09	10.41	3.00
67	8.89	161.97	18.05	2.71
78	13.78	200.32	29.79	2.48
89	20.77	237.68	47.06	2.20
100	30.20	269.51	71.50	1.84
111	41.95	290.31	104.26	1.43
122	54.89	293.67	143.14	1.02
133	65.73	272.34	174.85	.55
139	68.29	249.89	177.92	.32
144	67.13	218.15	164.10	.11
149	60.33	175.96	127.99	.00

TABLE 12-20: Kinetic energy of Jacob trap I - Prototype A2 Above water, shot 2

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.44
23	.82	29.72	.54	3.35
34	1.23	41.46	1.06	3.31
46	2.24	67.59	2.86	3.23
56	4.04	104.02	6.92	3.11
67	6.96	146.58	14.25	2.94
79	11.42	191.00	25.75	2.61
90	17.88	233.00	42.28	2.35
101	26.67	268.14	64.90	2.02
112	37.75	291.77	94.65	1.63
123	50.39	299.10	130.88	1.22
134	62.41	285.14	166.52	.75
146	69.09	244.77	179.63	.24
156	61.42	172.72	131.30	.00

TABLE 12-21: Kinetic energy of Jacob trap 1, Prototype A2, Under water, shot 1

Cummulative time (sec.) x10^3	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.44
21	.64	24.80	.38	3.38
31	.75	27.32	.46	3.35
41	1.12	38.36	.91	3.31
52	1.87	56.78	2.01	3.24
62	2.94	81.16	4.17	3.14
72	4.64	109.90	7.83	3.02
83	7.12	141.26	13.42	2.79
93	10.62	173.27	21.96	2.55
103	15.37	203.84	32.08	2.33
114	21.54	230.66	46.08	2.05
124	29.16	251.27	63.85	1.72
135	37.90	262.98	84.43	1.38
145	47.27	262.97	109.16	1.01
156	56.34	248.19	129.27	.62
166	60.10	215.43	132.79	.22
177	63.32	161.27	100.96	.00

TABLE 12-22: Kinetic energy of Jacob trap I - Prototype A2
Under water , shot 2

Cummulative time (sec.) x 10[4]	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.44
10	.81	33.19	.67	3.41
20	.89	34.84	.71	3.37
29	1.21	58.63	1.13	3.32
39	1.82	80.37	2.13	3.26
49	2.82	106.79	4.07	3.17
59	4.34	136.44	7.34	3.05
69	6.55	167.67	12.38	2.87
78	9.69	198.60	19.63	2.61
88	13.99	227.11	29.57	2.41
98	19.66	250.82	42.72	2.16
109	26.81	267.15	59.71	1.85
119	35.36	273.26	80.95	1.51
128	44.85	266.06	105.85	1.19
139	54.09	242.22	130.86	.82
149	60.76	198.14	146.28	.40
159	60.61	130.04	133.85	.10
168	47.01	34.01	76.53	.00

TABLE 12-23: Kinetic energy of Jacob trap I - Prototype B2
Above water, shot 1

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
.00	.00	.00	.00	3.63
15	.07	4.56	.02	3.62
31	.46	27.65	.76	3.57
46	.72	36.45	1.32	3.51
61	.98	42.12	1.77	3.44
77	1.46	52.64	2.80	3.34
92	2.45	72.78	5.43	3.22
107	4.44	104.16	11.39	3.04
122	8.14	145.36	23.17	2.84
138	14.63	191.96	43.70	2.58
153	25.13	236.52	76.09	2.17
168	40.50	268.95	123.55	1.74
182	59.90	277.02	185.99	1.21
197	77.26	246.42	239.12	.78
212	72.35	160.93	181.54	.48

TABLE 12-24: Kinetic energy of Jacob trap I - Prototype B2, Above water, shot 2

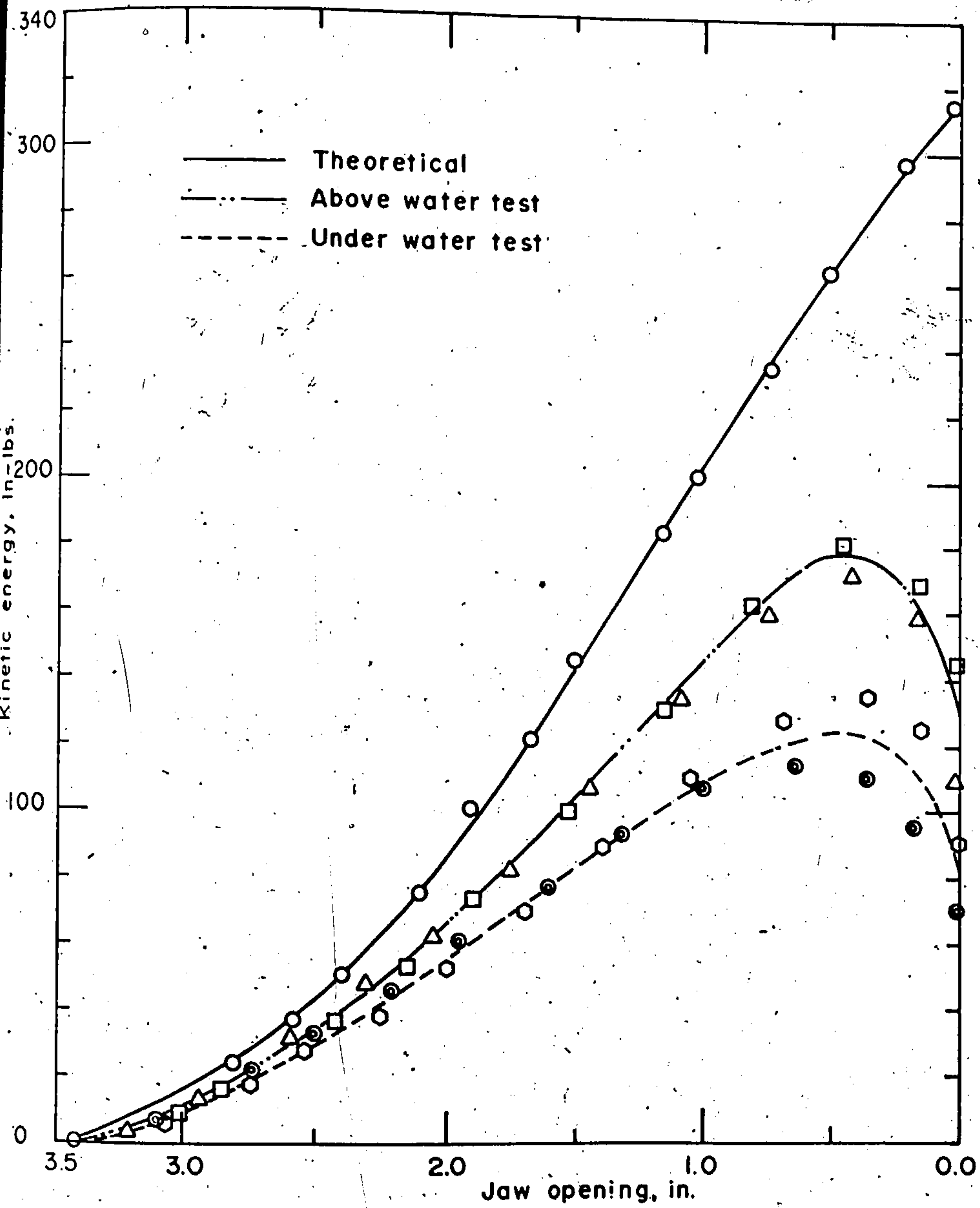
Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.63
23	.22	14.67	.21	3.62
31	.40	25.09	.62	3.59
46	.69	36.54	1.32	3.53
61	1.00	44.19	1.95	3.45
77	1.52	55.79	3.14	3.35
92	2.56	76.04	5.92	3.22
107	4.56	106.60	11.93	3.04
122	8.24	146.25	23.48	2.84
137	14.61	190.93	43.29	2.58
152	24.83	233.77	74.33	2.17
167	39.77	265.34	119.83	1.75
182	58.75	273.90	180.17	1.22
197	76.18	245.51	233.79	.79
212	73.15	164.11	186.03	.48

TABLE 12-25: Kinetic energy of Jacob trap I, Prototype B2, Under water, shot 1

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.63
10	.03	2.22	.00	3.62
20	.26	16.07	.25	3.60
30	.40	23.21	.53	3.57
40	.49	26.62	.70	3.54
50	.58	28.86	.82	3.50
60	.70	31.99	1.02	3.46
70	.91	37.65	1.42	3.42
80	1.26	46.98	2.22	3.36
90	1.83	60.70	3.74	3.28
100	2.73	79.04	6.41	3.19
110	4.13	101.81	10.81	3.06
120	6.22	128.32	17.60	2.92
130	9.28	157.45	27.45	2.79
140	13.61	187.62	41.08	2.61
150	19.55	216.78	59.16	2.34
160	27.39	242.43	82.46	2.04
170	37.23	261.60	111.59	1.78
180	48.81	270.89	146.36	1.43
190	61.03	266.47	183.38	1.11
200	71.18	244.10	210.74	.82
210	73.54	199.10	200.11	.50
220	57.40	126.36	113.86	.48

TABLE 12-26: Kinetic energy of Jacob trap I, Prototype B2
Under water, shot 2

Cummulative time (sec.) x 10^4	Angular Velocity of crank (rad/sec.)	Linear Velocity of slider (in/sec.)	Kinetic energy (in-lbs.)	Jaw Opening (in.)
00	.00	.00	.00	3.63
10	.01	.65	.00	3.62
20	.19	12.16	.15	3.61
30	.30	18.35	.33	3.58
40	.39	22.02	.48	3.56
50	.49	25.51	.65	3.53
60	.64	30.68	.94	3.49
70	.89	28.93	1.51	3.44
80	1.31	51.17	2.63	3.38
90	1.99	67.87	4.67	3.30
100	3.06	89.04	8.13	3.19
110	4.69	114.62	13.64	3.05
120	7.13	142.62	21.84	2.90
130	10.66	172.79	33.39	2.76
140	15.59	202.97	48.91	2.54
150	22.26	230.90	69.05	2.26
160	30.86	253.87	94.39	1.93
170	41.37	268.73	125.19	1.67
180	53.17	271.86	160.00	1.31
190	64.50	259.19	192.14	1.02
200	71.42	226.19	203.02	.75
210	66.17	167.90	158.20	.54



[illegible] 12-15: Kinetic energy - Jaw opening diagram of the Jacob [illegible] - Prototype A1

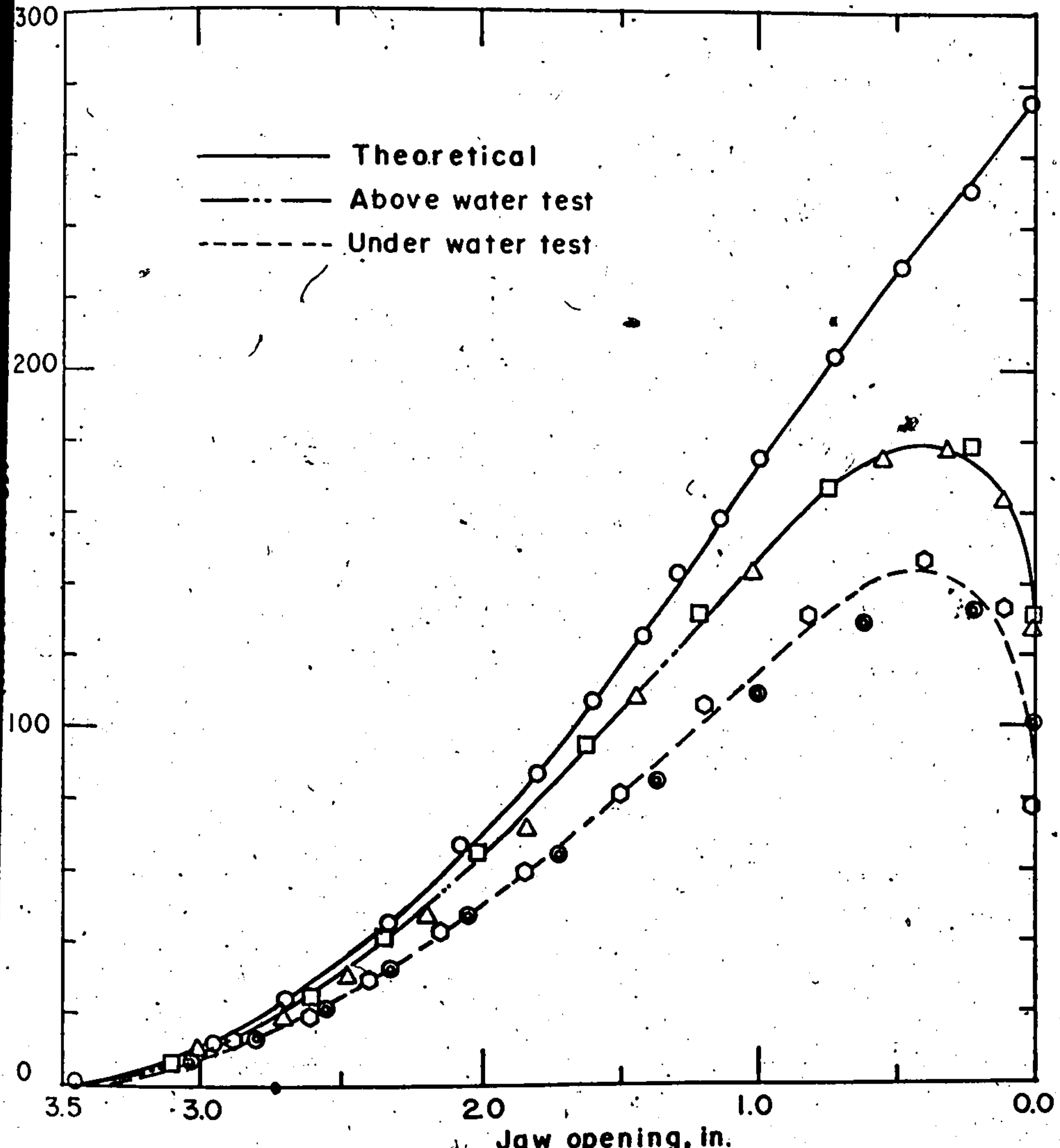


FIGURE 12-16: Kinetic energy - Jawopening diagram of the Jacob type 1 - Prototype A2

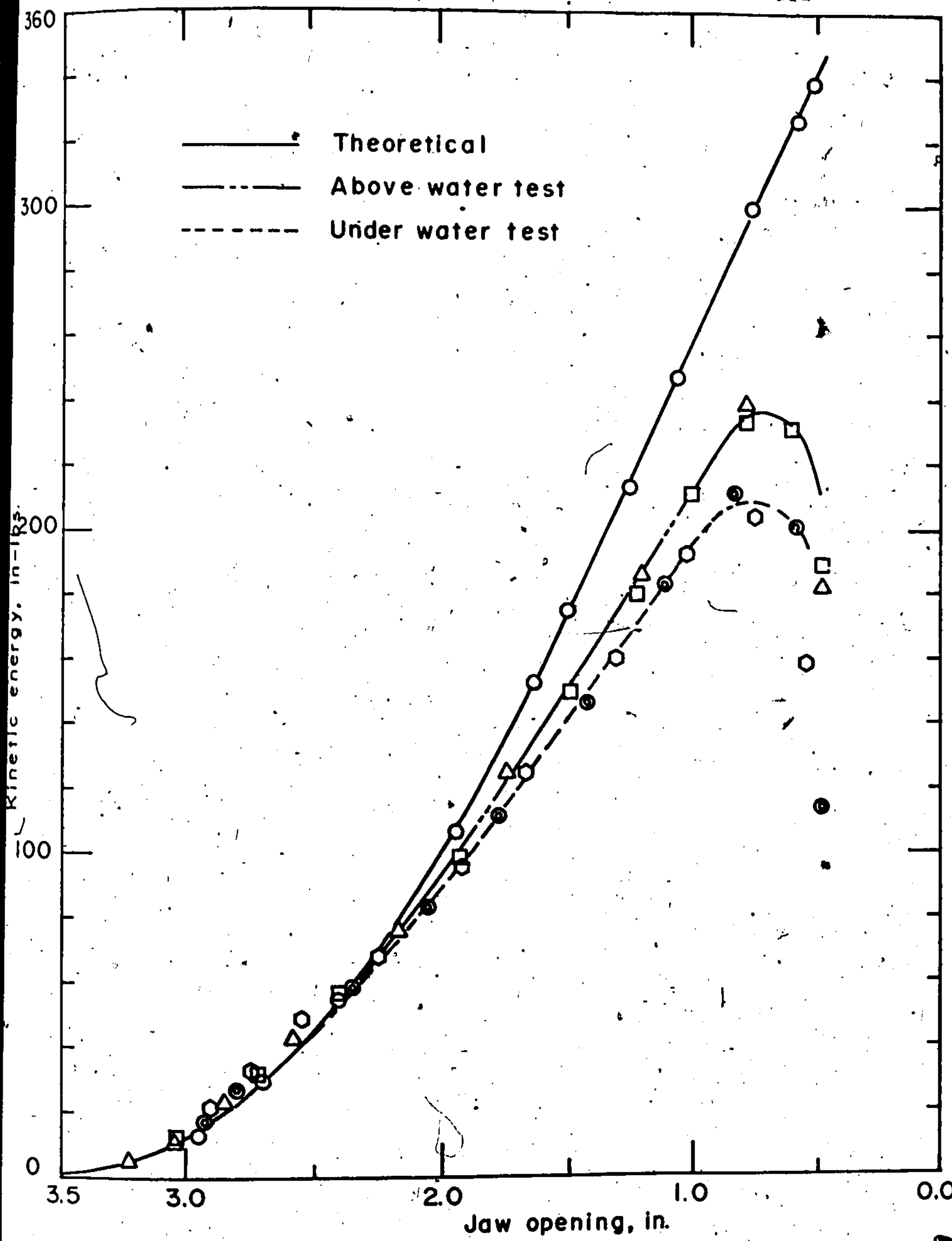


FIGURE 12-17: Kinetic energy - Jaw opening diagram of the Jacob ... I - Prototype B2.

TABLE 12-27: Comparison of the Kinetic energy to the Theoretical energy.

No.	Descriptions	Jacob trap I prototypes		
		A1	A2	B2
1	Maximum kinetic energy obtained (above water) (in-lbs.)	188	178	237
2	Maximum kinetic energy obtained (under water) (in-lbs.)	124	144	208
3	The jaw opening at which the maximum kinetic energy is obtained (in.)	0.43	0.4	0.73
4	Theoretical energy at the above jaw opening (in-lbs.)	272	235	315
5	Maximum theoretical energy (in-lbs.)	331.43	289.18	339.48
6	Percentage of 1 over 4 (%)	69.12	75.74	75.24
7	Percentage of 2 over 4 (%)	45.59	61.28	66.03
8	Percentage of 2 over 1 (%)	65.96	80.90	87.76
9	Percentage of 1 over 5 (%)	56.72	61.55	69.81

In Table 12-27 the maximum kinetic energy, above and under water, is tabulated and compared with the theoretical energy level at the jaw opening where the maximum kinetic energy is obtained. The underwater performances are improved considerably as the free end arm has been designed to reduce the under water friction loss.

In Figures 12-15 to 12-17, the kinetic energy increases to a maximum and then decreases rapidly contrary to the theoretical curve. This is probably due to the increasing friction losses as the trap closes and contact surfaces between the interior mechanism increase. The higher energy loss of the prototype A1 compared to the prototypes A2 and B2 in above and under water is due to the energy consumed to drive the additional trigger bar. Friction is particularilly high in the under water performance due to the temporary trigger brackets which are added to the spring frame rather than incorporated in it and this can be improved during final design.

13. DISCUSSION

The original concept of the Jacob trap has undergone considerable change in this project, and the trap, as finalized here, has many new features. Now the Jacob trap can be considered to have much potential for a humane trap with the following advantages:

a) The swinging stirrup will provide good animal control by self aligning the strike plane of jaw with the animal's movement and rendering the fatal blow on the right spot.

b) The strain energy is stored in the spring frame itself, which acts as a power pack, and works through the pin joints of mechanical linkages, not by a sliding and wedging action as in the conventional traps, thus ensuring less friction.

c) It has powerful clamping force which increase rapidly and continuously when the trap is closing due to the mechanical advantage of the mechanism.

d) The trap offers a free area through the jaw opening for the animal to approach since the trigger mechanism is not in the way of the jaw opening.

e) By modeling the strike bars and the stirrup properly, and offsetting the two strike bars, the trap has break-neck action without damaging the pelt.

f) The underwater performance of the trap is excellent compared to the conventional traps.

g) The trap has good safety features for the animal. The trigger can be adjusted in such a way that the trap can not be triggered by the muzzle or the paw. Even when the trap is triggered by the muzzle or the paw by pushing the stirrup, there is less chance of the animal being hurt because of the offsetting of the jaw relative to the cradle.

h) With proper setting tool, for example, similar to the car jack, and added safety device, the trap will be safe to use and quick to set.

The disadvantages of the Jacob trap are:

a) It is somewhat bulky due to the flat spring, but this may not be particularly a disadvantage with increased trapper's movability.

b) The inovative appearance may affect the early trapper's acceptability. It may be true to any new trap.

Four prototypes of the Jacob trap were manufactured as mentioned in Section 12-1.

The circular wire spring of the first prototype, Jacob trap III, was considered not suitable for this type of trap. The motions of the closing free end arms were not on the same plane, and, moreover, the angle between the two planes changed continuously resulting in twisting of the interior mechanism. Also, there was difficulty in making the spring from one piece of wire. The prototype was made out of two springs and welded at the bottom. Therefore, no further evaluation has been carried out on this alternative.

The Jacob trap I, prototype A1 was considered the most promising among the remaining three prototypes after the evaluation. Actually, the springs of the prototypes A2 and B2 were the alternatives to the A1 spring. The temporary brackets for the trigger bar in prototype A1 should be incorporated into the spring frame, and the evalatuion has pointed out the need for improvements in the following items:

a) The trap design is too sophisticated. Efforts should be exerted to simplify the mechanical parts, especially the hinge bracket, to cut down manufacturing and maintenance costs and the trap weight. Some parts may be replaced for lighter material (i.e. Aluminum) or stamped to profile with weight saving holes.

b) The strike bars, stirrup and cradle may need to be trimmed to give some minimum jaw opening at the closed position to avoid any cutting action. Also any sharp corners or edges should be rounded for the same reason.

c) More study is required to reduce the gap between the spring frame and the interior mechanism so that the animal's attention is not distracted to these openings.

d) Some type of anvil or cushion feature should be provided between the two hinge brackets to prevent any damage to the interior mechanism when the trap is triggered empty.

e) A stable device should be added to secure the trap to the ground upon setting.

f) A good setting tool is required for ease of setting and to avoid any accidental injuries to trappers, because the trap has a high clamping force and impact. Also, unless the trap is easy to set, trappers will be reluctant to use it. A safety pin passing through the strike bars can easily be incorporated for the set position.

g) It will be necessary to carry out testing with live animals to determine their reaction to the trap geometry. The prototypes are now ready for further testing at the University of Guelph.

APPENDICES

APPENDIX A: OPTIMIZATION PROGRAMMES FOR THE CONIBEAR TRAP SPRING - SEEK 1 AND SIMPLX.

Description:

The programme optimizes the design of the Conibear series stirrup type spring. There are two main programmes, one for the subroutine SEEK 1 and the other for the subroutine SIMPLX. The user can combine either one of the programmes with the following subroutines UREAL, CONST and ENRGY without any changes. OPTISEP[7] manual and Sections 3-2 and 3-3 should be referred to for the details. Most of the formulas used in the subroutine ENRGY are explained in Chapter 2 and Section 3-1.

Input:

The design variables and the input parameters are defined in the first part of the programme. Other input variables, related to the particular optimization strategy, are defined according to the OPTISEP[7] manual and can be altered to suit. There are two INPUT statements:

a) The DATA statement for RMIN which remains all zero in this case

b) The READ statement for the parameters as listed in the NAME LIST statement.

The user is required to provide the data cards according to the FORMATS.

Output:

In addition to the direct output from the OPTISEP subroutines, the programme prints out:

$X_1 \sim X_6$ The values of the design variables along with their definitions

FF1 The tangential force at the end of the free end arm when the spring is loaded by the primary deflection angle.

STS The maximum bending stress in the spring

ENGY The maximum strain energy stored in the spring

Other Information:

Often the programme yields different solutions with different sets of starting values. Although normal starting values are defined as:

X STRT (I) = (RMAX (I) + RMIN (I))/2.0,

it is better to change the starting values several times in the case when the programme is hung up. It cannot be overemphasized how the starting values do affect the result. A feasible and reasonable set of starting values give good results. Even if an optimum solution is obtained, it is better either to run the programme with a different set of the starting values or to use a different subroutine to check if the solution is not a local optimum.

As explained in Section 3-2, if it is required to use the subroutine EQUAL [7], add the subroutine as shown on page 227, change the dimension of the PSI(I) and put EQUAL = 2 in the main programme. Also the user should fill up the values of WDIA and FRAME, where WDIA = available or commercial size of the wire (in.)

FRAME = Inner dimension of the trap frame (in.)

It is difficult to get a solution with the equality constraints and this is why the parameters WDIA and FRAME were not incorporated into the main programme.

The average computer time to get a solution was 5 seconds central processing time per run utilizing the subroutine SEEK 1 on a CDC6400 computer. It was 15 seconds for the subroutine SIMPLX. In both cases, the subroutine EQUAL was not used.

```
HVMT,T60.
ATTACH,OPTISEP.
FTN.
LDSET,LIB=OPTISEP.
LGO.
       6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C  APPENDIX *A* OPTIMIZATION PROGRAM FOR THE CONIBEAR TRAP SPRING--SEEK1
C
C
C *** DEFINITION OF DESIGN VARIABLES ***
C
C     X(1) = WIRE DIAMETER (IN)
C     X(2) = MEAN COIL DIAMETER (IN)
C     X(3) = NUMBER OF TURNS OF COIL
C     X(4) = FREE END ARM LENGTH (IN)
C     X(5) = INITIAL COMPRESSION ANGLE (RAD)
C
C
C  **** DEFINITION OF INPUT PARAMETERS ****
C
C   X1MAX  = MAX. ALLOWABLE WIRE DIAMETER (IN.)
C   X2MAX  = MAX. ALLOWABLE MEAN COIL DIAMETER (IN.)
C   X3MAX  = MAX. ALLOWABLE NUMBER OF TURNS OF COIL
C   X4MAX  = MAX. ALLOWABLE FREE END ARM LENGTH (IN.)
C   X5MAX  = MAX. ALLOWABLE INITIAL COMPRESSION ANGLE (RAD)
C   DEEM   = CHORD OF ADDITIONAL COMP. ANGLE WITH FREE END ARM LENGTH AS
C            A RADIUS (IN.)
C   E      = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C   STW    = WORKING STRESS (LBS/SQ.-IN.)
C   FLOW   = MINIMUM REQUIRED ENERGY OUT OF THE TRAP (IN.-LBS)
C   SPWT   = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C   FINIT  = MIN. REQUIRED FORCE AT INITIAL DEFLECTION (AT THE END OF FREE
C            ARM) (LBS)
C   RM     = NUMBER OF SPRINGS ON THE TRAP
C   DLOOP  = MEAN DIAMETER OF THE ENDLOOP OF THE FREE END ARM (IN)
C SUBROUTINE ENRGY COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X( 5),RMAX( 5),RMIN( 5),XSTRT( 5),       PHI(13),PSI(1),
     1 WORK1( 5),WORK2( 5),WORK3( 5),WORK4( 5)
C
      COMMON /AA/ PI,DEEM,E,STW,FLOW,SPWT,FINIT,RM,DLOOP
      COMMON /BB/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX
C
      NAMELIST /INPUT/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX,DEEM,E,STW,FLOW,
     1                 SPWT,FINIT,RM,DLOOP
C
      DATA RMIN / 5 * 0.0 /
C
C READ, STORE AND WRITE OUT PARAMETERS AS LISTED IN NAMELIST
C
      READ (5, INPUT)
      WRITE(6, INPUT)
C
      PI=4.0*ATAN(1.0)
C
C DEFINE INPUT VARIABLES ACCORDING TO OPTISEP MANUAL
C
```

```
      N       = 5
      IPRINT  = 1
      IDATA   = 1
      NCONS   = 13
      NEQUS   = 0
      F       = .01
      G       = .01
      MAXM    = 100
      NSHOT   = 2
      NTEST   = 100
C
C
C GENERATE RMAX AND XSTRT (STARTING POINT OF X(I))
C
      RMAX(1) = X1MAX
      RMAX(2) = X2MAX
      RMAX(3) = X3MAX
      RMAX(4) = X4MAX
      RMAX(5) = X5MAX
C
      DO 3 I=1,N
      XSTRT(I)=(RMAX(I)+RMIN(I))/2.0
    3 CONTINUE
C
      CALL SEEK1(N, RMAX, RMIN, NCONS, NEQUS, F, G, XSTRT, NSHOT, NTEST,
     1MAXM, IPRINT, IDATA, X, U, PHI, PSI, WORK1, WORK2, WORK3, WORK4)
C
      CALL ANSWER(U, X, PHI, PSI, N, NCONS, NEQUS)
C
      CALL        ENRGY(X, FF1, STS,ENGY)
C
      WRITE(6, 50)
      WRITE(6,100) FF1,STS,ENGY
C
      TEST=-1.0E-10
      DO 4 I=1,NCONS
      IF(PHI(I) .LT. TEST) GO TO 5
    4 CONTINUE
C
      WRITE(6,200) (X(I),I=1,N)
    5 CONTINUE
C
   50 FORMAT(//)
  100 FORMAT(5X, *FORCE AT INITIAL DEFLECTION(LBS) . . . . =*, F15.6, //
     1         5X, *STRESS IN SPRING (LBS/SQ.IN.). . . . . . =*, F15.6, //
     1         5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . =*, F15.6,//)
  200 FORMAT(5X, *WIRE DIAMETER (IN.)  . . . . . . . . . . =*, F10.4, //
     1         5X, *MEAN COIL DIAMETER (IN.) . . . . . . . . =*, F10.4, //
     1         5X, *NUMBER OF TURNS OF COIL  . . . . . . . . =*, F10.4, //
     1         5X, *FREE END ARM LENGTH (IN.)  . . . . . . . =*, F10.4, //
     1         5X, *INITIAL COMP. ANGLE (RAD)  . . . . . . . =*, F10.4,//)
C
      STOP
      END
```

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```
HVMI.160.                                                          YI Y. J
ATTACH,OPTISEP,NEWOPT,ID=HVS11,CY=2.                           223
RIN.
LDSET,LIB OPTISEP.
LGO.
       6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C  APPENDIX *A* OPTIMIZATION PROGRAM FOR THE CONIBEAR TRAP SPRING--SIMPLEX
C
C
C
C *** DEFINITION OF DESIGN VARIABLES ***
C
C     X(1) = WIRE DIAMETER (IN)
C     X(2) = MEAN COIL DIAMETER (IN)
C     X(3) = NUMBER OF TURNS OF COIL
C     X(4) = FREE END ARM LENGTH (IN)
C     X(5)   INITIAL COMPRESSION ANGLE (RAD)
C
C
C **** DEFINITION OF INPUT PARAMETERS ****
C
C   X1MAX  - MAX. ALLOWABLE WIRE DIAMETER (IN.)
C   X2MAX  = MAX. ALLOWABLE MEAN COIL DIAMETER (IN.)
C   X3MAX  - MAX. ALLOWABLE NUMBER OF TURNS OF COIL
C   X4MAX  - MAX. ALLOWABLE FREE END ARM LENGTH (IN.)
C   X5MAX  - MAX. ALLOWABLE INITIAL COMPRESSION ANGLE (RAD)
C   DEFM   - CHORD OF ADDITIONAL COMP. ANGLE WITH FREE END ARM LENGTH AS
C            A RADIUS (IN.)
C   E      = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C   STW    = WORKING STRESS (LBS/SQ.-IN.)
C   FLOW   = MINIMUM REQUIRED ENERGY OUT OF THE TRAP (IN.-LBS)
C   SPWT   = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C   FINIT  = MIN. REQUIRED FORCE AT INITIAL DEFLECTION (AT THE END OF FREE
C            ARM) (LBS)
C   RM     = NUMBER OF SPRINGS ON THE TRAP
C   DLOOP  = MEAN DIAMETER OF THE ENDLOOP OF THE FREE END ARM (IN)
C SUBROUTINE ENRGY COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X( 5),RMAX( 5),RMIN( 5),XSTRT( 5),PHI(13), PSI(13),
     1 XA( 5, 6),XJ( 5),XH( 5),XS( 5),XL( 5),XO( 5),XR( 5),XE( 5),
     1 XC( 5), STEP( 5), FUN( 6)
C
      COMMON /AA/ PI,DEFM,E,STW,FLOW,SPWT,FINIT,RM,DLOOP
      COMMON /BB/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX
C
      NAMELIST /INPUT/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX,DEFM,E,STW,FLOW,
     1                 SPWT,FINIT,RM,DLOOP
C
      DATA RMIN / 5 * 0.0 /
C
C READ, STORE AND WRITE OUT PARAMETERS AS LISTED IN NAMELIST
C
      READ (5, INPUT)
      WRITE(6, INPUT)
C
      PI=4.0*ATAN(1.0)
C
C DEFINE INPUT VARIABLES ACCORDING TO OPTISEP MANUAL
```

```
      N         = 5
      NN        = N+1
      NCONS     = 13
      NEQUS     = 0
      MAXM      = 500
      IPRINT    = 1
      IDATA     = 1
      REDUCE    = .05
      F         = .1
      G         = 1.E-2
      R         = 1.0
      ALPHA     = 1.0
      BETA      = .5
      GAMA      = 2.0
C
C GENERATE RMAX AND XSTRT (STARTING POINT OF X(I))
C
      RMAX(1) = X1MAX
      RMAX(2) = X2MAX
      RMAX(3) = X3MAX
      RMAX(4) = X4MAX
      RMAX(5) = X5MAX
C
      DO 3 I=1,N
      XSTRT(I)=(RMAX(I)+RMIN(I))/2.0
    3 CONTINUE
C
      CALL SIMPLX(N,RMAX,RMIN,NCONS,NEQUS,XSTRT,NN,ALPHA,BETA,GAMA,
     1 REDUCE,R,F,G,MAXM,IPRINT,IDATA,U,X,PHI,PSI,XA,XJ,FUN,XH,XS,XL,XO,
     1 XR,XE,XC,STEP)
C
      CALL ANSWER(U, X, PHI, PSI, N, NCONS, NEQUS)
C
      CALL       ENRGY(X, FF1, STS,ENGY)
C
      WRITE(6, 50)
      WRITE(6,100) FF1,STS,ENGY
C
      TEST=-1.0E-10
      DO 4 I=1,NCONS
      IF(PHI(I) .LT. TEST) GO TO 5
    4 CONTINUE
C
      WRITE(6,200) (X(I),I=1,N)
    5 CONTINUE
C
   50 FORMAT(//)
  100 FORMAT(5X, *FORCE AT INITIAL DEFLECTION(LBS) . . . . =*, F15.6, //
     1       5X, *STRESS IN SPRING (LBS/SQ.IN.). . . . . . =*, F15.6, //
     1       5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . =*, F15.6,//)
  200 FORMAT(5X, *WIRE DIAMETER (IN.)  . . . . . . . . . . =*, F10.4, //
     1       5X, *MEAN COIL DIAMETER (IN.) . . . . . . . . =*, F10.4, //
     1       5X, *NUMBER OF TURNS OF COIL  . . . . . . . . =*, F10.4, //
     1       5X, *FREE END ARM LENGTH (IN.) . . . . . . . . =*, F10.4, //
     1       5X, *INITIAL COMP. ANGLE (RAD)  . . . . . . . =*, F10.4,//)
C
      STOP
      END
```

```
C
      SUBROUTINE UREAL(X,U)
C
      DIMENSION X(1)
C
      COMMON /AA/ PI,DEFM,E,STW,ELOW,SPWT,FINIT,RM,DLOOP
C
C OPTIMUM FUNCTION IS THE WEIGHT OF THE SPRING
C
      ARG=(DLOOP+X(1))/2.0
      U=SPWT*(PI/4.0)*(X(1)**2)*(PI*X(2)*X(3)+2.0*(X(4)-ARG+PI*DLOOP))   1
C
      RETURN
      END
C
      SUBROUTINE CONST(X,NCONS,PHI)
C
      DIMENSION X(1), PHI(1)
C
      COMMON /AA/ PI,DEFM,E,STW,ELOW,SPWT,FINIT,RM,DLOOP
      COMMON /BB/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX
C
      CALL        ENRGY(X, FF1, STS,ENGY)
C
C ALL DESIGN VARIABLES SHOULD BE LESS THAN MAX. ALLOWABLE VALUES SET
C
      PHI( 1) = X1MAX - X(1)
      PHI( 2) = X2MAX - X(2)
      PHI( 3) = X3MAX - X(3)
      PHI( 4) = X4MAX - X(4)
      PHI( 5) = X5MAX - X(5)
C
C ALL DESIGN VARIABLES SHOULD BE POSITIVE
C
      PHI( 6) = X(1)
      PHI( 7) = X(2)
      PHI( 8) = X(3)
      PHI( 9) = X(4)
      PHI(10) = X(5)
C
C ENERGY, STRESS AND INITIAL DEFLECTION FORCE RESTRICTION
C
      PHI(11) = ENGY  - ELOW
      PHI(12) = STW   - STS
      PHI(13) = FF1   - FINIT
C
      RETURN
      END
C
      SUBROUTINE ENRGY(X, FF1, STS,ENGY)
C
      DIMENSION X(1)
C
      COMMON /AA/ PI,DEFM,E,STW,ELOW,SPWT,FINIT,RM,DLOOP
C
C CHECK IF THERE IS ANY NEGATIVE DESIGN VARIABLE
C
      DO 2 I=1,5
      IF (X(I) .EQ. 0.0) X(I)=1.0E-4
```

```
    2  CONTINUE
C
C CALCULATE PARAMETERS TO COMPUTE ENERGY AND STRESS
C
      C=X(2)/X(1)
      ARG1=4.0*C*(C-1.0)
      IF(ARG1  .EQ. 0.0) ARG1=1.0E-4
      RK1=(4.0*(C**2)-C-1.0)/ARG1
C
      ARG3=DEFM/(2.0*X(4))
      IF(ABS(ARG3) .GT. 1.0) ARG3=1.0
      PHI2=2.0*ASIN(ARG3) + X(5)
C
C COMPUTE ENERGY
C
      ARG2=E*(X(1)**4)/(64.*(X(2)*X(3)+2.0*X(4)/(3.0*PI)))
      ENGY =RM*ARG2*((PHI2**2)-(X(5)**2))/2.0
C
C COMPUTE FORCE AT INITIAL DEFLECTION AT THE END OF FREE END ARM
C
      FF1=ARG2*X(5)/X(4)
C
C COMPUTE STRESS IN SPRING
C
      RMOM=ARG2*PHI2
      STS=32.*RK1*RMOM/(PI*(X(1)**3))
C
      RETURN
      END
        6400 END OF RECORD
           END OF FILE
```

CD TOT   0090

```
C
      SUBROUTINE EQUAL(X,PSI,NEQUS)
C
      DIMENSION X(1),PSI(1)
      COMMON /AA/ PI,DEFM,E,STW,ELOW,SRAT,FINIT,RM,DLOOP
C
      WDIA    =
      FRAME   =
C
      N=X(3)
      RN=FLOAT(N)
      A=(2.0*PI*(X(3)-RN)+X(5))/2.0
      B=PI/2.0-A
      ARG=(X(2)/2.0)*COS(B)+X(4)*SIN(B)
C
      PSI(1) = X(1) - WDIA
      PSI(2) = ARG  - FRAME/2.0  -
C
      RETURN
      END
```

CD TOT   0020

APPENDIX B: TRIM OR CALCULATION PROGRAMME FOR THE CONIBEAR TRAP SPRING.

Description:

The programme is either to trim the spring optimization result or to analyze the existing spring of the Conibear trap. It can also be used for springs similar to the Conibear trap spring.

Input:

The input parameters are defined in the first part of the programme, and there are four input statements.

a) The DATA statement for E and SPWT which remain the same if the material is not changed.

b) The READ statement of the trap name

c) The READ statement for the design variables $X_1 \sim X_5$ and DEFM.

d) The READ statement for the "MORE" which is required for the next set of the data if there is any.

The user should provide the data cards according to the FORMATS.

Output:

The programme prints out the input data along with their definitions and:

U The weight of the spring

FF1 The tangential force at the end of the free end arm when the spring is loaded by the initial deflection angle

STS The maximum bending stress in the spring

ENGY The maximum strain energy stored in the spring

Other Information:

The average computer time was 3 seconds central processing time for 3 sets of the data on a CDC6400 computer.

```
HVMT.                                                                 YI Y.
IIN.
EOF.                                                          230
      6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *B* TRIM OR CALCULATION PROGRAM FOR THE CONTBEAR TRAP SPRING
C
C *** DEFINITION OF DESIGN VARIABLES ***
C
C       X(1) - WIRE DIAMETER (IN)
C       X(2) - MEAN COIL DIAMETER (IN)
C       X(3) - NUMBER OF TURNS OF COIL
C       X(4) - FREE END ARM LENGTH (IN)
C       X(5) - INITIAL COMPRESSION ANGLE (RAD)
C
C  **** DEFINITION OF INPUT PARAMETERS ****
C
C     NAME    = TRAP NAME
C     DELM    = CHORD OF ADDITIONAL COMP. ANGLE WITH FREE END ARM LENGTH AS
C               A RADIUS (IN.)
C     E       = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C     SPWT    = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C     RM      = NUMBER OF SPRINGS ON THE TRAP
C     DLOOP   = MEAN DIAMETER OF THE ENDLOOP OF THE FREE END ARM (IN)
C SUBROUTINE ENRGY COMPUTES STRESS AND ENERGY OF THE SPRINGS (PRIVATE)
C
      DIMENSION X(5),NAME(8)
C
      COMMON/AAA/ DELM,E,SPWT,PI,RM
C
      DATA E, SPWT / 30.E+06, .2840 /
C
      PI=4.0*ATAN(1.0)
   10 READ(5,600) NAME
      READ(5,400) (X(I),I=1,5),DELM,DLOOP,RM
C
      ARG =DLOOP+X(1))/2.0
      U=SPWT*(PI/4.0)*(X(1)**2)*(PI*X(2)*X(3)+2.0*(X(4)-ARG+PI*DLOOP))
      CALL      ENRGY(X, FF1, STS,ENGY)
C
      WRITE(6, 50)
      WRITE(6,600) NAME
      WRITE(6, 50)
      WRITE(6,200) (X(I),I=1,5)
      WRITE(6,100) FF1,STS,ENGY,U
C
C GO BACK TO THE BEGINING OF THE PROGRAM FOR ANOTHER SET OF DATA
C
      READ(5,300) MORE
      IF(MORE .EQ. 4) GO TO 10
C
   50 FORMAT(///)
  100 FORMAT(5X, *FORCE AT INITIAL DEFLECTION(LBS) . . . . . . . . *, E15.6, //
     1       5X, *STRESS IN SPRING (LBS/SQ.IN.) . . . . . . . . . *, E15.6, //
     1       5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . . . *, E15.6//
     1       5X, *WEIGHT OF ONE SPRING (LBS) . . . . . . . . . . *, E15.6,///)
  200 FORMAT(5X, *WIRE DIAMETER (IN.)  . . . . . . . . . . . . . *, F10.4, //
     1       5X, *MEAN COIL DIAMETER (IN.) . . . . . . . . . . . *, F10.4, //
```

```
     1          5X, *NUMBER OF TURNS OF COIL  . . . . . . . . . . =*, F10.4, //
     1          5X, *FREE END ARM LENGTH (IN.)  . . . . . . . . . =*, F10.4, //
     1          5X, *INITIAL COMP. ANGLE (RAD)  . . . . . . . . . =*, F10.4,//)
 100 FORMAT(I2)
 200 FORMAT(8F10.0)
 300 FORMAT(8A10)

     STOP
     END

     SUBROUTINE ENGY(X, FFI, SIS,ENGY)

     DIMENSION X(1)

     COMMON /AA/ DEFM,E,SPMT,PI,RM
C
C CALCULATE PARAMETERS TO COMPUTE ENERGY AND STRESS
C
     C=X(2)/X(1)
     ARG1=4.0*C*(C-1.0)
     IF(ARG1 .EQ. 0.0) ARG1=1.0E-4
     RK1=(4.0*(C**2)-C-1.0)/ARG1

     ARG3=DEFM/(2.0*X(4))
     IF(ABS(ARG3) .GT. 1.0) ARG3=1.0
     PHI2=2.0*ASIN(ARG3) + X(5)

C COMPUTE ENERGY

     ARG2=E*(X(1)**4)/(64.*(X(2)*X(3)+2.0*X(4)/(3.0*PI)))
     ENGY =RM*ARG2*((PHI2**2)-(X(5)**2))/2.0

C COMPUTE FORCE AT INITIAL DEFLECTION AT THE END OF FREE END ARM
C
     FFI=ARG2*X(5)/X(4)

C COMPUTE STRESS IN SPRING

     RMOM=ARG2*PHI2
     SIS=32.*RK1*RMOM/(PI*(X(1)**3))

     RETURN
     END
        6400 END OF RECORD;
             END OF FILE
```

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APPENDIX C: ENERGY PREDICTION PROGRAMME FOR THE CONIBEAR TRAPS

Description:

This programme first smoothes the input data, computes the theoretical energy and finds the maximum and specific theoretical energy levels at specified jaw openings. The calculation details are explained in Chapter 4.

Input:

The input variables and the subroutines called are described in the first part of the programme. Most of the variables are named in the way shown in Figures 2-1, 4-1 and 4-6.

Note that SARM = ℓ_s, TARM = ℓ_t

There are four input statements:

a) The READ statement of the trap name.

b) The READ statement for the parameters as listed in the NAME LIST statment

c) The READ statement for the T(I) and S(I)

d) The READ statement for the "MORE" which is required for the next set of the data if there is any.

The user should provide the data cards according to the FORMATS.

Output:

I	Number of the measurements
T(I)	Nominal jaw openings as read in (in.)
S(I)	Distances between the necks of the spring as read in (in.)

THETA(I)	Trap angles (Deg.)
BETA(I)	Spring angles (Deg.)
PHI(I)	Deflection angles (Deg.)
DANG(I)	Released angles from the maximum deflection angles (Deg.)
ENGY(I)	Theoretical energy level (in-lbs.)
OP(I)	Nominal jaw openings at which the energy required (in.)
EXPEC(I)	Theoretical energy at OP(I)
S(IK)	Nominal jaw opening at the maximum energy level
EMAX	Theoretical energy at S(IK)

Also the programme plots out the graph of the spring angles BETA(I) against the trap angles THETA(I) for the original and smoothed data and the graph of the theoretical energy levels ENGY(I) against the nominal trap openings T(I).

Other Information:

If the number of the data T(I) and S(I) is over 100, the DIMENSION statement should be altered for the parameters whose arguments appeared 100, accordingly. If the values of the EXPEC(I) are not reasonable then the jaw opening OP(I) is not within the boundary of the table. The required computer time for 3 sets of the data was approximately 7.5 seconds of central processing time on a CDC6400 computer.

```
HYMIL.
ATTACH(MACLIB)
RTN.
LDSET(LIB=MACLIB)
LGO.
      .6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *C* ENERGY PREDICTION PROGRAM FOR THE CONIBEAR TRAP
C
C  **** DEFINITION OF INPUT VARIABLES ****
C
C   N      = NUMBER OF DISCRETE DATA OF T(I) AND S(I)
C   WDIA   = WIRE DIAMETER  OF THE SPRING (IN)
C   COIL   = MEAN COIL DIAMETER OF THE SPRING (IN)
C   TURN   = NUMBER OF COIL OF THE SPRING
C   ARM    = FREE END ARM LENGTH , OF THE SPRING (IN)
C   SARM   = SPRING ARM LENGTH TO THE NECK (IN)
C   TARM   = DISTANCE FROM FULCRUM TO OUTER FRAME OF THE TRAP FRAME (IN)
C   PHII   = INITIAL DEFLECTION ANGLE OF THE SPRING (DEG)
C   PHIMAX = MAX. DEFLECTION ANGLE OF THE SPRING (DEG)
C   T(I)   = NOMINAL JAW OPENING (IN)
C   S(I)   = DISTANCE BETWEEN NECKS OF THE SPRING (IN)
C   K      = NUMBER OF OPENINGS AT WHICH THE ENERGIES TO BE CALCULATED
C   OP     = OPENING OF TRAP AT WHICH THE ENERGY REQUIRED
C   WORD   = PUT 4 IN I2 FORMAT TO REPEAT PROCESS FOR NEXT TRAP
C   E      = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN)
C   RM     = NUMBER OF SPRINGS ON THE TRAP
C
C  SUBROUTINE LIST CALLED
C
C   LESQ   = TO FIND THE LEAST SQUARE FIT OF A SET OF POINTS (X,Y) TO A CURVE
C            Y=F(X) POLYNOMIAL OF A GIVEN DEG.(IN THIS CASE 5) IN X(LIB=MACLI
C   PLOTPT = STORES ORDINATES AND ABCISSAS FOR PLOT(LIB=MACLIB)
C   PHIPLT = PLOTS AND DESTROYS ALL STORED POINTS(LIB=MACLIB)
C   EXPRED = TO COMPUTE EXPECTED ENERGY AND FIND MAX. VALUE OF IT (PRIVATE)
C   FTABLE = SUBPROGRAM FOR LINEAR INTERPOLATION FROM A TABLE OF VALUES(PRIVA
C
      DIMENSION T(100),S(100),PHI(100),THETA(100),BETA(100),DANG(100),
     1          ENGY(100),OP(3),EXPEC(3),COEF(10),WORK(50),NAME(8)
C
      COMMON /AA/ E,WDIA,COIL,TURN,ARM,PHII,PHIMAX,RM
C
      NAMELIST /INPUT/ N,WDIA,COIL,TURN,ARM,SARM,TARM,PHII,PHIMAX,RM,
     1                 K,OP
C
      PI=4.0*ATAN(1.0)
      E=30.E+06
C
C TO READ AND STORE DATA
C
    2 READ (5,100) (NAME(I),I = 1,8)
      READ (5,INPUT)
      READ(5,200) (T(I),S(I),I=1,N)
C
C TO COMPUTE SPRING ANGLE AND TRAP ANGLE
C
      DO 3 I=1,N
      ARG1=.5*COIL/SARM
```

```
      ALPHA=ATAN(ARG1)
      ARG2=SQRT((SARM**2)+((0.5*COIL)**2))
      ARG3=.5*S(I)/ARG2
      GAMMA=ACOS(ARG3)
      BETA(I)=2.0*(PI/2.0-(ALPHA+GAMMA))
C
      ARG4=.5*T(I)/TARM
      THETA(I)=2.0*ASIN(ARG4)
    3 CONTINUE
C
C TO CONVERT DIMENSION OF ANGLE (RADIAN TO DEGREE)
C
      DO 4 I=1,N
      BETA(I)=BETA(I)*180./PI
      THETA(I)=THETA(I)*180./PI
    4 CONTINUE
C
C TO STORE ORIGINAL DATA TO PLOT
C
      DO 5 I=1,N
      CALL PLOTPT(THETA(I),BETA(I),35)
    5 CONTINUE
C
C TO CALL SUBROUTINE LESQ TO GET POLYNOMIAL APPROXIMATION
C
      CALL          LESQ(WORK,COEF,THETA,BETA,4,N)
C
      DO 6 I=1,N
      BETA(I)=COEF(1) + COEF(2)*THETA(I) + COEF(3)*(THETA(I)**2)
     1          + COEF(4)*(THETA(I)**3)+ COEF(5)*(THETA(I)**4)
    6 CONTINUE
C
C TO STORE SMOOTHED DATA TO PLOT
C
      DO 7 I=1,N
      CALL PLOTPT(THETA(I),BETA(I),39)
    7 CONTINUE
C
C TO CALL SUBROUTINE EPRED TO GET THEORETICAL ENERGY
C
      CALL          EPRED(PI,BETA,N,PHI,DANG,ENGY,IK,EMAX)
C
C TO GET THEORETICAL ENERGY AT A CERTAIN JAW OPENING
C
      DO 8 I=1,K
      EXPEC(I)=ETABLE(T,ENGY,OP(I),N)
    8 CONTINUE
C
C TO WRITE AND PLOT THE RESULTS
C
      WRITE(6, 50)
      WRITE (6,150) (NAME(I),I=1,8)
      WRITE(6,400) (COFF(I),I=1,5)
      WRITE(6,650)
      WRITE(6,300)
      WRITE(6,350) (I,T(I),S(I),THETA(I),BETA(I),PHI(I),DANG(I),
     1              ENGY(I),I=1,N)
      WRITE(6, 50)
      WRITE(6,550) (OP(I),EXPEC(I),I=1,K)
```

```
      WRITE(6,600) T(IK),EMAX
      WRITE(6,INPUT)
      CALL OUTPLT
      WRITE(6,450)
      WRITE (6,150) (NAME(I),I=1,8)
C
      DO 9 I=1,N
      CALL PLOTPT(T(I),ENGY(I),4)
    9 CONTINUE
C
      CALL OUTPLT
      WRITE(6,500)
      WRITE (6,150) (NAME(I),I=1,8)
C
C TO GO BACK TO EVALUATE NEXT TRAP IF ANY
C
      READ(5,250) MORE
      IF(MORE .EQ. 4) GO TO 2
C
   50 FORMAT(1H1)
  100 FORMAT(8A10)
  150 FORMAT (5X,*TRAP DESIGNATION*, 4X, 8A10, / 5X,*--- -----------*)
  200 FORMAT(2F10.0)
  250 FORMAT(I2)
  300 FORMAT(//)
  350 FORMAT(1X,/I5, 7F15.5 /)
  400 FORMAT(// 1X, *COFF. OF POLYNOMIAL =*, 5F16.6 //)
  450 FORMAT(/5X, *ABSCISSA . . . TRAP ANGLE(DEG),*, 3X,
     1             *ORDINATE . . . SPRING ANGLE(DEG)*, 3X,
     1             *(O ... ORIGINAL, S ... SMOOTHED DATA)*)
  500 FORMAT(/5X, *ABSCISSA . . . OPENING(IN.),*, 3X,
     1             *ORDINATE . . . ENERGY(IN-LBS)*)
  550 FORMAT(1X, *ENERGY(IN-LBS) AT *, F5.2, 2X, *OPENING OF JAW . . . .
     1 . . =*, F10.4 /)
  600 FORMAT(1X, *MAXIMUM.ENERGY(IN-LBS), JAW OPENING AT*, F9.4,
     1 * IN. =*, F10.4 /)
  650 FORMAT(4X, *NO.*, 4X, *NOM. OPENING*, 4X, *DIST. BTW.*, 5X, *TRAP
     1ANGLE*, 4X, *SPRING ANGLE*, 4X, *DEFLECTION*, 5X, *ANGLE*, 8X,
     1*THEORETICAL*, /15X, *(IN.)*, 5X, *SPRING NECK(IN)*, 4X, *(DEG.)*,
     110X, *(DEG.)*, 7X, *ANGLE(DEG.)*, 4X, *DIFF.(DEG.)*, 2X, *ENERGY(IN
     1-LBS)*)
C
      STOP
      END
C
      SUBROUTINE EPRED(PI,BETA,N,PHI,DANG,ENGY,IK,EMAX)
C
      DIMENSION PHI(1),BETA(1),DANG(1),ENGY(1)
C
      COMMON /AA/ E,WDIA,COIL,TURN,ARM,PHI1,PHIMAX,RM
C
      PHI(1)=PHIMAX
C
      DO 2 I=2,N
      PHI(I)=(BETA(N)+PHI1-BETA(I))
    2 CONTINUE
C
      DO 3 I=1,N
      DANG(I)=PHI(1)-PHI(I)
```

```
    3 CONTINUE
C
      ARG2=E*(WDIA**4)/(64.*(COIL*TURN+2.0*ARM/(3.0*PI)))
C
      ENGY(1)=0.0
      ARG3= PHI(1)*PI/180.
C
      DO 4 I=2,N
      ENGY(I)=RM*ARG2*((ARG3**2) - ((PHI(I)*PI/180.)**2))/2.0
    4 CONTINUE
C
C FIND OUT MAXIMUM ENERGY
C
      EMAX=ENGY(1)
      IK=1
      DO 5 I=2,N
      IF(ENGY(I) .LE. EMAX) GO TO 5
      EMAX=ENGY(I)
      IK=I
    5 CONTINUE
C
      RETURN
      END
C
      FUNCTION FTABLE(VAR,FUNC,XX,M)
C
C VAR=DISCRETE TABULAR VALUES OF THE VARIABLE
C FUNC=DISCRETE TABLULAR VALUES OF THE FUNCTION
C XX=GIVEN VALUE OF THE VARIABLE
C M=NUMBER OF STATIONS OR TABLE VALUES
C FTABLE=INTERPOLATED VALUE OF THE FUNCTION CORRESTONDING TO XX
C
      DIMENSION VAR(1), FUNC(1)
      NEND=M-1
      DO 10 I=1,NEND
      INT=I
      IF(XX .LT. VAR(I) .AND. XX .GE. VAR(I+1)) GO TO 11
   10 CONTINUE
   11 FTABLE=FUNC(INT)+(XX-VAR(INT))*(FUNC(INT+1)-FUNC(INT))/(VAR(INT+1)
     1 -VAR(INT))
      RETURN
      END
        6400 END OF RECORD
   CONIREAR TRAP NO. 120
 $INPUT N=11,WDIA=.1875,COIL=2.1250,TURN=2.3030,ARM=3.8750,SARM=3.3750,
 TARM=2.3438,PHI1=36.7500,PHIMAX=89.8670,RM=2.0,K=2,OP=2.,4.,0.$
4.6250    0.7500
4.5000     .8125
4.0000    1.0313
3.5000    1.2188
3.0000    1.4063
2.5000    1.6563
2.0000    2.0313
1.5000    2.5313
1.2500    3.0313
1.0000    3.4063
 .3750    3.6875
 4
   CONIREAR TRAP NO. 220
```

```
$INPUT N=14,WDIA=.2500,COIL=2.4375,TURN=2.3120,ARM=6.4375,SARM=5.5000,
TARM=3.7188,PHI1=35.2168,PHIMAX=87.1750,RM=2.0,K=3,OP=2.,4.,6.$
 7.0000      .7188
 6.5000      .9688
 6.0000     1.1563
 5.5000     1.3750
 5.0000     1.5313
 4.5000     1.7500
 4.0000     2.0625
 3.5000     2.4063
 3.0000     2.7500
 2.5000     3.2188
 2.0000     3.8750
 1.5000     4.8750
 1.2500     5.1875
  .9375     5.4375
 4
  CONIBEAR TRAP NO. 330
$INPUT N=25,WDIA=.3125,COIL=2.8750,TURN=2.3100,ARM=8.7500,SARM=7.2500,
TARM=5.1563,PHI1=30.5000,PHIMAX=79.5000,RM=2.0,K=3,OP=2.,4.,6.$
10.0625     1.0625
 9.8750     1.2500
 9.5000     1.3750
 9.3750     1.5313
 9.0000     1.6406
 8.5000     1.8549
 8.0000     2.0625
 7.5000     2.2813
 7.0000     2.3750
 6.5000     2.6875
 6.2500     2.8750
 6.0000     2.9688
 5.5000     3.2500
 5.0000     3.5938
 4.5000     3.8542
 4.4375     4.0000
 4.0000     4.2500
 3.8750     4.4375
 3.5000     4.8438
 3.0000     5.2083
 2.8750     5.5000
 2.5000     6.0313
 2.3125     6.0625
 2.0000     6.7188
 1.8750     7.4375
 1            END OF FILE
```

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APPENDIX D: KINETIC ENERGY CALCULATION PROGRAMMES - FOR TWO MEASURED ANGLES AND ONE MEASURED ANGLE FROM CONIBEAR TRAPS

Description:

The programme first smooths the input data and computes the nominal jaw openings, the closing times, and the kinetic energies of both the trap frame and the free end arm of the spring at various jaw openings. Some of the calculation methods are explained in Section 5-2.

Input:

The input parameters, and the subroutine names called are defined in the first part of the programme.

There are four READ statements for

a) the trap name

b) the input parameters as listed in the NAME LIST statement

c) the data of FRAME(I), ANG1(I) and ANG2(I)

d) the MORE which is required for the next set of data if there is any.

The user should provide the data cards according to the FORMATS.

Output:

I	Number of the measurement
CUMTIM(I)	Time elapsed to the jaw opening (sec.)
ANG1(I)	Trap angle moved (rad.)

OPEN(I)	Nominal jaw opening (in.)
AVEL1(I)	Angular velocity of the trap frame (rad./sec.)
AVEL2(I)	Angular velocity of the free end arm of the spring (rad./sec.)
ENGY1(I)	Kinetic energy of the trap frame (in-lbs.)
ENGY2(I)	Kinetic energy of the spring arm (in-lbs.)
ENGY(I)	Total Kinetic energy of the above two (in-lbs.)
OP(I)	Nominal jaw opening at which the energy level is required (in.)
EXPEC(I)	Kinetic energy at OP(I)
OPEN(IK)	Nominal jaw opening at the maximum energy level
EMAX	Kinetic energy at OPEN(IK)

Also the programme plots out the graph of the above three kinds of kinetic energies against the nominal jaw openings. In the graph, the characters "F", "S", and "T" represent the kinetic energy levels in the same order.

Other Information:

If the number of the measurements or the data is over 200, the DIMENSION statement should be altered for the parameters whose arguments are 200, accordingly. It is required to check the original data carefully because one blunder or unreasonable value could affect the whole curve in the process of the polynomial approximation. If the values of the EXPEC(I) are not reasonable, then the jaw opening OP(I) is not within the boundary of the table. The required computer time for 2 sets of the data was approximately 9.5 seconds of central processing time on a CDC6400 computer. For the purpose of reference, the programme, which reads and processes only the data for the trap frame, is listed separately

```
ATTACH,MACLIB.
RFL.
LDSET(LIB=MACLIB)
LGO.
      6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *D* KINETIC ENERGY CALCULATION PROGRAM--FOR TWO MEASURED ANGLES
C              FROM CONIBEAR TRAP
C
C
C **** DEFINITION OF INPUT VARIABLES ****
C
C  NAME    = TRAP NAME
C  DIST    = DISTANCE FROM FULCRUM TO OUTER FRAME(IN)
C  ERTIA1  = MOMENT OF INERTIA OF TRAP FRAME(LBS-SQ.IN)
C  ERTIA2  = MOMENT OF INERTIA OF SPRING ARM (LBS-SQ.IN)
C  N       = NUMBER OF EXPOSURES CONSIDERED
C  BIAS    = ANGLE OF JAW MEASURED AT LAST READING OF ANGULAR MOVEMENT(DEG)
C  PULSE   = TIME BETWEEN PULSES ON FILM(SEC)
C  FRAME   = NUMBER OF FRAMES PER PULSE INTERVAL
C  ANG1    = CUMULATIVE ANGLES TRAVERESED FOR TRAP FRAME(DEG)
C  ANG2    = CUMULATIVE ANGLES TRAVERESED FOR TRAP SPRING(DEG)
C  RM      = NUMBER OF SPRING ON TRAP
C  K       = NUMBER OF OPENINGS AT WHICH THE ENERGIES TO BE CALCULATED
C  OP      = OPENING OF TRAP AT WHICH THE ENERGY REQUIRED
C  MORE    = PUT 4 IN I2 FORMAT TO REPEAT PROCESS FOR NEXT TRAP
C
C  SUBROUTINE LIST CALLED
C
C  PLOTPT = STORES ORDINATES AND ABCISSAS FOR PLOT(LIB=MACLIB)
C  OUTPLT = PLOTS AND DESTROYS ALL STORED POINTS(LIB=MACLIB)
C  LESQ   = TO FIND THE LEAST SQUARE FIT OF A SET OF POINTS (X,Y) TO A CURVE
C           Y=F(X) POLYNOMIAL OF A GIVEN DEG.(IN THIS CASE 5) IN X(LIB=MACLIB
C  ENRGY  = TO COMPUTE KINETIC ENERGY (PRIVATE PROGRAM)
C  TRIM   = TRIM THE INPUT DATA ANG1 DISCARDING UNREASONABLE ONES(PRIVATE)
C  FTABLE = SUBPROGRAM FOR LINEAR INTERPOLATION FROM A TABLE OF VALUES(PRIVAT
C
      DIMENSION NAME(8),FRAME(200),ANG1(200),ANG2(200),TIME(200),
     1          CUMTIM(200),AVEL1(200),AVEL2(200),ENGY1(200),ENGY2(200),
     1          ENGY(200),OPEN(200),OP(3),ESPEC(3),COEF(10),WORK(50),
     1          COFS(10)
C
      COMMON /AA/ ERTIA1,ERTIA2,RM
      NAMELIST /INPUT/ DIST,ERTIA1,ERTIA2,N ,BIAS,PULSE,RM,K,OP
C
      PI     = 4.0*ATAN(1.0)
C
C READ AND STORE REQUIRED DATA
C
  444 READ (5,100) (NAME(I),I = 1,8)
      READ(5,INPUT)
      READ(5,102) (FRAME(I),ANG1(I),ANG2(I),I=1,N)
      SET=ANG1(N)
C
C COMPUTE TIME TAKEN BETWEEN FILM EXPOSURES AND CUMULATIVE TIME
C
      TIME(1)=0.0
```

```
      CUMTIM(1)=0.0
      DO 4 I=2,N
      TIME(I)=PULSE /FRAME(I)
      CUMTIM(I)=CUMTIM(I-1)+TIME(I)
    4 CONTINUE
C
C SMOOTH THE CURVE OF INPUT DATA ANG1(I) AND REDEFINE ANG1(I) ACCORDINGLY
C BY USING MACLIB LESQ (LEAST SQUARE APPROXIMATION)
C
      CALL      LESQ(WORK,COEF,CUMTIM,ANG1,5,N)
      ANG1(1)=0.0
      DO 5 I=2,N
      ANG1(I)=COEF(1) + COEF(2)*CUMTIM(I) + COEF(3)*(CUMTIM(I)**2)
     1        + COEF(4)*(CUMTIM(I)**3) + COEF(5)*(CUMTIM(I)**4)
     1        + COEF(6)*(CUMTIM(I)**5)
    5 CONTINUE
C
C REDEFINE THE BIAS ACCORDING TO NEW VALUES OF CUMULATIVE ANGLE
C
      BIAS=SET-ANG1(N)+BIAS
      IF(BIAS .LT. 0.0) BIAS=0.0
C
C SMOOTH THE CURVE OF INPUT DATA ANG2(I) AND REDEFINE ANG2(I) ACCORDINGLY
C BY USING MACLIB LESQ (LEAST SQUARE APPROXIMATION)
C
      CALL      LESQ(WORK,COES,CUMTIM,ANG2,5,N)
      ANG2(1)=0.0
      DO 6 I=2,N
      ANG2(I)=COES(1) + COES(2)*CUMTIM(I) + COES(3)*(CUMTIM(I)**2)
     1        + COES(4)*(CUMTIM(I)**3) + COES(5)*(CUMTIM(I)**4)
     1        + COES(6)*(CUMTIM(I)**5)
    6 CONTINUE
C
C CALCULATE ANGULAR VELOCITY OF TRAP FRAME(AVEL1) AND COIL SPRING(AVEL2)
C
      AVEL1(1)=0.0
      AVEL2(1)=0.0
      DO 7 I=2,N
      DANG1=(ANG1(I)-ANG1(I-1))/2.0
      AVEL1(I)=DANG1    *PI/(180.*TIME(I))
      DANG2=(ANG2(I)-ANG2(I-1))/2.0
      AVEL2(I)=DANG2*PI/(180.*TIME(I))
    7 CONTINUE
C
C SUBROUTINE ENRGY COMPUTES KINETIC ENERGIES
C
      CALL      ENRGY(N,AVEL1,AVEL2,ENGY1,ENGY2,ENGY,IK,EMAX)
C
C CALCULATE THE INCREMENTAL JAW OPENING
C
      DO 8 I=1,N
      ARG1=(ANG1(N)+BIAS-ANG1(I))*PI/(2.*180.)
      OPEN(I) = 2.0* DIST *SIN(ARG1)
    8 CONTINUE
C
C COMPUTE THE ENERGY LEVEL AT GIVEN OPENING(BY INTERPOLATION)
C
      DO 9 I=1,K
      ESPEC(I)=FTABLE(OPEN,ENGY,OP(I),N)
```

```
   9  CONTINUE
C
C WRITE OUT THE RESULTS
C
      WRITE(6, 99)
      WRITE (6,104)
      WRITE (6,105) (NAME(I),I=1,8)
      WRITE(6,104)
      WRITE(6,103) (COFF(I),I=1,6)
      WRITE(6,114) (COES(I),I=1,6)
      WRITE(6,106)  DIST,ERTIA1,ERTIA2,N, PULSE,ANG1(N),BIAS,CUMTIM(N)
      WRITE(6,104)
      WRITE (6,107)
      WRITE (6,104)
      WRITE(6,108) (I,CUMTIM(I),ANG1(I),OPEN(I),AVEL1(I),AVEL2(I),
     1              ENGY1(I),ENGY2(I),ENGY(I), I=1,N)
      WRITE(6,104)
      WRITE(6,109) (OP(I),ESPEC(I),I=1,K)
      WRITE(6,110) OPEN(IK),EMAX
C
C STORE THE DATA AND PLOT OUT
C
      DO 11 I=1,N
      CALL PLOTPT(CUMTIM(I),ENGY(I),4)
   11 CONTINUE
      CALL OUTPLT
      WRITE(6,111)
      WRITE (6,105) (NAME(I),I=1,8)
C
      DO 12 I=1,N
      CALL PLOTPT(OPEN(I),ENGY(I),40)
      CALL PLOTPT(OPEN(I),ENGY1(I),26)
      CALL PLOTPT(OPEN(I),ENGY2(I),39)
   12 CONTINUE
      CALL OUTPLT
      WRITE(6,112)
      WRITE (6,105) (NAME(I),I=1,8)
C
      DO 13 I=1,N
      CALL PLOTPT(ANG1(I),ENGY(I),4)
   13 CONTINUE
      CALL OUTPLT
      WRITE(6,113)
      WRITE (6,105) (NAME(I),I=1,8)
C
C GO BACK TO THE BEGINING OF THIS PROGRAM FOR NEXT TRAP IF THERE IS MORE
C
      READ (5,101)MORE
      IF(MORE.EQ.4) GO TO 444
C
   99 FORMAT (1H1)
  100 FORMAT(8A10)
  101 FORMAT (I2)
  102 FORMAT(3F10.0)
  103 FORMAT(1X, *COFF. OF EQUATION(FRAME)  ANG=F(CUMTIM) =*, 6E13.4 //)
  104 FORMAT (///)
  105 FORMAT (5X,*TRAP DESIGNATION*, 4X, 8A10, / 5X,*---- -----------*)
  106 FORMAT(1X, *DISTANCE FROM FULCRUM TO OUTER FRAME(IN) . . . . . . . .
     1 . . = *, F10.4, //
```

```
     1         1X, *INERTIA OF TRAP FRAME*, 10H(W*(R**2)), * LBA-SQ.IN) .
     1. . . . . . . . = *, F10.4, //
     1         1X, *INERTIA OF SPRING*, 10H(W*(R**2)), * LBA-SQ.IN) . . .
     1. . . . . . . . = *, F10.4, //
     1         1X, *NUMBER OF EXPOSURES CONSIDERED . . . . . . . . . . . .
     1 . . = *, I10,    //
     1         1X, *TIME BETWEEN PULSES ON FILM(SEC) . . . . . . . . . . .
     1 . . = *, F10.4, //
     1         1X, *TOTAL ANGLE SWEEP(DEG). . . . . . . . . . . . . . . . .
     1 . . = *, F10.4, //
     1         1X, *REMAINING ANGLE AT THE END OF MEASUREMENT(DEG) . . . .
     1 . . = *, F10.4, //
     1         1X, *TOTAL TIME TAKEN FOR THE SWEEP(SEC)   . . . . . . . . .
     1 . . = *, F10.4, //)
 107 FORMAT(1X,
     1*FRAME   CUMULATIVE  CUMULATIVE   JAW OPENING   ANGULAR VELOCITY
     1ANGULAR VELOCITY  KINETIC ENERGY  KINETIC ENERGY  KINETIC ENERGY*,
     1 / 1X,
     1*NUMBER  TIME(SEC)    ANGLE(DEG)     (INCHES)      TRAP(RAD/SEC)
     1SPRING(RAD/SEC)     TRAP(IN-LBS)    SPRING(IN-LBS)  TOTAL(IN-LBS)*)
 108 FORMAT((1X, I3, 3X,F10.4, 2(3X,F10.4), 2(7X,F10.4), 3X,
     1          3(6X,F10.4) //))
 109 FORMAT(1X, *ENERGY(IN-LBS) AT *, F5.2, 2X, *OPENING OF JAW . . . .
     1 . . =*, F10.4 /)
 110 FORMAT(1X, *MAXIMUM ENERGY(IN-LBS), JAW OPENING AT*, F9.4,
     1 * IN. =*, F10.4 /)
 111 FORMAT(/5X, *ABSCISSA . . . CUM. TIME(SEC),*, 3X,
     1              *ORDINATE . . . ENERGY(IN-LBS)*)
 112 FORMAT(/5X, *ABSCISSA . . . NOM. JAW OPENING(IN.),*, 3X,
     1              *ORDINATE . . . KINETIC ENERGY(T=TOTAL,F=FRAME,S=SPRIN
     1G, LBS)*)
 113 FORMAT(/5X, *ABSCISSA. . . . CUM. ANGLE(DEG),*, 3X,
     1              *ORDINATE . . . ENERGY(IN-LBS)*)
 114 FORMAT(1X, *COFF. OF EQUATION(SPRING) ANG=F(CUMTIM) =*, 6E13.4 //)
C
      STOP
      END
C
      SUBROUTINE ENRGY(N,AVEL1,AVEL2,ENGY1,ENGY2,ENGY,IK,EMAX)
C
      DIMENSION AVEL1(1),AVEL2(1),ENGY1(1),ENGY2(1),ENGY(1)
      COMMON /AA/ ERTIA1,ERTIA2,RM
C
      RI1=ERTIA1/(12.*32.2)
      RI2=ERTIA2/(12.*32.2)
C
C COMPUTE KINETIC ENERGY
C
      DO 3 I=1,N
      ENGY1(I)=    RI1*(AVEL1(I)**2)
      ENGY2(I)=RM*RI2*(AVEL2(I)**2)
      ENGY(I)=ENGY1(I)+ENGY2(I)
    3 CONTINUE
C
C FIND OUT MAXIMUM ENERGY
C
      EMAX=ENGY(1)
      IK=1
      DO 4 I=2,N
```

```
      IF(ENGY(I) .LE. EMAX) GO TO 4
      EMAX=ENGY(I)
      IK=I
    4 CONTINUE
C
      RETURN
      END
C
      FUNCTION ETABLE(VAR,FUNC,XX,M)
C
C VAR=DISCRETE TABULAR VALUES OF THE VARIABLE
C FUNC=DISCRETE TABULAR VALUES OF THE FUNCTION
C XX=GIVEN VALUE OF THE VARIABLE
C M=NUMBER OF STATIONS OR TABLE VALUES
C ETABLE=INTERPOLATED VALUE OF THE FUNCTION CORRESPONDING TO XX
C
      DIMENSION VAR(1), FUNC(1)
      NEND=M-1
      DO 10 I=1,NEND
      INT=I
      IF(XX .LT. VAR(I) .AND. XX .GE. VAR(I+1)) GO TO 11
   10 CONTINUE
   11 ETABLE=FUNC(INT)+(XX-VAR(INT))*(FUNC(INT+1)-FUNC(INT))/(VAR(INT+
     1 -VAR(INT))
      RETURN
      END
        6400 END OF RECORD
             END OF FILE

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```

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```
      ...,4A0.
ATTACH,MACLIB.
FTN.
LDSET(LIB=MACLIB)
LGO.
      * 6600 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX KDK KINETIC ENERGY CALCULATION PROGRAM--FOR ONE MEASURED ANGLE
C               FROM CONIBEAR TRAP
C
C
C **** DEFINITION OF INPUT VARIABLES ****
C
C   NAME   - TRAP NAME
C   DIST   - DISTANCE FROM FULCRUM TO OUTER FRAME(IN)
C   ERTIA  - MOMENT OF INERTIA OF TRAP(LBS-SQ.IN)
C   N      - NUMBER OF EXPOSURES CONSIDERED
C   BIAS   - ANGLE OF JAW MEASURED AT LAST READING OF ANGULAR MOVEMENT(DEG)
C   PULSE  - TIME BETWEEN PULSES ON FILM(SEC)
C   FRAME  - NUMBER OF FRAMES PER PULSE INTERVAL
C   ANG1   - CUMULATIVE ANGLES TRAVERSED(DEG)
C   K      - NUMBER OF OPENINGS AT WHICH THE ENERGIES TO BE CALCULATED
C   OP     - OPENING OF TRAP AT WHICH THE ENERGY REQUIRED
C   MORE   - PUT 4 IN I2 FORMAT TO REPEAT PROCESS FOR NEXT TRAP
C
C SUBROUTINE LIST CALLED
C
C   PLOTPT - STORES ORDINATES AND ABCISSAS FOR PLOT(LIB=MACLIB)
C   OUTPLT - PLOTS AND DESTROYS ALL STORED POINTS(LIB=MACLIB)
C   LSQ    - TO FIND THE LEAST SQUARE FIT OF A SET OF POINTS (X,Y) TO A CURVE
C            Y=F(X) POLYNOMIAL OF A GIVEN DEG.(IN THIS CASE 5) IN X(LIB=MACLIB)
C   ENRGY  - TO COMPUTE KINETIC ENERGY (PRIVATE PROGRAM)
C   FTABLE - SUBPROGRAM FOR LINEAR INTERPOLATION FROM A TABLE OF VALUES(PRIVAT
C
      DIMENSION NAME(8),FRAME(200),ANG1(200),OP(2),ANG(200),TIME(200),
     1          CUMTIM(200),AVEL(200),DANG(200),ENGY(200),OPEN(200),
     1          ESPEC(2),COEF(10),WORK( 50)
C
      NAMELIST /INPUT/ DIST,ERTIA,N ,BIAS,PULSE,       K,OP
C
      PI     = 4.0*ATAN(1.0)
C
C READ AND STORE REQUIRED DATA
C
  444 READ (5,100) (NAME(I),I = 1,8)
      READ(5,INPUT)
      READ(5,102) (FRAME(I),ANG1(I),I=1,N)
      SET=ANG1(N)
C
C COMPUTE TIME TAKEN BETWEEN FILM EXPOSURES AND CUMULATIVE TIME
C
      TIME(1)=0.0
      CUMTIM(1)=0.0
      DO 5 I=2,N
      TIME(I)=PULSE /FRAME(I)
      CUMTIM(I)=CUMTIM(I-1)+TIME(I)
    5 CONTINUE
C
```

```
C SMOOTH THE CURVE OF INPUT DATA ANG1(I) TO GET ANG(I).
C BY USING MACLIB LESQ (LEAST SQUARE APPROXIMATION)
C
      CALL        LESQ(WORK,COFF,CUMTIM,ANG1,5,N)
      ANG(1)=0.0
      DO 6 I=2,N
      ANG(I)=COFF(1) + COFF(2)*CUMTIM(I) + COFF(3)*(CUMTIM(I)**2)
     1         + COFF(4)*(CUMTIM(I)**3) + COFF(5)*(CUMTIM(I)**4)
     1         + COFF(6)*(CUMTIM(I)**5)
    6 CONTINUE
C
C REDEFINE THE BIAS ACCORDING TO NEW VALUES OF CUMULATIVE ANGLE
C
      BIAS=SET      -ANG(N)+BIAS
      IF(BIAS .LT. 0.0) BIAS=0.0
C
C CALCULATE ANGLE DIFFERENCE AND ANGULAR VELOCITY
C
      AVEL(1)=0.0
      DANG(1)=0.0
      DO 7 I=2,N
      DANG(I)=ANG(I)-ANG(I-1)
      AVEL (I)=DANG(I   )*PI/(180.*TIME(I))
    7 CONTINUE
C
C SUBROUTINE ENRGY COMPUTES KINETIC ENERGIES
C
      CALL         ENRGY(ERTIA,N,AVEL,ENGY,IK,EMAX)
C
C CALCULATE THE INCREMENTAL JAW OPENING
C
      DO 8 I=1,N
      PHI    =((ANG(N)+BIAS-ANG(I))/2.0)*PI/180.
      OPEN(I) = 2.0* DIST *SIN(PHI)
    8 CONTINUE
C
C COMPUTE THE ENERGY LEVEL AT GIVEN OPENING(BY INTERPOLATION)
C
      DO 9 I=1,K
      ESPEC(I)=FTABLE(OPEN,ENGY,OP(I),N)
    9 CONTINUE
C
C WRITE OUT THE RESULTS
C
      WRITE(6, 99)
      WRITE (6,104)
      WRITE (6,105) (NAME(I),I=1,8)
      WRITE(6,104)
      WRITE(6,103) (COFF(I),I=1,6)
      WRITE(6,106)   DIST,ERTIA,N, PULSE,ANG(N),BIAS,CUMTIM(N)
      WRITE(6,104)
      WRITE (6,107)
      WRITE (6,104)
      WRITE(6,108) (I,TIME(I),CUMTIM(I),DANG(I),   ANG(I),OPEN(I),
     1              AVEL(I),ENGY(I), I=1,N)
      WRITE(6,104)
      WRITE(6,109) (OP(I),ESPEC(I),I=1,K)
      WRITE(6,110) OPEN(IK),EMAX
C
```

```
C STORE THE DATA AND PLOT OUT
C
      DO 12 I=1,N
      CALL PLOTPT(OPEN(I),ENGY(I),4)
   12 CONTINUE
      CALL OUTPLT
      WRITE(6,112)
      WRITE (6,105) (NAME(I),I=1,8)
C
C GO BACK TO THE BEGINING OF THIS PROGRAM FOR NEXT TRAP IF THERE IS MORE
C
      READ (5,101)MORE
      IF(MORE.EQ.4) GO TO 444
C
   99 FORMAT (1H1)
  100 FORMAT(8A10)
  101 FORMAT (I2)
  102 FORMAT(2F10.0)
  103 FORMAT(1X, *COEF. OF EQUATION ANG=F(CUMTIM) =*, 6F13.4 //)
  104 FORMAT (//)
  105 FORMAT (5X,*TRAP DESIGNATION*, 4X, 8A10, / 5X,*---- -----------*)
  106 FORMAT(1X, *DISTANCE FROM FULCRUM TO OUTER FRAME(IN) . . . . . . .
     1 . . = *, F10.4, //
     1          1X, *INERTIA OF TRAP*, 10H(W*(R**2),, *,LBA-SQ.IN) . . . .
     1. . . . . . . = *, F10.4, //
     1          1X, *NUMBER OF EXPOSURES CONSIDERED . . . . . . . . . . .
     1 . . = *, I10,    //
     1          1X, *TIME BETWEEN PULSES ON FILM(SEC) . . . . . . . . . .
     1 . . = *, F10.4, //
     1          1X, *TOTAL ANGLE SWEEP(DEG) . . . . . . . . . . . . . . .
     1 . . = *, F10.4, //
     1          1X, *REMAINING ANGLE AT THE END OF MEASUREMENT(DEG) . . .
     1 . . = *, F10.4, //
     1          1X, *TOTAL TIME TAKEN FOR THE SWEEP(SEC)  . . . . . . . .
     1 . . = *, F10.4, ///)
  107 FORMAT(1X, *FRAME*, 5X, *TIME TAKEN*, 4X, *CUMULATIVE*, 3X,
     1          *ANGLE MOVED*, 2X, *CUMULATIVE*, 3X, *JAW OPENING*, 3X,
     1          *ANGULAR VELOCITY*, 2X, *KINETIC ENERGY*, /
     1          1X, *NUMBER*, 7X, *(SEC)*, 6X, *TIME(SEC)*, 6X, *(DEG)*,
     1          6X, *ANGLE(DEG)*, 5X, *(INCHES)*, 7X, *(RAD/SEC)*,
     1          8X, *(IN.-LBS)*)
  108 FORMAT((1X, I5,  5(3X, F10.4),  2(7X, F10.4) / ))
  109 FORMAT(1X, *ENERGY(IN-LBS) AT *, F5.2, 2X, *OPENING OF JAW . . . .
     1 . . =*, F10.4 /)
  110 FORMAT(1X, *MAXIMUM ENERGY(IN-LBS), JAW OPENING AT*, F9.4,
     1 * IN. =*, F10.4 /)
  112 FORMAT(/5X, *ABSCISSA . . . OPENING(IN.),*, 3X,
     1                  *ORDINATE . . . ENERGY(IN-LBS)*)
C
      STOP
      END
C
      SUBROUTINE ENRGY(FRTIA,N,AVEL,ENGY,IK,EMAX)
C
      DIMENSION AVEL(1),ENGY(1)
C
      RI=FRTIA/(32.2*12.)
C
C COMPUTE KINETIC ENERGY
```

```
C
      DO 3 I=1,N
      ENGY(I)=.5*RI*(AVEL(I)**2)
    3 CONTINUE
C
C FIND OUT MAXIMUM ENERGY
C
      EMAX=ENGY(1)
      IK=1
      DO 4 I=2,N
      IF(ENGY(I) .LE. EMAX) GO TO 4
      EMAX=ENGY(I)
      IK=I
    4 CONTINUE
C
      RETURN
      END
C
      FUNCTION ETABLE(VAR,FUNC,XX,M)
C
C VAR=DISCRETE TABULAR VALUES OF THE VARIABLE
C FUNC=DISCRETE TABULULAR VALUES OF THE FUNCTION
C XX=GIVEN VALUE OF THE VARIABLE
C M=NUMBER OF STATIONS OR TABLE VALUES
C ETABLE=INTERPOLATED VALUE OF THE FUNCTION CORRESTONDING TO XX
C
      DIMENSION VAR(1), FUNC(1)
      NEND=M-1
      DO 10 I=1,NEND
      INT=I
      IF(XX .LT. VAR(I) .AND. XX .GE. VAR(I+1)) GO TO 11
   10 CONTINUE
   11 ETABLE=FUNC(INT)+(XX-VAR(INT))*(FUNC(INT+1)-FUNC(INT))/(VAR(INT+1)
     1 -VAR(INT))
      RETURN
      END
        6400 END OF RECORD
             END OF FILE
```

CD TOT 0215

APPENDIX E: OPTIMIZATION PROGRAMME FOR THE FLAT SPRING - JACOB TRAP

Description:

This programme finds the optimum design for the flat spring of the Jacob trap utilizing the OPTISEP[7] subroutine SEEK 1. Programming information is explained in Section 10-7. Most of the formulas and the approximation methods used in the subroutine EVLTN are explained in Section 10-2, 10-4, 10-5 and 10-6. The same notations or the names of the notations are used where possible.

Input:

The definitions of the design variables and the input parameters are listed in the first part of the programme. The other parameters in the main programme are defined according to the OPTISEP manual.

There are two input statements:

a) The DATA statement for the RMIN which remain all zero in the case.

b) The READ statement for the parameters as listed in the NAMELIST statement.

Output:

In addition to the direct output from the OPTISEP subroutine the programme prints out:

The values of the design variables with their definitions and:

PDEF: The intial horizontal deflection at the end of the free end arm.

FF1: The horizontal force at the PDEF

FF2: The horizontal force at full deflection at the end of the free end arm.

SK: The spring constant.

STS: The maximum stress in the spring.

ENRGY: The maximum strain energy stored in the spring.

Other Information:

The general information is explained in the first part of the section on - Other Information in Appendix A. In the subroutine EVLTN, the value of JUMP can be any integer number 1, 2, 3... This is the step size of the force increments. A small step size will yield more accurate result while a larger number will reduce the computer time. $I_{max.}$ is set to 200 since the maximum horizontal force range at the end of the free end arm is below 200 lbs. in this case.

The average computer time required for a solution was 35 sec. central processing time per run with the value, JUMP, set to 5, on a CDC 6400 computer.

```
HVMT,T60.
ATTACH,OPTISEP.
FIN.
LOSET,FIP=OPTISEP.
LGO.
      6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *E* OPTIMIZATION PROGRAM FOR THE FLAT SPRING--JACOB TRAP
C               NO DEFLECTION ALLOWED IN THE FREE END ARM
C
C *** DEFINITION OF DESIGN VARIABLES ***
C
C     X(1) = THICKNESS OF THE SPRING (IN.)
C     X(2) = WIDTH OF FLAT SPRING (IN)
C     X(3) = FREE END ARM LENGTH (IN.)
C     X(4) = BASE LENGTH (IN.)
C     X(5) = REDIUS OF CURVATURE OF THE CURVED PORTION (IN.)
C     X(6) = ANGLE OF THE CURVATURE (RAD.)
C
C **** DEFINITION OF INPUT PARAMETERS ****
C ALL THE INPUT PARAMETERS SHOULD BE ABSOLUTE VALUES
C
C   X1MAX  = MAX. ALLOWABLE THICKNESS OF THE SPRING (IN.)
C   X2MAX  = MAX. ALLOWABLE WIDTH OF THE FLAT SPRING (IN.)
C   X3MAX  = MAX. ALLOWABLE FREE END ARM LENGTH (IN.)
C   X4MAX  = MAX. ALLOWABLE BASE LENGTH (IN.)
C   X5MAX  = MAX. ALLOWABLE RADIUS OF CURVATURE OF THE CURVED PORTION (IN.
C   X6MAX  = MAX. ALLOWABLE ANGLE OF CURVATURE (RAD.)
C   DEFM   = HORIZONTAL DEFLECTION FOR THE DESIGN (IN.)
C   E      = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C   HMIN   = MIN. ALLOWABLE HEIGHT OF THE TRAP (IN.)
C   WMAX   = MAX. ALLOWABLE WIDTH OF THE TRAP (IN.)
C   STW    = ALLOWABLE DESIGN STRESS (OR WORKING STRESS) (LBS/SQ.IN.)
C   FLOW   = MINIMUM REQUIRED ENERGY OUT OF THE TRAP (IN.-LBS)
C   SPWT   = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C   FINIT  = MIN. REQUIRED HORIZONTAL FORCE AT INITIAL DEFLECTION (LBS.)
C     HE   = MAX. ALLOWABLE DISTANCE BETWEEN END POINTS OF THE FREE END AR
C
C SUBROUTINE EVLTN COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X( 6),RMAX( 6),RMIN( 6),XSTRT( 6),      PHI(20),PSI(1),
     1 WORK1( 6),WORK2( 6),WORK3( 6),WORK4( 6)
C
      COMMON /AA/  X1MAX,X2MAX,X3MAX,X4MAX,X5MAX,X6MAX
      COMMON /BB/  DEFM,E,HMIN,WMAX,STW,PI,FLOW,SPWT,FINIT,HE
C
      NAMELIST /INPUT/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX,X6MAX,
     1                 DEFM,E,HMIN,WMAX,STW,FLOW,SPWT,FINIT,HE
C
      DATA RMIN / 6 * 0.0 /
C
C READ, STORE AND WRITE OUT PARAMETERS AS LISTED IN NAMELIST
C
      READ (5, INPUT)
      WRITE(6, INPUT)
C
      PI=4.0*ATAN(1.0)
C
```

```
C DEFINE INPUT VARIABLES ACCORDING TO OPTISEP MANUAL
C
      N        = 6
      IPRINT   = 1
      IDATA    = 1
      NCONS    = 20
      NEQUS    = 0
      F        = .01
      G        = .01
      MAXM     = 100
      NSHOT    = 2
      NTEST    = 100
C
C GENERATE RMAX AND XSTRT (STARTING POINT OF X(I))
C
      RMAX(1)= X1MAX
      RMAX(2)= X2MAX
      RMAX(3)= X3MAX
      RMAX(4)= X4MAX
      RMAX(5)= X5MAX
      RMAX(6)= X6MAX
C
      DO 3 I=1,N
      XSTRT(I)=(RMAX(I)+RMIN(I))/2.0
    3 CONTINUE
C
      CALL SEEK1(N, RMAX, RMIN, NCONS, NEQUS, F, G, XSTRT, NSHOT, NTEST,
     1 MAXM, IPRINT, IDATA, X, U, PHI, PSI, WORK1, WORK2, WORK3, WORK4)
C
      CALL ANSWER(U, X, PHI, PSI, N, NCONS, NEQUS)
      CALL        EVLTN(X,RR,RDEF,H,SK,STS,ENRGY,FF1,FF2)
C
      WRITE(6,100)
      WRITE(6,200) (X(I),I=1,N),RDEF,FF1,FF2,SK,STS,ENRGY
  100 FORMAT(///)
  200 FORMAT(5X, *THICKNESS OF THE SPRING (IN.)  . . . . . . =*, E15.6, //
     1        5X, *WIDTH OF THE SPRING (IN.)  . . . . . . . . =*, E15.6, //
     1        5X, *FREE END ARM LENGTH (IN.)  . . . . . . . . =*, E15.6, //
     1        5X, *BASE LENGTH (IN.) . . . . . . . . . . . . =*, E15.6, //
     1        5X, *RADIUS OF CURVATURE (IN.)  . . . . . . . . =*, E15.6, //
     1        5X, *ANGLE OF CURVATURE (RAD.)  . . . . . . . . =*, E15.6, //
     1        5X, *INITIAL HORIZONTAL DEFLECTION (IN.)  . . . =*, E15.6, //
     1        5X, *HORIZ. FORCE AT INITIAL DEFLECTION (LBS) =*, E15.6, //
     1        5X, *HORIZ. FORCE AT FULL DEFLECTION (LBS)  . . =*, E15.6, //
     1        5X, *SPRING CONSTANT (LBS/IN.)  . . . . . . . . =*, E15.6, //
     1        5X, *STRESS IN SPRING (LBS/SQ.IN) . . . . . . . =*, E15.6, //
     1        5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =*, E15.6, /)
C
      STOP
      END
```

```
C
      SUBROUTINE UREAL(X, U)
C
      DIMENSION X(1)
C
      COMMON /BB/  DEFM,E,HMIN,WMAX,STW,PI,ELOW,SPWT,FINIT,HE
C
C OPTIMUM FUNCTION IS THE WEIGHT OF THE SPRING
C
      U=2.*SPWT * X(1)  * ( X(2)*(X(4)+X(5)*X(6)) + (.5+X(2))*X(3)/2.0) B.
C
      RETURN
      END
C
      SUBROUTINE CONST(X, NCONS, PHI)
C
      DIMENSION X(1), PHI(1)
C
      COMMON /AA/  X1MAX,X2MAX,X3MAX,X4MAX,X5MAX,X6MAX
      COMMON /BB/  DEFM,E,HMIN,WMAX,STW,PI,ELOW,SPWT,FINIT,HE
C
C ALL DESIGN VARIABLES SHOULD BE LESS THAN MAX. ALLOWABLE VALUES SET
C
      PHI( 1) = X1MAX - X(1)
      PHI( 2) = X2MAX - X(2)
      PHI( 3) = X3MAX - X(3)
      PHI( 4) = X4MAX - X(4)
      PHI( 5) = X5MAX - X(5)
      PHI( 6) = X6MAX - X(6)
C
C ALL DESIGN VARIABLES SHOULD BE POSITIVE
C
      X1MIN = X1MAX
      PHI( 7) = X(1) - X1MIN
      PHI( 8) = X(2)
      PHI( 9) = X(3)
      PHI(10) = X(4)
      PHI(11) = X(5)
      PHI(12) = X(6)
C
C IF ABOVE CONSTRAINTS ARE NOT SATISFIED ARBITRARY PENALTY VALUES ARE GIVEN
C TO THE REMAINING CONSTRAINTS TO SAVE COMPUTER TIME REQUIRED TO CALL SUBRO
C EVLTN.
C
      DO 3 I=1,12
      IF(PHI(I) .LT. -1.0E-10) GO TO 4
    3 CONTINUE
C
      CALL         EVLTN(X,BB,PDEF,H,SK,STS,ENRGY,FF1,FF2)
C
C BB HAS TO BE POSITIVE AND LESS THAN X(4)
C
      PHI(13) = BB
      PHI(14) = X(4) - BB
C
C ENERGY, STRESS AND INITIAL DEFLECTION FORCE RESTRICTION
C
      PHI(15) = ENRGY - ELOW
      PHI(16) = STW   - STS
```

```
      PHI(17) = ABS(FF1) - FINIT
C
C RESTRICTION FOR HEIGHT, WIDTH AND DISTANCE BETWEEN END POINTS OF FREE END
C
      PHI(18) = H      - HMIN
      PHI(19) = WMAX   - 2.*(X(4)+X(5))
      PHI(20) = HE     - 2.*(X(4)-BB)
      GO TO 6
C
    4 DO 5 I=13,NCONS
      PHI( I) = -1.0E+10
    5 CONTINUE
    6 CONTINUE
C
      RETURN
      END
C
      SUBROUTINE EVLTN(X,BB,PDEF,H,SK,STS,ENRGY,FF1,FF2)
C
C THE PROGRAM IS FOR THE FORCE WHICH IS APPLIED AT THE END OF THE LEFT FREE
C ARM AND DIRECTED RIGHT TO LEFT.
C
      DIMENSION X(1),F(500),DEFX(500),DEFY(500)
      DIMENSION DEFX1(500),DEFX2(500),DEFY1(500),DEFY2(500)
C
      COMMON /BB/  DEFM,E,HMAX,WMAX,STW,PI,ELOW,SPWT,FINIT,HE
C
      DO  1 I=1,6
      IF (X(I) .EQ. 0.0) X(I)=1.0E-04
    1 CONTINUE
C
      PHI=X(6)
      RAD=X(5)
      ARC=X(5)*X(6)
      BETA = PHI   - PI/2.0
      BB = X(3)*SIN(BETA) - X(5)*COS(BETA)
      H  =   X(5)*(1.0+SIN(BETA)) + X(3)*COS(BETA)
      RI = X(2)*(X(1) **3) / 12.0
      PDEF=HE/2.0 - (X(4)-BB)
C
C JUMP IS THE INCREMENT OF THE FORCE, AND IMAX IS THE MAX. ITERATION ALLOWE
C
      JUMP=5
      IMAX=200
      J=0
C
C TEST IS TOTAL HORIZONTAL DEFLECTION ALLOWED
C
      TEST=DEFM+PDEF
C
      I=JUMP
      FUNIT=    -FLOAT(JUMP)
   44 CONTINUE
C
C DEFLECTION DUE TO BASE SECTION OF THE SPRING
C
      F(I)=    -FLOAT(I)
```

```
      THETA    = F(I)*   H*X(4)/(E*RI)
      DEFY1(I)=H*SIN(THETA) + BB*(COS(THETA)-1.0)
      DEFX1(I)=H*(COS(THETA)-1.0) - BB*SIN(THETA) + F(I)*H*(X(4)**2)
     1           /(2.*E*RI)
C
C DEFLECTION DUE TO CURVED SECTION OF THE SPRING
C
      RK=X(3)/RAD
      CY1 = .5*PHI-.25*SIN(2.0*PHI)+RK-RK*COS(PHI)
      CX1 = .75-COS(PHI)+.25*COS(2.0*PHI)
      CY2   = RK*PHI   - RK*SIN(PHI ) - COS(PHI ) + .25*COS(2.0*PHI) +.75
      CX2 = 1.5*PHI-2.0*SIN(PHI)+.25*SIN(2.0*PHI)
      CY3 = RK*PHI-COS(PHI)+1.0
      CX3 = PHI-SIN(PHI)
C
      BETA=PHI-PI/2.0
C
      FY=FUNIT*COS(BETA)
      FX=FUNIT*SIN(BETA)
C
      DELTA=(RAD**2) * (FY*CY3+FX*CX3) / (E*RI)
      DY=( RAD**3) * (FY*CY1+FX*CX1) / (E*RI) + X(3)*SIN(DELTA)
      DX=(RAD**3) * (FY*CY2+FX*CX2) / (E*RI) + X(3)*(1.0-COS(DELTA))
C
      DEF=SQRT((DX**2)+(DY**2))
      GAMMA=ATAN( DX/DY)
      ETA=BETA-GAMMA
C
      DYY=      -DEF*COS(ETA)
      DXX=       DEF*SIN(ETA)
C
      IF(I .NE. JUMP) GO TO 2
      DEFY2(I)=DYY
      DEFX2(I)=DXX
      GO TO 3
    2 CONTINUE
      DEFY2(I)=DEFY2(I-JUMP) + DYY
      DEFX2(I)=DEFX2(I-JUMP) + DXX
C
C COMBINED DEFLECTION OF ABOVE TWO
C
    3 CONTINUE
      DEFY(I) = DEFY1(I) + DEFY2(I)
      DEFX(I) = DEFX1(I) + DEFX2(I)
C
C TO DECIDE HORIZONTAL FORCE AT INITIAL DEFLECTION
C
      IF(J .NE. 0) GO TO 4
      IF (ABS(DEFY(I)) .GE. PDEF) J=1
    4 CONTINUE
C
C BY PASS IF DEFY(I) REACHES TO TEST
C
C
      IF (ABS(DEFY(I)) .GE. TEST) GO TO 5
C
C TEST IF IT REACHED MAXIMUM ITERATION ALLOWED
```

```
C
      IF(I .EQ. IMAX) GO TO 6
C
C REDEFINE THE CONFIGURATION OF THE SPRING
C
      PHI=PHI+DELTA
      RAD=ARC/PHI
      I=I+JUMP
      GO TO 44
C
C COMPUTE THE ENERGY(FF1 AND FF2 ARE HORIZONTAL FORCES AT INITIAL AND FINAL
C DEFLECTIONS)
C
    5 CONTINUE
      FF1=F(J)
      IF(PDEF .EQ. 0.0) FF1=0.0
      FF2=F(I)
      ENRGY=ABS(FF1+FF2)*DEFM
C
C COMPUTE THE MAX. STRESS(BENDING) IN THE SPRING
C
      RMAX=FF2*(X(3)+X(5))
      Z = ( X(1)**2)*X(2) / 6.0
      AREA =  X(1)*X(2)
      STS=ABS(RMAX/Z + FF2/AREA)
C
C COMPUTE SPRING CONSTANT
C
      SK= ABS(FF2/TEST)
C
      RETURN
    6 CONTINUE
      SK    = - 1.0E+10
      STS   = - 1.0E+10
      ENRGY = - 1.0E+10
      FF1   = - 1.0E+10
      FF2   = - 1.0E+10
C
      RETURN
      END
```

CD TOT 0213

APPENDIX F: TRIM OR CALCULATION PROGRAMME FOR THE FLAT SPRING - JACOB TRAP.

Description:

The programme can be used to trim the spring optimization result or to analyze the fabricated spring of the Jacob trap (flat spring). Two programmes are filed, one for the spring with the rigid free end arm and the other with the flexible free end arm. The difference is in subroutine FVLTN. The former uses the formulae in Sections 10-2, 10-4, and 10-5, and the latter, Sections 10-3, 10-4 and 10-5.

Input:

The input parameters are defined in the first part of the programme. There are four input statments:

a) The DATA statement for E and SPWT, which remain the same if the material is not changed.

b) The READ statement of the trap name.

c) The READ statement for the design variables $X_1 \sim X_6$, DEFM and HE.

d) The READ statement for "MORE" for the next set of the data if there is any.

The user should provide the data cards according to the FORMATS.

Output:

The programme prints out the input data along with their definitions and:

PDEF: The initial horizontal deflection at the end of the free end arm.

FF1: The horizontal force at the PDEF.

FF2: The horizontal force at full deflection at the end of the free end arm.

SK: The spring constant

STS: The maximum stress in the spring

ENGRY: The maximum strain energy stored in the spring.

W: The weight of the spring.

Other Information:

The average computer time was 8 sec. central processing time for 3 sets of the data on a CDC 6400 computer. (With the value of JUMP set to 1 in subroutine EVLTH).

```
6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *E* TRIM OR CALCULATION PROGRAM FOR THE FLAT SPRING--JACOB TRA
C                 NO DEFLECTION ALLOWED IN THE FREE END ARMS
C
C **** DEFINITION OF INPUT PARAMETERS ****
C
C     X(1)   - THICKNESS OF THE SPRING (IN.)
C     X(2)   - WIDTH OF FLAT SPRING (IN)
C     X(3)   - FREE END ARM LENGTH (IN.)
C     X(4)   - BASE LENGTH (IN.)
C     X(5)   - REDIUS OF CURVATURE OF THE CURVED PORTION (IN.)
C     X(6)   - ANGLE OF THE CURVATURE (RAD.)
C
C   DEEM     = HORIZONTIAL DEFLECTION FOR THE  DESIGN (IN.)
C   E        = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C   SPWT     = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C     HE     - MAX. ALLOWABLE DISTANCE BETWEEN END POINTS OF THE FREE END A
C
C SUBROUTINE EVLTN COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X(6),NAME(8)
C
      COMMON /AA/ DEEM,E,SPWT,PI,HE
C
      DATA      E,SPWT /        30.E+06, .284 /
C
      N = 6
      PI=4.0*ATAN(1.0)
C
   10 READ(5,150) NAME
      READ(5,300) (X(I),I=1,N),DEEM,HE
C
      W=2.*SPWT * X(1)   * ( X(2)*(X(4)+X(5)*X(6)) + (.5+X(2)))*X(3)/2.0) B.
      CALL       EVLTN(X,BB,PDEF,H,SK,SIS,ENRGY,FF1,FF2)
C
      WRITE(6,100)
      WRITE(6,150) NAME
      WRITE(6, 50)
      WRITE(6,200) (X(I),I=1,N),PDEF,DEEM,FF1,FF2,SK,SIS,ENRGY,W
C
C GO BACK TO THE BEGINING OF THE PROGRAM FOR ANOTHER SET OF DATA
C
      READ(5,400) MORE
      IF(MORE .EQ. 4) GO TO 10
C
   50 FORMAT(//)
  100 FORMAT(1H1, ///)
  150 FORMAT(8A10)
  200 FORMAT(5X, *THICKNESS OF THE SPRING (IN.)  . . . . . . . =*, E15.6, //
     1          5X, *WIDTH OF THE SPRING (IN.)  . . . . . . . . . =*, E15.6, //
     1          5X, *FREE END ARM LENGTH (IN.)  . . . . . . . . . =*, E15.6, //
     1          5X, *BASE LENGTH (IN.)  . . . . . . . . . . . . . =*, E15.6, //
     1          5X, *RADIUS OF CURCATURE (IN.)  . . . . . . . . . =*, E15.6, //
     1          5X, *ANGLE OF CURVATURE (RAD.) . . . . . . . . .
```

```
     1          5X, *INITIAL HORIZONTAL DEFLECTION (IN.)  . . =*, F15.6, //
     1          5X, *ADDITIONAL HORIZ. DEFLECTION(IN.)  . . . =*, F15.6, //
     1          5X, *HORIZ. FORCE AT INITIAL DEFLECTION (LBS) =*, F15.6, //
     1          5X, *HORIZ. FORCE AT FULL DEFLECTION (LBS)  . =*, F15.6, //
     1          5X, *SPRING CONSTANT (LBS/IN.)  . . . . . . . =*, F15.6, //
     1          5X, *STRESS IN SPRING (LBS/SQ.IN) . . . . . . =*, F15.6, //
     1          5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . =*, F15.6, //
     1          5X, *WEIGHT OF THE SPRING (LBS) . . . . . . . =*, F15.6, /)
 300 FORMAT(8F10.0)
 400 FORMAT(I2)
C
      STOP
      END
C
      SUBROUTINE EVLIN(X,BB,PDEF,H,SK,STS,ENRGY,FF1,FF2)
C
C THE PROGRAM IS FOR THE FORCE WHICH IS APPLIED AT THE END OF THE LEFT FRI
C ARM AND DIRECTED RIGHT TO LEFT.
C
      DIMENSION X(1),F(500),DEFX(500),DEFY(500)
      DIMENSION DEFX1(500),DEFX2(500),DEFY1(500),DEFY2(500)
C
      COMMON /AA/ DEFM,E,SPWT,PI,HF
C
      PHI=X(6)
      RAD=X(5)
      ARC=X(5)*X(6)
      BETA = PHI   - PI/2.0
      BB  = X(3)*SIN(BETA) - X(5)*COS(BETA)
      H   =    X(5)*(1.0+SIN(BETA)) + X(3)*COS(BETA)
      RI = X(2)*(X(1) **3) / 12.0
      PDEF=HF/2.0 - (X(4)-BB)
C
C JUMP IS THE INCREMENT OF THE FORCE
C
      JUMP=1
      J=0
C
C WRITE OUT HEADINGS
C
      WRITE(6,100)
      WRITE(6,200)
C
C TEST IS TOTAL HORIZONTAL DEFLECTION ALLOWED
C
      TEST=DEFM+PDEF
C
      I=JUMP
      FUNIT=    -FLOAT(JUMP)
   44 CONTINUE
C
C DEFLECTION DUE TO BASE SECTION OF THE SPRING
C
      F(I)=     -FLOAT(I)
      THETA     = F(I)*    H*X(4)/(E*RI)
      DEFY1(I)=H*SIN(THETA) + BB*(COS(THETA)-1.0)
      DEFX1(I)=H*(COS(THETA)-1.0) - BB*SIN(THETA) + F(I)*H*(X(4)**2)
     1         /(2.*E*RI)
C
```

```
C DEFLECTION DUE TO CURVED SECTION OF THE SPRING
C
      RK=X(3)/RAD
      CY1 = .5*PHI-.25*SIN(2.0*PHI)+RK-RK*COS(PHI)
      CX1 = .75-COS(PHI)+.25*COS(2.0*PHI)
      CY2 = RK*PHI  - RK*SIN(PHI ) - COS(PHI ) + .25*COS(2.0*PHI) +.7
      CX2 = 1.5*PHI-2.0*SIN(PHI)+.25*SIN(2.0*PHI)
      CY3 = RK*PHI-COS(PHI)+1.0
      CX3 = PHI-SIN(PHI)
C
      BETA=PHI-PI/2.0
C
      FY=FUNIT*COS(BETA)
      FX=FUNIT*SIN(BETA)
C
      DELTA=(RAD**2) * (FY*CY3+FX*CX3) / (E*RI)
      DY=( RAD**3) * (FY*CY1+FX*CX1) / (E*RI) + X(2)*SIN(DELTA)
      DX=(RAD**3) * (FY*CY2+FX*CX2) / (E*RI) + X(2)*(1.0-COS(DELTA))
C
      DEF=SQRT((DX**2)+(DY**2))
      GAMMA=ATAN( DX/DY)
      ETA=BETA-GAMMA
C
      DYY=      -DEF*COS(ETA)
      DXX=       DEF*SIN(ETA)
C
      IF(I .NE. JUMP) GO TO 2
      DEFY2(I)=DYY
      DEFX2(I)=DXX
      GO TO 3
    2 CONTINUE
      DEFY2(I)=DEFY2(I-JUMP) + DYY
      DEFX2(I)=DEFX2(I-JUMP) + DXX
C
C COMBINED DEFLECTION OF ABOVE TWO
C
    3 CONTINUE
      DEFY(I) = DEFY1(I) + DEFY2(I)
      DEFX(I) = DEFX1(I) + DEFX2(I)
C
C TO DECIDE HORIZONTAL FORCE AT INITIAL DEFLECTION
C
      IF(J .NE. 0) GO TO 4
      IF (ABS(DEFY(I)) .GE. PDEF) J=I
    4 CONTINUE
C
C BY PASS IF DEFY(I) REACHES TO TEST
C
      WRITE(6,300) F(I),DEFX1(I),DEFX2(I),DEFX(I),DEFY1(I),DEFY2(I),
     1             DEFY(I)
C
      IF (ABS(DEFY(I)) .GE. TEST) GO TO 5
C
C REDEFINE THE CONFIGURATION OF THE SPRING
C
      PHI=PHI+DELTA
      RAD=ARC/PHI
      I=I+JUMP
      GO TO 44
```

```
C
C COMPUTE THE ENERGY(FF1 AND FF2 ARE HORIZONTAL FORCES AT INITIAL AND FINAL
C DEFLECTIONS)
C
  6 CONTINUE
    FF1=F(J)
    IF(DDEF .EQ. 0.0) FF1=0.0
    FF2=F(I)
    ENRGY=ABS(FF1+FF2)*DEFM                                                B.
C
C COMPUTE THE MAX. STRESS(BENDING) IN THE SPRING
C
    BMAX=FF2*(X(3)+X(5))
    Z = ( X(1)**2)*X(2) / 6.0
    AREA = X(1)*X(2)
    STS=ABS(BMAX/Z + FF2/AREA)
C
C COMPUTE SPRING CONSTANT
C
    SK = ABS(FF2/TEST)
C
100 FORMAT(1H1, //)
200 FORMAT(6X, *F(I)*, 7X, *DEFX1(I)*, 7X, *DEFX2(I)*, 7X, * DEFX(I)*,
  1        7X, *DEFY1(I)*, 7X, *DEFY2(I)*, 7X, * DEFY(I)*, //)
300 FORMAT(1X, F8.1, 6E15.4 /)
C
    RETURN
    END
      6400 END OF-RECORD
/ *** JACOB TRAP I (DESIGN A) ***
.1000    2.2500    5.2500    .4375    1.8750    1.9200    2.500    1.875
4
  *** JACOB TRAP I (DESIGN B) ***
.1000    2.000     4.6250    .34375   1.9375    1.9809    2.500    1.875
4
*** JACOB TRAP III (DESIGN) ***
.1720    2.300     12.50     1.1875   2.3750    1.8326    5.00     1.875
        END OF FILE
```

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```
HWNT.
ATTACH(MACLIB)
FTN.
LOSET(LIB=MACLIB)
LGO.
      6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *F* TRIM OR CALCULATION PROGRAM FOR THE FLAT SPRING--JACOB TRA
C             FLEXIBLE FREE END ARMS
C
C  **** DEFINITION OF INPUT PARAMETERS ****
C
C       X(1)  = THICKNESS OF THE SPRING (IN.)
C       X(2)  = WIDTH OF FLAT SPRING (IN)
C       X(3)  = FREE END ARM LENGTH (IN.)
C       X(4)  = BASE LENGTH (IN.)
C       X(5)  = REDIUS OF CURVATURE OF THE CURVED PORTION (IN.)
C       X(6)  = ANGLE OF THE CURVATURE (RAD.)
C
C   DEFM    = HORIZONTAL DEFLECTION FOR THE  DESIGN (IN.)
C    E      = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C   SPWT    = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C    HE     = MAX. ALLOWABLE DISTANCE BETWEEN END POINTS OF THE FREE END A
C
C SUBROUTINE EVLTN COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X(6),NAME(8)
C
      COMMON /AA/ DEFM,E,SPWT,PI,HE
C
      DATA       E,SPWT /          30.E+06, .284 /
C
      N = 6
      PI=4.0*ATAN(1.0)
C
   10 READ(5,150) NAME
      READ(5,300) (X(I),I=1,N),DEFM,HE
C
      U=2.*SPWT * X(1) * X(2)  * (X(4)+X(5)*X(6) + X(3))
      CALL       EVLTN(X,PP,PDEF,H,SK,STS,ENRGY,FF1,FF2)
C
      WRITE(6,100)
      WRITE(6,150) NAME
      WRITE(6, 50)
      WRITE(6,200) (X(I),I=1,N),PDEF,DEFM,FF1,FF2,SK,STS,ENRGY,U
C
C GO BACK TO THE BEGINING OF THE PROGRAM FOR ANOTHER SET OF DATA
C
      READ(5,400) MORE
      IF(MORE .EQ. 4) GO TO 10
C
   50 FORMAT(///)
  100 FORMAT(1H1, ////)
  150 FORMAT(8A10)
  200 FORMAT(5X, *THICKNESS OF THE SPRING (IN.) . . . . . . . =*, F15.6, //
     1           5X, *WIDTH OF THE SPRING (IN.) . . . . . . . . . =*, F15.6, //
     1           5X, *FREE END ARM LENGTH (IN.). . . . . . . . . . =*, F15.6, //
     1           5X, *BASE LENGTH (IN.) . . . . . . . . .
```

```
     1        5X, *RADIUS OF CURCATURE (IN.)  . . . . . . . . =*, F15.6, //
     1        5X, *ANGLE OF CURVATURE (RAD.)  . . . . . . . . =*, F15.6, //
     1        5X, *INITIAL HORIZONTAL DEFLECTION (IN.)  . . . =*, F15.6, //
     1        5X, *ADDITIONAL HORIZ. DEFLECTION(IN.)  . . . . =*, F15.6, //
     1        5X, *HORIZ. FORCE AT INITIAL DEFLECTION (LBS) =*, F15.6, //
     1        5X, *HORIZ. FORCE AT FULL DEFLECTION (LBS)  . =*, F15.6, //
     1        5X, *SPRING CONSTANT (LBS/IN.)  . . . . . . . . =*, F15.6, //
     1        5X, *STRESS IN SPRING (LBS/SQ.IN) . . . . . . . =*, F15.6, //
     1        5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . =*, F15.6, //
     1        5X, *WEIGHT OF THE SPRING (LBS) . . . . . . . . =*, F15.6, /)
  300 FORMAT(8F10.0)
  400 FORMAT(I2)
C
      STOP
      END
C
C
      SUBROUTINE EVLIN(X,RB,PDEF,H,SK,STS,ENRGY,FF1,FF2)
C
C THE PROGRAM IS FOR THE FORCE WHICH IS APPLIED AT THE END OF THE LEFT FREE
C ARM AND DIRECTED RIGHT TO LEFT.
C
      DIMENSION X(1),F(500),DEFX(500),DEFY(500)
      DIMENSION DEFX1(500),DEFX2(500),DEFY1(500),DEFY2(500)
C
      COMMON /AA/ DEFM,E,SPWT,PI,HE
C
      PHI=X(6)
      RAD=X(5)
      ARC=X(5)*X(6)
      BETA = PHI  - PI/2.0
      RB = X(3)*SIN(BETA) - X(5)*COS(BETA)
      H =    X(5)*(1.0+SIN(BETA)) + X(3)*COS(BETA)
      RI = X(2)*(X(1)**3) / 12.0
      PDEF=0.0
C
C JUMP IS THE INCREMENT OF THE FORCE
C
      JUMP=1
      J=0
C
C WRITE OUT HEADINGS
C
      WRITE(6,100)
      WRITE(6,200)
C
C TEST IS TOTAL HORIZONTAL DEFLECTION ALLOWED
C
      TEST=DEFM+PDEF
C
      I=JUMP
      FUNIT=    -FLOAT(JUMP)
   44 CONTINUE
C
C DEFLECTION DUE TO BASE SECTION OF THE SPRING
C
      F(I)=    -FLOAT(I)
      THETA    = F(I)*   H*X(4)/(E*RI)
      DEFY1(I)=H*SIN(THETA) + RB*(COS(THETA)-1.0)
```

```
      DEFX1(I)=UU*(COS(THETA)-1.0) - RR*SIN(THETA) + F(I)*UU*(X(4)**2)
     1              /(2.*E*RI)
C
C DEFLECTION DUE TO CURVED SECTION OF THE SPRING
C
      RK=X(3)/RAD
      CY   = .33*(RK**3) +   (RK**2)*PHI   + 2.0*RK - 2.0*RK*COS(PHI )
     1   + 0.5*PHI   - 0.25*SIN(2.0*PHI )
      CX1    = RK*PHI   - RK*SIN(PHI ) - COS(PHI ) + .25*COS(2.0*PHI) +.75
      CY2  = CX1
      CX2  = 1.5*PHI-2.0*SIN(PHI)+.25*SIN(2.0*PHI)
      CY3  = RK*PHI-COS(PHI)+1.0
      CX3  = PHI-SIN(PHI)
C
      BETA=PHI-PI/2.0
C
      FY=FUNIT*COS(BETA)
      FX=FUNIT*SIN(BETA)
C
      DELTA=(RAD**2) * (FY*CY3+FX*CX3) / (E*RI)
      DY=( RAD**3) * (FY*CY1+FX*CX1) / (E*RI)
      DX=(RAD**3) * (FY*CY2+FX*CX2) / (E*RI) + X(2)*(1.0-COS(DELTA))
C
      DEF=SQRT((DX**2)+(DY**2))
      GAMMA=ATAN( DX/DY)
      ETA=BETA-GAMMA
C
      DYY=       -DEF*COS(ETA)
      DXX=        DEF*SIN(ETA)
C
      IF(I .NE. JUMP) GO TO 2
      DEFY2(I)=DYY
      DEFX2(I)=DXX
      GO TO 3
    2 CONTINUE
      DEFY2(I)=DEFY2(I-JUMP) + DYY
      DEFX2(I)=DEFX2(I-JUMP) + DXX
C
C COMBINED DEFLECTION OF ABOVE TWO
C
    3 CONTINUE
      DEFY(I) = DEFY1(I) + DEFY2(I)
      DEFX(I) = DEFX1(I) + DEFX2(I)
C
C TO DECIDE HORIZONTAL FORCE AT INITIAL DEFLECTION
C
      IF(J .NE. 0) GO TO 4
      IF (ABS(DEFY(I)) .GE. PDEF) J=I
    4 CONTINUE
C
C BY PASS IF DEFY(I) REACHES TO TEST
C
      WRITE(6,200) F(I),DEFX1(I),DEFX2(I),DEFX(I),DEFY1(I),DEFY2(I),
     1                 DEFY(I)
C
      IF (ABS(DEFY(I)) .GE. TEST) GO TO 5
C
C REDEFINE THE CONFIGURATION OF THE SPRING
C
```

```
      PHI=PHI+DELTA
      RAD=ARC/PHI
      I=I+JUMP
      GO TO 44
C
C COMPUTE THE ENERGY(FF1 AND FF2 ARE HORIZONTAL FORCES AT INITIAL AND FINAL
C DEFLECTIONS)
C
   46 CONTINUE
      FF1=F(J)
      IF(DDEF .EQ. 0.0) FF1=0.0
      FF2=F(I)
      ENRGY=ABS(FF1+FF2)*DEFM                                          B. S.
C
C COMPUTE THE MAX. STRESS(BENDING) IN THE SPRING
C
      RMAX=FF2*(X(3)+X(5))
      Z = ( X(1)**2)*X(2) / 6.0
      AREA = X(1)*X(2)
      STS=ABS(RMAX/Z + FF2/AREA)
C
C COMPUTE SPRING CONSTANT
C
      SK= ABS(FF2/TEST)
C
  100 FORMAT(1H1, //)
  200 FORMAT(6X,' *F(I)*, 7X, *DEFX1(I)*, 7X, *DEFX2(I)*, 7X, * DEFX(I)*,
     1 7X, *DEFY1(I)*, 7X, *DEFY2(I)*, 7X, * DEFY(I)*, //)
  300 FORMAT(1X, F8.1, 6F15.4 /)
C
      RETURN
      END
        6400 END OF RECORD
 *** JACOB TRAP I (MR. TSCHOEPE'S, DESIGN) ***      1.7802    3.5000    2.000
.0678     1.5000     5.0000    .2000    1.0000
4
 *** JACOB TRAP I (MR. TSCHOEPE'S, FABRICATED) ***  1.7104    3.5000    2.000
.0680     1.5000     5.4375    .15625   1.1250
4
 *** JACOB TRAP II (MR. TSCHOEPE'S, DESIGN) ***     1.7802    4.1750    2.000
.1000     1.7500     7.7500    .4500    1.2000
4
 *** JACOB TRAP II (MR. TSCHOEPE'S, FABRICATED) *** 1.7035    4.1750    2.000
.1000     1.7500     7.1875    .40625   1.3125
4
 *** JACOB TRAP III (MR. TSCHOEPE'S, DESIGN) ***    1.7802    6.5000    2.000
.1250     2.0000    10.3000    .5000    1.7500
4
 *** JACOB TRAP III (MR. TSCHOEPE'S, FABRICATED) ***  1.7628  6.5000    2.000
.1265     2.02344   10.0625    .3281    2.0000
        END OF FILE

                         CD TOT   0228
```

APPENDIX G: OPTIMIZATION PROGRAMME FOR THE CIRCULAR WIRE SPRING FOR THE JACOB TRAP - SEEK 1 AND SIMPLX

Description:

This programme finds the optimum design of the circular wire spring for the Jacob trap. There are two main programmes one for the subroutine SEEK 1 and the other for the subroutine SIMPLX. The user can combine either one of the programmes with the following subroutines UREAL, CONST, and ENGRY without any changes.

OPTISEP[7] manual and Section 11-3 should be referred for the details. Most of the formulae used in the subroutine ENGRY are explained in Sections 11-1 and 11-2.

Input:

The design variables and the input parameters are defined in the first part of the programme. Other input parameters related to the particular optimization strategy are set according to the OPTISEP[7] manual and can be altered to suit.

There are two input statements:

a) the DATA statement for the RMIN and they remain all zero in this case.

b) The READ statement for the parameters as listed in the NAMELIST statement.

The user is required to provide the data cards according to the FORMATS.

Output:

In addition to the direct output from the OPTISEP subroutines the programme prints out:

$X_1 \sim X_6$: The values of the design variables along with their definitions.

FF1: The tangential force at the end of the free end arm when the spring is loaded by the initial deflection angle.

STS: The maximum bending stress in the spring.

ENGY: The maximum strain energy stored in the spring.

Other information:

The general information is explained in the first part of the section on - Other Information in Appendix "A". If it is required to use the subroutine EQUAL[7] add the subroutine as shown on page 2/4 without changing anything in the main programme. In the subroutine EQUAL, the constant for the available wire size should be altered to suit.

The average computer time to get a solution was 5 sec. central processing time per run utilizing the subroutine SEEK 1 on a CDC 6400 computer. It was 15 sec. for the subroutine SIMPLX.

```
HUNT,T60.
ATTACH,OPTISER.
FTN,.
LDSET,LIB=OPTISER.
LGO.
      6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *G* OPTIMIZATION PROGRAM FOR CIRCULAR WIRE SPRING FOR THE JACO
C               --SEEK1
C
C *** DEFINITION OF DESIGN VARIABLES ***
C
C     X(1) = WIRE DIAMETER (IN)
C     X(2) = MEAN COIL DIAMETER (IN)
C     X(3) = NUMBER OF TURNS OF COIL
C     X(4) = FREE END ARM LENGTH (IN)
C     X(5) = INITIAL COMPRESSION ANGLE (RAD)
C
C *** DEFINITION OF INPUT PARAMETERS ***
C
C     X1MAX  = MAX. ALLOWABLE WIRE DIAMETER (IN.)
C     X2MAX  = MAX. ALLOWABLE MEAN COIL DIAMETER (IN.)
C     X3MAX  = MAX. ALLOWABLE NUMBER OF TURNS OF COIL
C     X4MAX  = MAX. ALLOWABLE FREE END ARM LENGTH (IN.)
C     X5MAX  = MAX. ALLOWABLE INITIAL COMPRESSION ANGLE (RAD)
C     DEFM   = CHORD OF ADDITIONAL DEFLECTION ANGLE WITH FREE END ARM LENGT
C              A RADIUS (IN.)
C     E      = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C     STW    = WORKING STRESS (LBS/SQ.-IN.)
C     FLOW   = MINIMUM REQUIRED ENERGY OUT OF THE TRAP (IN.-LBS)
C     SPWT   = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C     FINIT  = MIN. REQUIRED FORCE AT INITIAL DEFLECTION (AT THE END OF FREE
C              ARM) (LBS)
C     BASE   = BASE LENGTH OF THE TRAP (IN.)
C     HMIN   = MINIMUM HEIGHT OF TRAP (IN.)
C SUBROUTINE ENRGY COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X( 5),RMAX( 5),RMIN( 5),XSTRT( 5),      PHI(14),PSI(1),
     1 WORK1( 5),WORK2( 5),WORK3( 5),WORK4( 5)
C
      COMMON /AA/ PI,DEFM,E,STW,FLOW,SPWT,FINIT,BASE,HMIN
      COMMON /BB/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX
C
      NAMELIST /INPUT/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX,DEFM,E,STW,FLOW,
     1                 SPWT,FINIT,BASE,HMIN
C
      DATA RMIN / 5 * 0.0 /
C
C READ, STORE AND WRITE OUT PARAMETERS AS LISTED IN NAMELIST
C
      READ (5, INPUT)
      WRITE(6, INPUT)
C
      PI=4.0*ATAN(1.0)
C
C DEFINE INPUT VARIABLES ACCORDING TO OPTISER MANUAL
C
```

```
      N      = 6
      IPRINT = 1
      IDATA  = 1
      NCONS  = 14
      NEQUS  = 0
      F      = .01
      G      = .04
      MAXM   = 100
      NSHOT  = 2
      NTEST  = 100
C
C GENERATE RMAX AND XSTRT (STARTING POINT OF X(I))
C
      RMAX(1) = X1MAX
      RMAX(2) = X2MAX
      RMAX(3) = X3MAX
      RMAX(4) = X4MAX
      RMAX(5) = X5MAX
C
      DO 3 I=1,N
      XSTRT(I)=(RMAX(I)+RMIN(I))/2.0
    3 CONTINUE
C
      CALL SEEK1(N, RMAX, RMIN, NCONS, NEQUS, F, G, XSTRT, NSHOT, NTEST
     1 MAXM, IPRINT, IDATA, X, U, PHI, PSI, WORK1, WORK2, WORK3, WORK4)
C
      CALL ANSWER(U, X, PHI, PSI, N, NCONS, NEQUS)
C
      CALL       ENRGY(X, FF1, STS,ENGY)
C
      WRITE(6, 50)
      WRITE(6,100) FF1,STS,ENGY
C
      TEST=-1.0E-10
      DO 4 I=1,NCONS
      IF(PHI(I) .LT. TEST) GO TO 5
    4 CONTINUE
C
      WRITE(6,200) (X(I),I=1,N)
    5 CONTINUE
C
   50 FORMAT(//)
  100 FORMAT(5X, *FORCE AT INITIAL DEFLECTION(LBS). . . . . =*, F15.6, /
     1         5X, *STRESS IN SPRING (LBS/SQ.IN.). . . . . . =*, F15.6, /
     1         5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . =*, F15.6//
  200 FORMAT(5X, *WIRE DIAMETER (IN.) . . . . . . . . . . . =*, F10.4, /
     1         5X, *MEAN COIL DIAMETER (IN.) . . . . . . . . =*, F10.4, /
     1         5X, *NUMBER OF TURNS OF COIL . . . . . . . . . =*, F10.4, /
     1         5X, *FREE END ARM LENGTH (IN.) . . . . . . . . =*, F10.4, /
     1         5X, *INITIAL DEFLECTION ANLGE (RAD.) . . . . . =*, F10.4//
C
      STOP
      END
```

CDTOT 0112

```
ATTACH,OPTISCD.
RUN.
LGO.
      6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX *G* OPTIMIZATION PROGRAM FOR CIRCULAR WIRE SPRING FOR THE JACOB
C                --SIMPLX
C
C
C
C *** DEFINITION OF DESIGN VARIABLES ***
C
C     X(1) = WIRE DIAMETER (IN)
C     X(2) = MEAN COIL DIAMETER (IN)
C     X(3) = NUMBER OF TURNS OF COIL
C     X(4) = FREE END ARM LENGTH (IN)
C     X(5) = INITIAL COMPRESSION ANGLE (RAD)
C
C
C **** DEFINITION OF INPUT PARAMETERS ****
C
C   X1MAX   = MAX. ALLOWABLE WIRE DIAMETER (IN.)
C   X2MAX   = MAX. ALLOWABLE MEAN COIL DIAMETER (IN.)
C   X3MAX   = MAX. ALLOWABLE NUMBER OF TURNS OF COIL
C   X4MAX   = MAX. ALLOWABLE FREE END ARM LENGTH (IN.)
C   X5MAX   = MAX. ALLOWABLE INITIAL COMPRESSION ANGLE (RAD)
C   DEEM    = CHORD OF ADDITIONAL DEFLECTION ANGLE WITH FREE END ARM LENGTH
C             A RADIUS (IN.)
C   E       = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C   STW     = WORKING STRESS (LBS/SQ.-IN.)
C   ELOW    = MINIMUM REQUIRED ENERGY OUT OF THE TRAP (IN.-LBS)
C   SPWT    = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C   FINIT   = MIN. REQUIRED FORCE AT INITIAL DEFLECTION (AT THE END OF FREE
C             ARM) (LBS)
C   BASE    = BASE LENGTH OF THE TRAP (IN.)
C   HMIN    = MINIMUM HEIGHT OF TRAP (IN.)
C SUBROUTINE ENRGY COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X( 5),RMAX( 5),RMIN( 5),XSTRT( 5),PHI(14), PSI(1),
     1 XA( 5, 6),XJ( 5),XH( 5),XS( 5),XL( 5),XO( 5),XR( 5),XE( 5),
     1 XC( 5), STEP( 5), FUN( 6)
C
      COMMON /AA/ PI,DEEM,E,STW,ELOW,SPWT,FINIT,BASE,HMIN
      COMMON /BB/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX
C
      NAMELIST /INPUT/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX,DEEM,E,STW,ELOW,
     1                 SPWT,FINIT,BASE,HMIN
C
C
      DATA RMIN / 5 * 0.0 /
C
C READ, STORE AND WRITE OUT PARAMETERS AS LISTED IN NAMELIST
C
      READ (5, INPUT)
      WRITE(6, INPUT)
C
      PI=4.0*ATAN(1.0)
```

```
C DEFINE INPUT VARIABLES ACCORDING TO OPTISEP MANUAL
C
      N      = 5
      NN     = N+1
      NCONS  = 14
      NEQUS  = 0
      MAXM   = 500
      IPRINT = 1
      IDATA  = 1
      REDUCE = .05
      E      = .1
      G      = 2.E-2
      R      = 1.0
      ALPHA  = 1.0
      BETA   = .5
      GAMA   = 2.0
C
C GENERATE RMAX AND XSTRT (STARTING POINT OF X(I))
C
      RMAX(1) = X1MAX
      RMAX(2) = X2MAX
      RMAX(3) = X3MAX
      RMAX(4) = X4MAX
      RMAX(5) = X5MAX
C
      DO 3 I=1,N
      XSTRT(I)=(RMAX(I)+RMIN(I))/2.0
    3 CONTINUE
C
      CALL SIMPLX(N,RMAX,RMIN,NCONS,NEQUS,XSTRT,NN,ALPHA,BETA,GAMA,
     1 REDUCE,R,E,G,MAXM,IPRINT,IDATA,U,X,PHI,PSI,XA,XJ,FUN,XU,XS,XL,XO,
     1 XR,XE,XC,STEP)
C
      CALL ANSWER(U, X, PHI, PSI, N, NCONS, NEQUS)
C
      CALL        ENRGY(X, FEI, STS,ENGY)
C
      WRITE(6, 50)
      WRITE(6,100) FEI,STS,ENGY
C
      TEST=-1.0E-10
      DO 4 I=1,NCONS
      IF(PHI(I) .LT. TEST) GO TO 5
    4 CONTINUE
C
      WRITE(6,200) (X(I),I=1,N)
    5 CONTINUE
C
   50 FORMAT(///)
  100 FORMAT(5X, *FORCE AT INITIAL DEFLECTION(LBS). . . . . =*, F15.6, //
     1       5X, *STRESS IN SPRING (LBS/SQ.IN.). . . . . =*, F15.6, //
     1       5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . =*, F15.6,//)
  200 FORMAT(5X, *WIRE DIAMETER (IN.) . . . . . . . . . =*, F10.4, //
     1       5X, *MEAN COIL DIAMETER (IN.) . . . . . . . =*, F10.4, //
     1       5X, *NUMBER OF TURNS OF COIL . . . . . . . =*, F10.4, //
     1       5X, *FREE END ARM LENGTH (IN.) . . . . . . =*, F10.4, //
     1       5X, *INITIAL DEFLECTION ANLGE (RAD.) . . . . =*, F10.4,//)
     1
```

STOP
END

CDTOT 0120

```
C
      SUBROUTINE ORLAL(X,U)
C
      DIMENSION X(1)
C
      COMMON /AA/ PI,DEFM,E,STW,ELOW,SPWT,FINIT,BASE,HMIN
C
C OPTIMUM FUNCTION IS THE WEIGHT OF THE SPRING
C
      U=2.*SPWT*(PI/4.0)*(X(1)**2)*(PI*X(2)*X(3)+X(4)+.25*X(2)*(PI-2.)
     1  +BASE/2.)
C
      RETURN
      END
C
      SUBROUTINE CONS (X,NCONS,PHI)
C
      DIMENSION X(1), PHI(1)
C
      COMMON /AA/ PI,DEFM,E,STW,ELOW,SPWT,FINIT,BASE,HMIN
      COMMON /BB/ X1MAX,X2MAX,X3MAX,X4MAX,X5MAX
C
      CALL      ENRGY(X, FF1, STS,ENGY)
C
C ALL DESIGN VARIABLES SHOULD BE LESS THAN MAX. ALLOWABLE VALUES SET
C
      PHI( 1) = X1MAX - X(1)
      PHI( 2) = X2MAX - X(2)
      PHI( 3) = X3MAX - X(3)
      PHI( 4) = X4MAX - X(4)
      PHI( 5) = X5MAX - X(5)
C
C ALL DESIGN VARIABLES SHOULD BE POSITIVE
C
      PHI( 6) = X(1)
      PHI( 7) = X(2)
      PHI( 8) = X(3)
      PHI( 9) = X(4)
      PHI(10) = X(5)
C
C ENERGY, STRESS AND INITIAL DEFLECTION FORCE RESTRICTION
C
      PHI(11) = ENGY  - ELOW
      PHI(12) = STW   - STS
      PHI(13) = FF1   - FINIT
      H= X(4)+X(2)/2.0
      PHI(14) = H     - HMIN
C
      RETURN
      END
C
      SUBROUTINE ENRGY(X, FF1, STS,ENGY)
C
      DIMENSION X(1)
C
      COMMON /AA/ PI,DEFM,E,STW,ELOW,SPWT,FINIT,BASE,HMIN
C
C CHECK IF THERE IS ANY NEGATIVE DESIGN VARIABLE
C
```

```
      DO 2 I=1,5
      IF (X(I) .EQ. 0.0) X(I)=1.0E-4
    2 CONTINUE
C
C CALCULATE PARAMETERS TO COMPUTE ENERGY AND STRESS
C
      C=X(2)/X(1)
      ARG1=4.0*C*(C-1.0)
      IF(ARG1 .EQ. 0.0) ARG1=1.0E-4
      RK1=(4.0*(C**2)-C-1.0)/ARG1
C
      ARG3=DEFM/(2.0*X(4))
      IF(ABS(ARG3) .GT. 1.0) ARG3=1.0
      PHI2=2.0*ASIN(ARG3) + X(5)
C
C COMPUTE ENERGY
C
      ARG2=E*(X(1)**4)/(64.*(X(2)*X(3)+     X(4)/(3.0*PI)))
      ENGY =ARG2*((PHI2**2)-(X(5)**2))
C
C COMPUTE FORCE AT INITIAL DEFLECTION AT THE END OF FREE END ARM
C
      FF1=ARG2*X(5)/X(4)
C
C COMPUTE STRESS IN SPRING
C
      RMOM=ARG2*PHI2
      STS=32.*RK1*RMOM/(PI*(X(1)**3))
C
      RETURN
      END
        6400 END OF RECORD
$INPUT X1MAX=.50,X2MAX=3.10,X3MAX=3.10,X4MAX=13.50,X5MAX=.50,DEFM=5.0,
E=30.E+06,STW=0.190E+06,ELOW=800.0,SPWT=0.284,BASE=7.50,RMIN=13.0,FINIT=20
           END OF FILE
```

```
C
      SUBROUTINE EQUAL(X,PSI,NEQUS)
C
C     WIRE DIAMETER SHOULD BE EQUAL TO SELECTED COMMERCIAL SIZE
C
      DIMENSION X(1),PSI(1)
C
      PSI(1) = .4375 - X(1)
C
      RETURN
      END
```

APPENDIX H: TRIM OR CALCULATION PROGRAMME FOR THE CIRCULAR WIRE SPRING - JACOB TRAP

Description:

This programme is used to trim the spring optimization result or to analyze the fabricated spring of the Jacob trap.

Input:

The input parameters are defined in the first part of the programme, and there are four input statements:

a) The DATA statement for E and SPWT, which remain the same if the material is not changed.

b) The READ statement of the trap name.

c) The READ statement for the design variables $X_1 \sim X_5$, DEFM and BASE.

d) The READ statement for the "MORE" which is required for the next set of the data if there is any.

The user should provide the data cards according to the FORMATS.

Output:

The programme prints out the input data along with their definitions and:

U: The weight of the spring frame.

FF1: The tangential force at the end of the free end arm when the spring is loaded by the initial deflection angle.

STS: The maximum bending stress in the spring.

ENGY: The maximum strain energy stored in the spring.

Other Information:

The average computer time was 3 sec. central processing time for 3 sets of the data on a CDC 6400 computer.

```
      6400 END OF RECORD.
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C APPENDIX    TRIM OR CALCULATION PROGRAM FOR THE CIRCULAR WIRE SPRING
C              --JACOB TRAP
C
C
C *** DEFINITION OF DESIGN VARIABLES ***
C
C      X(1) - WIRE DIAMETER (IN)
C      X(2) - MEAN COIL DIAMETER (IN)
C      X(3) - NUMBER OF TURNS OF COIL
C      X(4) - FREE END ARM LENGTH (IN)
C      X(5) - INITIAL COMPRESSION ANGLE (RAD)
C
C
C ***** DEFINITION OF INPUT PARAMETERS *****
C
C   DEEM   = CHORD OF ADDITIONAL DEFLECTION ANGLE WITH FREE END ARM LENGTH
C            A RADIUS (IN.)
C   E      = MODULUS OF ELASTICITY OF THE MATERIAL (LBS/SQ.IN.)
C   SPWT   = WEIGHT PER CU. IN. OF THE MATERIAL (LBS/CU.IN.)
C   BASE   = BASE LENGTH OF THE TRAP (IN.)
C
C SUBROUTINE ENRGY COMPUTES STRESS AND ENERGY OF THE SPRING (PRIVATE)
C
      DIMENSION X(5),NAME(8)
C
      COMMON /AA/ DEEM,E,SPWT,PI
C
      DATA E, SPWT / 30.E+06, .2840 /
C
   10 READ(5,150) NAME
      READ(5,400)     (X(I),I=1,5),DEEM,BASE
C
      PI=4.0*ATAN(1.0)
C
      U=2.*SPWT*(PI/4.0)*(X(1)**2)*(PI*X(2)*X(3)+X(4)+.25*X(2)*(PI-2.)
     1  +BASE/2.)
      CALL    ENRGY(X, EE1, STS,ENGY)
C
      WRITE(6,250)
      WRITE(6,150) NAME
      WRITE(6, 50)
      WRITE(6,200) (X(I),I=1,5), DEEM, BASE
      WRITE(6,100) U,EE1,STS,ENGY
C
C GO BACK TO THE BEGINING OF THE PROGRAM FOR ANOTHER SET OF DATA
C
      READ(5,300) MORE
      IF(MORE .EQ. 4) GO TO 10
C
   50 FORMAT(//)
  100 FORMAT(5X,*WEIGHT OF THE SPRING (LBS) . . . . . . . =*, E15.6, //
     1       5X, *FORCE AT INITIAL DEFLECTION(LBS) . . . . =*, E15.6, //
     1       5X, *STRESS IN SPRING (LBS/SQ.IN.). . . . . .
```

```
     1        5X, *MAXIMUM ENERGY (IN.-LBS) . . . . . . . . . . =*, E15.6,//)
 100 FORMAT(8A10)
 200 FORMAT(5X, *WIRE DIAMETER (IN.) . . . . . . . . . . . . . =*, F10.4, //
     1        5X, *MEAN COIL DIAMETER (IN.) . . . . . . . . . . =*, F10.4, //
     1        5X, *NUMBER OF TURNS OF COIL . . . . . . . . . . =*, F10.4, //
     1        5X, *FREE END ARM LENGTH (IN.) . . . . . . . . . =*, F10.4, //
     1        5X, *INITIAL COMP. ANGLE (RAD) . . . . . . . . . =*, F10.4, //
     1        5X, *CHORD OF ADDITIONAL DEF. ANGLE (IN.) . . . =*, F10.4, //
     1        5X, *BASE LENGTH OF THE TRAP (IN.) . . . . . . =*, F10.4,//)
 300 FORMAT(1H1, ///)
 400 FORMAT(I2)
 500 FORMAT(7F10.0)

     STOP
     END

     SUBROUTINE ENERGY(X, FF1, STS,ENGY)                                JACOB

     DIMENSION X(1)

     COMMON /AA/ DEFM,E,SPWT,PI

C    CALCULATE PARAMETERS TO COMPUTE ENERGY AND STRESS

     C=X(2)/X(1)
     ARG1=4.0*C*(C-1.0)
     IF(ARG1 .EQ. 0.0) ARG1=1.0E-4
     RKI=(4.0*(C**2)-C-1.0)/ARG1

     ARG3=DEFM/(2.0*X(4))
     IF(ABS(ARG3) .GT. 1.0) ARG3=1.0
     PHI2=2.0*ASIN(ARG3) + X(5)

C    COMPUTE ENERGY                                                     JACOB
     ARG2=E*(X(1)**4)/(64.*(X(2)*X(3)+     X(4)/(2.0*PI)))              B. SIDE
     ENGY =ARG2*((PHI2**2)-(X(5)**2))

C    COMPUTE FORCE AT INITIAL DEFLECTION AT THE END OF FREE END ARM

     FF1=ARG2*X(5)/X(4)

C    COMPUTE STRESS IN SPRING

     RMOM=ARG2*PHI2
     STS=32.*RKI*RMOM/(PI*(X(1)**3))

     RETURN
     END
```

6400 END OF RECORD

```
*** TRIMMED RESULT OF JACOB III (CIRCULAR WIRE HELICAL TORSION SPRING)
.4375     2.750     2.9194     12.50     .3316     5.00     7.50
4
*** TRIMMED RESULT OF JACOB I (CIRCULAR WIRE HELICAL TORSION SPRING) DESIGN
.3120     2.125     2.9083     6.00      .4363     2.50     3.50
4
*** TRIMMED RESULT OF JACOB I (CIRCULAR WIRE HELICAL TORSION SPRING) DESIGN
.2430     2.00      2.9431     6.00      .2182     2.50     2.50
```

APPENDIX I: KINETIC ENERGY ANALYSIS PROGRAMME FOR THE JACOB TRAP

Description:

The programme converts the high speed film readings into actual slider positions of the imaginary slider crank mechanism, (Section 12-5) and the crank angles are computed from the slider positions. The angular and linear velocity; and then the kinetic energy of the crank and the coupler link is calculated from the change rates of the crank angles and the slider positions. The equations and methods used in Subroutines ANGLE and ENRGY are explained in Section 12-5. The kinetic energy level and other output data are related to the jaw opening numerically from the table read in.

Input:

The input parameters and the subroutines called are defined or explained in the first part of the programme. There are 7 READ statements:

a) The trap name.

b) The input parameters as listed in the NAMELIST statement.

c) The number of exposures considered on the high speed film (i.e. data of S1)

d) The data of FRAME (I) and S1(I).

e) The number of measurements of S2.

f) The data of S2(I) and OPN(I).

g) The integer number for MORE, for the next set of the data if there is any.

The user should provide the data cards according to the specified FORMATS.

Output:

The programme prints out the title and all the input parameters with their descriptions along with the following values:

I:	Number of the data.
CUMTIM(I):	Time elapsed to the jaw opening.
PHI(I):	The crank angles.
S(I):	The actual slider positions.
CAVEL(I):	The angular velocities of the crank.
SLVEL(I):	The linear velocities of the slider.
OPEN(I):	The jaw openings.
ENGY(I):	The total kinetic energies at the jaw openings.
OP(I):	The jaw opening at which the energy level is required.
EXPEC(I):	The kinetic energy at OP(I).
OPEN(lk)	The jaw opening at the maximum energy level.
E_{max}:	The amxlmum energy at OPEN(lk).

Also the programme plots out two graphs, the kinetic energy level against the time elapsed and the kinetic energy level against jaw opening.

Other information:

The user should review, it is suggested, Subroutine ADJUST before he provides the data from the high speed film. Also it is important to examine the film readings carefully since one blunder could affect the whole curve in the process of the polynomial approximation.

If the values of the EXPEC(I) are not reasonable, then the jaw opening OP(I) is not within the boundary of the Table read in. For the programming information, Sections 12-5 and 12-8 should be referred.

The required computer time for 12 sets of the data was 18.81 sec. of central processing time on a CDC 6400 computer.

```
     ,T40.                                                        286    YI Y. J.
     ,MACLIB.
  
     LIB=MACLIB)
  
     -6400 END OF RECORD
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)

  APPENDIX *I* KINETIC ENERGY CALCULATION PROGRAM--JACOB TRAP

  THE MOTION OF THE JACOB TRAP IS SIMULATED AS A SLIDER CRANK MECHANISM, THAT
  THE STRIKE BAR AND THE FULCRUM BECOME THE COUPLER LINK AND THE SLIDER PIN.
  BE IS CALLED AS I.S.C. (IMAGINARY SLIDER CRANK) MECHANISM IN THE FOLLOWING.

  ****DEFINITION OF INPUT PARAMETERS ****

    NAME    = TRAP NAME
    A(1)    = CRANK LENGTH OF THE I.S.C. MECHANISM (IN)
    A(2)    = LENGTH OF THE COUPLER LINK (IN)
    A(3)    = OFFSET OF THE I.S.C. MECHANISM (IN)
    ETIA1   = MOMENT OF INERTIA OF THE FREE END ARM AGAINST THE IMAGINARY CRANK
              SHAFT(LBS/SQ.IN)
    ETIA2   = MOMENT OF INERTIA OF THE COUPLER LINK AGAINST ITS CENTER OF GRAVI
              (LBS-SQ.IN)
    WT2     = WEIGHT OF THE COUPLER LINK(LBS)
    BIAS    = AMOUNT TO BE DEDUCTED FROM S2 (OR S1) TO GET THE SLIDER POSITION
              OF THE I.S.C. MECHANISM (IN)
    XX, YY  = COORDINATEDS OF THE CENTER OF GRAVITY OF THE COUPLER LINK FROM THE
              CRANK PIN AS DEFINED IN THE TEXT (IN)
    PULSE   = TIME BETWEEN PULSES ON THE HIGH SPEED FILM(SEC)
    K       = NUMBER OF OPENINGS AT WHICH THE ENERGIES TO BE CALCULATED
    OP      = OPENING OF THE TRAP AT WHICH THE ENERGY REQUIRED
    N       = NUMBER OF EXPOSURES CONSIDERED ON THE FILM
    FRAME   = NUMBER OF FRAMES PER PULSE INTERVAL
    S1      = DISTANCE FROM THE FULCRUM TO THE BOTTOM OF THE TRAP AS READ FROM
              THE HIGH SPEED FILM (IN)
    KO      = NUMBER OF THE MEASUREMENTS OF S2
    S2      = MEASURED DISTANCE FROM THE FULCRUM TO THE BOTTOM OF THE TRAP (IN)
    OPN     = JAW OPENING MEASURED AT THE SLIDER POSITION S2(IN)
    MORE    = PUT 4 IN I2 FORMAT TO REPEAT THE PROCEDURE FOR THE NEXT SET OF DAT
              IF THERE IS ANY

  SUBROUTINE LIST CALLED

    ADJUST = TO CONVERT THE S1 AND S2 TO THE SLIDER POSITIONS OF THE I.S.C.
             MECHANISM
    LESQ   = TO FIND THE LEAST SQUARE FIT OF A SET OF POINTS (X,Y) TO A CURVE
             Y=F(X) POLYNOMIAL OF A GIVEN DEG.(IN THIS CASE 5) IN X(LIB=MACLIB)
    ANGLE  = TO COMPUTE THE CRANK ANGLES CORRESPONDING TO THE SLIDER POSITIONS
    ENRGY  = TO COMPUTE THE KINETIC ENERGIES (PRIVATE PROGRAM)
    ETABLE = SUBPROGRAM FOR LINEAR INTERPOLATION FROM A TABLE OF VALUES(PRIVATE
    PLOTPT = STORES ORDINATES AND ABCISSAS FOR PLOT(LIB=MACLIB)
    OUTPLT = PLOTS AND DESTROYS ALL STORED POINTS(LIB=MACLIB)

      DIMENSION NAME(8),FRAME(200),S1(200),S2(100),OPN(100)
      DIMENSION A(3),OP(3),ESPEC(3),COEF(10),WORK(50)
      DIMENSION S(200),TIME(200),CUMTIM(200),PHI(200),CAVEL(200),
     1          SLVEL(200),ENGY(200),OPEN(200)
      COMMON /AA/   PI,ETIA1,ETIA2,XX,YY,WT2
```

```
C
      NAMELIST /INPUT/ A,ETIA1,ETIA2,WT2,BIAS,XX,YY,      PULSE,K,OP
C
      PI     = 4.0*ATAN(1.0)
C
C READ AND STORE THE REQUIRED DATA
C
  444 READ (5,100) (NAME(I),I = 1,8)
      READ(5,INPUT)
      READ(5,103) N
      READ(5,102) (FRAME(I),S1(I),I=1,N)
      READ(5,103) KO
      READ(5,102) (S2(I),OPN(I),I=1,KO)
C
C CONVERT THE DATA OF S1 AND S2 INTO THE SLIDER POSITIONS OF THE I.S.C.
C MECHANISM
C
      CALL        ADJUST(N,KO,BIAS,S1,S2,S)
C
C COMPUTE THE TIME TAKEN BETWEEN THE FILM EXPOSURES AND THE CUMULATIVE TI
C
      TIME(1)=0.0
      CUMTIM(1)=0.0
      DO 5 I=2,N
      TIME(I)=PULSE /FRAME(I)
      CUMTIM(I)=CUMTIM(I-1)+TIME(I)
    5 CONTINUE
C
C SMOOTH THE CURVE OF THE DATA S(I) BY USING MACLIB SUBROUTINE LESQ (LEAS
C SQUARE APPROXIMATION)
C
      CALL        LESQ(WORK,COEF,CUMTIM, S , 5,N)
      DO 6 I=1,N
      S(I)   =COEF(1) + COEF(2)*CUMTIM(I) + COEF(3)*(CUMTIM(I)**2)
     1         + COEF(4)*(CUMTIM(I)**3) + COEF(5)*(CUMTIM(I)**4)
     1         + COEF(6)*(CUMTIM(I)**5)
    6 CONTINUE
C
      STROKE=S(1)-S(N)
C
C CALCULATE THE CRANK ANGLE PHI CORRESPONDING TO THE SLIDER POSITION
C
      CALL        ANGLE(A,S,N,PHI)
C
C CALCULATE THE ANGULAR VELOCITY OF THE CRANK AND LINEAR VELOCITY OF THE
C
      CAVEL(1)=0.0
      SLVEL(1)=0.0
      DO 7 I=2,N
      CAVEL(I)=(PHI(I-1)-PHI(I))/TIME(I)
      SLVEL(I)=(S(I-1)-S(I))/TIME(I)
    7 CONTINUE
C
C TO FIND THE JAW OPENINGS AT THE NEW SLIDER POSITIONS(BY INTERPOLATION)
C
      OPEN(1)=OPN(1)
      OPEN(N)=OPN(KO)
      N1=N-1
```

```
      DO 8 I=2,N1
      OPEN(I)=ETABLE(S2,OPN,S(I),KO)
    8 CONTINUE
C
C SUBROUTINE ENRGY COMPUTES THE KINETIC ENERGIES
C
      CALL         ENRGY(N,A,PHI,CAVEL,SLVEL,ENGY,IK,EMAX)
C
C COMPUTE THE ENERGY LEVEL AT A GIVEN OPENING(BY INTERPOLATION)
C
      DO 9 I=1,K
      ESPEC(I)=ETABLE(OPEN,ENGY,OP(I),N)
    9 CONTINUE
C
C WRITE OUT THE RESULTS
C
      WRITE(6, 99)
      WRITE (6,104)
      WRITE (6,105) (NAME(I),I=1,8)
      WRITE(6,104)
      WRITE(6,106) ETIA1,ETIA2,XX,YY,WT2,N,PULSE,CUMTIM(N),STROKE
      WRITE(6,104)
      WRITE (6,107)
      WRITE (6,104)
C
      DO 10 I=1,N
      PHI(I)=PHI(I)*180./PI
   10 CONTINUE
      WRITE(6,108) (I,        CUMTIM(I),PHI(I),S(I),CAVEL(I),SLVEL(I),
     1               OPEN(I),ENGY(I), I=1,N)
      WRITE(6,104)
      WRITE(6,109) (OP(I),ESPEC(I),I=1,K)
      WRITE(6,110) OPEN(IK),EMAX
C
C STORE THE DATA AND PLOT OUT.
C
      DO 11 I=1,N
      CALL PLOTPT(CUMTIM(I),ENGY(I),4)
   11 CONTINUE
      CALL OUTPLT
      WRITE(6,111)
      WRITE (6,105) (NAME(I),I=1,8)
C
      DO 12 I=1,N
      CALL PLOTPT(OPEN(I),   ENGY(I),4)
   12 CONTINUE
      CALL OUTPLT
      WRITE(6,112)
      WRITE (6,105) (NAME(I),I=1,8)
C
C GO BACK TO THE BEGINING OF THIS PROGRAM FOR THE NEXT TRAP IF THERE IS A
C
      READ (5,101)MORE
      IF(MORE.EQ.4) GO TO 444
C
   99 FORMAT (1H1)
  100 FORMAT(8A10)
```

```
101 FORMAT (I2)
102 FORMAT(2F10.0)
103 FORMAT(I5)
104 FORMAT (///)
105 FORMAT (5X,*TRAP DESIGNATION*, 4X, 8A10, / 5X,*---- -----------*)
106 FORMAT(1X, *INERTIA OF THE FREE END ARM *, 10H(W*(R**2)),, *(LBS-SQ
   1.IN) . . . . . . . = *, F10.4, //
   1      1X, *INERTIA OF THE STRIKE BAR    *, 10H(W*(R**2)),, *(LBS-SQ
   1.IN)  . . . . . .  = *, F10.4, //
   1      1X, *COORDINATES OF THE C.G. OF THE STRIKE BAR FROM THE HIN
   1GE  . . = *, 2F10.4, //
   1      1X, *WEIGHT OF THE STRIKE BAR(LBS)  . . . . . . . . . . . . .
   1 . . . . = *, F10.4, //
   1      1X, *NUMBER OF EXPOSURES CONSIDERED . . . . . . . . . . . . .
   1 . . . . = *, I10,   //
   1      1X, *TIME BETWEEN PULSES ON THE FILM(SEC) . . . . . . . . . .
   1 . . . . = *, F10.4, //
   1      1X, *TOTAL TIME TAKEN FOR THE STROKE(IN)  . . . . . . . . . .
   1 . . . . = *, F10.4, //
   1      1X, *TOTAL STROKE OF THE SLIDER(IN) . . . . . . . . . . . . .
   1 . . . . = *, F10.4, //)
107 FORMAT(1X, *FRAME*, 4X,                              *CUMULATIVE*, 5X,
   1      *CRANK ANGLE*, 4X, *SLIDER* 9X, *ANGULAR VELOCITY*, 3X,
   1      *LINEAR VELOCITY*, 5X, *JAW OPENING*, 5X, *KINETIC ENERGY*,
   1                                      *TIME (SEC)*, 8X, *(DEG)*,
   1    / 1X, *NUMBER*, 3X,
   1      7X, *POSITION(IN)*, 3X, *OF CRANK(RAD/SEC)*, 2X,
   1      *OF SLIDER(IN/SEC)*, 5X, *(IN.)*, 12X, *(IN.-LBS)* )
108 FORMAT((1X, I5,  3(5X, F10.4),  4(7X, F10.4) / ))
109 FORMAT(1X, *ENERGY(IN-LBS) AT *, F5.2, 2X, *OPENING OF JAW . . . .
   1 . . =*, F10.4 /)
110 FORMAT(1X, *MAXIMUM ENERGY(IN-LBS), JAW OPENING AT*, F9.4,
   1 *, IN. :=*, F10.4 /)
111 FORMAT(/5X, *ABSCISSA . . . CUM. TIME(SEC)*, 3X,
   1              *ORDINATE . . . ENERGY(IN-LBS)*)
112 FORMAT(/5X, *ABSCISSA . . . OPENING(IN.)*, 3X,
   1              *ORDINATE . . . ENERGY(IN-LBS)*)
C
      STOP
      END
C
      SUBROUTINE ADJUST(N,KO,BIAS,S1,S2,S)
      DIMENSION S1(1),S2(1),S(1)
C
      ARG1=S1(1)-S1(N)
      ARG2=S2(1)-S2(KO)
C
C COMPUTE FIRST THE ACTUAL DISTANCE FROM THE FULCRUM TO THE BOTTOM OF THE TR
C BY PROPORTION AND THEN DEDUCT BIAS TO GET THE SLIDER POSITION OF THE I.S.C.
C MECHANISM
C
      DO 3 I=1,N
      S(I)=S2(1)-(ARG2/ARG1)*(S1(1)-S1(I))-BIAS
    3 CONTINUE
C
C CONVERT S2 INTO THE SLIDER POSITION OF THE I.S.C. MECHANISM
C
      DO 4 I=1,KO
      S2(I)=S2(I) -BIAS
```

```
    4 CONTINUE
C
      RETURN
      END
C
      SUBROUTINE ANGLE(A,S,N,PHI)
C
      DIMENSION A(1),S(1),PHI(1)
      COMMON /AA/    PI,FTIA1,FTIA2,XX,YY,WT2
C
      DO 3 I=1,N
      ARG1=(A(1)**2)-(A(2)**2)+(A(3)**2)+(S(I)**2)
      AA=4.0*(A(1)**2)*((S(I)**2)+(A(3)**2))
      BB=-4.0*A(1)*A(3)*ARG1
      CC=(ARG1**2)-4.0*(A(1)**2)*(S(I)**2)
C
      ARG2=(BB**2)-4.0*AA*CC
      SQ=SQRT     (ARG2)
      ROOT=(-BB+SQ)/(2.0*AA)
      PHI(I)=ASIN(ROOT)
    3 CONTINUE
C
      RETURN
      END
C
      SUBROUTINE ENRGY(N,A,PHI,CAVEL,SLVEL,ENGY,IK,EMAX)
C
      DIMENSION A(1),PHI(1),CAVEL(1),SLVEL(1),ENGY(1)
      COMMON /AA/    PI,FTIA1,FTIA2,XX,YY,WT2
C
      RI1=FTIA1/(12.*32.2)
      RI2=FTIA2/(12.*32.2)
      RM=WT2/(12.*32.2)
      ENGY(1)=0.0
C
      DO 4 I=2,N
C
C COMPUTE THE ENERGY(E1) OF THE CRANK
C
      E1=.5*RI1*(CAVEL(I)**2)
C
C COMPUTE THE ENERGIES (LINEAR(E2) $ ANGULA(E3)) OF COUPLER LINK
C
      ARGT=(A(1)*SIN(PHI(I))-A(3))/A(2)
      IF(ABS(ARG1) .GT. 1.0) ARG1=1.0
      THETA=ASIN(ARG1)
      VSH=SLVEL(I)*COS(THETA)
      VSV=SLVEL(I)*SIN(THETA)
C
      ARG2=PI/2.0 + PHI(I) - THETA
      VCH= A(1)*CAVEL(I)*COS(ARG2)
      VCV=-A(1)*CAVEL(I)*SIN(ARG2)
      IF(ABS(VCV) .EQ. ABS(VSV)) GO TO 2
      X=A(2)*VCV/(VCV-VSV)
      GO TO 3
    2 X=A(2)/2.0
C
    3 Y=SQRT(((XX -X)**2)+( YY **2))
```

```
      VANG=VSV/(A(2)-X)
      RI2=RI2+RM*(Y**2)
      E2=.5*RM*(VSU**2)
      E3=.5*RI2*(VANG**2)
C
C ADD UP TO GET THE  TOTAL ENERGY
C
      ENGY(I)=(E1+E2+E3)*2.0
C
    4 CONTINUE
C
C FIND OUT THE MAXIMUM ENERGY
C
      EMAX=ENGY(1)
      IK=1
      DO 5 I=2,M
      IF(ENGY(I) .LE. EMAX) GO TO 5
      EMAX=ENGY(I)
      IK=I
    5 CONTINUE
C
      RETURN
      END
C
      FUNCTION ETABLE(VAR,FUNC,XX,M)
C
C VAR=DISCRETE TABULAR VALUES OF THE VARIABLE
C FUNC=DISCRETE TABULAR VALUES OF THE FUNCTION
C XX=GIVEN VALUE OF THE VARIABLE
C M=NUMBER OF STATIONS OR TABLE VALUES
C ETABLE=INTERPOLATED VALUE OF THE FUNCTION CORRESPONDING TO XX
C
      DIMENSION VAR(1), FUNC(1)
      MEND=M-1
      DO 10 I=1,MEND
      INT=I
      IF(XX .LT. VAR(I) .AND. XX .GE. VAR(I+1)) GO TO 11
   10 CONTINUE
   11 ETABLE=FUNC(INT)+(XX-VAR(INT))*(FUNC(INT+1)-FUNC(INT))/(VAR(INT+1)
     1 -VAR(INT))
      RETURN
      END
        6400 END OF RECORD
             END OF FILE
```

CDTOT 0335

APPENDIX J

HUMANE TRAP DEVELOPMENT PROPOSAL

submitted to

The Canadian Federation of Humane Societies

Humane Trap Development Committee

by

W.R. Newcombe
Department of Mechanical Engineering
McMaster University
Hamilton 16, Ontario

March 1, 1973

W.R. Newcombe

Dr. G.F. Round
Chairman, Dept. of Mechanical Engineering

Dr. L.W. Shemilt
Dean of Engineering

Dr. D.R. McCalla
Acting Vice-President Science and Engineering Division

H.C. [illegible]
for H.T.D.C

SUMMARY

The Department of Mechanical Engineering proposes to undertake the third phase of the humane trap development programme in 1973.

The work will be undertaken in three parts:

1. Design, manufacture, test and evaluate Jacob prototypes with swinging, sling-type trigger.

2. Continue spring optimization programme, and design new springs for the New Conibear series.

3. Carry out an analytical study in an attempt to develop a method of predicting the energy diagram of a closing trap.

The project is to be completed by December 31, 1973, and the total expenditure should not exceed $6000.00. This will be carried out as a graduate student research project in the Master of Mechanical Engineering design programme.

Liason is to be maintained with the zoological research programme at Guelph University.

HUMANE TRAP DEVELOPMENT

PROPOSED PROGRAMME - 1973

INTRODUCTION

A large part of the work performed so far has involved the evaluation of commercial traps and inventor's prototypes. Twenty-two different traps have been evaluated for energy, closing time, clamping force, prying force and general overall design. Several of these have been evaluated during underwater operation as well.

Prototypes of the New Jacob series were manufactured, and the detailed design of these along with that of the New Conibear Series was studied with the aim of optimizing the general overall design in a qualitative manner to obtain the best possible trap. Many of the decisions had to be made on an intuitive basis because it was found that there was no information on the physical and behavioural characteristics of the relevant animals.

A programme designed to obtain this information has been started at Guelph University, and information of this nature is required before intelligent decisions can be made for finalized design. A calibrated variable energy laboratory trap device was designed and built for use at Guelph so that zoological studies can be carried out to determine the minimum energy levels which must be incorporated in a trap for a particular animal type.

It was suspected that the springs on certain trap series were overstressed, and a test programme substantiated this. Some work was carried out on the development of an optimization programme for the design of stirrup-type springs to produce the required amount of energy for a trap in the most efficient way.

The work that will be carried out in this third phase will be a refinement of the work already performed on the optimization of the Jacob Trap concept and on the optimization programme for springs and re-design of springs for the Conibear Series as well as for the Jacob Series. Information obtained from the Guelph study will be required as a direct input to this, and close liason will be maintained with Guelph.

DESCRIPTION OF PROPOSED WORK

1. After the design study was carried out on the first prototype of the Jacob Trap a new concept involving a swinging, sling-type trigger which should provide good animal control has been proposed. Although this will be difficult to implement practically, it has sufficient potential to warrant further study. Further prototypes of the Jacob design will be produced with this new trigger for full evaluation at McMaster and at Guelph. Also, C-type triggers will be designed and tested. An investigation will be carried out in an attempt to reduce the probable high energy loss of the existing design for underwater operation. The overall design of the Jacob Series will be optimized with the aim of developing this trap to the point where it may be classified as a humane trap.

2. The spring optimization programme will be completed and new springs for the Conibear Series will be designed. The phenomenon where the trap jaws lead the motion of the spring arms in the early part of the closing motion will be investigated to determine if this is an undesirable condition resulting in a loss of striking power. If so, an attempt will be made to redesign the system to remedy this. Optimum spring design will also be required for the Jacob traps.

3. An analytical study will be carried out in an attempt to develop a method which can be used to predict the energy diagram of a closing trap. In conjunction with the spring optimization programme this would enable the designer to predict the energy output of any trap being designed.

BUDGET - 1973

Overdraft from 1972	$ 297.87
Student support — 12 months @ $350.00	4200.00
Computer time — 2 hours @ $378.00	756.00
Supplies	300.00
Shop charges	225.00
Photographic work	100.00
Travel - Guelph etc.	100.00
Printing and miscellaneous	21.13
TOTAL	$6000.00

SCHEDULE

The work will be carried out as a graduate student research project in the Master of Mechanical Engineering design programme, and will be scheduled as follows:

March, April - Programme to start on a part-time basis with a review of previous work and preparation of drawings for additional prototypes of Jacob traps.

May 1 - Programme to proceed on a full-time basis
Design prototypes
Order material and equipment
Commence spring optimization programme

June 1 - Manufacture prototypes
Continue spring optimization

July 1	-	Complete spring optimization programme
		Redesign springs for Conibear series
		Commence analytical method for energy prediction
		Commence test and evaluation programme on Jacob prototypes
August 1	-	Continue evaluation and analytical programme
September 1	-	Begin final report and continue programmes as required

FACILITIES

Equipment and facilities required for the programme are presently available. This includes: a high-speed camera and film analyzer, glass-ended tank for underwater evaluation, large research computer and a fully equipped machine shop. Sufficient laboratory space exists in the Mechanical Engineering Department.

Traps other than the Jacob prototypes are to be supplied from the Humane Trap Development Committee.

REPORTING

To ensure that progress is satisfactory it is suggested that periodic oral reports be made to the Humane Trap Development Committee rather than burden the project with paper work. This procedure will ensure that the Committee is kept informed of the state of the project, and may influence its direction at critical decision points.

At the completion of the project the graduate student researcher will prepare a comprehensive thesis on the work done. This thesis, or abstract from it will constitute the final report.

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